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Workshop on Oil and Gas Environmental Effects Monitoring

Bedford Institute of Oceanography Dartmouth, Nova Scotia, May 26-30, 2003

Canada

November 2003

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November 2003

Workshop on Offshore Oil and Gas Environmental Effects Monitoring, Bedford Institute of Oceanography Dartmouth, Nova Scotia, May 26-30, 2003

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November 30, 2003

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Executive Summary

A workshop was held on May 26 to 30, 2003 at the Bedford Institute of Oceanography on Offshore Oil and Gas Environmental Effects Monitoring. The workshop was sponsored by the Environmental Studies Research Fund, Fisheries and Oceans Canada, the Program of Energy Research and Development, Petroleum Research Atlantic Canada, Environment Canada, the National Energy Board, the Canadian Association of Petroleum Producers, the Canada-Nova Scotia Offshore Petroleum Board and the Canada-Newfoundland Offshore Petroleum Board.

Offshore oil and gas drilling operations take place in some of the world's most biologically productive oceanic waters. An ongoing concern related to the development of the offshore oil and gas industry is that exposure to contaminants from waste discharges may cause ill effects on fish and fish habitat. Uncertainty related to the significance of potential environmental impacts from operational waste discharges has resulted in the establishment of rigorous and costly mitigation measures (waste treatment technologies) and monitoring programs at offshore oil and gas production sites in Canada (e.g. Cohasset/Panuke, Sable Offshore Energy, White Rose, Terra Nova, and Hibernia) and elsewhere. Environmental Effects Monitoring (EEM) programs are undertaken to verify environmental impact assessment predictions, to detect any unforeseen effects, and to help identify cause-effect relationships. The evaluation of EEM results advances our understanding of the impacts of the offshore oil and gas industry, contributing to improvements in drilling and production operations, mitigation measures, and the revision of regulatory guidelines for waste treatment (i.e. responsive management).

Monitoring has been carried out world wide for many offshore developments over the past three decades and much has been learned about the fate of drilling and production contaminants and their biological effects. Monitoring has been conducted at all offshore production platforms operating in Canadian waters since before the start of the first offshore oil development off Nova Scotia in 1992. EEM programs have rapidly evolved in response to new knowledge on the transport, fate, and effects of potential contaminants, changes in regulatory requirements, and improved impact assessment technologies and statistical approaches for data interpretation. The workshop provided an international forum for sharing information on lessons learned from past and ongoing EEM programs, the development of predictive risk assessment models, new approaches and technologies to monitor for potential alterations in fish health and community structure. The workshop was attended by 165 registered participants and included 77 presentations by scientists and environmental managers from Canada (44), the United States (13), Norway (10), the United Kingdom (8), and the Netherlands (2).

The workshop was followed by a half-day open forum entitled *Strengthening the Linkage between Environmental Effects Monitoring and Environmental Management for the Offshore*. This forum was organised jointly by representatives from the Department of Fisheries and Oceans (Oceans Sector) and industry (Canadian Association of Petroleum Producers). Key points that emerged during the preceding scientific workshop were reviewed at the forum by the workshop rapporteur, Dr. Roger Green (University of

Western Ontario). Dr. Green's review noted a general disposition among workshop presenters that environmental effects from offshore oil and gas operational activities are generally limited in temporal and spatial scale. A panel discussed the relationship between environmental effects monitoring and the regulatory environment, and an open discussion was held.

Résumé

Du 26 au 30 mai 2003, l'Institut océanographique de Bedford a été l'hôte d'un atelier sur la surveillance des effets environnementaux de l'exploitation des hydrocarbures extracôtiers. L'atelier était parrainé par le Fonds pour l'étude de l'environnement, Pêches et Océans Canada, le Programme de recherche et de développement énergétiques, Petroleum Research Atlantic Canada, Environnement Canada, l'Office national de l'énergie, l'Association canadienne des producteurs pétroliers, l'Office Canada–Nouvelle-Écosse des hydrocarbures extracôtiers et l'Office Canada–Terre-Neuve des hydrocarbures extracôtiers.

Les opérations de forage pétrolier et gazier en mer ont lieu dans certaines des eaux océaniques les plus bioproductives de notre planète. L'une des préoccupations que continue de soulever l'industrie des hydrocarbures extracôtiers concerne le potentiel d'effets négatifs que les contaminants libérés par les déchets peuvent avoir sur les poissons et leur habitat. L'incertitude quant à l'ampleur des effets sur l'environnement que pourraient causer les déchets d'exploitation a entraîné la mise en place, à grand prix, de mesures d'atténuation (technologies de traitement des déchets) et de programmes de surveillance rigoureux visant les lieux de production d'hydrocarbures au large des côtes canadiennes (p. ex. : Cohasset/Panuke, Sable Offshore Energy, White Rose, Terra Nova, Hibernia) et ailleurs. Des études de suivi des effets sur l'environnement (ESEE) permettent de vérifier si les effets environnementaux prévus lors d'évaluations se sont bel et bien produits, de détecter les effets imprévus et d'établir des relations de cause à effet. À la lumière des conclusions des ESEE, il nous est possible d'approfondir notre compréhension des effets environnementaux de l'industrie des hydrocarbures extracôtiers, ouvrant ainsi la voie à de meilleures opérations de forage et de production, à des mesures d'atténuation plus efficaces et à la révision des directives sur le traitement des déchets (p. ex. : gestion corrective).

De nombreux projets extracôtiers ont fait l'objet de surveillance partout dans le monde depuis 30 ans et nous en avons beaucoup appris sur le devenir et les effets biologiques des contaminants issus du forage et de la production. Des activités de surveillance étaient déjà menées sur les lieux de toutes les plates-formes de production extracôtière situées en eaux canadiennes avant même le début du premier projet de mise en valeur du pétrole au large de la Nouvelle-Écosse, en 1992. Les programmes d'ESEE ont rapidement évolué en fonction des nouvelles connaissances sur la propagation, le devenir et les effets des contaminants potentiels, aux changements apportés aux exigences de la réglementation et aux progrès en matière de technologies d'évaluation des effets et de méthodes statistiques d'interprétation des données. Lors de l'atelier, des discussions ouvertes ont permis aux participants de divers pays de partager les connaissances acquises par le biais de programmes d'ESEE passés ou en cours, sur l'élaboration de modèles prévisionnels d'évaluation des risques et sur les nouvelles méthodes et techniques de surveillance des changements qui pourraient être observés sur la santé et la structure des populations de poissons. Les 165 participants inscrits à l'atelier ont pu assister à 77 exposés présentés par des scientifiques et des gestionnaires de l'environnement du Canada (44), des États-Unis (13), de la Norvège (10), du Royaume-Uni (8) et des Pays-Bas (2).

L'atelier a été suivi d'une discussion libre d'une demi-journée sur le thème *Renforcer les liens entre la surveillance des effets sur l'environnement et la gestion environnementale au large des côtes*, organisée en collaboration par le secteur des Océans de Pêches et Océans Canada et l'industrie, représentée par l'Association canadienne des producteurs pétroliers. Les grands points qui avaient émergé des ateliers scientifiques précédents ont été passés en revue par le rapporteur, M. Roger Green (Université Western Ontario). M. Green a relevé que, parmi les exposants, on observe un certain consensus selon lequel les effets environnementaux de l'exploitation des hydrocarbures extracôtiers sont généralement restreints en termes de leur durée et de leur étendue géographique. Un groupe de discussion s'est penché sur la relation entre le suivi des effets environnementaux et le contexte de réglementation, qui a fait l'objet d'une discussion ouverte par la suite.

Preface

Environmental effects monitoring (EEM) programs are undertaken to verify environmental impact assessment predictions, to detect any unforeseen effects, and to advance our understanding of any impacts from the offshore oil and gas industry. This knowledge contributes to improvements in drilling and production operations, mitigation measures, and the revision of regulatory guidelines and regulations for waste treatment (responsive management). EEM programs are rapidly evolving in response to new knowledge on the transport, fate, and effects of potential contaminants, changes in regulatory requirements, and the development of improved EEM approaches and technologies.

The Offshore Oil and Gas Environmental Effects Monitoring Workshop was developed to address two central questions**:**

- *Are EEM programs giving us the information we need?*
- *How can they be improved?*

The workshop focused on approaches and technologies for carrying out EEM and consisted of three sessions that were designed to include presentations on the following program themes and sub-themes:

SESSION 1 EEM and Environmental Management

- EEM information required by stakeholders (regulators, environmental managers, and others).
- Direct application of EEM results (responsive management).
- Linking EEM to ecosystem management.

SESSION 2 EEM Methodologies: Lessons Learned

- International case studies: what works, what does not work, and emerging issues.
- Sampling techniques, data handling, and quality assurance procedures.
- Understanding ecological effects (spatial and temporal scales, cause and effect, trophic interactions).
- Effects on commercially and ecologically important species.

SESSION 3 EEM Methodologies and Technologies

- Air-borne contaminants and biological effects.
- Pelagic contaminants and biological effects.
- Benthic contaminants and biological effects.
- Advanced technologies and their application (statistical, analytical, engineering, *in situ* surveillance, monitoring systems, bioassay methods using indicator, field-collected, and caged species).
- Environmental indicators and indices.
- Cumulative effects monitoring.

An open discussion forum followed the workshop on **'Strengthening the Linkage between EEM and Environmental Management for the Offshore**'. The forum provided an opportunity for participants to review essential points that emerged during the workshop, to hear from a plenary speaker and a panel on the relationship between EEM and the regulatory environment, and to participate in an open discussion.

Acknowledgements

1. Workshop Organising Committee

Shelley Armsworthy	Fisheries and Oceans Canada, Marine Environmental Sciences Division (MESD)
Dave Burley	Canada-Newfoundland Offshore Petroleum Board
Peter J. Cranford	Workshop co-chair, Fisheries and Oceans Canada, MESD
Brian Giroux	Scotia Fundy Mobile Gear Fishermen's Association
Geoffrey Hurley	EnCana Corporation
Kenneth Lee	Workshop co-chair, Fisheries and Oceans Canada, Centre for Offshore Oil and Gas Environmental Research (COOGER)
Jennifer Matthews	Petroleum Research Atlantic Canada
Jim McComiskey	National Energy Board
Ted Potter	Fisheries and Oceans Canada, Oceans and Environment Division
Eric Theriault	Canada-Nova Scotia Offshore Petroleum Board
Brian Veitch	Memorial University of Newfoundland
Debra Walsh	Canadian Association of Petroleum Producers
Peter Wells	Environment Canada
Urban Williams	Petro-Canada

2. Session Co-Chairs

Torgeir Bakke	Norwegian Institute for Water Research (NIVA)
Paul Boehm	Battelle
Jan van Dalfsen	TNO-Environment
Charles Hannah	Fisheries and Oceans Canada, Oceans Science Division
Geoff Hurley	EnCana Corporation
Paul Montagna	University of Texas Marine Science Institute
Jerry Neff	Battelle
Stanley Rice	National Marine Fisheries Service, NOAA
Steinar Sanni	RFR Akvamiljø
Jeff Short	National Marine Fisheries Service, NOAA
John Thain	Centre for Environment, Fisheries and Aquaculture Science
Knut-Erik Tollefsen	Norwegian Institute for Water Research (NIVA)
Brian Veitch	Memorial University of Newfoundland
Peter Wells	Environment Canada

3. Workshop Sponsors

Fisheries and Oceans Canada
Environmental Studies Research Fund
Program for Energy Research and Development
Petroleum Research Atlantic Canada
Environment Canada
Canadian Association of Petroleum Producers
Canada-Newfoundland Offshore Petroleum Board

Canada-Nova Scotia Offshore Petroleum Board
National Energy Board

4. Workshop Contributors
Center for Offshore Oil and Gas Environmental Research (COOGER)
EnCana Corporation
Petro-Canada

5. Workshop Secretariat
Griffiths Muecke Associates (Anne Muecke and Lesley Griffiths)

6. Workshop Rapporteur
Roger Green, University of Western Ontario

7. Volunteers

Rosalie Allen	Fisheries and Oceans Canada, COOGER
Debbie Anderson	Fisheries and Oceans Canada, MESD
Amanda Barrett	Petroleum Research Atlantic Canada
Ginette Belbin	Fisheries and Oceans Canada, COOGER
Robert Benjamin	Fisheries and Oceans Canada, MESD
Kelly Bentham	Canadian Coast Guard Service
Cynthia Bourbonnais	Fisheries and Oceans Canada, MESD
Victoria Burdett-Coutts	Fisheries and Oceans Canada, Invertebrate Fisheries Division (IFD)
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Gary Wohlgeschaffen	Fisheries and Oceans Canada, COOGER
Tana Worcester	Fisheries and Oceans Canada, IFD

1. Workshop and Friday Forum Schedules

1.1 Platform Presentations Program

Monday May 27th, 2003

SESSION 1: EEM and Environmental Management
Session Co-Chairs: Brian Veitch, Jan van Dalfsen, and Geoff Hurley

10:30	**Workshop Opening in BIO Main Auditorium** ▪ Welcome to BIO by **Dr. Michael Sinclair** (DFO Regional Director, Science) ▪ Opening Remarks by **Dr. Kenneth Lee** (Workshop Co-Chair) ▪ Workshop Introduction by **Dr. Peter Cranford** (Workshop Co-Chair)
11:00	**Keynote 1: Offshore Oil and Gas Environmental Effects Monitoring Investigations Conducted by the U.S. Minerals Management Service** ***Ahlfeld, Thomas E.*** *U.S. Dept. of the Interior/Minerals Management Service, Branch of Environmental Sciences (4041), 381 Elden Street, Herndon, VA, 20170, USA*
11:40	**Overview of Environmental Risk Assessment and Monitoring: Past, Present, and Future** ***van Dalfsen, Jan A.****, M. Smit, and C.C. Karman* *TNO-Environment, Energy and Process Innovation, Dept. for Ecological Risk Studies, PO Box 57, 1780 AB Den Helder, The Netherlands*
12:00	**'Designing out' EEM** ***Hurley, Geoffrey*** *EnCana Resources, Halifax, NS, Canada*
1:40	**Evaluation of Offshore Drilling Cuttings Management Technologies Using Multicriteria Decision-Making** ***Worakanok, Thanyamanta (Bo) (student)*** *Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, NL, Canada*
2:00	**Adequacy of Monitoring Programs for Production and Exploratory Wells on the Grand Banks of Newfoundland** ***Payne, Jerry F.*** *Fisheries and Oceans Canada, P.O. Box 5667, St. John's, NL, Canada*
2:20	**Concept for the Environmental Impact Factor for Drilling discharges** ***Smit, Mathijs G.D.,*** *R.G. Jak, and J.A. van Dalfsen* *TNO Environment, Energy and Process Innovation, Department for Ecological Risk Studies, PO BOX 57, 1780 AB, Den Helder, The Netherlands*
2:40	**The Efficacy of *In-Situ* Remediation Techniques to Enhance Recovery of an Oil-Contaminated Salt Marsh** ***Lee, Kenneth*** *Centre for Offshore Oil and Gas Environmental Research, Bedford Institute of Oceanography, Fisheries and Oceans Canada P.O. Box 1006, Dartmouth, NS, B2Y 4A2, Canada*

3:40	**Prioritising Environmental Effects Monitoring (EEM) Programs: A Risk-Based Strategy** ***Sadiq, Rehan***[1], *Brian Veitch*[2], *Tahir Husain*[2], *and Neil Bose*[2] [1]*Institute for Research in Construction, National Research Council, Ottawa, ON, K1A 0R6, Canada;* [2]*Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, NL, A1B 3X5, Canada*
4:00	**A Community Based Approach to Environmental Effects Monitoring in the Beaufort Sea** ***Cott, Kelly J.***[1], *D.G. Cobb*[2], *and D.B. Chiperzak*[3] [1]*Fisheries and Oceans Canada, Box 1871, Inuvik, NT, X0E 0T0, Canada;* [2]*Fisheries and Oceans Canada, 501 University Cr., Winnipeg, MB, R3T 2N6, Canada;* [3]*Fisheries and Oceans Canada, Suite 101, 5204 50th Ave, Yellowknife, NT, X1A 1E2, Canada*
4:20	**Development of Effect Monitoring, Risk Estimates, and Decision Making for the Deep-Sea** ***Skadsheim, Arnfinn****, J.F. Børseth, A. Bjørnstad, E. Aas, and S. Sanni* *RF-Akvamiljø, Mekjarvik 12, N-4070 Randaberg, Norway*
4:40	**Environmental Effects Monitoring for Exploration Drilling of Single Wells** ***Buchanan, Robert A.***[1], *N. Collins*[2], *A. Mathieu*[3], *and P. Stewart*[4] [1]*LGL Limited, St. John's, NL, Canada;* [2]*CEF Consultants, Halifax, NS, Canada;* [3]*Oceans Ltd., St. John's, NL, Canada;* [4]*Envirosphere Consultants, Halifax, NS, Canada*
5:00	**Deciding When to Monitor Oil Spills: A Plan for Implementing Environmental Effects Monitoring During Production-Related Oil Spills in Eastern Canada** ***Trudel, Ken*** *S.L. Ross Environmental Research Ltd., 717 Belfast Road, Suite 200, Ottawa, ON, Canada*

Tuesday May 27th, 2003

SESSION 2: EEM Methodologies: Lessons Learned

Session Co-Chairs: AM - Jerry Neff and Paul Boehm; PM - Jeff Short and Peter Wells

8:40	**Sampling Design and Tools Used in SOEI's Offshore Environmental Effects Monitoring Program** *Belford, S.L.*[1], ***Cal Ross***[2], *and S.M. Fudge*[1] [1]*Jacques Whitford Environment Limited;* [2]*Sable Offshore Energy Inc. (Exxon/Mobil)*
09:00	**Sixteen Years of Harmonised Monitoring of Effects of Drilling Waste from Norwegian Offshore Installations. What Works and What Doesn't?** ***Bakke, Torgeir***[1] *and I. Nilssen*[2] [1]*Norwegian Institute for Water Research, POB 173, Kjelsas, N-0411 Oslo, Norway;* [2]*Norwegian Pollution Control Authority, POB 8100 Dep, N-0032 Oslo, Norway*
09:20	**Quantifying Post-Exploration Drill Impacts in South Caspian Sea Sediments** ***Maxon, Cynda L.***[1], *R.D. Tait*[2], *and F.C. Newton III*[1] [1]*Battelle Memorial Institute, 2382 Faraday Ave., Ste. 120, Carlsbad, CA, 92008, USA;* [2]*ExxonMobil Production Company, 800 Bell St., Houston, TX, 77002, USA*

09:40	**Sediment Profile Imaging: Impact Assessment in the South Caspian Sea** *Germano, Joseph D.[1], **Russell D.Tait**[2], David G. Browning[1], and Frederick Newton III[3]* *[1]Germano & Associates, Inc., Bellevue, WA, USA; [2]ExxonMobil Production Company, Houston, TX, USA; [3]Battelle Memorial Institute, Carlsbad, CA, USA*
10:00	**Long-term Trends and Monitoring of the Macrobenthos at Sullom Voe Oil Terminal, Shetland, UK** ***Woodham, Annette**[1], C. Dalgleish[1], P.F. Kingston[2], and J.M. Mair[2]* *[1]ERT (Scotland) Ltd, Research Ave. 1, Heriot-Watt University, Edinburgh, EH14 4AP, UK; [2]Centre for Marine Biodiversity and Biotechnology, School of Life Sciences, John Muir Building, Heriot-Watt University, Edinburgh, EH14 4AS, UK*
11:00	**Terra Nova Environmental Effects Monitoring Program: from EIS onward** ***DeBlois, Elisabeth M.**[1], C. Leeder[1], M. Murdoch[2], K.C. Penney[1], M.D. Paine[3], F. Power[4], and U.P. Williams[4]* *[1]Jacques Whitford Environment Ltd., St. John's, NL, Canada; [2]Jacques Whitford Environment Ltd., Fredericton, NB, Canada; [3]Paine, Ledge and Associates, North Vancouver, BC, Canada; [4]Petro-Canada East Coast Operations, St. John's, NL, Canada*
11:20	**Environmental Effects of Mercury in Permitted Discharges from Offshore Platforms in the U.S. Gulf of Mexico** ***Neff, Jerry M.**[1], J.P. Ray[2], J.P. Smith[3], and M.E. Parker[3].* *[1]Battelle Memorial Institute, Duxbury, MA, USA; [2]Shell Global Solutions, Houston, TX, USA; [3]ExxonMobil, Houston, TX, USA*
11:40	**Assessment of Environmental Impacts from Drilling Muds and Cuttings Disposal, Offshore Brunei** ***Presented by Steven Fudge*** *Sayle, Steve[1], M. Seymour[2], and E. Hickey[1]* *[1]Adinin-Jacques Whitford; [2]Brunei Shell Petroleum*
12:00	**Lessons for Offshore Oil and Gas EEM from the Pulp and Paper and Metal Mining EEM Programs** ***Courtenay, Simon C.**[1], S.D. St-Jean[1], K.R. Munkittrick[2], K. Kim[3], and W.R. Parker[4]* *[1]Fisheries and Oceans Canada, Gulf Fisheries Centre, Moncton, NB, Canada; [2]Department of Biology, University of New Brunswick, Saint John, NB, Canada; [3]Environment Canada, Dartmouth, NS, Canada; [4]Environment Canada, Fredericton, NB, Canada*
1:40	**Chronic Effects of Synthetic Drilling Muds on Sea Scallops (*Placopecten magellanicus*)** ***Armsworthy, Shelley**, P.J. Cranford, K. Lee, V. Burdett-Coutts, K. Querbach, and S. Magee* *Fisheries and Oceans Canada, PO Box 1006, Dartmouth, NS, B2Y 4A2, Canada*
2:00	**Distinguishing Between Artificial Reef Effects and Platform Effects on Benthos** ***Montagna, Paul A.**[1], S.C. Jarvis[1,3], and M.C. Kennicutt II[2]* *[1]University of Texas Marine Science Institute, 750 Channel View Drive, Port Aransas, TX, 78373, USA; [2]Geochemical and Environmental Research Group, Texas A&M University, 833 Graham Road, College Station, TX, 77845, USA; [3]Emu Ltd, Marine Laboratory, Ferry Road, Hayling Island, Hampshire, PO11 0DG, UK*

2:20	**Bioindicator Studies on Fish Health Around the Terra Nova Development Site on the Grand Banks** ***Mathieu Anne[1]***, *B. French[1], M. Dawe[1], E. Deblois[2], F. Power[3], and U. Williams[3]* *[1]OCEANS LTD, St. John's, NL, Canada; [2]Jacques Whitford Environment LTD, St. John's, NL, Canada; [3]Petro Canada, East Coast Operations, St. John's, NL, Canada*
2:40	**Gas Pipelines and the American Lobster, *Homarus americanus*** ***Cooper, Richard A.***[1], *M. Clancy[2], and J.S. Cobb[3].* *[1]University of Connecticut, Avery Point Campus. Groton CT, 06340, USA; [2]Boston University, Boston, MA, 02215, USA; [3]University of Rhode Island, Kingston, RI, 02881, USA*
3:40	**Long Term Lessons Learned from the *Exxon Valdez*: Acute Toxicity versus Chronic Embryotoxicity** ***Rice, Stanley D.****, J.W. Short, R. Heintz, and M.G. Carls* *Auke Bay Laboratory, National Marine Fisheries Service, 11305 Glacier Highway, Juneau, AK, 99801, USA*
4:00	**Monitoring Oil Persistence on Beaches- SCAT versus Stratified Random Sampling Designs** ***Short, Jeffrey W.,*** *Mandy R. Lindeberg, Patricia M. Harris, Jacek M. Maselko, Jerome J. Pella, and Stanley D. Rice* *Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 11305 Glacier Highway, Juneau, AK, USA*
4:20	**Monitoring and Mitigating the Effects of Open-Water Seismic Operations on Marine Mammals in the Southeastern Beaufort Sea, 2001-2002** *Miller, G.W.[1],* ***Peter Millman[2]****, R.A. Davis[1], V.D. Moulton[3], A. MacGillivray[4], D. Hannay[4], M. Holst[1], R.E. Elliott[1], A. Serrano[1], and S. Carr[4]* *[1]LGL Limited, Environmental Research Associates, 22 Fisher St., P.O. Box 280, King City, ON, L7B 1A6, Canada; [2]Devon Canada Corporation, 1600-324 Eighth Ave. SW, Calgary, AB, T2P 2Z5, Canada; [3]LGL Limited, environmental research associates, Box 13248, Stn. A, 388 Kenmount Rd., St. John's NL, A1B 4A5, Canada; [4]JASCO Research Ltd., Ste 2101-4464 Markham St., Victoria, BC, V8Z 7X8, Canada*
4:40	**Effects of Seismic Energy on Snow Crab (*Chionoecetes opilio*)** ***Christian, John R.***[1], *A. Mathieu[2], D. White[2] and R.A. Buchanan[1]* *[1]LGL Limited, St. John's, NL, Canada; [2]Oceans Ltd., St. John's, NL, Canada*
5:00	**Sediment Quality in Depositional Areas of Shelikof Strait and Outermost Cook Inlet** ***Brown, John S.*** *and P.D. Boehm* *Battelle, 255 Bear Hill Road, Waltham, MA 02451, USA*

Wednesday May 28th, 2003

SESSION 2: EEM Methodologies: Lessons Learned
Session Co-Chairs: AM – Paul Montagna and Cal Ross; PM - Torgeir Bakke and Steinar Sanni

8:40	**Keynote 2: Marine Coastal Monitoring Designs: Examples for Offshore Oil and Gas EEM** ***Green, Roger H.*** *Dept. of Biology, University of Western Ontario, London, ON, N6A 5B7, Canada*
9:20	**Distribution of Suspended Particulate Drilling Wastes at the Hibernia Oilfield** ***Muschenheim, D. Kee**, T.G. Milligan, A. Stewart, and B. Law* *Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada*
9:40	**Quantifying fine-grained drill waste in Scotian Shelf Suspended Sediments** ***Milligan, Tim G.**, T. Tedford, D.K. Muschenheim, and C. Hannah* *Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada*
10:00	**Scallops as Sentinel Organisms for Monitoring Environmental Effects of Offshore Oil and Gas Operations** ***Cranford, Peter J.**[1], S.L. Armsworthy[1], and K. Lee[2]* *Fisheries and Oceans Canada, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, NS, B2Y 4A2, Canada: [1]Marine Environmental Sciences Division; [2]Canada Centre for Offshore Oil and Gas Environmental Research*
11:00	**Grain Size Normalisation of Sediment Heavy Metal Data** ***Yeats, Phil A.*** *Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada*
11:20	**Using Ba/Al Ratios to Estimate Baseline Barium Sediment Concentrations and Monitor Changes in Barium Concentrations on a Regional Scale in Newfoundland's Off Shore Oil Field** ***Veinott, Geoff*** *Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre, P.O. Box 5667, St. John's, NL, A1C 5X1, Canada*
11:40	**BioSea – A Research Project to Provide Knowledge and Data for Predicting and Monitoring Potential Biological Effects in the Arctic by Oil Industry** ***Sanni, Steinar**[1] and Melania Buffagni[2]* *[1]Akvamiljø a/s, Mekjarvik 12, N- 4070 Randaberg, Norway; [2]ENI s.p.a. - Agip Division, Area Field Laboratories, Environmental lab., dpt. LAPO, P.O. Box 12069, 20120 Milano, Italy*
12:00	**Environmental Monitoring of Oil and Gas Activities in Deep Waters West of Britain: Challenges and New Approaches** ***Hartley, John P.*** *Hartley Anderson Ltd., Blackstone, Dudwick, Ellon, Aberdeenshire AB41 8 ER, UK*
1:40	**The Cuttings Pile Issue: How to Provide the Necessary Information to Assess the Impacts of Cuttings and Mud Accumulations Around Offshore**

	Installations? *Grethe Kjeilen and* ***Stig Westerlund*** *RF- Rogaland Research, Norway*
2:00	**Transport Properties of Discharged Synthetic Based Drilling Wastes** ***Haibo, Niu (student)*** *Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, NL, Canada*
2:20	**Assessing Environmental Fate and Behaviour of Oil Discharges in Marine Ecosystem: Using Fugacity Model** ***Khan, M. Ibrahim (student)*** *and M.R. Islam* *Oil and Gas Program, Faculty of Engineering, Dalhousie University, Halifax, NS, Canada*
2:40	**The Role of Mass Balance Models in Offshore Oil and Gas Environmental Effects Monitoring** ***Warren, Christopher (student)*** *and D. Mackay* *Canadian Environmental Modelling Centre, Trent University, Peterborough, ON, K9J 7B8, Canada*
3:40	**Can *In Situ* Invertebrate Communities Directly or Indirectly Affect Toxicity Test Results?** ***Paine, Michael D****[1]., E.M. DeBlois[2], S. Whiteway[2], F. Power[3], and U. Williams[3]* *[1]Paine, Ledge and Associates, North Vancouver, BC, Canada; [2]Jacques Whitford Environment Ltd., St. John's, NL, Canada; [3]Petro-Canada, St. John's, NL, Canada*
4:00	**Livebottom Impact Reduction, Mitigation, and Monitoring for the Construction of a Subsea Natural Gas Pipeline in the Gulf of Mexico** ***Ellsworth, Susan W.****[1], D.E. Martin[2], R. Schaul[3], and J. Schmidt[1]* *[1]ENSR International; [2]Williams Companies; [3]Sea Byte, Inc.*
4:20	**Aspects of Polycyclic Aromatic Hydrocarbons in Offshore Sediments in the Azeri Sector of the Caspian Sea** ***Boehm, Paul D.****[1], C.L. Maxon[2], F.C. Newton[2] , J.S. Brown[1], and Y. Galperin[2]* *[1]Battelle Memorial Institute, 255 Bear Hill Road, Waltham, MA, 02451, USA; [2]Battelle Memorial Institute, 2382 Faraday Ave., Ste. 120, Carlsbad, CA, 92008, USA*
4:40	**Monitoring for PAH Exposure Using Bile Metabolites and Concentrations in Tissues: Continuing to Raise Questions** ***Hellou, Jocelyne****[1], T.K. Collier[2], F. Ariese[3], and J. Leonard[1]* *[1]Marine Chemistry Section, Marine Environmental Sciences Division, Bedford Institute of Oceanography, Dartmouth, NS, B2Y 4A2, Canada; [2]Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd East, Seattle, WA, 98112, USA; [3]Vrije Universiteit, Instituut voor Milieuvraagstukken, de Boelelaan 1115, NL-1081 HV Amsterdam, The Netherlands*

Thursday May 28th, 2003

SESSION 3: EEM Methodologies and Technologies
Session Co-Chairs: AM – Knut-Erik Tollefsen and Stanley Rice; PM - John Thain and Charles Hannah

8:40	**Keynote 3: Ongoing Monitoring Programs Relevant for the Offshore Oil and Gas Industry in Norway, Emphasising Methods and Trends Seen in the Perspective of the Development of Hydrocarbon and Produced Water Discharges** ***Melbye, Alf*** *SINTEF Applied Chemistry, Marine Environmental Technology, S.P. Andersens vei 15 A, 7465 Trondheim*
9:20	**Evaluation of Risks from Produced Water Discharges in Atlantic Canada** ***Lee, Kenneth***[1]*, Kumiko Azetsu-Scott*[2]*, Phil Yeats*[3]*, Sherry Niven*[3]*, Gary Wohlgeschaffen*[1]*, John Dalziel*[3]*, Tim Milligan*[3]*, Charles Hannah*[2]*, and Alain Vezina*[2] *Fisheries and Oceans Canada, P.O. Box 1006, Dartmouth, NS, B2Y 4A2, Canada:* [1]*Centre for Offshore Oil and Gas Environmental Research;* [2]*Ocean Sciences Division;* [3]*Marine Environmental Sciences Division*
9:40	**Environmental Modelling of Produced Water and Indicators for EEM** ***Berry, Jody A. (student)***[1] *and P.G. Wells*[1,2] [1]*Halifax, NS, Canada;* [2]*Environment Canada, Environmental Conservation Branch, 45 Aldeney Drive, Dartmouth, NS, Canada*
10:00	**Assessing the Impact of Produced Water Discharges in the North Sea – Comparison of Field Monitoring and Modelling** ***Durell, Gregory S.***[1]*, T. Røe-Utvik*[2]*, S. Johnsen*[3]*, T. Frost*[3]*, and J. Neff*[1] [1]*Battelle, 397 Washington Street, Duxbury, MA, 02332, USA;* [2]*Norsk Hydro, Sandsli, N-5020 Bergen, Norway;* [3]*Statoil Research Centre, N-7005 Trondheim, Norway*
11:00	**Biological Effects in Pelagic Ecosystems – An Overview of the ICES Workshop BECPELAG** *Hylland, K., G. Becker, J. Klungsøyr, T. Lang, A. McIntosh, B. Serigstad,* ***John E. Thain****, K.V. Thomas, T.I.R. Utvik, D. Vethaak, and W. Wosniok* *NIVA, P.O.Box 173, Kjelsas, N-0411 Oslo, Norway*
11:20	**The Experience From Using *In Situ* Deployment of Live Organisms and Passive Samplers During the ICES BECPELAG Workshop** ***Thain, John E.****, K. Hylland, B. Serigstad, G. Becker, J. Klungsøyr, T. Lang, A. McIntosh, K.V. Thomas, T.I.R. Utvik, D. Vethaak, and W. Wosniok* *CEFAS, Burnham-on-Crouch, Remembrance avenue, Essex, CMO 8HA, UK*
11:40	**An Assessment of the *In Vitro* Oestrogen Receptor Agonist Potency and Alkylphenol Content of Produced Water Discharges into the North Sea** ***Thomas, Kevin V.****, J. Balaam, M.R. Hurst, and J.E. Thain* *CEFAS, Burnham on Crouch, Essex, CM0 8HA, UK*
12:00	**Development and Field Validation of the EIF as a Produced Water Discharge Management Tool** ***Frost, Tone Karin*** *and S. Johnsen,* *Statoil Research Centre, Norway*

1:40	**Bioassay-Directed Fractionation and Chemical Identification of Complex Effluents from Oil Production Activities** ***Tollefsen, Knut-Erik*[1]*, Merete Grung*[1]*, Christian Dye*[2]*, Marc Berntssen*[3]*, Thomas Hartnick*[4]*, Leif Norrgren*[5]*, Jan Balaam*[6]*, and Kevin Thomas* [6] *[1]NIVA-Norwegian Institute for Water Research, Norway, [2]NILU - Norwegian Institute for Air Research, Norway, [3]NIFES - Norwegian Institute for Fisheries and Seafood Research, Norway, [4]Jordforsk, Norway, [5]SLU - Swedish Agricultural University, Sweden, [6]Centre for Environment, Fisheries & Aquaculture Science, UK*
2:00	**Evaluation of bblt, a Drilling Mud Dispersal Model, at North Triumph (Scotian Shelf)** ***Hannah, Charles****, Adam Drozdowski, Kee Muschenheim, and John Loder* *Bedford Institute of Oceanography, Dartmouth, NS, Canada*
2:20	***In Situ*** **Deployment of Fish, Mussels and Passive Samplers to Monitor Accumulation and Effects of Contaminants** ***Serigstad, Bjorn*** *Ocean Climate A/S / Institute of Marine Research, Østre Natlandsfjellet 13, N-5098 Bergen, Norway*
2:40	**Potential Effects of Produced Water Discharges from Offshore Oil and Gas Production Activities on the Early Life Stages of Haddock (*Melanogrammus aeglefinus*), Lobster (*Homarus americanus*) and Sea Scallop (*Placopecten magellanicus*)** ***Querbach, Kirsten***[1]*, G. Maillet*[2]*, P. Cranford*[1]*, C. Taggart*[2]*, K. Lee*[3]*, and J. Grant*[2] *[1]Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, B2Y 4A2, Canada; [2]Dalhousie University, Department of Oceanography, Halifax, NS, B3H 4J1, Canada; [3]Centre for Offshore Oil and Gas Environmental Research, Bedford Institute of Oceanography, Fisheries and Oceans Canada P.O. Box 1006, Dartmouth, NS, B2Y 4A2, Canada*
3:40	**Impacts of Nutrient Inputs from Produced Water on Marine Planktonic Production: An Ecosystem Modelling Approach** *Khelifa, Ali*[1]*, Markus Pahlow*[2]*,* ***Alain Vézina***[2]*, Kenneth Lee*[3]*, and Charles Hannah*[2] *[1]Department of Oceanography, Dalhousie University, Halifax, NS, B3H 4J1, Canada; Fisheries and Oceans Canada, P.O. Box 1006, Dartmouth, NS, B2Y 4A2, Canada: [2]Ocean Sciences Division; [3]Centre for Offshore Oil and Gas Environmental Research*
4:00	**Seasonal and Spatial Patterns of Marine Bird and Mammal Occurrences Recorded on Offshore Support Vessel Transects on the Grand Banks** ***Montevecchi, W.A.****, C.M. Burke, G.K. Davoren, and F.K. Wiese* *Biopsychology Program, Memorial University of Newfoundland, St. John's, NL, A1B 3X9, Canada*
4:20	**Interaction and Remediation of Oil Spills in Ice Infested Waters: An Experimental and Numerical Investigation** ***Bjorndalen, Nancy (student)***[1]*, S. Mustafiz*[1]*, A. Basu*[1]*, K. Lee*[2]*, and M.R. Islam*[1] *[1]D510, 1360 Barrington Street, Dalhousie University, Halifax, NS, B3J 2X4, Canada; [3]Centre for Offshore Oil and Gas Environmental Research, Bedford Institute of Oceanography, Fisheries and Oceans Canada P.O. Box 1006, Dartmouth, NS, B2Y 4A2, Canada*

1.2 Friday Forum Schedule

The objective of the Forum was to address linkages between environmental effects monitoring and environmental management for the Offshore.

Friday, May 30th, 2003
Chair: Ted Potter, Fisheries and Oceans Canada

9:00	Overview of the Offshore Oil and Gas EEM Workshop Roger H. Green[1], Workshop Rapporteur
9:30	EEM Under the Fisheries Act: Lessons Learned and Future Directions Kathleen Hedley[2], Plenary Speaker
10:00	Refreshment Break
10:20	Panel Discussion: Each panellist has five minutes to present their perspective on EEM, followed by a moderated response/discussion among the panel members. This is followed by questions from the audience. - Moderator - Mr. Carey Ryan - ENGO - Dr. Robert Rangely - Industry - Mr. Cal Ross - Regulatory - Mr. Andrew Parker - Academic - Ian McLaren - Plenary Speaker - Kathleen Hedley
11:50	Forum closing

[1]Dr. Roger H. Green is an environmental biologist with the University of Western Ontario whose research emphasises the use of freshwater and marine invertebrates for bio-monitoring. In addition he consults and collaborates in a variety of impact and monitoring studies such as oil spills, oil and gas development, and contaminant and heated effluent discharges.

[2]Kathleen Hedley is the manager of the National EEM Office with Environment Canada in Ottawa. Her office is responsible for:

- Developing the national EEM programs
- Leading national analysis of EEM Data
- Ensuring national consistency in the implementation of the EEM program
- Leading multi-stakeholder consultations on EEM programs
- Tracking EEM-related research to ensure EEM programs evolve with science
- Promoting use of environmental effects as a basis for environmental risk management

2. Platform Presentation Abstracts with Questions and Answers

2.1 Session 1 - EEM and Environmental Management

Offshore Oil and Gas Environmental Effects Monitoring Investigations Conducted by the U.S. Minerals Management Service

Ahlfeld, Thomas E.
U.S. Dept. of the Interior/Minerals Management Service, Branch of Environmental Sciences (4041), 381 Elden Street, Herndon, VA, 20170, USA

This presentation will provide a summary of lessons learned from completed and ongoing monitoring projects conducted by the Minerals Management Service (MMS). These include investigations designed to determine the environmental effects associated with oil and gas exploration activities, the effects of long-term offshore production activities, effects of oil spills, and effects on habitats and biological communities of special concern such as the Flower Garden Banks National Marine Sanctuary. The future direction of MMS environmental effects monitoring will also be discussed.

Question 1: Do you think you could provide advice to regulators if you didn't have a government-run program?
Answer: We rely on the program. We need to get information and that corresponds with the timing of development. The Federal program is required.

Question 2: How is this related to the Beaufort Sea research project?
Answer: There is a symposium session in October 2003 and a report of that research will follow. It is expected that another phase of research will follow. Information and reports on this will be available through the Minerals Management Service website.

Overview of Environmental Risk Assessment and Monitoring: Past, Present, and Future

van Dalfsen, J.A.*, M. Smit, and C.C. Karman*
TNO-Environment, Energy and Process Innovation, Dept. for Ecological Risk Studies
PO Box 57, 1780 AB Den Helder, The Netherlands

In Northwestern Europe, OSPAR regulations and guidelines are followed. The CHARM model is used as a Hazard and Risk assessment model for the purpose of E&P chemicals, notification and environmental care within the offshore oil and gas industry. Recently, it has been agreed upon that risk assessment should become a general approach within OSPAR as a measurement for reducing the environmental impacts. Increased concerns over the potential impact produced by the oil and gas industry's move to new areas – often defined as sensitive due to vulnerable species and populations – has identified the need to evaluate critically the methodological links between Environmental Risk Assessment, Biological Effect Monitoring (= the field validation methods) and relevant ecological impacts. Validation is required to ensure that the assessments are reliable, ranging from field validation of laboratory results (field monitoring) to performance testing of computer models such as DREAM, PROTEUS and CHARM. However, the

results of impact monitoring studies and environmental risk assessment models have not been, or cannot be, compared in a general, scientifically sound manner, mainly due to missing links between the two methodologies. Moreover, the ecological relevance of biomarker responses is poorly defined, being actually the parameter on which threshold levels for environmental impact should be based. This paper gives an overview of the development of the present regulations and requirement for NW Europe. To illustrate this, examples of recent and past EEM programs are given. Furthermore the need is discussed to couple ecosystem management and risk assessment using biomarkers in order to validate risk assessment models making use of biological effect monitoring.

Question 1: Why was the 10km distance chosen?
Answer: We didn't know where the potential effects might occur, so we measured at a greater distance. We did find that most effects were within 500-1000m.

'Designing Out' EEM
Hurley, Geoffrey
EnCana, Halifax, NS, Canada

Using appropriate engineering design supported by company policies and procedures, the need for EEM can be 'designed out' in the early stages of project planning. The benefits of this strategy include reduced environmental impact, reduced operations costs, timely regulatory approvals, and increased company goodwill. The proposed EnCana Deep Panuke Project was guided based on this 'designing-out' strategy. Examples include the proposed injection of waste acid gases, Codes of Practice for sensitive areas and the use of formal risk assessments for decision making. EnCana believes that by avoiding potential environmental impacts through sound design, the requirements for EEM are minimised.

Question 1: Why minimise the effects, should this not invite monitoring?
Answer: It doesn't preclude monitoring but it reduces the scope of it. The costs of EEM are high and this can tip the balance in decision making on a project. This will allow for verification.

Question 2: Identifying and avoiding potential issues in pre-project design makes things easier on the regulators. I encourage such an approach.
Answer: Regulators don't have an easy time, and this provides industry time to make adjustments.

Evaluation of Offshore Drilling Cuttings Management Technologies using Multicriteria Decision-Making
Worakanok, Thanyamanta (student)
Faculty of Engineering, Memorial University of Newfoundland, St. John's, NL, A1B 3X5, Canada

Offshore oil exploration industries, due to stringent environmental regulations and high risk and cost of ship-to-shore treatment alternative, are interested to find on-site cost-effective solutions to manage drill cuttings for their drilling operations. Consequently, on-site management techniques for drilling cuttings are the focus of this study. Among a number of existing and emerging technologies, each technology for managing drilling cuttings varies in technical, environmental, and economic points of views. In order to select a drilling cuttings management plan to be applied on an offshore platform, a thorough study of options is critical. In this study, multi-criteria decision-making has been applied to help assess twelve cuttings management alternatives. The criteria include one threshold criterion, namely conformity with regulations, and four major categories of decision-making criteria: technical feasibility, rig compatibility, environmental impacts, and costs. The alternatives evaluated include the technologies that are currently used offshore, those used onshore but with potential for offshore applications, and innovative technologies. The criteria are given weights corresponding to their significance. For comparison purposes, quantitative and qualitative scoring schemes are applied to represent the properties of management alternatives. Assumed uncertainties are also assigned to each score to illustrate their impact on the reliability of the final results. The total score for each option and its associated uncertainty is then calculated using the additive overall value model. The management options are then ranked according to the results of the evaluation, and the three existing technologies with the highest overall scores are recommended as the optimum technologies. Due to the unavailability of data for the innovative technologies, only the technical and environmental aspects are taken into consideration. The evaluation method is then analysed, and the dominating or the most significant evaluation criteria are specified.

Question 1: You used multi-criteria. How useful is this for looking at environmental effects?
Answer: It is useful because it involves discharge of cuttings into the oceans. This method is preferred by industry and complies with the regulations.

Question 2: The negative part of the equation was related to costs. Was the cost of environmental effects on things such as fisheries and tourism included?
Answer: One of the criteria is post-treatment activity and those activities are the types of things included, although not in terms of financial cost.

Adequacy of Monitoring Programs for Production and Exploratory Wells on the Grand Banks of Newfoundland

Payne, Jerry F.
Science, Oceans and Environment Branch, Fisheries and Oceans Canada, P.O. Box 5667, St. John's, NL, A1C 5X1, Canada

The offshore oil and gas industry, which is developing off the east coast of Canada, will continue to be in the public eye over the next few decades with respect to concerns for potential effects on fisheries and the environment. Overall, the majority of information available from field and laboratory studies suggests that offshore impacts will likely be

minimal. However, monitoring programs are required to assess hypotheses about nature and scale of impacts as well as to possibly uncover new insights, which can only come from such programs. The Department of Fisheries and Oceans in the Newfoundland Region has generally recommended that components of an EEM program should include physical, chemical, and biological oceanography, monitoring for potential effects on fish, fish habitat and fish quality (taint), as well as more traditional chemical monitoring of waters and sediments. It is also recognised that somewhat different approaches may be required for different sites due to differences in eco-toxicological potential of discharges (e.g. gas versus oil wells), species or resources at risk, habitat types and current regimes. Likewise, since EEM should follow a feedback process, caution is warranted with respect to locking into rigid or "harmonised" programs. The Region has also recognised as a fundamental principle, that many EEM programs place emphasis on determining the nature and extent of any adverse effects on fish and the fishing industry (e.g. real or phantom fears about fish contamination, which may have major socio-economic consequences). The importance of "assurance", "comfort", or "check" monitoring cannot be overstated in this regard. The Canada Newfoundland Offshore Petroleum Board is the regulatory authority for development in the Grand Banks area. The monitoring programs being carried out in the Newfoundland Region with respect to oil and gas activities equal or surpass those being carried out in the North Sea, the Gulf of Mexico, and Australia. This will be discussed. What about exploratory drilling? Given that exploratory drilling may soon come under Canadian Environmental Assessment Act, major questions are being asked about the need for either extensive baseline work or EEM programs for exploratory drilling. This question will also be discussed in relation to pertinent laboratory and field studies.

A Concept for the Environmental Impact Factor for Drilling Discharges

Smit, M.G.D.*, R.G. Jak, and J.A. van Dalfsen*
TNO Environment, Energy and Process Innovation, Department for Ecological Risk Studies, PO BOX 57, 1780 AB, Den Helder, The Netherlands

The EIF concept (Environmental Impact Factor) is a methodology developed within the DREAM project (Dose-related Risk and Effect Assessment Model) in which Norwegian oil companies together with consultants from Norway and the Netherlands developed an ERA model for produced water releases. The DREAM model is based on a 3D-dispersion model for produced water combined with a PEC:PNEC approach. The EIF is approved by the Norwegian authorities to be the tool for defining platform-specific risk-reducing measures. In 2002, a new research project started to develop an EIF for drilling discharges, next to the EIF for produced water releases. It is the objective of the industries and the authorities that this EIF will be used for reducing the environmental impact of the drilling process (selection of applied chemicals and improving techniques). In this presentation, the basic concept for an EIF for drilling discharges will be presented. Attention will be given to the acute effects of drilling discharges to the water column as well as chronic effects to the benthic community. Both toxicological and physical effects of chemicals and suspended matter from muds and cuttings will be taken into account.

When fully developed, this risk assessment approach will totally integrate (effect) monitoring and environmental management.

Question 1: Does the Environmental Impact Factor take into account stimulatory effects, for example, of produced water?
Answer: It is not yet part of the program. We've been following the guidelines. We know that there may be some beneficial effects to the environment. We go from risk assessment to effects assessment.

Question 2: There seems to be a knowledge gap. How do you bring in chronic toxicity when you have been dealing primarily with acute toxicity?
Answer: It is a drawback that we haven't addressed chronic toxicity. We have done long-term studies, and we see normal response curves. There is stimulation and other mechanisms going on. We need to bring biology and other things into the assessment.

The Efficacy of *In-Situ* Remediation Techniques to Enhance Recovery of an Oil-Contaminated Salt Marsh

Kenneth Lee
Centre for Offshore Oil and Gas Environmental Research, Bedford Institute of Oceanography Fisheries and Oceans Canada P.O. Box 1006 Dartmouth, NS, B2Y 4A2, Canada

Wetlands are among the most sensitive of habitats to oil spills. A field experiment was conducted on a salt marsh in Atlantic Canada to determine the significance of bioremediation by nutrient enrichment in enhancing wetland restoration. Six experimental treatments were monitored: (1) unoiled control (2) unoiled control + nutrients, (3) oil with no treatment (natural attenuation), (4) oil + nutrients, (5) oil + nutrients with plants cut back, (6) oil + nutrients with disking (tilling) to enrich oxygen penetration. Remediation success was quantified by determining changes in the composition and concentration of the residual oil, plant recovery, and reduction in sediment toxicity. The experimental results advocate natural attenuation as the clean-up strategy for the ecotype under study. Within the untreated plots, significant recovery of the predominant plant species within the marsh (*Spartina alterniflora*) was observed after 20 weeks and approximately 90% of the resolved n-alkanes and 70% of the parent and alkyl-substituted polyaromatic hydrocarbons (PAH) were biodegraded.

Question 1: Is there anything about the oil type that your results are dependent upon?
Answer: The type of oil makes a difference in toxicity. This oil was pre-weathered until it lost some of the volatile hydrocarbons. We tried to simulate the oil type that would come ashore.

Question 2: What was the specific gravity used?
Answer: 0.85 specific gravity. 18% of the oil was weathered off.

Prioritising Environmental Effects Monitoring (EEM) Programs: A Risk-Based Strategy

Rehan, Sadiq[1]*, Brian Veitch*[2]*, Tahir Husain*[2]*, and Neil Bose*[2]

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Municipal and industrial waste discharges into water bodies (oceans, rivers) deteriorate ambient water quality. Environmental effect monitoring (EEM) programs are designed to detect any adverse effects of undesirable substances at various locations in the receiving water body. Population- and concentration-based approaches are used for the design of EEM programs. The population-based approach prioritises the EEM program using the density or sensitivity of receptors (ecological entities). The concentration-based approach prioritises the EEM program using the intensity of stressors (pollutant concentrations). The population and concentration-based methods focus on frequency and potential hazard of damage, respectively. Ecological risk can be measured only if receptors are exposed to pollutants in concentrations sufficient to cause adverse effects. Existing methods do not always consider both factors simultaneously. The proposed approach ranks the EEM program based on ecological risk posed to a given population for controlled discharges or accidental spills. The risk-based method can be very helpful for designing and prioritising economical EEM programs. The method is applied to a case study.

Comment: This is the framework around the EEM. Zone of influence versus biology is a more structured approach. There is no criticism towards similar studies.

Question 1: Why not rely on statistical analysis with regression?
Answer: This is a naive model! The model was built to answer the simple questions posed by the workshop co-ordinators to the presenters.

A Community-Based Approach to Environmental Effects Monitoring in the Beaufort Sea

Cott, K.J.[1]*, Cobb, D.G.*[2] *and D.B. Chiperzak*[3]

[1]*Fisheries and Oceans Canada, Box 1871, Inuvik, X0E 0T0, NT, Canada;* [2]*Fisheries and Oceans Canada, 501 University Cr., Winnipeg, R3T 2N6, MB, Canada;* [3]*Fisheries and Oceans Canada, Suite 101, 5204 50th Ave, Yellowknife, X1A 1E2, NT, Canada*

Renewed interest in oil and natural gas in the Beaufort Sea has led to concerns about environmental effects resulting from the oil and gas activities. While environmental effects monitoring programs are being conducted by the industry to meet regulatory requirements, and by government agencies in relation to cumulative impact assessment, nobody feels the importance of understanding the environmental changes resulting from oil and gas activities more than the people that live in coastal communities. With the settlement of land claims in Canada's Arctic, a co-management approach to resource allocation and use, research, and monitoring has been established. This new form of governance in the Arctic is dependent on a high level of community involvement and

consultation. The Tariuq (Ocean) community-based monitoring program was piloted in Tuktoyaktuk and Aklavik in 2001 as one of the initiatives under the Beaufort Sea Integrated Management Planning Initiative. It is consistent with the principles outlined in Canada's *Oceans Act* and *Canada's Oceans Strategy*. The program engages coastal communities in monitoring the health of the Beaufort Sea through their participation in the selection of indicators, conducting of monitoring activities, review of monitoring results, and finally, the dissemination of the findings back to the community. Concurrently, it builds capacity within the communities and presents an opportunity to engage and train youth in scientific sampling methods. Community-based monitoring provides the benefits of incorporating traditional knowledge and scientific methodology into a monitoring program. It can also provide a broader spatial and temporal coverage than industry and government monitoring programs.

Question 1: How are these people trained in fish health?
Answer: They are trained in the collection of fish tissue data through gill netting and a few other techniques. Most of the analysis is done by DFO.

Comment: Similar initiatives are taking place in Alaska, in terms of community-based ecosystem approach.

Development of Effects Monitoring, Risk Estimates, and Decision-Making for the Deep-Sea

***Skadsheim, A.**, J.F. Børseth, A. Bjørnstad, E. Aas, and S. Sanni*
RF-Akvamiljø, Mekjarvik 12, N-4070 Randaberg, Norway

Past three decades of activity in the North Sea the oil and gas industry is progressing towards deeper waters off the Atlantic shelf margin and into the Arctic. This parallels the Canadian development. Regarding the fate of discharges and their potential for impact, both Atlantic sides have types of current systems and many species in common, and the industrial activities occur in some of the world's most biologically productive oceanic waters. Thus, many methods may possibly be generally applicable with respect to area and depth. In parallel to programs on environmental impact and risk assessment in shallow waters, we have initiated research on exposure, uptake, and effects in the deep-sea. We have found that at high pressure the solubility of some hydrocarbons changes in oil, water, and lipids. This influences uptake dynamics and the poorly studied effect expression. Descriptions and verifications are required to elucidate to which degree knowledge gained at surface water conditions may be applicable for the deep-sea and how organisms may be moved between depths and kept alive for data sampling. For many groups of marine organisms, toxic end points on hydrocarbons have not been recorded at any depth. However, it is acknowledged that body burdens and a suite effects parameters measured in parallel on different organisms will improve the authorities' and the industry's decision-making and provide a basis for future monitoring. Such a suite of parameters, or a "toolbox" of methods, facilitates step-wise decisions based on increasingly specific data covering statistical predictive power, cause-effect relationships, ecological relevance, and cost-effective methods. We pursue a lab and field development

of risk estimates and effect based monitoring. It includes basic studies of deep-sea organisms, caging and submersion of shallow water organisms for site specific monitoring, and studies on how biomarker (effect) techniques developed for shallow waters may work in the deep-sea. A high-pressure experimental set-up is used to study uptake and effects (biomarkers) in live marine organisms. Examples on the types of methods will be presented and illustrated with results from the laboratory and deep-sea fieldwork.

Question 1: Can you give a rough appreciation of this program?
Answer: Understanding objectives versus cost to get the deliverables is the toughest part of the program. We must establish a structured first approach.

Environmental Effects Monitoring for Exploration Drilling of Single Wells

Buchanan, R.A.[1]*, N. Collins*[2]*, A. Mathieu*[3]*, and P. Stewart*[4]
[1]LGL Limited, St. John's, NL, Canada; [2]CEF Consultants, Halifax, NS, Canada; [3]Oceans Ltd., St. John's, NL, Canada; [4]Envirosphere Consultants, Halifax, NS, Canada

The government-industry Environmental Studies Research Fund (ESRF) contracted LGL Limited, CEF Consultants Ltd., OCEANS Ltd., and Envirosphere Consultants Ltd. to design a strategy for environmental effects monitoring (EEM) for single offshore exploratory wells on the east coast of Canada. Ideally, monitoring programs should test impact predictions made during environmental assessment, address stakeholder concerns, succeed in detecting effects, be scientifically and statistically defensible, and be cost-effective. Monitoring of development wells and/or production platforms has been carried out for many developments worldwide, sometimes for years at a time. In contrast, monitoring a single exploratory well in the North Atlantic presents a number of special challenges such as the speculative nature of exploration, short lead times, generally small areas of effects, and difficult to detect signals. Background research for the study included interviews with a range of NGOs, fishing industry, and oil and gas representatives, and a literature review. Following the selection of appropriate variables for evaluation, EEM strategies were developed. A scenario approach was used to determine which study designs were generally applicable, and which ones were site-specific. Statistical approaches were reviewed to determine optimum sampling strategy and allocation of resources.

Deciding When to Monitor Oil Spills: A Plan for Implementing Environmental Effects Monitoring During Production-Related Oil Spills in Eastern Canada

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This paper describes a three-tiered system for conducting environmental effects monitoring (EEM) for marine oil spills. Marine oil spills can be very large and destructive, but most are small, causing little damage. When spills occur, EEM is needed

for a variety of purposes, but EEM can be costly. A detailed EEM plan has been developed to address the unique EEM needs of marine oil spills on an effective and cost-effective basis. This paper describes the plan's implementation system that matches the level of monitoring effort (and cost) to the level of environmental damage caused by the spill. The plan addresses EEM needs for human health protection and environmental damage assessment. EEM for each target group (e.g. marine birds, commercial fishery species) involves numerous tasks. The plan divides the tasks for each target group into three tiers, each successive tier gathering more data and more reliable data than the one before. In some cases, the objectives of monitoring shift as the scale of damage increases. The level of monitoring effort is linked to observed levels of damage or to observed predictors of spill damage, such as the type and size of spill and persistence of oil. The paper describes the system, using plans for marine birds and commercial fishery species to illustrate the application. Monitoring objectives, rationales for the tiers and criteria/standards for escalating from one monitoring tier to the next are discussed. The method is based on experience in historical spills, but focuses on the industrial and environmental conditions of Canada's eastern coast. The linkages and differences between EEM for routine E&P and for spills are also discussed, as are the unique challenges of dealing with spills of both condensates and viscous oils.

Question 1: Have you had any success in fingerprinting oiled birds?
Answer: This is outside of the field but radioisotopes are being used and other data is available in the literature.

2.2 Session 2 - EEM Methodologies: Lessons Learned

Sampling Design and Tools Used in SOEI's Offshore Environmental Effects Monitoring Program

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Sable Offshore Energy Inc. (SOEI) is required to conduct an offshore Environmental Effects Monitoring (EEM) Program as a condition of the Development Plan approval granted by the Canada-Nova Scotia Offshore Petroleum Board (CNSPOB). The offshore EEM program for Tier 1 commenced in June 1998 and is ongoing. The basic strategy of the SOEI EEM design was to take measurements with sufficient spatial coverage to determine drilling waste and produced water deposition, movement, and fate/impact of discharged waste. The sampling was based on a standard grid design with the major and minor axes aligned to the mean current and most probable storm path directions. This design provided a good characterisation of the zone of influence and of the magnitude and spatial extent of potential impacts. The benthic boundary layer was sampled using purpose-built equipment developed at the Bedford Institute of Oceanography. These water samples were analysed for particle size and barium in the particulate matter. Underwater video and still camera footage provided a benthic habitat description and document the epifaunal community. Sediment samples were collected using grabs. The sediment samples were analysed for particle size, metals, total organic carbon, total

inorganic carbon, total hydrocarbon, and polycyclic aromatic hydrocarbons. Sediment toxicity testing used standardised and accepted Environment Canada procedures and tested whole sediment and interstitial water. The EEM program included establishment of caged mussels to monitor for drill waste and produced water effects on taint and body burden. Scallops from natural beds were analysed for hydrocarbon body burden and organoleptic evaluation tests. Year-round offshore monitoring of seabirds and marine mammals was also conducted by trained offshore observers on platforms and vessels. Monitoring of seals, birds and beach debris on Sable Island relative to the oil and gas developments are ongoing projects co-sponsored by SOEI. As the SOEI Project has progressed from the drilling phase to the production phase, the EEM program has been successfully modified to focus on appropriate studies and parameters that have provided a meaningful evaluation of change.

Question 1: How effective do you see your monitoring program in terms of relation of the studies with the grain size?
Answer: It may not provide the best results. It may need to be adjusted.

Question 2: Could you comment briefly on the constraints you find in monitoring in an area where the environment (and sediment) is so dynamic?
Answer: Yes, this is a difficult area. We can find very different signatures. Depending on when we do our sampling, sometimes we can find presence of a pbm layer. However, if we go after a storm there is nothing of that. With some of the techniques we apply, we can have some positive results but in some cases, we do not. There are difficulties in both, actual physical working and interpretation of the data in this dynamic environment.

Question 3: Have you broadened your sampling to show a regional effect?
Answer: Yes, we have done it. And it does not show any signal of moving towards the state our model predicted. No regional effects shown.

Question 4: Your sampling and methodology for testing may not be appropriate for the type of effects you're willing to detect.
Answer: Yes, this is not the best test for this environment. The amphipod test was shown to be one of the most appropriate at the time of the selection, but I agree it may need to be improved.

Sixteen Years of Harmonised Monitoring of Effects of Drilling Waste from Norwegian Offshore Installations. What Works and What Doesn't?

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The fate and effects of drilling waste discharged to the sea from Norwegian offshore installations have been monitored annually according to essentially the same standard procedures since 1987. The results are reported to the Norwegian Pollution Control Authority and assessed for guideline compliance and scientific quality by an independent

Scientific Expert Committee. The monitoring covers physical, chemical and biological characterisation of surface sediments at about 50 fields and single installations. Since 1996 the petroleum fields have been grouped in 6 latitudinal regions, monitored in a 3-year cycle. Each year 350–400 sediment stations are surveyed according to official guidelines. The prime elements of success for the benthic monitoring program have been: 1) procedural standardisation at all steps from planning to reporting; 2) implementation and documentation of accuracy and precision both for chemical and biological analyses; 3) application of a standard set of univariate and multivariate techniques for analysis and interpretation of physical/chemical and biological data; 4) generation of long time series facilitating temporal trend analysis; 5) formalised interaction between operators, authorities and the scientific community in conducting and evaluating the monitoring; and 6) strong coordination among the operators in executing the surveys. Main future challenges are to agree on optimal statistical definition of significant sediment contamination, on harmonised interpretation of subtle changes in bottom fauna assemblages, and on maintenance and strengthening of the taxonomic expertise required.

Question 1: Was the selection of the original sites based on mappings or on any other criteria?
Answer: There are guidelines set out by operators and regulators. Some criteria were, for instance, sediment substrate. We try to keep the sites for the sake of the time variance.

Question 2: Would you consider bioassays as an additional value to the program?
Answer: We have problems with linking low concentrations of hydrocarbons with the environment in natural conditions. We cannot see that community assemblages are changing with low concentrations of hydrocarbon. However, in experiments, the effects of oil and synthetic components show some effects on more than bioassays.

Quantifying Post-Exploration Drill Impacts in South Caspian Sea Sediments

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Physical, chemical and biological sediment data comprise the monitoring triad typically used to gauge potential impacts from offshore oil exploration and production activities, where benthic communities are potentially at risk from associated hydrocarbon and metal contaminants. Adverse biological effects from drilling operations are often difficult to determine due to system variability and confounding factors, including water depth, sediment grain size, and contaminants from other sources. This study presents the results of two sediment studies, which make use of a tiered analytical approach to optimise sampling design, identify key biological variables and assess threshold effect levels appropriate to quantify post-drilling impacts to the benthic environment. The approach, which is applicable to other investigations concerned with spatial and temporal variability, uses simple univariate statistics to examine sediment data collected over 80-800 m depth from a 600 km^2 prospective structure operated by Exxon Azerbaijan Operating Company in the south Caspian Sea.

Sediment Profile Imaging: Impact Assessment in the South Caspian Sea

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A baseline Sediment Profile Imaging (SPI) survey was conducted in May 2000 along two offshore transects in the south basin of the Caspian Sea, offshore Azerbaijan, in water depths ranging from 80 to 900 metres. The SPI survey was part of a comprehensive baseline environmental assessment at and around several well locations targeted for exploration drilling by ExxonMobil affiliates. A second survey was conducted in fall 2002, approximately nine months after the completion of exploration drilling. The post-drill sampling design relied on increased sampling density around the two well sites to assess the horizontal and vertical extent of discharged cuttings from synthetic and water-based muds and to compare pre-and post-drill conditions of the sedimentary environment. Both surveys included analysis of co-located sediment samples for chemical and benthic community parameters. The extent of the cuttings footprint as well as evidence of benthic recolonization were readily detected in the sediment profile images. Results were supported by traditional benthic community analyses of co-located surface sediments.

Question 1: Do you have any data on dissolved oxygen?
Answer: Not direct measures. Estimations are 10% saturation in the area.

Question 2: Have you also seen or studied oil and synthetic muds in the area?
Answer: There is a type of these muds in background conditions. In a radius on the order of 4 to 5 km. Their occurrence is both natural and introduced. There are also other types of synthetic muds. We don't have actual photographs but we have data.

Question 3: How sure are you that the effects don't go further than the 200 m?
Answer: There are 20 or so publications on benthos in the area. We're pretty sure they don't extend to a greater depth than 200 m.

Long-term Trends and Monitoring of the Macrobenthos at Sullom Voe Oil Terminal, Shetland, UK

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Published literature on marine macrobenthos communities includes relatively few reports of continuous long-term (i.e. greater than ten years) data sets. Such data are particularly important in determining natural temporal fluctuations, and provide essential background information for the interpretation of monitoring results. Extended studies can also provide valuable insights into longer-term changes such as those connected with climate change.

As part of its monitoring strategy for the Sullom Voe oil terminal in the Shetland Isles, UK, BP Exploration Operating Company Ltd (BP) has conducted an ongoing sampling program of the macrobenthos since 1979. The eleven sampling stations are located near the treated ballast-water outfall, within an area of particularly high macrofaunal biodiversity and recognised conservation importance. During the present study, the combined dataset derived from the individual surveys was rationalised to accommodate developments in taxonomic knowledge and practises over the monitoring period. An assessment is made of the impact of laboratory subsampling introduced in the later surveys. No effects on the macrofaunal communities from the outfall discharges were detected. The paper describes the natural trends and fluctuations that have occurred over 23 years, and the factors possibly influencing them. The results are considered in relation to BP's requirements for continued monitoring of the area. The natural variability of indices traditionally used in monitoring studies is examined, and their value in monitoring programs assessed. The work is expected to enhance the interpretation of future monitoring surveys and improve assessment of the overall impact of terminal effluent.

Question 1: The methods you are using to detect hydrocarbon contamination are not the most updated. Are you planning to include the new methods in your study?
Answer: We did not want to change the technique for the long term monitoring program to provide the trend analysis. Therefore, we are keeping them for that purpose. However, the new methods you refer to had been included in our analysis. We are applying infra red analysis for consistency, as well as gas chromatography, and gas chromatography-mass spectroscopy.

Terra Nova Environmental Effects Monitoring Program: from EIS Onward

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This presentation focuses on a review of the history of the Terra Nova Environmental Effects Monitoring (EEM) program and includes a discussion on how effectively the program meets its objectives. In 1996, Petro-Canada submitted an Environmental Effect Statement (EIS) for the Terra Nova Development outlining anticipated project effects. As a condition of project approval, an EEM program was designed with input from stakeholders and international and national specialists. The primary purpose of the EEM was to test effects predictions made in the EIS. As such, the program was established to detect change in the quality of the receiving environment through examination of sediment quality, water quality and ultimately biological resources. As part of the program, toxicity, hydrocarbon content, and concentrations of 23 metals are measured on sediment samples. Benthic infaunal community structure is also assessed. Hydrocarbon, metal and chlorophyll concentrations are measured on water samples. Metals and hydrocarbon body burden, taste and morphometrics and life history characteristics are

assessed for Atlantic scallop and American plaice. Additional fish health measurements, including MFO induction and histopathology, are measured on American plaice. The strength of the Terra Nova EEM program results from these many supporting program elements. A weight of evidence approach is used to assess project effects to the receiving environment. Since its inception in 2000, the program has proven effective at detecting very small inter-annual changes in the marine environment unrelated to project activity and therefore provides a powerful tool for detecting and identifying project effects outlined in the EIS.

Question 1: Noise pollution is becoming an increasing issue. Is Terra Nova considering this component?
Answer: No we don't have that component included in our study.

Question 2: What's the distribution of Icelandic scallop in the area?
Answer: I don't know.

Question 3: Do you conduct heavy crude oil analysis?
Answer: No we don't. We analyse C32. We are not taking oil from the field at this point.

Question 4: What kind of mud are you using?
Answer: Synthetic mud.

Environmental Effects of Mercury in Permitted Discharges from Offshore Platforms in the U.S. Gulf of Mexico

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Several thousand oil and gas wells have been drilled in U.S. territorial waters of the Gulf of Mexico. The U.S. EPA permits discharge to offshore Gulf waters of water-based drilling mud and associated drill cuttings, and synthetic based drill cuttings, if the barite in the drilling muds contains less than 1 ppm mercury and 2 ppm cadmium. There is concern that mercury associated with permitted discharges could enter the local marine food web and pose a hazard to fin- and shellfish and human consumers of fishery products. Produced water usually contains less than 0.1 ppb mercury; about 3.6 kg/year of mercury is discharged to the Gulf in produced water. Drilling muds that meet the EPA criterion of <1 ppm mercury in barite contain an average of about 0.1 ppm mercury. Drill cuttings usually contain a slightly lower mercury concentration. An estimated 153 kg of mercury was discharged to the Gulf of Mexico in 2001 in permitted discharges of drilling mud and cuttings. The mercury in drilling muds and cuttings is present primarily as insoluble sulfide inclusions in insoluble barite. Conditions in sediments near platforms where the drilling mud mercury accumulates are not favourable for conversion of the insoluble mercury in drilling muds and cuttings into more mobile, toxic forms. Several investigations of mercury concentrations in edible soft tissues of fish and shrimp from the vicinity of offshore platforms have revealed that tissue mercury concentrations are low

and in the range of mercury concentrations in marine animals of the same or similar species from marine waters away from the influence of offshore platforms. Thus, mercury from platform discharges is not entering local food chains and is not harming marine animals or their consumers, including humans.

Question 1: If you consider erosion aspects, isn't there risk that this narrow window for unfavourable conditions would change and make the Hg bioavailable?
Answer: Yes, in anoxic conditions the window for unfavourable effects is narrow. In some scenarios, you may have a zone where MeHg is possible. For this to happen you need very specific conditions and chemical reactions that occur in different levels. Though this would rarely occur we need to take a closer look at these issues. Those are issues to focus on in further studies.

Assessment of Environmental Impacts from Drilling Muds and Cuttings Disposal, Offshore Brunei

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In 2000-2001, an offshore survey and environmental assessment were conducted of drilling activities offshore Brunei. A primary focus was to evaluate the environmental effects of disposal of oil-based mud (OBM), ester-based synthetic mud (ESBM), and water based mud (WBM) in the tropical marine environment of the South China Sea. A number of well sites were surveyed for each of the mud types, encompassing varying water depths (20 - 500 m) and time elapsed since drilling (1 - 40 years). Key parameters (e.g. hydrocarbons, esters, metals, and redox) were examined at all sampling locations, depending on the drilling muds used. Side-scan sonar, detailed hydrographic imaging, seabed video, current information, and benthic sampling results were also interpreted. A modified radial sampling pattern was used. The results of the comparison of the environmental effects of previous ocean disposal of OBM, WBM, and ESBM was used to prepare guidelines for at-sea disposal of mud and cuttings based on the sensitivity of the receiving environment. The survey results and detailed habitat sensitivity mapping were used to prepare comprehensive site-specific guidelines for WBM and ESBM disposal offshore Brunei. Using a "receiving environment" approach, the guidelines specify detailed instructions for WBM and ESBM offshore disposal in each of seven management areas ranked according to environmental sensitivity. The ranking, in terms of sensitivity of environmental components are as follows: 1) Shallow coral reefs; 2) Deep reefs; 3) Juvenile shrimp nursery areas; 4) Adult shrimp shallow coastal areas; 5) Adult shrimp mid-shelf areas; 6) the Brunei continental shelf; and, 7) Continental slope and deep water.

Question 1: Could you provide more specific information on the volume of total discharge in the area?
Answer: Past activities were significant. Like at Hibernia, for example, you have multi-well developments. We're talking about a zone or portion of what has been discharged. I

believe that thousands of tons of cuttings have been discharged during the four years. We are continuing to develop into deep areas in the future.

Question 2: This question was on the topic of coral reef monitoring.
Answer: The sampling in coral reef was done by divers and video. They have published methods and results in previous papers. Some reefs have been impacted by past activities. Many coral reefs are not affected.

Question 3: How many operators are in the area?
Answer: All I know is that this program has been implemented and in place by Shell. I believe Shell is the only operator in the area.

Question 4: There are important rivers in the nearby area. Do the river outflows affect the area?
Answer: Yes, there is at least one important river in the proximity. I don't think it carries much to the sea to affect the environment… The coral reefs are more to the east.

Lessons for Offshore Oil and Gas EEM from the Pulp and Paper and Metal Mining EEM Programs

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The Canadian Environmental Effects Monitoring (EEM) program is a mandatory, industry-funded monitoring program designed to determine whether environmental effects occur where pulp mills or mines discharge effluent. The EEM program determines the effectiveness of regulations in protecting fish, fish habitat, and the use of fisheries resources by humans. The program is structured into 3-4 year cycles of monitoring and data interpretation. For each cycle, the industrial facility designs a site-specific field monitoring study, conducts the study and submits an interpretive report and supporting data to Environment Canada. Each study may include an adult fish survey, a benthic invertebrate community survey to assess effects on fish habitat, a fish tainting study and chemical analysis of fish tissue. An effect is defined as a statistically significant difference in a measured parameter between an area exposed to effluent and a reference area. Human health consumption guidelines are used to establish the significance of contaminant levels in fish tissues. The EEM program was implemented in 1992 for pulp and paper effluents and expanded to include metal mining in 2002. The Canadian regulations represent the only nationally regulated monitoring program worldwide and EEM assessments are being considered for application to municipal sewage effluents. Other sectors, including oil and gas operations, may follow. EEM development has been a "learn as you do" exercise with continual modification and improvement in both monitoring design and tools. The metal mining EEM program was modified from the pulp and paper program to include tiered, sequential modules addressing different

questions ranging from identification of an effect through to identification of the cause of that effect. Monitoring tools, including caged bivalves and mesocosms (field bioassays), were introduced to facilitate these latter modules and also to be used as alternative approaches in situations not amenable to standard field surveys.

Question 1: What species are you working with in the cage? In recent work, they are trying to bring West Coast species and keep them deep.
Answer: We're working with: *edulis* (blue mussels). I don't know about that.

Question 2: Is hormone discharge being monitored?
Answer: Yes, Environment Canada considers this component.

Chronic Effects of Synthetic Drilling Muds on Sea Scallops (*Placopecten magellanicus*)

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Laboratory studies were conducted to assess the potential biological effects of low concentrations of used synthetic (*SBM*) and ester-based drilling mud (*EBM*) on sea scallops (*Placopecten magellanicus*). Different types and concentrations of *SBM* and *EBM* formulations and their major components were tested during four chronic exposure experiments with sea scallops. Toxicity was assessed from lethal and sublethal (somatic and reproductive tissue growth, and feeding rate) effects. Sea scallop survivorship in all treatments (0.07 to 9.55 mg/l) was 87% or greater. Growth of all scallop tissues was significantly affected by Novaplus® *SBM* concentrations greater than 0.91 (winter exposure) and 1.52 mg/l (summer). Petrofree® (*EBM*) and IPAR-3® *SBM* significantly affected growth of all tissues at concentrations greater than 1.35 and 1.42 mg/l, respectively. Tissue growth was significantly reduced by 0.72 mg/l of Suspentone®. Growth reductions resulted primarily from reduced energy intake resulting from depressed clearance rates. Scallop feeding was sensitive to suspended *SBM*, showing significant reductions in clearance rate at Novaplus® and IPAR-3® concentrations greater than 0.16 and 1.42mg/l, respectively. Clearance rate was significantly reduced, relative to controls, at 0.12mg/l of barite. Scallop tissue growth was not significantly impacted by similar chronic exposures to barite. However, the barite settled rapidly in the growth tanks, such that the scallops were exposed to considerably lower concentrations than intended. Solid fractions found in most drilling muds (primarily bentontite and barite) appear to be the cause of *SBM* and *EBM* impacts on sea scallops.

Question 1: How can you compare the statistics?
Answer: We did this individually for each experiment but haven't brought the results together for multivariate statistics. All are likely to have similar effects.

Question 2: What are the hydrocarbon levels you are measuring?
Answer: Total resolved hydrocarbons at the hundredth of thousandths level (150mg/l).

Question 3: What is the source of the scallops? Why the high mortality?
Answer: Georges or Brown's Bank, so there are different physiological patterns. George's are more active. There was an acclamation procedure where they were placed in tanks two weeks prior to exposure.

Distinguishing Between Artificial Reef Effects and Platform Effects on Benthos

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Offshore hydrocarbon production effects are localised in the Gulf of Mexico extending only 200 m from platforms. Effects are caused by the contaminant gradient or the fouling community on platform legs. To distinguish between contaminant and reef effects, meiofauna were sampled at production platforms (reef and contaminant effects), artificial reefs (reef, but no contaminant effects), platform removal sites (contaminant, but no reef effects), and controls (no contaminants or reef effects), and replicated in three blocks. The removal sites had higher concentrations of many contaminants than reef or control sites, but lower concentrations than platform sites. Reduced meiobenthic abundances and altered Harpacticoida community structure were primarily a function of reef effects, not contaminant effects. The habitat influence is likely a result of complex ecological interactions near platforms. The reef effect appears to be important in controlling meiofauna near platforms where contaminants are low because of drilling and production techniques used in the Gulf of Mexico. The finding that contaminants alone do not explain faunal patterns around offshore platforms indicates that future studies should include appropriate artificial reef control sites.

Question 1: Problems with pseudo-replication. Would you consider use of the chi-square?
Answer: No real need for that.

Question 2: In comparing the different sites did you compare differences in lifespans? Did you allow time for maturation, for the artificial reef?
Answer: No, we did not allow time for renewal. Once it was past a year, we were not worried.

Question 3: How was the identification of species and genetics?
Answer: They are easy to identify. We looked at the taxonomy.

Bioindicator Studies on Fish Health around the Terra Nova Development Site on the Grand Banks

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Bioindicators or health effect indicators have potential to identify adverse health conditions in fish in advance of effects on populations. Thus they can be valuable early warning tools for addressing concerns of a real or perceptual nature by fishing and public interests about the scope of any potential impacts of contaminants on fish stocks. Sub-lethal effects have been observed around some petroleum development sites in the North Sea and the Gulf of Mexico. The Grand Banks is one of the world's richest fishing grounds and a number of fish stocks are presently under recovery. Terra Nova has included a fish health component in their EEM Program. American plaice (*Hippoglossoides platessoides*) is an important commercial flatfish on the Grand Banks and was chosen as an indicator species in consultation with DFO. Studies have been carried out on fish taken in the near vicinity of the development site as well as at a reference site approximately 20 km further south. The health effect indicators studied included skin and organ lesions, levels of mixed-function-oxygenase (MFO) enzymes, haematology (differential blood cell counts) and a variety of histopathological indices in liver (necrosis, nuclear pleomorphism, megalocytic hepatosis, eosinophilic, basophilic and clear cell foci, hydropic vacuolation and neoplasms) and gill (hyperplasia, oedema, fusion and clubbing) tissues. These indicators have been extensively used in laboratory and field investigations with various fish species and studies on external lesions, MFO enzymes and histopathology have been specifically endorsed by agencies such as the London-Paris Convention for use in environmental monitoring and assessment programs. Comparable bioindicator results have been obtained at both development and reference sites during three surveys (1997, 2000 and 2001) indicating that the health status of American plaice at the Terra Nova development site is presently similar to that at the Reference site.

Question 1: Do the fish migrate?
Answer: Yes, they move around a fairly large distance.

Question 2: The hydrocarbons on platforms are elevated, but are the species too migratory to be exposed?
Answer: There is no difference in the hydrocarbon levels in place.

Question 3: Interesting study. With respect to site selection, you need a source of PAH's, so I wouldn't expect any impacts.
Answer: We didn't expect any.

Gas Pipelines and the American Lobster, *Homarus americanus*

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During the 1970s and 1980s, over 100 manned (occupied) submersible divers were made on the outer continental shelf, upper continental slope, Georges Bank and submarine canyons heads in a research program termed "The Megabenthic Study of the New England Continental Shelf". A major focus of this program was the definition of migratory behavior and overall ecology of the offshore American lobster, *Homarus americanus*. Coincident with these in-situ investigations was an extensive tagging program of the lobster, operating from research and commercial fishing vessels in the vicinity of a number of submarine canyons, Corsair to Hudson. These studies have yielded considerable information on the ecology and behavior of the lobster and a number of other megabenthic fauna that might be affected by the presence of a gas pipeline running along and parallel to the outer continental shelf, eastern Georges Bank to northern New Jersey. An exposed (unburied), 2-4 foot diameter pipeline will almost certainly impede the normal onshore and offshore migration of this deep water population of lobsters. This migration is done by walking, not swimming. Although lobsters very readily walk up and over steep inclines, as evidenced by their movement along steep walls of the canyons, their migrations will be likely be "blocked" by any kind of "overhanging" structure such as that presented by an unburied length of 3-4 foot diameter pipe. The spring-to-early-summer onshore migration of lobsters to eastern Georges Bank SW to northern New Jersey and the return to deep water in the summer and fall to complete their reproductive cycle is critically important to maintaining a number of multi-million dollar fisheries in five (5) U.S. coastal states (MA, RI, CT, NY and NJ) and Georges Bank. Suggestions for modifying pipe encasements in order to solve this problem are presented as is an assessment of the reactions of several megabenthic species to the presence of buried and unburied pipeline structures.

Question 1: What do we have to do to help the lobsters?
Answer: Ramps or some type of fish ladders – perhaps fibreglass with a reinforced grating. It wouldn't need to be solid. Lobsters, when going in the current, are set like a sail and hide against the current.

Question 2: In the west, there is a benthic investigation looking at barriers for Dungeness crab (a large crab fishery). The crab are mobile and a 2ft pipeline buried halfway wouldn't be expected to be a barrier.
Answer: Finfish don't seem to have any trouble, but others might have problems.

Long Term Lessons Learned from the *Exxon Valdez*: Acute Toxicity versus Chronic Embryotoxicity

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Chronic exposure of embryonic life stages can lead to poor recruitment and population effects, although the effects can be subtle and very difficult to measure. Traditionally, acute toxicity (physical or chemical) receives the most attention during the biological damage assessment following a spill. Persistence of oil is sometimes followed on

impacted shorelines, as well as bioavailability. Long-term effects are seldom followed, for a combination of several reasons. They are often subtle, require large sampling schemes, and are very difficult to separate from other confounding effects, or from normal seasonal or annual variation. Consequently, most damage assessments underestimate the long-term effects. The Exxon Valdez spill was uniquely followed for persistence, bioavailability, and consequences to several species, and collectively offers the best case history for long-term damage. The case for embryotoxicity in pink salmon, which spawn in the heavily impacted intertidal zone, provides a model that demonstrates the subtle but effective impact of weathered crude oil on important biological processes. Field studies demonstrated the population effects at several streams for up to four years past the spill, and laboratory exposure studies demonstrated the embryotoxicity mechanisms at low level exposures to parts per billion of polyaromatic aromatics (PAH). Short-term effects on survival and abnormalities were first measured. Delayed (post-exposure) effects on growth and adult returns from the marine environment have also been measured, demonstrating how the fitness of the population can be reduced even when there are no apparent symptoms at the time of release. These studies demonstrate the importance of embryotoxicity on the long-term fitness of fish, and the significance of long term pollution on recruitment.

Question 1: Were only a small percentage of creeks in the Sound affected? Were the populations within variability?
Answer: Only a small number of creeks were affected. It is hard to measure variability as populations vary widely (could be up to 100 000 or as low as 2 000).

Monitoring Oil Persistence on Beaches- SCAT vs. Stratified Random Sampling Designs

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The usual method for monitoring oil persistence on beaches following spills relies on visual inspection of the entire affected region by "shoreline clean-up assessment teams" (SCAT), often augmented by excavation of pits to evaluate the persistence of subsurface oil. While this approach is practical for directing clean-up efforts immediately after spills, it does not provide rigorous estimates of contaminated beach area or of stranded oil volumes that can be used to statistically evaluate the significance of apparent changes with time. Comparison of results and projections based on SCAT-based estimates of intertidal oil from the 1989 Exxon Valdez oil spill in Prince William Sound (PWS) with results from a random sampling design 12 years later (2001) suggests that the SCAT method may have serious shortcomings when used to monitoring oil persistence. Assumptions regarding the correlation of visually evident surface oil and cryptic subsurface oil are usually not evaluated as part of the SCAT protocol. Stratified random sampling designs avoid these problems and can produce meaningfully precise estimates of oiled area and volume that permit a statistical assessment of the significance of

temporal trends, as well as upper bounds for the extent of impacts. Our 2001 study of the amount of oil remaining on the shoreline of PWS showed that only about 15% of surface oil occurrences were associated with subsurface oil, so the distributions of surface and subsurface were very different. Our study also provides an example of a practical stratified random sampling method, and illustrates how sampling design parameters affect statistical power. Power analyses based on the study results suggest that optimum power is achieved when unnecessary stratification is avoided, and that sampling effort should be carefully balanced between selecting sufficient beaches for sampling and the intensity of sampling on selected beaches.

Question 1: If you take it further down to low tides or beyond how does the curve change?
Answer: Somewhere in the lower tidal – around zero. There are oil-covered beaches from 0 to 4.5 m during the first few days after a spill.

Monitoring Seismic Effects on Marine Mammals - Southeastern Beaufort Sea, 2001-2002

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Devon Canada conducted 3D streamer seismic surveys offshore of the Mackenzie Delta during 2001-02. Marine seismic projects use airguns that emit strong sounds into the water to acquire data to determine the presence and likely locations of geological structures that might contain hydrocarbon deposits. Given the auditory and behavioural sensitivity of marine mammals to underwater sounds, seismic projects have the potential to impact marine mammals. Ringed (*Phoca hispida*) and bearded (*Erignathus barbatus*) seals, and beluga (*Delphinapterus leucas*) and bowhead (*Balaena mysticetus*) whales occur in the survey area, and are harvested by subsistence hunters. There was concern during community consultations that the seismic program might affect the subsistence hunt, subsistence fisheries, or marine mammals. In order to address these concerns, a monitoring and mitigation program emphasising community involvement was designed to assess the effects of the seismic operations. The monitoring program consisted of three primary components: observations from the seismic ship, aerial surveys, and acoustic measurements. Mitigation measures included: (1) delay of seismic operations until early August to avoid the peak period of occurrence of beluga whales, (2) shutting down airgun operations if whales were detected near (≤1000 m) the seismic vessel, (3) gradual ramp up (soft start) of the airgun arrays, and (4) avoidance of beluga harvesting areas. Scientists and Inuvialuit conducted the monitoring program. During the two-year program, there were nine airgun array shutdowns for whales (all bowheads) within the 1000 m "safety radius". Based on monitoring results, seals and bowhead whales avoided

relatively small zones around the seismic ship, and beluga whales avoided a considerably larger zone. The localised avoidance of the seismic vessel by some marine mammals did not affect the subsistence hunt, as successful beluga hunts occurred in 2001 and 2002.

Question 1: The safety criteria of 180dB, what is this based on?
Answer: It is based on US studies on mid-sized toothed whales. Panels of experts say that there is potential for hearing damage after 180dB.

Question 2: Is there a time scale of the avoidance?
Answer: This was hard to quantify with the beluga. Bowhead has a deflected migration for 20-30 km for 15-20 hours afterward.

Question 3: Are acoustic calibrations done at the same depth and location?
Answer: Acoustics were acquired at a variety of conditions, at the same depth range.

Effects of Seismic Energy on Snow Crab (*Chionoecetes opilio*)

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The government-industry Environmental Studies Research Fund (ESRF) contracted LGL Limited and OCEANS Ltd. to investigate the potential effects of seismic energy on snow crab (*Chionoecetes opilio*). A single 40 cu in sleeve gun and a 200 cu in seven-sleeve gun array were used to treat both caged and uncaged snow crabs on a natural Newfoundland crab ground. Legal-sized males, sublegal-sized males, and egg-bearing females were treated in the study. Distances between the seismic source and the treated crab were manipulated in order to study the effects of various received sound levels, including levels similar to those normally received by Newfoundland crab under full marine seismic operations. All received sound levels were measured using a calibrated hydrophone. Potential physiological, pathological and behavioural effects on the crabs were investigated using various approaches. These included field collection and laboratory analysis of samples of haemolymph, hepatopancreatic tissue, heart tissue, gill tissue and statocysts, field observations of acute effects (e.g., mortality, limpness), experimental commercial fishing, and underwater videography. Some treatment and control animals were also transferred to holding tanks in order to study any potential delayed effects on the crabs.

Question 1: Why are you using a volume of 40 cubic inches?
Answer: We used 40 cubic inch air gun and shortened the distance between the animals and the gun.

Question 2: What is the likelihood in practical terms of the female being affected as such?
Answer: We took the worst case scenario, so more work is needed to determine thresholds. The eggs are under the female and the animals are on the bottom sometimes at substantial water depths. They are not likely to be subjected to similar effects in the field.

Sediment Quality in Depositional Areas of Shelikof Strait and Outermost Cook Inlet

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A multi-disciplinary 2-year sediment quality study was conducted in Cook Inlet and the Shelikof Strait of Alaska for the Minerals Management Service (MMS). The objectives were as follows: to examine the potential for the transport and accumulation of oil and gas contaminants in depositional areas in outermost Cook Inlet and Shelikof Strait; to determine whether the contaminants in these areas have accumulated relative to pre-industrial concentrations and could be correlated to specific discharge or spill events (i.e., chemical fingerprinting); and to determine whether any environmental risks are posed by exposure to the PAH and metal contaminants. Using a set of four primary working hypotheses, two years of field and laboratory studies were completed. The sampling program was based on a stratified random design for the selection of sampling sites in four regional down-gradient study zones. Surface sediment, sediment cores, and biota samples were collected. Chemical measurements (hydrocarbons and trace metals), biological measurements (reporter gene CYP1A1 induction, P450 measurements in fish livers and sediments, and sediment toxicity), and rapid benthic ecological measurements (sediment profile imaging camera), were combined to create a sediment quality triad for this program. Over 250 sediment and fish tissue samples were analysed during the course of the study. The results were used to characterise the current and future risks from OCS oil and gas exploration and production activities in the region.

Question 1: What is the fish size, movement patterns, and diet?
Answer: The halibut are 50cm to 2m, predatory and very mobile – they move in and out of the Strait. Cod are 5-10lbs, feed on benthos. It is difficult to find resident fish.

Question 2: With the biomarkers, what sort of levels did you get in the sediment.
Answer: I can't give equivalents off the top of my head, but it was in the range for uncontaminated sediments.

Marine Coastal Monitoring Designs: Examples for Offshore Oil and Gas Environmental Effects Monitoring

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Marine coastal monitoring design strategies vary among three broad categories: major spills (e.g. oil spills), chronic point-source pollution (e.g. outfalls and oil/gas platforms), and multiple inputs (e.g. from rivers). In all cases the study design has both a temporal and a spatial component. Environmental effects monitoring of offshore oil & gas exploration and exploitation could fall into either of the first two categories – the first if something like a blowout was a concern, and the second where long-term chronic

pollution, e.g. by drilling muds or leakage of hydrocarbons, was the primary concern. Here I briefly consider the first category and then spend most of my time on the second category. With major spills, the temporal and spatial components interact strongly, i.e. the spatial extent and the nature of the impact change rapidly over a short time. "Before-spill" data are extremely desirable but rarely available. Usually impacted and un-impacted sites are in different areas leading to a confounding of impact effects with natural spatial pattern. With chronic point source pollution a "bullseye" design usually captures the spatial component (directions and distances) while an equally-spaced series of times, often of indefinite duration, captures the temporal component. Spatial and temporal components interact slightly, for example, seasonal variation in current direction. Examples are from the Gulf of Mexico, offshore northwestern Australia, and Atlantic Canada. Cost-effective implementation of monitoring chronic point source pollution for offshore oil & gas EEM requires difficult choices within the bullseye design concept: How far away from the platform or platforms should the greatest distance be? How should the distances be scaled – arithmetic or geometric? How many directions should there be, and must/should the angles between them be equal? Is there a directional current pattern, either generally or seasonally? If there is more than one platform, do their potential effects overlap? Are they close enough that direction from one platform has the same meaning as that direction from another platform? Must/should there be replicate sampling within each distance x direction combination for each platform? If not, then where does the error variance in statistical analysis come from, or should we forget hypothesis-testing and just describe effects? Can multivariate statistical methods be used effectively and unambiguously for describing effects for example at the level of the biological community? Should statistical analysis be based on distance as a category variable i.e. "rings" or distance as a continuous variable as in km? Are there some untried design possibilities, for example sampling in a completely randomized design within the spatial component but with allocation proportional to predicted distance and direction of effects?

Question 1: What about stepwise regression analysis?
Answer: Well, I am not very keen on the regression analysis. If you have a correlated prediction … you can get spurious results and analyse up a situation. You may leave out good variables. In case of applying it, I'd go very carefully with it. Step wise. I'd do it completely manual, rather than using any of the statistical packages available.

Question 2: Why use random selection of stations for a regression design instead of fixed grid? Something like setting a doses design.
Answer: Well, it could be okay. You'd be most unbiased towards the confounding factors. Let's try it.

Distribution of Suspended Particulate Drilling Wastes at the Hibernia Oilfield
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Annual surveys of the distribution of suspended particulate drilling wastes were carried out around the Hibernia gravity base structure (GBS) on the Grand Banks of Newfoundland from 1995 through 2000. Orthogonal transects, ranging from 0.5 to 20 km from the GBS, were sampled for water column and benthic boundary layer total suspended particulate matter (SPM), organic content, disaggregated inorganic grain size (DIGS), optical backscatter, *in situ* floc size, and high-resolution seafloor imaging. Time series sampling was conducted over two consecutive tidal cycles at each of three stations at 1.0, 2.5, and 10 km from the GBS. Simultaneous measurement of currents in the benthic boundary layer was carried out using electromagnetic, acoustic and acoustic doppler current meters. Filtered samples were analysed for their particle size spectral characteristics and an algorithm was developed to identify the signature of the bentonite fraction of the discharged drilling muds. The baseline survey was completed in 1995, before emplacement of the Hibernia platform. The results of this survey showed a clean environment depauperate in fine particulate matter. The first operational phase survey was completed in October 1997, 4 months after emplacement of the GBS. Particulate drilling waste signatures were observed in the water column, but not in the benthic boundary layer, at low concentration levels. Further operational surveys were carried out in the summers of 1998, 1999, and 2000. The sampling pattern revealed gradually increasing concentrations of fine particulate drilling wastes, especially to the north and northwest of the platform, but that overall concentrations remained low. Wastes were detected both in the water column and benthic boundary layer, with the majority of material detected within 2 km of the platform. Current meter data indicated that transport thresholds for fine drilling wastes are exceeded more frequently than previously thought. The gradual drilling waste accumulation warrants future surveys.

Quantifying Fine-Grained Drill Waste in Scotian Shelf Suspended Sediments

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Laboratory studies have shown that bentonite and barite, the two major components of water based drilling mud, can affect the growth of suspension feeding organisms. The disaggregated inorganic grain size (DIGS) distribution of bentonite is unusual in that it is dominated by the smallest grain sizes, giving it a negative source slope. This distribution is in marked contrast to that of naturally occurring suspensions on continental shelves, which tend to be positively skewed. Using the shape of the bentonite size distribution to identify drilling wastes, field sampling near an operational drilling platform on the Scotian Shelf found elevated concentrations in the surface plume associated with the discharge of water-based drilling mud and in the benthic boundary layer (BBL). Flocculation was identified as the mechanism for the rapid settling of drill wastes containing bentonite to the near bed region. Based on these findings, models were developed to predict the concentration of fine-grained drill wastes in the BBL. To verify the model, a method to estimate the concentration of drill waste in the BBL using the

DIGS of suspended sediment samples was developed. Results from studies carried out on the Scotian Shelf will be presented.

Scallops as Sentinel Organisms for Monitoring Environmental Effects of Offshore Oil and Gas Operations

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Two environmental effects monitoring technologies were tested at the Hibernia offshore oil production field that use scallops as sensitive sentinel organisms for assessing operational waste bioavailability, and for relating contaminant exposure and dose to the onset of biological effects. Six bivalve cages containing caged Icelandic scallops, sea scallops, mussels and semi- permeable membrane devices (SPMD) were placed on the seabed between 0.5 and 6 km distances to the Hibernia platform. The cages incorporated a new inexpensive subsurface float release system that prevented mooring loss due to ship collisions with surface floats. Bottom video and grab samples were collected at the same sites for benthic community and sediment metals analysis. The spatial extent of contamination at the six sites was determined from tissue and SPMD hydrocarbon measurements and from sediment barium concentrations (normalized to aluminum). A new barium extraction methodology was developed for this study to improve recovery from sediment containing high barite concentrations. Standard methods for extraction of Ba were shown inefficient at concentrations greater than 200 $\mu g\ g^{-1}$. Spatial trends in biological effects were assessed from measurements of caged bivalve survival and sublethal effects (shell and tissue growth), and from differences in benthic species richness between stations. The second EEM tool consists of an *in situ* automated Biological Effects Monitoring System (HABITRAP) that provides time-series data on drilling waste exposure (barium sedimentation rate) and bivalve biodeposition rate, a measure known to be sensitive to the presence of drilling wastes. Observations of scallop responses to temporal and spatial variations in metal exposure and hydrocarbon body burden are presented and compared with results from benthic community analysis.

Question 1: Caged scallop as monitoring tool. Why did you use them and not native species?
Answer: I completely support using the native scallop. The problem with using the caged scallop is that you remove some of the confounding effects at the monitoring level. You want to use animals with the same exact condition, the same background. You can do that with a native population, but it's a bit more difficult.

Grain Size Normalisation of Sediment Heavy Metal Data

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Getting maximum information from sediment heavy metal data depends on grain size normalisation of the data. Small anomalies that would otherwise be missed can be identified if a good grain-size normalised background distribution can be established. Geochemical normalisation for shelf sediments using aluminum or lithium will be described. Value of this approach in assessing sediment heavy metal concentrations for the Sable Offshore Energy Project will be illustrated using data from the 1998 baseline surveys at Venture and Thebaud. Anomalous concentrations of iron, manganese, lead, chromium, vanadium and zinc are identified using this technique.

Question 1: I like it a lot. I am surprised you did not go to look for a ratio; with a log/log scale could do so.
Answer: I tried not to go looking for a ratio. Because it does not go through the zero. Though, yes, some plots may fit better using log/log.

Question 2: Why don't tolerance limits expand out as extrapolate?
Answer: They should. I took the simplest approach; I am not a good statistician.

Question 3: At high concentration of barium, they behave different from the low concentrations. Maybe they did not dissolve all and that's why it is showing what you found in your plot?
Answer: Maybe. You may be right.

Using Ba/Al Ratios to Estimate Baseline Barium Sediment Concentrations and Monitor Changes in Barium Concentrations on a Regional Scale in Newfoundland's Off Shore Oil Field

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There is over a 4-fold difference between the lowest and highest sediment Ba concentrations (≈70-320 ppm) reported in baseline studies carried out by the three major players (Hibernia, Husky, and Petro-Canada) in Newfoundland's off shore oil industry. Such large differences among sediment samples cause problems for environmental monitoring programs that are attempting to separate sediment with naturally high Ba concentrations from those elevated in Ba from industry related activities. One of the causes of the difference in Ba concentrations among sediment samples is the variability in the grain size of the samples. Trace elements, including Ba, are more readily sequestered by fine-grained sediment than coarser materials. To correct for grain-size effects and examine multiple dependent and independent variables, the current effects model employed by the oil industry is a highly complex regression analysis. Since Ba is one of the few trace elements that are known to be discharged during drilling operations and is consistently detected in sediment analyses, it is proposed that Ba be treated separately. A simple technique for eliminating the grain-size effect on Ba concentrations is to normalise the Ba concentrations to Al. The resulting relationship is an estimate of

the expected natural or baseline range of Ba concentrations. Confidence intervals can be calculated for any given Al/Ba ratio, and the expected maximum Ba concentration for a given site can be determined. Once baseline values are established, Ba concentrations above these values would be considered enrichment.

Question 1: At the beginning of the program we looked at the same analysis you suggested. Normalising to aluminum was discussed. The aim of the study was to focus on biological effects and based on that, we made the decision. More than for size, etc, the standards were to focus on biological reference mainly.
Answer: OK. I selected this because it is a simpler presentation of the data.

Biosea – A Research Project to Provide Knowledge and Data for Predicting and Monitoring Potential Biological Effects in the Arctic by Oil Industry

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Oil industry is currently extending exploration and production activities into the Arctic. Methods to meet the demands for environmental monitoring and prediction must be adapted. Several European countries are currently implementing new discharge policies, and new methods are being developed to measure and predict biological effects. Corresponding methods for use in arctic waters are presently not operative. BioSea is a research project financed by oil company Norsk Agip (Norwegian subsidiary of Italian Eni s.p.a.-Agip division) to adapt such methods to Arctic conditions. The project will use the concept of biomarkers (biological effect parameters) to expand the capacity to monitor and predict the environmental impact of discharges to Arctic conditions. A further aim is to develop the necessary knowledge to establish decision-making tools based on predictions of biological effects. Different types of Arctic marine organisms (fish, crustaceans, molluscs, echinoderms) will be exposed to oil dispersions in laboratory studies. Several types of biological signals and effects will be measured, and dose-response relationships will be established for integration in risk assessment models. A selection of biomarker signal parameters for future monitoring in the field will be made, as well as protocols for their effective use. The selected parameters will be validated in the field, and existing background levels for these parameters in the Arctic will be measured. A special emphasis will be put on evaluation of genotoxic biomarkers. Special attention will be paid to possible combined effects with pollutants from other sources.

Environmental Monitoring of Oil and Gas Activities in Deep Waters West of Britain: Challenges and New Approaches

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Hydrocarbon exploration and production continues to develop to the west of Britain. This area remains poorly understood, despite the head start given by the groundbreaking research carried out between 1868 and 1870 from HMSs *Porcupine* and *Lightning*. The environmental monitoring approaches adopted for the North Sea have only limited application to these deep water areas. This is because of the water depth (to >2500 m), complexity of the hydrographic regime particularly to the north of the Wyville Thomson Ridge, varied topography, and surficial sediments containing much rocky material deposited and sculpted during the last glaciation and the subsequent redistribution of finer particles. In addition, the fauna of the area is poorly known both in terms of identity, with between 20 and 40% of peracarid crustaceans being undescribed, and in basic ecology. The design and conduct of meaningful environmental monitoring in such areas presents a number of challenges including what to monitor, how and where. These challenges are compounded by legislative and company controls on discharges to the sea. The approaches taken to date are summarised, together with their perceived benefits and disadvantages. The approaches include standard shallow water strategies, nested series of geophysical surveys linked to remote sampling and/or photographic survey, and deployment of benthic landers. The collaborative initiatives of the Atlantic Frontier Environmental Network and the Managing Impacts in the Marine Environment research program are described, together with some of their achievements and offspring programs. It is clear that innovative thinking and collaborative efforts are key to providing the understanding of deep water areas needed for effective biodiversity protection and environmental management.

Question 1: Could you address the subject of chemosynthetic organisms?
Answer: Mud volcanoes that have sulfur seepage are known to have presence chemosynthetic organisms. An example of this is in the Barents Sea. However, we have not discovered this yet. The possibility is there, but we haven't yet.

The Cuttings Pile Issue: How to Provide the Necessary Information to Assess the Impacts of Cuttings and Mud Accumulations around Offshore Installations?
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RF- Rogaland Research

In the North Sea area, there is currently a focus on environmental aspects of field decommissioning. Relevant issues in that context are the presence, content and quantities of drilling residues (cuttings piles) on the seabed around installations, and the likely development of such piles with time and relevant field decommissioning options. Traditional offshore monitoring in the North Sea investigates the cumulative effects to the seabed in the area from all offshore activities, including also the contribution from discharged drilling waste. As fields in the North Sea are maturing, and several fields are to be decommissioned and installations removed, there has been an increasing awareness that the accumulations underneath and around the installations may need special attention. During the last 3-5 years, considerable effort has been made by operators and operators associations particularly in Norway and the UK to characterise cuttings piles and assess their potential impacts. Following on from the experiences made while

investigating piles, guidelines for characterisation of cuttings piles have been issued. These guidelines describe how to map (physical extent), sample, analyse (chemical, physical and biological parameters), and report to give a good description of the pile characteristics. More specifically, the operative objectives of cuttings pile investigations are:

- ✓ To estimate the area, volume and surface topography of a cuttings pile, and the position relative to the installation(s),
- ✓ To assess the chemical composition (organic and inorganic) and load of contaminants in a pile,
- ✓ To assess the biological 'climate' on and close to the pile for comparison with surrounding area,
- ✓ To describe the physical structure of the pile material and the biogeochemical environment to be able to assess the natural 'restitution' potential of a pile.

References are made to specific characterisations carried out, and relevant parameters are being addressed.

Question 1: Often we see high concentrations of trace metals but low fractionation (bioavailability) of these metals.
Answer: It would be nice to be able to correlate leaching data with biological effects, to see how bioavailable is incorporated biologically.

Question 2: From a management perspective, is it more important to get a broad overview of cuttings piles or to acquire deeper knowledge of the stratification within cuttings piles?
Answer: Still need more data on stratification, though it might not be necessary to do everywhere.

Transport Properties of Discharged Synthetic Based Drilling Wastes
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There is a growing concern over the potential environmental effects of offshore discharges of drilling cuttings and synthetic based drilling fluids (*SBFs*) in hydrocarbon exploration and production operations. As a result, more research is required to understand the mechanism of fate and transport of these cuttings in water and sediment once these cuttings are discharged in the water bodies. The transport and fate of *SBF* cutting in the marine environment is influenced by the settling velocity and flocculation processes. To have a better understanding of these processes, a digital imaging system was employed. The effects of particle shape and size on the settling mechanism and the effects of salinity, fluid shear, discharge concentration and oily components on the rate of flocculation and the settling speeds of flocs were studied. The cutting sample for this study was collected from an oil well exploration in east coast Canada. The settling velocities of coarse particles from both untreated and thermally treated cuttings were measured in a 2.5m high and 14cm inner diameter Plexiglas settling column using both

freshwater and seawater. The flocculation of fine grain particles was performed using a laboratory paddle stirrer in both freshwater and seawater. The applied shears ranged from 25 to 200 s^{-1}, and the concentrations ranged from 25 to 200mg/L. In order to study the effects of oily components on flocculation, a thermally treated sample was also used. From the experimental results it was shown that the untreated cuttings tend to clump together and settle fast while the treated cuttings settle as individual particles with relatively low speeds. The settling velocities of both treated and untreated coarse particles were found to be functions of both particle sphericity and diameter following a power law relation. It was demonstrated by the flocculation tests that the steady state median floc size decreases as the shear stress and concentration increase, and the particles flocculate faster in seawater than in freshwater. For the same diameter and salinity, the flocs formed at high fluid shears and concentrations have higher settling velocity than do flocs formed at low shears and concentrations. It was also shown that the floc formed by untreated cuttings settle faster than flocs formed by thermally treated cuttings in the same conditions under which the flocs were produced.

Question 1: Did floc size vary with concentration?
Answer: Yes.

Question 2: Did you investigate different types of muds?
Answer: I used synthetic-based muds only. There are different types, but I only used one type.

Question 3: Would you expect to see different properties for different synthetic-based muds?
Answer: Not really, but I would expect to see differences with water-based muds.

Assessing Environmental Fate and Behaviour of Oil Discharges in Marine Ecosystem: Using Fugacity Model

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More than 700 million gallons of oil enters in the marine ecosystem every year. The major sources of oil discharges are rain-off, oil spills, natural seepage, blowouts, leaky submerged pipelines, and offshore drillings. Effects of oil discharges in the marine environment are much more severe than in any Atlantic environment. Oil can harm the environment in many different ways, i.e. the physical damages directly impact wildlife, fisheries, aquaculture, and the toxicity of the oil itself can poison exposed organisms. The degree of effects of oil depends on many different factors such as, concentration, exposed time, and the type of oil. Oil begins to spread and weather immediately after being released at sea. These processes break down and change the oils' physical and chemical properties. As these processes occur, the oil pollutes the surface resources and a wide range of subsurface marine organisms that are import components in a complex food chain. Furthermore, oil has different effect levels on different organisms. For instance, it

has acute effects on organisms that may be seriously injured, lethal effects that kill the exposed organism very shortly, and sub-lethal toxic effects that are subtle and often longer lasting. To better understand the impacts and its new branch environmental effect monitoring (EEM) of oil in the marine ecosystem, it is important to study the environmental fate of oil. This presentation will focus on the likely behaviour of toxic compounds of oil in the marine environment. It will also address the simulated results of different levels of fugacity models to understand the fate of oils. Finally, this presentation will describe the transformation of different quantities of oil transport and bioaccumulation in the air, water, and sediment.

Question 1: How do you account for biological processes in your thermodynamic model?
Answer: You can estimate the total number of animals in the water column and, during the transformation phase, you could incorporate this into the model.

Question 2: Do you use only one algorithm for transport from water to seabed?
Answer: No, there isn't only one way to do this.

Question 3: How is bioavailability expressed in the model?
Answer: The model doesn't take into account specific organisms, but you could look at total carbon or lipid tissue as an estimation.

The Role of Mass Balance Models in Offshore Oil and Gas Environmental Effects Monitoring

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It is suggested that mass balance models can play a valuable role in assessing the impacts of offshore oil and gas operations. These models attempt to describe the fate of hydrocarbons released into the marine environment during production or from accidental spills. Traditionally trajectory models have provided valuable forecasts of the movement of oil, but the focus here is on models which assess transport and transformation processes and seek to establish the masses of hydrocarbon components in various states and subject to various fates including evaporation, degradation, dissolution, dispersion, uptake by biota, association with solid substrates and present as surface slicks. Average concentration ranges can be estimated and compared with monitoring data. Estimates can be made of the nature and extent of contamination of biota. The merits of remedial actions such as the use of chemical dispersants can be evaluated. It is concluded that the availability of even an approximate model can be valuable in providing the operators, regulatory agencies and other stakeholders with the likely “big picture” of the impacts of oil on the physical and biological components of the potentially impacted marine ecosystem.

Question 1: What do you do when you get complex physical structures of hydrocarbons?

Answer: I did some work looking at gasoline and grouping constituents based on their properties. Then I ran the model with these groups as "boxes' to see what was going on.

Question 2: But what about things like the asphalt patches after the Exxon Valdez spill?
Answer: The model is only good at handling dissolved hydrocarbons, for example, looking at the toxicity of particles and use of dispersants. Weathered oil is problematic because the interactions are physical rather than chemical.

Question 3: It seems as though the number of boxes that you'd need to take into account could expand rapidly, e.g. BBL, produced water also has toxicity, metals are not in equilibrium, etc. How do you model these?
Answer: You have to be conscious of starting simple with what you have and what you understand. Not all processes are essential to model. It could be a life-long study, but you take a stab at it and see how far you can get. You have to try.

Question 4: How would you divide funding between modelling and monitoring?
Answer: Modelling is relatively inexpensive; you just need the data, the expertise and a computer. I would say funding for modelling is important because I want to get paid…
Answer from colleague: Spend 90% on monitoring and 10% on modelling, but the 10% you spend on modelling will double the value of the monitoring.

Question 5: Have you done any predictions of reaction rates with mercury?
Answer: Mercury is complicated because you have to deal with elemental versus methyl mercury, which is beyond this framework. The model only deals with things like photolysis, hydrolysis, etc.

Can *In Situ* Invertebrate Communities Directly or Indirectly Affect Toxicity Test Results?

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The Sediment Quality Triad examines relationships among sediment physical and chemical characteristics, toxicity, and *in situ* communities (usually benthic invertebrates). Toxicity test endpoints and invertebrate community metrics are treated as complementary biological response measures to physical or chemical alteration or variance. The Triad was used to assess effects from the Terra Nova offshore oil development on the Grand Banks. During baseline sampling (1997), toxicity to Microtox occurred at 4 of 54 stations. After drilling started, Microtox toxicity occurred at 15 (2000) and 19 (2001) of 49 stations. Toxicity was uncorrelated with distances from drill centres, and with concentrations of hydrocarbons from drilling muds, indicating that it was not an effect of drilling activity. Toxicity in 2000-01, but not 1997, occurred where strontium and total inorganic carbon concentrations were high. Benthic invertebrate richness and diversity were also greatest there. We hypothesized that toxicity was associated with decomposing bivalves and other larger shelled invertebrates. These organisms make a significant

contribution to richness, since communities are otherwise dominated by small soft-bodied polychaetes. Strontium and TIC (primarily from calcium carbonates) concentrations should also be greater where shelled invertebrates, dead or alive, are more abundant. However, Microtox toxicity was uncorrelated with ammonia, sulphur and redox levels, all of which are potential indicators of decomposition. Although the precise cause of the toxicity remains undetermined, it obviously does not negatively affect invertebrates. For the purposes of EEM, Microtox may be strongly affected by some natural factor unrelated to drilling activity.

Question 1: DFO will be doing video grabs and looking at sites far from rigs. You could do analysis of sediments from these sites.
Answer: I will also be giving this talk to the sediment toxicity workshop.

Question 2: What was the size of bivalve fragments in the samples?
Answer: I don't know offhand.

Question 3: Was there a possibility of sewage enrichment?
Answer: Not likely. There are such small amounts generated.

Question 4: Porifermifea secrete a substance to keep others away. Meiofauna may be contributing to toxicity.
Answers: There is still the high correlation with shell fragments to consider.

Question 5: I read a paper in which an acorn worm excreted bromophenols that had an inhibitory effect. There could be secretions by mucus dependant creatures.
Answer: I don't know how much further I will pursue this. The point of the presentation was to show how our methodologies were sensitive enough to detect unexpected effects.

Livebottom Impact Reduction, Mitigation, and Monitoring for the Construction of a Subsea Natural Gas Pipeline in the Gulf of Mexico

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The construction of a 36-inch-diameter pipeline known as the Gulfstream Natural Gas System (Gulfstream) was proposed to transport natural gas from onshore sources in Mississippi and Alabama to peninsular Florida traversing approximately 420 miles of seafloor in the eastern Gulf of Mexico and Tampa Bay. Seagrasses and live bottom (low-relief hard substrate dominated by sponges and soft corals) are prevalent on the West Florida Shelf and were the most ecologically important and sensitive marine habitats that could be impacted by the pipeline construction. Project proponents were required to map the resources, predict the extent/severity of impacts during permitting, conduct post-construction impact assessments, mitigate for unavoidable impacts, and monitor recovery

of impact areas and colonization of mitigation areas. Impacts to seafloor resources could occur through barge anchoring, excavation where the pipeline must be lowered, and elsewhere by placement of the heavy pipe on the seafloor. Impacts to seagrasses were avoided completely, and potential live bottom impacts were reduced by over 98 percent through the use of horizontal direction drills (HDDs), rerouting, submarine plows for lowering the pipeline, dynamically-positioned burybarges to pull the plow, and buoys on laybarge anchor cables. Mitigation consisted of placing limestone boulders and limestone/concrete modules over 57 acres of seafloor. Some mitigation areas were "seeded" by attaching macrobenthos removed from areas to be impacted by pipeline burial. Mitigation and impact monitoring included the establishment of semi-permanently marked transects in control and impact areas and semi-permanent plots in mitigation and control areas. Monitoring using still and video photography and diver counts is to take place over five successive years following construction. Performance criteria include percent biotal cover, richness, and diversity of the macrobenthic communities. The project was constructed in 2001-2002. Mitigation was installed and impact assessment surveys commenced in 2002 and will be completed in 2003.

Question 1: How much did implementation of mitigation measures cost?
Answer: Likely millions of dollars. It cost ten million dollars just for the limestone project. The anchor mitigation measures increased costs by 10% and slowed them down considerably. It would be a good exercise to calculate out.

Aspects of Polycyclic Aromatic Hydrocarbons in Offshore Sediments in the Azeri Sector of the Caspian Sea

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A thorough assessment of oil and gas drilling impacts requires a detailed understanding of the pre-drilling baseline. In areas of considerable seepages and historical exploration and spillage it is important to be able to use strategies and techniques that can distinguish the background from any incremental addition of chemicals from drilling and production. In the present study, a detailed investigation of the composition and concentration of polycyclic aromatic hydrocarbons (PAH) (2 to 6 ringed parent and alkylated homologous series) and saturated hydrocarbons in sediments of Caspian Sea, 220 to 645 m in Azerbaijan waters, was conducted. Sediments in the study area consisted primarily of fine and very fine silts, and average sediment organic carbon exceeded 3% of sediment dry weight. Significant levels of petroleum-related hydrocarbons, measured as polycyclic aromatic hydrocarbons (PAH) and saturated (aliphatic) hydrocarbons (SHC), were evident throughout the Absheron region. Total PAH concentrations ranged from 830 to 3600 $ng \cdot g^{-1}$ with a mean total concentration for all stations of 1700 $ng \cdot g^{-1}$. Most sediments showed a relatively uniform distribution PAH, with variations in PAH levels being directly related to TOC and silt/clay content of the sediments. However, PAH inputs related to an underwater "mud volcano" in the eastern part of the study area were evidenced by significantly higher absolute PAH levels, a higher proportion of low

molecular weight PAH, and higher PAH/TOC ratios in surrounding sediments. The background levels of PAHs and SHCs in the Absheron region are attributed predominantly to petrogenic sources with minor contributions of pyrogenic (combustion related) PAH components. Assessment of potential impacts from future oil exploration and production activities need to take into account the relatively high pre-exploration, petrogenic PAH levels in the regions sediments.

Question 1: Wouldn't the fingerprint of the mud volcano be similar to that of the reserve?
Answer: Yes, one would expect it to be similar. However, the signature would likely be more weathered from the mud volcano.

Question 2: What is a mud volcano?
Answer: It is a geological feature of eroded mud with seepages of oil and gas. My colleagues would be able to explain better.

Question 3: Isn't there a complex biomarker issue because of the mud volcano?
Answer: We don't know what the oil looks like yet, but there might be similar biomarkers. With good baseline data, we may be able to detect changes in the total concentrations.

Monitoring for PAH Exposure Using Bile Metabolites and Concentrations in Tissues: Continuing to Raise Questions

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Polycyclic aromatic hydrocarbons (PAH) can be detected in air, water and sediments, and the associated toxicity covers a range of end points. There is a widespread interest in monitoring for exposure to these contaminants in humans, other vertebrates and invertebrates. Monitoring can involve analysing the exposure media or the exposed organisms. Metabolites of PAH can serve as short-term biomarkers of exposure for animals with active mixed-function oxygenase enzymes. Analysing for PAH metabolites in urine represents a non-invasive approach used to determine exposure in humans. Similar approaches have been developed to monitor PAH exposure of fish by analysing bile samples. The European Union-supported QUASIMEME bile metabolites group worked to produce 2 certified finfish bile reference materials. CRM 720 was produced from sediment-exposed flounder, while CRM 721 was produced from crude oil-exposed plaice. These CRMs provide the means for QA/QC when analysing for these biomarkers. Since PAH can be found in various combustion and petroleum sources, chemical markers/ratios between PAH and tissues are needed to constrain exposure time and source, along with potential risk. Results concerning the fate of some predominant PAHs in the marine environment will be discussed, from a field and laboratory perspective.

This will include results on fingerprints in whole finfish collected in the Northwest Atlantic; the residence time of these PAH in organs of flounder after a single oral exposure and in trout during continuous exposure. Results will be compared to previous studies and field observations done near Seattle, on the northwest coast of the USA. Questions will be raised regarding the detection, formation, elimination of PAH and their metabolites relative to source in terms of bioaccumulation in tissues, bile metabolites in gall bladder bile and DNA-adducts in liver.

2.3 Session 3 - EEM Methodologies and Technologies

Ongoing Monitoring Programs Relevant for the Offshore Oil and Gas Industry in Norway, Emphasising Methods and Trends Seen in the Perspective of the Development of Hydrocarbon and Produced Water Discharges

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The keynote presentation will present the ongoing monitoring programs relevant for the offshore oil and gas industry in Norway, with emphasis on methods and trends seen in the perspective of the development of hydrocarbon and produced water discharges. The presentation will point at the tight connection between risk-based discharge management and environmental monitoring, at and newer methods to be applied for future environmental monitoring.

Question 1: Who pays for regional environmental assessment?
Answer: Oil companies. There is an association of oil companies.

Question 2: What are the main challenges for oil monitoring in deep water?
Answer: There is higher spreading and lower concentrations of regular discharges (drilling waste). Risk assessment is needed.

Question 3: Chemical dispersants aren't well spoken of. Are they used?
Answer: They are not banned. I think Exxon Mobil uses them in their strategy.

Question 4: You have spent time and money on the water column. Is anyone looking at the sea surface-air interface?
Answer: Not yet. This has not come up as a theme and is not mentioned in the guidelines.

Question 5: Are there any wildlife people involved with the program?
Answer: Not for regular discharges, only for spills.

Question 6: What about barium in produced water? Don't want to confound with drilling discharges.
Answer: I do have the data somewhere.

Evaluation of Risks from Produced Water Discharges in Atlantic Canada

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Produced water discharges—comprised largely of natural formation water within the oil and/or gas reservoir and injected seawater to maintain reservoir pressure—account for the largest volume of waste from offshore production facilities. Chemical analysis of samples of produced water from reserves in Atlantic Canada have shown that the concentrations of both inorganic and organic contaminants to be highly variable over temporal and spatial scales. Elevated concentrations of Al, Cd, Co, Cu, Fe, Pb, Mn, Ni, and Zn have been reported. Laboratory studies have verified that stimulatory and/or inhibitory biological effects may be induced by produced water discharge streams containing hydrocarbon levels deemed acceptable by the current *Offshore Waste Treatment Guidelines*. Elevated concentrations of inorganic nutrients in produced water, as well as biodegradable organic constituents may alter the rates of primary production and/or changes in microbial community structure in offshore waters. In terms of toxicity, the results from the Microtox® assay (inhibition of bacterial bioluminescence) have shown that the impact of produced water discharges may be altered by physico-chemical processes following their discharge into open ocean waters. For example, the dissolved metals in produced water samples from a Scotian Shelf site were found to flocculate into large particles that settled rapidly (>100 m d^{-1}). This process may mediate the rapid transport of organic and inorganic contaminants to the surface microlayer and/or the benthic environment. Predictive models are being formulated to determine the environmental future significance of such contaminant transport mechanisms. It is noted that with limited discharge volumes at the present time, no significant changes (either stimulatory or inhibitory) were observed with distance from the Hibernia Gravity Base Structure for depth profiles of microbial activity.

Environmental Modeling of Produced Water and Indicators for EEM

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Produced water is the largest volume waste stream component of the offshore oil and gas industry. Produced water is a complex and variable mixture of metals, dispersed hydrocarbons, dissolved hydrocarbons, and organic acids. The prediction of chemical fate and effects in the marine environment is extremely important to mitigate adverse effects on the Scotian Shelf. Modeling provides an examination of dispersion and possible environmental partitioning. The modeling results indicate the spatial and communities that should be examined during monitoring studies. Analysis of environmental effects is

developed through an integrated modelling approach. The first model is a hydrodynamic dispersion model that describes how a wastewater plume will react in the ambient oceanic environment. The second model considers the physical-chemical properties of toxic components and describes likely partitioning in environmental media, water, suspended sediment, biota and sediment. The final model component is the ERA framework that allows the characterization of risk for the local ecosystem.

Question 1: In your presentation, you said that benzene was persistent? Most models indicate that benzene will evaporate.
Answer: It took 3 hrs to reach 1 km. Within that time, we didn't see an effect. Produced water was disposed of at 10m below surface, so possibly it didn't have time to reach the surface. Stratification encourages higher persistence. Also the water is colder here, so there is more persistence.

Assessing the Impact of Produced Water Discharges in the North Sea – Comparison of Field Monitoring and Modelling

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The North Sea Water Column Monitoring Program includes determining the impact of produced water discharges in major oil and gas production areas in the Norwegian Sector of the North Sea. The work focuses on produced-water originating contaminants that may bioaccumulate and/or cause toxic effects. The fate and effects of the contaminants are determined using both field-based techniques and through modelling, and the results from the two approaches are compared for model validation, and to refine the model and assessment techniques. This model is subsequently used to develop the EIF (Environmental Impact Factor) for each discharge; the EIF is a risk-based tool used to manage the produced water discharges in Norway. Specialised sampling and analytical techniques are employed to measure contaminant concentrations in the sea near and distant to discharges, and to determine the potential for bioaccumulation and effects. Concentrations and potential effects are also determined using a dispersion-and-risk model, with produced water input data and site-specific environmental conditions. The results from both approaches are presented and compared for the Tampen and Ekofisk region in the North Sea, and the overall potential for impact discussed. Localised, elevated contaminant concentrations are observed near some discharges, with background concentrations typically being reached within a few kilometres of the discharge. The fate and potential effects of the discharged contaminants depend greatly on the characteristics of the discharge, the chemical composition of the discharge, and the mixing and spreading mechanisms in the ocean around the platform. The combined field monitoring and modelling approach, with the incorporation of the EIF, provides a powerful and effective approach for managing produced water discharges.

Question 1: How is the critical level defined?

Answer: Mussels come to equilibrium within 20-25 days - this is the body burden. It is based on the lipid content. We determine the amount of contaminant and compare to the critical body burden value for potential for impact. We ask, has it reached the critical body burden where impact would be expected? These levels have been published and supported for organic contaminants.

Biological Effects in Pelagic Ecosystems – An Overview of the ICES Workshop BECPELAG

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The ICES workshop on biological effects in pelagic ecosystems (BECPELAG) was a multi-national, multi-discipline workshop aimed at establishing suitable techniques for monitoring the effects of contaminants on pelagic ecosystems. During seven research cruises in 2001, pelagic organisms were collected and caged deployed at four sites in the German Bight and at four sites in the vicinity of an oil platform in the northern North Sea (Tampen area). The main objective of the workshop was to bring together scientists involved in relevant work in a practical workshop in order to assess the ability of selected methods to detect biological effects of contaminants in pelagic ecosystems. A second objective was to recommend methods for future water column monitoring programs. The workshop has involved more than 30 research groups in 12 European countries. The studied systems and organisms include different components of the pelagic ecosystem, from bacteria and microzooplankton through zooplankton and fish larvae to juvenile and adult pelagic fish. In addition to field-collected specimens, Atlantic cod and blue mussels were caged at 8 selected locations. SPMDs (semi-permeable membrane devices) were deployed at each site, extracted and the extracts tested for biological activity as well as analysed for PAH content. Solid-phase extracts of water and produced water were also tested in a range of *in vitro* test systems. The biological methods used within the workshop ranged from bacterial diversity through responses in wild and caged organisms to responses in *in vitro* tests of extracts with whole organisms and cell cultures. Chemical analyses were carried out in extracts and biota for a range of determinands, including PAHs, PAH metabolites, alkylphenols, organochlorines, organotins, metals and PBDEs. There were clear gradients in both areas for some contaminants, e.g. PAHs. Exposure-related responses were seen in both wild and caged organisms, including histopathological changes and biomarker responses. Only the most sensitive *in vitro* methods could detect toxicity of SPMD or SPE extracts. This paper will review the methodologies and science behind the BECPELAG and how the results have been used as a platform to develop a strategy for future monitoring and management of pelagic ecosystems. The results support an integrated chemical and biological approach. Furthermore, the collection of wild organisms should be supported by the use of caging due to the large variability in wild specimens.

Question 1: You mentioned the difficulty of separating zooplankton species in the field. There has been a fair amount published that says species level analysis is expensive and difficult, is it needed?
Answer: This is not my area of expertise, but I think there is a need to find out what's there. The workshop was to establish what could be done, and this was seen as a problem that needed to be resolved.

Question 2: One of your tables showed effects on early life-stages. I was wondering what species was studied and whether it was fieldwork or lab work?
Answer: I don't know, again this is not my field. 40-50 people brought their techniques to the workshop. One can't be a master of all of them. Go to website for more information: www.niva.no/pelagic/web

The Experience from Using *In Situ* Deployment of Live Organisms and Passive Samplers during the ICES BECPELAG Workshop

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Due to the inherent variable exposure of pelagic organisms to water-borne contaminants, there has been an increasing interest in *in situ* deployment of caged organisms and passive samplers. *In situ* deployment generally either uses blue mussels and SPMDs in combination or a fish species (e.g. cod, stickleback, or flounder). Combined deployment of blue mussels and SPMDs has been used both in coastal monitoring and in the monitoring of discharges from offshore oil activities. Flounder and stickleback has been used to monitor contaminants in estuaries and fjords, whereas cod has mainly been used in oil-related monitoring, both inshore and offshore. During the BECPELAG workshop, cages were deployed for 6 weeks at 8 locations, 4 in the North Sea (an oil rig transect) and 4 in the German Bight (in a transect from Elbe/Weser). Caged organisms were blue mussels, Atlantic cod, and 3-spined stickleback. In addition, passive samplers (SPMD and DGT units) were deployed on each rig. Cages for offshore deployment in waters have special requirements. The design must be optimised for easy introduction and removal of the fish from the cages, thereby avoiding unnecessary stress to the fish. The entire buoy/cage structure must be easily available and amenable to quick deployment and retrieval. Finally, the caged fish should have access to food during deployment. Blue mussels were deployed in tubular mesh stockings attached to the main fish cage. The cod deployed during BECPELAG were all in good condition following retrieval, although condition indices varied between locations. Earlier studies have shown that a light source used with the cages would ensure a food supply for the fish and that was found to be the case here as well. The stickleback cages were not suitable for mid-ocean deployment and there was total mortality. Preliminary data indicates that there were indeed gradients and that the caged organisms reflect the different exposures. *In situ* techniques provide an important link between laboratory experiments and field observations.

Question 1: You stated that *in situ* studies lend themselves to control and replicates; however, you only used five stations. These are pseudo-replicates.
Answer: There are practical considerations to take into account.

An Assessment of the *In Vitro* Oestrogen Receptor Agonist Potency and Alkylphenol Content of Produced Water Discharges into the North Sea
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This presentation describes the application of the *in vitro* yeast oestrogen screen (YES) to determine the oestrogen receptor (ER) agonist potency of produced waters from the UK and Norwegian sectors of the North Sea. Initially five effluents were collected, extracted *in situ* offshore and tested were shown to contain ER agonists. A toxicity identification evaluation (TIE) approach was then used to identify $C_{2\text{-}9}$ alkylphenols as the principal ER agonists present in the produced water samples collected. A wider study was then initiated to investigate the *in vitro* ER agonist potency and alkylphenol content of all produced water discharges in the UK sector of the North Sea. The results of the TIE study and subsequent monitoring study are both described and discussed.

Question 1: What is the sensitivity of this test compared to other tests?
Answer: We haven't established the sensitivity of the test yet. It is the most sensitive end point, though.

Question 2: Did you combine fractions again afterwards to see if response is additive?
Answer: We didn't do any confirmation, but the additive nature has been shown in another paper.

Development and Field Validation of the EIF as a Produced Water Discharge Management Tool
***Frost, T.K.** and S. Johnsen,*
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In 1999, the EIF (Environmental Impact Factor) was introduced as a produced-water-discharge management tool by the offshore oil and gas production industry in the Norwegian part of the North Sea. This tool, based on the EU standards for environmental risk assessment, was developed to meet the challenge related to the 2005 zero harmful discharges goal. In 2000, the industry reported the EIF for all Norwegian oil and gas fields to the national authorities. The EIF expresses environmental risk as a function of the PEC/PNEC ratio, where PEC (Predicted Environmental Concentration) represents environmental abundance of different chemical constituents in produced water. PNEC (Predicted No Effect Concentration) reflects the tolerance level of the marine ecosystem towards a certain chemical pollutant, based on the intrinsic toxicity of this compound. When applied in produced water management, the EIF expresses the environment risk as a water volume where PEC exceeds PNEC in the recipient. The EIF will also indicate

which chemical compounds of the discharge have the highest potential to cause this risk. In parallel with the development and implementation of EIF, Norwegian authorities launched a national program for offshore environmental monitoring of the water column. Partly, this program is designed to validate the different elements included in the EIF, and the primary phase (1999 – 2002) was focusing on measuring concentrations of produced water compounds in the recipient, comparing these with the corresponding levels predicted by the EIF model.

Question 1: This model uses the addition of various components. Is the assumption of additive effects appropriate?
Answer: It is an appropriate assumption because we don't know any better. I haven't seen any convincing data showing a synergistic effect. We will use this technique until we see evidence to change it. We can take some of this into account by using the weighting factor.

Question 2: The model isn't species specific.
Answer: We need to develop the risk assessment part of it to take into account local biota.

Bioassay-Directed Fractionation and Chemical Identification of Complex Effluents from Oil Production Activities

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Oil production platforms discharge large volumes of produced water (PW) containing various chemicals that may pose a threat to organisms living in the recipient. This applies in particular to groups of organic chemicals that are known to produce various toxic effects including reproductive disturbances, mutagenicity and carcinogenicity. In the present project, PW from a production platform in the Norwegian sector of the North Sea was subjected to a bioassay-directed fractionation and chemical identification procedure to identify ecologically relevant groups of toxic chemicals present. This procedure, which is a combination of large volume solid-phase chemical extraction, RP-HPLC fractionation, multiple microscale bioassay testing and chemical analysis, was found to separate the complex sample matrix efficiently in order to detect and identify toxic chemicals. Briefly, the bioassays, which include microtox™, mutatox™, yeast estrogen screen (YES), yeast androgen screen (YAS), fish egg microinjection and fish hepatocytes with multiple biomarker and effect endpoint analysis, show that PW contains acute toxic chemicals, CYP1A inducers, oxidative stressors, estrogen mimics and mutagenic chemicals. No androgenicity was found in raw extracts and individual fractions. The major toxicological activity measured by the choice of bioassays was found in fractions with mid to low polarity (log K_{OW} = 2.2-5.2), whereas acute toxicity and mutagenicity

was also found in more polar fractions (log K_{OW} = 1.0-2.2). Ongoing studies with fish egg microinjection of ecologically relevant toxic fractions are anticipated to elucidate whether components in PW may also act as embryotoxic. High-resolution GC/MS and LC/MS (TOF) analysis was deployed on selected fractions of ecological relevance (log K_{OW} > 2.5) to identify the individual components responsible for the observed toxic activity.

Question 1: How long did it take to complete one sample?
Answer: There was quite a bit of initial lab set-up. But you can get quick and smooth results if you have the staff and dedication.

Evaluation of bblt, a Drilling Mud Dispersal Model, at North Triumph (Scotian Shelf)

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The bblt model (benthic boundary layer transport model) was used to simulate the drift and dispersion of suspended drilling muds near the drilling platform at North Triumph on Sable Island Bank during a drilling program in the fall of 1999. The goal was to use the observations of barium in the water column obtained by the Environmental Effects Monitoring (EEM) program to test the model. The simulations focussed on barite ($BaSO_4$), the primary weighting agent in the drill muds used. The model was able to reproduce the very low concentrations (generally < 1 μgL^{-1}) observed during the EEM program. Over the entire drilling program, the model also predicts barite concentrations > 100 $\mu g\ L^{-1}$ (=0.1 mg L^{-1} the no effects concentration for scallops) for several days within a few kilometres of the rig. However, there were no EEM observations during periods of active discharge to validate this prediction.

Question 1: Are there significant effects on the marine and planktonic ecosystem? And what scale?
Answer: I don't know what scale as we are just at preliminary stages. It is likely to be a local scale, but this is only one-dimensional.

Question 2: Could technology with satellites see a bloom around a platform, the stimulatory effect?
Answer: That depends on the scale and effect, if it is less than 1km than it isn't likely to be seen. There can also be bacterial effects that cannot be seen from space.

In Situ **Deployment of Fish, Mussels, and Passive Samplers to Monitor Accumulation and Effects of Contaminants**

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Due to the inherent variable exposure of pelagic organisms to water-borne contaminants, there has been an increasing interest in *in situ* deployment of caged organisms and passive samplers.
Deployment of caged fish, combined with blue mussels and SPMDs, has been used successfully both in coastal monitoring and in monitoring of discharges from offshore oil activities in Norwegian and German waters. Each cage has a light source that attracts zooplankton and small fishes, which acts as food for the caged fish. By using this method, the fish are exposed to the water as well as to potential contamination entering the fish through the food chain in the particular area where the cage is deployed. This self-feeding caging system has been tested with 3 different species (cod, saithe and haddock). The fish have been kept in the cages for up to 12 months with no additional feeding, and mortality rates have been less than 5%. This method has been used in four different monitoring projects. (1) A 4-month caging experiment at the discharge site from an oil refinery in a Norwegian fjord. Clear gradients on accumulation of hydrocarbons and the level of bile metabolites in the fish were found. (2) Monitoring of accumulation and effects of the effluents from the Troll B oil production platform in the North Sea, with a sea depth of 330 m. Samples were taken every 6 weeks over a 6-month period. No significant effects found. (3) Test of light as food attraction at different locations along a transect from the inner part of a Norwegian fjord to a location ca. 45 miles offshore. Variation in food supply and growth was found. (4) The BecPelag workshop in the North Sea in 2001: 5 cages along an anticipated gradient from the Statfjord B platform in the North Sea, and 5 cages in the German Bight. Gradients were found. *In situ* techniques provide an important link between laboratory experiments and field observations.

Potential Effects of Produced Water Discharges from Offshore Oil and Gas Production Activities on the Early Life Stages of Haddock (*Melanogrammus aeglefinus*), Lobster (*Homarus americanus*), and Sea Scallop (*Placopecten magellanicus*)

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The potential impact of offshore drilling wastes to larval invertebrates was explored. Acute and chronic effects of exposure to produced water (PW) from offshore drilling were quantified for the early life stages of haddock (*Melanogrammus aeglefinus*), lobster (*Homarus americanus*) and sea scallop (*Placopecten magellanicus*) in terms of survival, growth and fertilization success. During 96-h exposures to 0-25% PW, yolk-sac haddock larvae, fed stage-I lobster larvae, and scallop veligers each displayed significant reductions in survival at 10 and 25%. The average size of scallop veligers was significantly reduced after exposure to 10 and 25% PW. Scallop fertilization success was significantly reduced at all concentrations ≥ 1%. During 18-d chronic exposures to concentrations of 0-10% PW, significant reductions in scallop veliger survival and size were observed in the 10% treatment. Chronic exposure of the diatom, *Thalassiosira pseudonana* to 10% PW resulted in a significant reduction in physiological condition

though there was no effect on chlorophyll-a concentration. The results of this study indicate some sensitivity of the developmental stages of haddock, lobster and sea scallop to produced water.

Question 1: Chronic tests, what did you do to keep the constant exposure?
Answer: We removed algae and added to bring it back to the initial levels.

Question 2: Generally in bivalves the faster growing died more often. In Peterson's study it was said that sexual maturity is associated with size, so there is likely more pressure to grow quickly, but these animals could be less robust.
Answer: The bigger animals were quite young.

Question 3: How was the experiment set up? How was the produced water stored?
Answer: Lobsters in 10 vials and 3 animals in each one, there were some issues with cannibalism. Produced water was stored under nitrogen gas in a cool place. The experiments were conducted in a refrigerator.

Impacts of Nutrient Inputs from Produced Water on Marine Planktonic Production: An Ecosystem Modelling Approach

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An ecosystem modelling approach is proposed to investigate the effects of ammonia (NH_4) and volatile fatty acids (VFA), two nutrient components of produced water of major environmental concern, on the annual production of the planktonic community. The inputs of NH_4 and VFA were simulated in the model as distinct source terms of dissolved inorganic nitrogen and dissolved organic carbon, respectively, in the differential equations describing the ecosystem dynamics. Application to the Scotian Shelf shows that the discharge of produced water from offshore oil and gas exploitation can have substantial effects on the plankton community. Annual production of bacteria and zooplankton may increase by factors of 10 and 3.5, respectively, under poor dilution conditions, e.g. 100 m^3/day dispersed over an area of 100x100m or less. The impact of produced water in the bottom 40 to 50 m of the water column (total depth 140 m) is negligible. Phytoplankton and chlorophyll production are affected mostly near the surface. However, bacterial and zooplankton productions are affected up to a depth of about 100 m. The strongest effect is obtained at a depth of about 60 m. Produced water can also affect the seasonal dynamics of the plankton ecosystem. The depth-integrated annual maximum in bacterial production occurs 9 days earlier with produced water inputs than without. However, vertical profiles show that the largest seasonal shift occurs at a depth of about 80 m. For bacterial and chlorophyll production, it may reach about 11 and

18 days, respectively. Results showed also that produced water has some impact on the localisation of the production maximum in the vertical. The strongest shift of about 5 m toward the surface is observed for bacterial production. Based on the results obtained, it is hypothesised that the potential impact of produced water on the marine environment could be minimized, by alterations in diffuser design and placement in the environment. We recommend using the modelling procedure proposed in this study to optimise design and placement of diffusers of produced water.

Question 1: What was the threshold concentration for influence?
Answer: Predicted concentrations are transient, we need longer duration to see lab impacts. If you have that concentration, animals will respond but we need longer duration to see other effects.

Seasonal and Spatial Patterns of Marine Bird and Mammal Occurrences Recorded on Offshore Support Vessel Transects on the Grand Banks

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Globally significant communities of birds and mammals occur on the Grand Banks of eastern Canada, yet there is a disappointing lack of information on their changing diversity, distribution and abundance. Working through the Canadian Newfoundland Offshore Petroleum Board (CNOPB) with the support of the Environmental Studies Revolving Fund and of Husky Oil, Memorial University of Newfoundland has been conducting standardized monthly seabird and marine mammal surveys that integrate oceanographic data on offshore support vessels traveling between St. John's and the Hibernia and Terra Nova platforms since 1999. Shearwaters, storm-petrels, kittiwakes and murres were the most common seabirds observed but marked seasonal changes in oceanography and species diversity, distributions and abundances of birds and mammals occurred. Most birds were recorded during summer, when breeding seabirds were mainly inshore near colonies, and high numbers of Southern Hemisphere shearwaters were offshore. High numbers of birds also occurred during migration (October and May). From November through April, Dovekies and murres, the species most vulnerable to oil pollution, were the most abundant seabirds. Oiled Dovekies were observed at Hibernia in February and at other times by vessel crews. Humpback Whales were frequently feeding at Hibernia, and with Minke Whales, were the most common mammals during summer and autumn; porpoises and dolphins were also recorded during summer. Concentrations of birds occurred in a branch of the Labrador Current about mid-way between St. John's and Hibernia. Seabird densities, especially Greater and Sooty Shearwaters, increased within a 500 m radius of offshore platforms due to light attraction, food availability and roosting refuge. Great Black-backed Gulls were common offshore and observed feeding at Hibernia at night on fishes attracted to platform lighting that also attract storm-petrels and Dovekies. These surveys need to continue to keep assessing the dynamic relationships of seabirds and mammals within the NW Atlantic ecosystem in order to help management effectiveness and reduce risks.

Question 1: Petro-Canada has a dedicated observer and we've been collecting data for a long time. We have the Leach's Storm Petrel recovery program and only 6 birds have been lost.
Answer: We stress independent trained observers.

Question 2: Where is the chronic oil coming from?
Answer: 99% of oil is from illegal bilging.

Question 3: Chronic pollution is not the case from oil and gas. Oiled birds have been washing up in Placentia Bay for years before oil and gas activities. Objectivity should be the goal.
Answer: We just want to demonstrate potential problems.

Interaction and Remediation of Oil Spills in Ice Infested Waters: An Experimental and Numerical Investigation

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Environmentally friendly remediation of oil spills is a major concern of the petroleum community. This is especially true for the removal of oil from ice-infested waters where frigid temperatures and ice impede clean-up procedures and many remediation techniques become ineffectual. Fish-scale powder is proposed as an environmentally sound and economically viable remediation option to solve this problem. A series of experiments was conducted to determine if fish-scale powder is viable as a remediation medium for oil slicks on ice. The results from this experiment have been compared to the experimental results with the conventional remediation medium, bentonite. The fish scale is found to absorb oil spill and form fine emulsions that would be easier for microbes to biodegrade. Another aspect is the possibility of re-using the oil-fish scale media for other applications, such as drilling mud, land-farming media, etc. Indeed, the oil media possess excellent filtration and viscosity parameters that can lead to the formation of biodegradable drilling mud. The nature of oil spreading with and without the remediation mediums was examined, and a numerical model was developed based on these observations. The experimental and numerical investigation examined various aspects of oil spills including the viscosity of the oil and interfacial tension. As well, the effect of temperature will be discussed and scaling-up criteria will be studied.

Question 1: It is curious why you compared bentonite and not things already available?
Answer: Bentonite is a commonly used substance and we had to pick one.

Question 2: What is the soaking capacity of the fish scales?
Answer: We only looked at 6ml, which is why we're developing a numerical model. I can't answer that at this time.

3. Poster Presentations Abstracts

Screening Assessment of Environmental Effects of PEMEX Operations in Sonda de Campeche, Mexico

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In 2001, Petróleos Mexicanos (PEMEX) conducted a screening-level analysis of environmental conditions near offshore exploration and production operations in the Sonda de Campeche, off the coast of the State of Campeche, Mexico. The primary purpose was to determine, using available data, if past or current operations have resulted in potentially significant adverse impacts on human health or the environment. A consortium of the Insituto Mexicano del Petróleo, Battelle Memorial Institute, Universidad Nacional Autónoma de México, and Universidad Autónoma Metropolitana conducted the study using data provided by PEMEX, other regional environmental monitoring data, industrial norms, and Mexican and international standards. Impacts from routine discharges and accidental spills from platforms were generally low to moderate, with the primary source of impacts being past discharges of produced water and muds. Sediment chemistry results show oil-related signatures in the vicinity of the oldest fields, but these results are confounded by the presence of natural seeps. The estimated flux from natural seeps is several orders of magnitude above the reported influx due to spills from platforms. Spills of muds and crude oils were no more frequent, but were larger, on average, than in the northern Gulf. Bioaccumulation appears to be low and below human health criteria in the general region, although data on individual PAHs in biological tissues are unavailable for the platform area. Produced water is currently being treated at an onshore installation and primarily discharged to the sea. Sediment monitoring shows high concentrations of petroleum-derived organic compounds in that area. Fisheries data show shifts in species and size classes of commercial catch, but overfishing of stocks limits the utility of these data for determining effects from petroleum operations. Satellite imagery shows land runoff is the overwhelming determinant of primary productivity within the region. Data on benthic species are sparse near offshore operations.

Using Genetic Diversity as an Indicator in Marine Monitoring Programs

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A loss of genetic diversity may be an "early warning" sentinel that ecological change is occurring. A loss of genetic variation could be deterministic (due to selection) or random (due to genetic drift). Regardless of the evolutionary mechanism, a population with decreasing size will exhibit reduced genetic diversity because of increased inbreeding and genetic drift. Most meiofauna (e.g., nematodes or harpacticoid copepods) have direct benthic development, whereas most macrofauna (e.g., polychaetes or mollusks) have larval dispersal stages. This means meiofauna are integrating stressor effects over small local scales over their entire life cycle. In contrast, macrofauna are integrating stressor effects over much wider spatial scales proportional to the distance larvae can disperse. Populations of Harpacticoida (Crustacea: Copepoda) lose genetic diversity near (< 100 m) hydrocarbon production platforms in the Gulf of Mexico. The reduced genetic diversity was found in populations of five species and at three platforms, indicating the results are statistically robust and are likely a general finding. Populations exposed to pollutants also lose genetic diversity in cultures. These two results support a deterministic hypothesis that hydrocarbon and trace metal contaminants associated with production platforms cause differential selection on populations living near platforms. Genetic techniques may be useful in studies to monitor ecological health of aquatic systems. In particular, population measures could be an earlier warning sign of incipient degradation. The largest potential for the techniques is to combine it with life-history information from different groups of organisms to build "designer" indicators that will be useful to detect changes of biotic responses for different levels of stressor fields at different spatial scales.

Short-Term Effect of IPAR-3 and Diesel on Immune Responses in Mussels

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Synthetic-based muds can present lesser environmental risks than water-based muds. One of the base oils used in muds off the East Coast is IPAR-3 (PureDrill IA-35), a synthetic isoalkane composed of aliphatic carbon compounds. It is commonly accepted that aliphatic hydrocarbons have a much lower toxicity potential than PAHs. Some authors have suggested that PAHs could have a toxic effect on immune responses in shellfish. In this study, we investigated the short-term effect of water soluble fractions (WSF) of IPAR on cellular immune response in mussels (*Mytilus sp*.) and compared it to aromatic hydrocarbon enriched fractions of diesel which can act in many ways as surrogate sources of soluble hydrocarbons from crude petroleum and production waters. Any toxicant that interferes with hemocyte functions may increase vulnerability of targeted organisms and ultimately lead to expression of disease. Different immune responses were investigated in hemocytes including: number, capacity to phagocytose zymosan particles,

adherence to surfaces and maintenance of cytoskeleton integrity. Studies were carried out *in vitro* by preincubating hemocytes with IPAR and diesel WSF prior to measuring phagocytosis and cytoskeleton integrity. Short-term *in vivo* immune responses were also investigated by injecting animals with zymosan particles and measuring phagocytosis and cell numbers in the same mussels before and after exposure to water soluble fractions. Overall, the data indicate no short-term effect of IPAR on the cellular responses investigated. On the other hand, hemocyte immune response was affected by diesel WSF in the 10 ppm range (supported by PERD and ESRF).

Marine Bird and Mammal Surveys from Offshore Support Vessels and Ships of Opportunity on the Grand Banks

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Marine birds are the most conspicuous, wide-ranging and easily surveyed marine animals and have been used as indicators of marine ecosystem conditions for decades. Marine birds and mammals are top predators in ocean food webs and are sensitive to oceanographic and human-induced perturbations and their interactions. Long-term knowledge of their distribution, abundance, and behaviour is useful in determining conditions at lower trophic levels in marine ecosystems. The principle objectives of conducting surveys from offshore support vessels and ships of opportunity are to fill gaps in our current knowledge of seasonal distributions of marine birds and mammals in the Northwest Atlantic and to assess their interactions with hydrocarbon developments. Marine birds and mammals are surveyed monthly by independent observers from support vessels travelling to and from oil platforms on the Grand Banks. Sea-surface temperatures collected using a data logging system onboard Maersk support vessels are related to seasonal species occurrences, distribution, and abundance. Supplementary observations are gathered from ships of opportunity (Canadian Coast Guard research vessels) that expand the spatial range of surveys and contribute biological variables (sampling of fish and crustacean prey of marine birds and mammals) that are unavailable on support vessels. Observed events at and around offshore platforms (e.g. oiled birds and foraging activity) help describe mechanisms that attract marine birds and mammals to offshore platforms and assess their degree of vulnerability to associated oil pollution and flaring. This assessment and documenting variability in the spatial and temporal distributions and abundances of marine birds and mammals on the Grand Banks will benefit conservation. This research will further provide government, industry, and scientific and public communities with information necessary to manage operations and to minimise impacts on the marine ecosystem.

An Integrated Approach for Environmental Decision-Making for Offshore Oil and Gas Operations

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Environmental risk assessment and risk management is being integrated with developments in autonomous underwater vehicle technology through a research program entitled Offshore Environmental Engineering using Autonomous Underwater Vehicles (AUV). The program is a partnership between the Ocean Engineering Research Centre at Memorial University of Newfoundland and the Institute for Marine Dynamics of the National Research Council Canada, together with several other academic and industrial concerns. Three elements of the overall project are presented and described in this poster presentation:

- Assessment of candidate sensors to be deployed on an autonomous underwater vehicle for environmental effects research and monitoring missions. Recent trials of an *AUV* with an underwater mass spectrometer payload are the focus of this part of the presentation.
- Results of a laboratory study of the settling characteristics of drilling waste. This work is in support of transport and fate modelling, and includes flocculation, settling, deposition, and erosion properties of drill cutting in quiescent and dynamic conditions.
- Evaluation of offshore drilling waste treatment technologies. Drilling waste treatment technologies applicable to cuttings with adhering synthetic base fluids are evaluated from technical, environmental, and economical points of view. Different treatment technologies are compared and the options ranked using a multi criteria decision-making approach.

The Results of Ten Years of Beached Bird Surveys on Sable Island

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The results of ten years of beached bird surveys on Sable Island (January 1993 to December 2002) are presented. In 100 surveys roughly 6000 bird corpses representing over 40 species were found. Numbers of beached birds and species composition were subject to large fluctuations reflecting both the seasonal distribution of species and the effects of weather. The oiling rate, the fraction of oiled corpses of the total number of dead birds found on the beach, was approximately 45%. High rates of oiling were typical of auks, and low rates were typical for birds such as shearwaters and gulls. The results of the 1993-2002 program do not indicate either increasing or decreasing trends in proportion of birds found oiled, and suggest no change in chronic oiling during the last decade. Sable Island is located in a region with a relatively high level of marine traffic which discharges significant amounts of oil into the sea (Chardine, 1991). In addition, the Sable Island Bank is at the centre of development of offshore energy resources off Nova Scotia. Production platforms are located southeast, south and southwest of the island, and further exploration activities are underway and planned for the region. Because of its unique offshore location Sable Island has been used as a monitoring station for both marine litter (Lucas, 1989) and stranded cetaceans (Lucas and Hooker, 2000), and the island's proximity to areas of heavy marine traffic and offshore energy development

make it a useful platform for monitoring trends in oiled seabird species and numbers in the Scotian Shelf region.

The ICES Workshop on Biological Effects in Pelagic Ecosystems (BECPELAG): *In Situ* Techniques

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There is a lack of agreed methods to assess the impact of contaminants in pelagic ecosystems. Earlier workshops arranged under the auspices of ICES and IOC have stimulated research into the use of biological effects methods to monitor contaminant impacts in benthic ecosystems. Many of the techniques developed have now been incorporated in national and international monitoring programs. There has been increasing interest throughout the past years to commence co-ordinated studies on effects in organisms representing pelagic ecosystems as a basis for future monitoring programs. The *in situ* methods used within the workshop included caged Atlantic cod and blue mussels. Cages were deployed at four locations close to the Norwegian oil fields and at four locations in German Bight in April 2001. In June, approximately six weeks later, the cages and organisms were retrieved and samples taken for a range of biological effects techniques. Samples were obtained on a contaminant gradient in the German Bight and at three stations in the vicinity of an oil field in the central/northern North Sea plus a reference area. Details of the scope of the workshop will be presented, along with the methodology of deep-sea caging and the rationale for using *in-situ* methods. A suite of bioassay and biomarker methods were used on the organisms retreived: MT induction, AChE, GST, histopathology, histochemistry, vtg, CYP1A protein, DNA damage, PAH metabolites, EROD, antioxidant enzymes, immunotoxicity and scope for growth. More information at: http://www.niva.no/pelagic/web/

ICES Biological Effects Monitoring in Pelagic Ecosystems (BECPELAG) Workshop: Field Sampling

Hylland, Ketil, *Gerd Becker, Jarle Klungsøyr, Thomas Lang, Alistair McIntosh, Bjørn Serigstad, John Thain, Kevin Thomas, Toril Inga Røe Utvik, Dick Vethaak, and Werner Wosniok*
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The ICES biological effects monitoring in pelagic ecosystems (BECPELAG) workshop has been a multi-national, multi-discipline workshop aimed at establishing suitable techniques for monitoring the effects of contaminants on pelagic ecosystems. During seven research cruises in 2001, pelagic organisms were collected at four locations in the German Bight and at four locations in a transect from an oil platform in the North Sea. The studied systems and organisms ranged from bacteria through zooplankton and fish larvae to juvenile and adult fish (saithe, mackerel, and herring). Endpoints in the studies, performed by laboratories in 12 different European countries, include community studies

as well as a suite of biomarker methods. The biomarkers include EROD activity, AChE activity, GST activity, histopathology, histochemistry, vtg concentration, CYP protein levels, DNA damage, PAH metabolites, antioxidant enzyme induction, and cellular energy allocation. Some selected tissues are extracted for bioassay studies. Chemical analyses for the same organisms and tissues included PAHs, PAH metabolites, organochlorines, organotins, brominated compounds, and metals. The design of the sampling and preliminary results will be presented. More information can be found at the web-site for the workshop: www.niva.no/pelagic/web/.

The ICES Workshop on Biological Effects of Contaminants in Pelagic Ecosystems (BECPELAG): *In Vitro* Bioassays

Thomas, K.V., *G. Becker, K. Hylland, J. Klungsøyr, T. Lang, A. McIntosh, B. Serigstad, J. Thain, T.I.R. Utvik, D. Vethaak, and W. Wosniok*
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The ICES biological effects monitoring in pelagic ecosystems (BECPELAG) workshop has been a multi-national, multi-dicipline workshop aimed at establishing suitable techniques for monitoring the effects of contaminants on pelagic ecosystems. One of the many activities that have been concurrently performed is the extraction of water samples using SPMDs, blue mussels, and large volume SPE followed by *in vitro* testing and targeted chemical analysis of the concentrated extracts. SPMDs were deployed at four sites in the German Bight and four sites in a transect from an oil plaform in the North Sea. Water samples for extraction were taken at the same eight locations. The following *in vitro* assays were used during the workshop: AChE inhibition, fish hepatocytes, DR-CALUX, ER-CALUX, AR-CALUX, Microtox, Mutatox, yeast oestrogen and androgen screen (YES & YAS), *Danio rerio*, Oyster (*Crassostrea gigas*) embryo, *Tisbe battagliai*, *Skeletonema costatum*, yolk-sack turbot (*Scophthalmus maximus*) larvae and *Acartia tonsa.* The presentation gives an overview of strategy and the methods used. More information at: http://www.niva.no/pelagic/web/.

Monitoring Birds and Marine Mammals on Offshore Vessels and Drilling Rigs

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The Oil and Gas Observer Program (OGOP) provides fisheries-industry led observer/liaison coverage of oil and gas activities in the offshore. The program is operated by the fisheries industry and has been in operation for nine years. The program is also building and maintaining trust between the petroleum and fisheries industries. It is providing the two industries with feedback about environmental and fisheries issues and helping to minimize conflicts between the two industries. OGOP utilizes qualified fisheries observers who have a background in the fisheries industry. They monitor all activities, which may affect the fisheries industry and conduct bird, marine mammal and turtle observations. OGOP has provided fisheries observers on various EnCana programs including seismic vessels and drilling rigs (shallow and deep water). A summary of

fisheries observer reports from these surveys over the past four years is presented. The datasets include information on marine mammals and birds sightings in terms of species, number of individuals and location. Additional information collected on marine mammals includes number of juveniles, behaviour, and any human activity in the area.

Cohassett EEM Program

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The Cohasset Project, operated by EnCana Corporation, was Canada's first offshore oil project and produced over 44 million barrels of oil between June 1992 and Dec 1999. The Project consisted of a jack-up drilling rig converted for production use, two fixed steel platforms with interconnecting flowlines, a million-barrel storage tanker, and a shuttle tanker. Almost twenty wells were drilled over the life of the Project, fourteen with a low toxicity mineral oil that was treated and discharged overboard. The principle Environmental Effects Monitoring program for the Project was a shellfish tainting study using mussels nets suspended at varying distances from the jack-up rig. During the Project's regulatory review and EEM workshop, taint (an abnormal smell or taste) from the drilling muds was identified as a major concern among the fishing industry due to the potential impact to their livelihood. To assist in the analysis, total hydrocarbon loading was also carried out with the taint study. The data that was obtained from this program, from April of 1993 to June of 1999, consistently shows that any taint observed from the Project is limited to 500 meters from the rig, with few exceptions. In 1997, EnCana introduced the Cuttings Injection technology to the East Coast offshore and discontinued overboard discharge of oil based cuttings. No further taint and only background levels of hydrocarbons were observed. With the review and approval of the Canada-Nova Scotia Offshore Petroleum Board, EnCana was able to terminate this EEM program prior to the Cohasset Project completion.

Partitioning, Exposure and Effects Associated with Environmental Mixtures of Contaminants, Including Petroleum and Combustion Hydrocarbons

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Polycyclic aromatic hydrocarbons (PAH) associated with petroleum and combustion sources were analysed in water and particles to examine their partitioning between the two phases and interpret their potential bioavailability to pelagic and benthic organisms. Sampling was done in Halifax Harbour, at three sites located near different point sources of contamination, with water temperatures ranging from 1 to 18^0C. Three out of 27 water samples displayed significantly higher levels of PAH than the others and were associated with petroleum sources of contamination. The fingerprint observed for the water-soluble hydrocarbons was compared to the particle-bound PAH, with differences and similarities observed between sites for specific alkylated and parental PAH. The contaminants'

signature determined over 5-6 hrs of individual sampling was further compared to that observed in surface sediments collected nearby, to discuss general depositional trends. The bioccumulation of PAH in local inter-tidal mussels collected in parallel to the water and particles reflected the relative availability of contaminants from these matrices over many months. The uptake of PAH by filter feeders was evaluated relative to the uptake by amphipods that burrow in sediments. *Corophium volutator* were collected from a pristine beach in Nova Scotia and exposed to harbour sediments in the laboratory. Similar biological effects were determined in mussels and amphipods, i.e. lipid content for both species, condition indices for mussels and body residue for amphipods, as well as survival and sex ratio for mussels, as opposed to reproductive success and behavioural response of amphipods. To interpret the results, the physical-chemical properties of detected PAH was expanded to other non-ionic lipophilic contaminants, also known to be discharged from the various point sources of contamination located around Halifax Harbour. Although direct cause-effect relationships need laboratory experiments to make conclusive statements, there are strong arguments to interpret the observations. Knowledge gained from coastal work near mixed sources of contamination is useful to offshore investigations related to the production of oil and gas.

Long-Term Response of Benthos to Production Platforms in the Gulf of Mexico

Montagna, Paul A.[1] *and D.E. Harper*[2]

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Meio- and macro-infaunal communities around three gas platforms on the continental shelf (29 - 157 m water depths) in the Gulf of Mexico were assessed for sublethal or persistent effects of chronic exposure to contaminants associated with long-term production. Subsamples of boxcores were collected from five distances (30- 3000 m) along five radii from each platform during winter and spring in two years. In contrast to platforms in the North Sea, effects were very localized, extending to 100 m from the platforms. Total polychaetes and non-selective deposit feeding nematode density increases near platforms. Amphipod and harpacticoid abundance and diversity declined, and harpacticoid reproductive success declined near platforms. Organic enrichment, contamination by toxicants (e.g., heavy metals and hydrocarbons), and changes in sediment granulometry are confounded along the gradient of distance from platforms. However, the pattern of community change in both meiofauna and macrofauna around these gas production platforms follows an emerging paradigm of response in which density increases of deposit feeding polychaetes and nematodes indicate organic enrichment while density declines of harpacticoids and amphipods indicate toxicity.

Monitoring and Regulating Explosive-Based Winter Seismic Exploration in Waterbodies Not Frozen to the Bottom, Mackenzie Delta-Beaufort Region, Northwest Territories 2000-2002

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The winter of 2000/2001 saw a resurgence of oil & gas exploration in the Mackenzie Delta/Beaufort Region of the NWT. Explosives were the primary energy source for seismic exploration, including seismic lines crossing lakes, rivers and marine environments. Companies followed setback distances outlined in DFO's Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters when setting charges within waterbodies. The guidelines outline that, in order to protect fish, the instantaneous pressure change (IPC) in the water column resulting from charge detonation should never exceed 100kPa. Monitoring by industry revealed that some of the detonated charges produced IPC higher than 100kPa. Additional monitoring required by DFO determined that approximately 50% of the remaining charges (n=430) "over-pressured". This led to DFO outlining a series of requirements for winter seismic exploration in 2001/2002, including doubling the setback distance for a given charge buried within any waterbody not frozen to the bottom. In the winter of 2001/2002 seismic activity increased with over 11,000 km of 2D and 3D seismic lines proposed. Companies applied to conduct tests in hopes of proving that shallower setbacks, than those now required by DFO, could consistently result in IPC below 100kPa within their specific project areas. Testing and monitoring programs were authorized under the Fisheries Act. The test results dictated that eleven of twelve seismic programs had to increase their setback distances for their production shooting up to 5X the distance outlined in the guidelines. Despite using setback distances greatly increased from what was proposed, approximately 1 out of 10 charges monitored (n=507) over-pressured. Although the reasons for overpressures are not fully understood, the use of explosives is unpredictable and should not be used for seismic exploration in potentially fish bearing waters. To date, companies have not proposed explosives in waterbodies for 2002/2003 seismic exploration.

Lipid Soluble Vitamins A and E as Integrative Measures of Fish Health for EEM

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The lipid soluble vitamins A (retinoids) and E (tocopherols) are essential for basal metabolism in fishes. Vitamin A is required for growth, reproduction and for maintaining epithelial tissues. Embryological development is also dependent on adequate stores and the appropriate metabolism of vitamin A. Vitamin E, whose main activity is as a cellular antioxidant, is also required for growth, reproduction and development. Tissue concentrations of both vitamins are altered in organisms exposed to several classes of environmental contaminants, including polyaromatic hydrocarbons (PAHs). Because of their importance for a variety of cellular processes and their sensitivity to environmental contaminants, vitamins A and E can be useful indicators of fish health in an EEM framework. A renewed interest in oil and gas in the Beaufort Sea has raised concerns about the health of the ecosystem and subsistence food resources among coastal community members. In partnership with two coastal communities of the Inuvialuit

Settlement Region, DFO Oceans Programs established the Tariuq (Ocean) community-based monitoring program, which has been piloted for the past two years. As one of the indicators selected, marine and anadromous fish were sampled in 2001 and 2002. Tissue samples were collected for a number of analyses. Mean concentrations of vitamins A and E are reported in liver, the primary vitamin storage organ for several species of fish. In addition to mean concentrations of vitamins, the primary vitamin storage forms are enumerated in the species examined. These data provide useful baseline information against which adverse reactions to environmental perturbations can then be assessed in the Beaufort Sea.

The Environmental Sensitivity of Cold Water Corals

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The cold water coral *Lophelia pertusa* is widely distributed, but most records are from the NE Atlantic where it can form large reef structures supporting a highly diverse animal community. With increasing human exploitation of the continental shelf and slope, concern has been raised about the effects of these activities on marine ecosystems and species, especially habitat-forming species such as *L. pertusa*. Over the last twenty to thirty years, *L. pertusa* has colonized oil production platforms in the northern North Sea. By comparing sites that have been exposed to drill cuttings and other discharges with others distant from such exposure, we hope to better understand how tolerant this species is to oil and gas activity. We are currently mapping the distribution of *L. pertusa* on oil industry infrastructure in the North Sea. *L. pertusa* is widespread in the northern North Sea and to date two occurrences have been recorded from the central North Sea. The coral has been found on structures installed between 1975 and 1988. In order to understand the environmental sensitivity of this species, we plan to monitor the ambient conditions around coral colonies on the oil platforms and to assay the sensitivity of *L. pertusa* to stressors in the laboratory. We will use self-contained instrument packages attached to platform structures to monitor particle flux and hydrodynamic regime around living coral colonies. We are examining the skeletal chemistry of the coral (carbon and oxygen stable isotope analysis) as a growth proxy for *L. pertusa*. We will also look for visual signs of effects from the exposed and control sites during routine visual inspection of the platform structures by remotely operated vehicle. Furthermore, we will examine whether *L. pertusa* retains an archive of past contamination by analyzing its skeleton for trace elements commonly used in drilling fluids using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Finally, we will sample live colonies of *L. pertusa* to use in laboratory studies of coral behaviour, growth and physiology in response to varying levels of sedimentation and varying concentrations of drilling fluids.

Environmental Design: Reuse of Offshore Oil and Gas Production Platforms

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Although there have been many different proposals involving the reuse of offshore platforms, none have really taken hold. Alternative energy testing, laboratories, educational facilities are among the most admirable. But the facilities provided would need so much renovation, and the operating cost would be so high for the institution involved, that this option is not even considered. *What if the facilities provided were designed with the intent of reuse in mind?* The amount of embodied energy and material that is used to construct each platform is incredible, so it would seem to be common sense that the platforms be reused. Oil and gas platforms themselves represent billion dollar investments. The disposal of these facilities is equally large, if not in terms of money, at least in terms of environmental damage. Hundreds of millions of dollars, and incalculable energy is spent to either reclaim the steel or to sink the facility. This investigation proposes to spend a fraction of the hundreds of millions of dollars usually spent disposing of the facility, up front. To create an inhabitable, sustainable, environmentally conscious offshore facility, that can be reused for whatever idea a particular group may have, with limited renovation. Three elements of this investigation will be presented in this poster:

- A critical assessment of the current habitat of the offshore worker, space, material and construction. How do the current facilities respond to the isolation, boredom, and danger of day to day life. How do they support group dynamics and safety?
- Using this assessment as a starting point, a design proposal that looks to environmental awareness, responsibility, and sustainability for inspiration. A proposal that looks at recycling materials, passive energy production techniques, sustainability and creating a pleasant, inhabitable living environment.

Building on this design proposal, a strategy for the reuse of a facility can be formed. This strategy will be in the form of a case study, using one of the facilities off the coast of California.

WebTide and WebDrogue: Open Source Tidal Predictions and Trajectory Modelling

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Numerical models are complex beasts that generally require specialists to run them and process the output for use by colleagues, clients, and the public (‘the users’). Our poster will describe software that allows the user to interact directly with model output for two applications. WebTide is a desktop application that allows the user to extract tidal predictions for any place and time inside the available model domains. The primary model domain is the Northwest Atlantic Ocean from Cape Cod to Davis Strait. WebDrogue allows the user to track particles in flow fields created by combining the seasonal mean currents, the tidal currents and additional contributions due to wind forcing. The particles can be tracked at the surface and at 25 and 100 m depths for several regions of Atlantic Canada. The two applications use a very similar interface and allow the user to be completely independent of the modellers. The interface is based on Java so that it can be supported on both Windows and Linux/unix platforms and uses open source

tools for the mapping and plotting functions. All the source code is provided with the distribution. The software is designed so that new model domains and data files can be added easily and the interface is weakly coupled with the underlying application so that the interface can be easily modified for other applications. WebTide and WebDrogue can be downloaded from
http://www.mar.dfo-mpo.gc.ca/science/ocean/coastal_hydrodynamics/main.html

Conflict of Oil and Gas Activities in Cape Breton, Nova Scotia, Canada: An Approach of Resolution

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A persuasive analysis of a complex conflict was done as regards to oil and gas activities in Cape Breton. The introduction sets this particular problem in a theoretical context, with a number of relevant variable sets discussed. The CNSOPB and its role are discussed, and it was specific and interesting. The Environmental groups and residents of Cape Breton have attacked the petroleum industry and government citing environmental threats as a need to prohibit development in nearshore areas. Fishery and tourism industry have a contradiction with large-scale hydrocarbon developments. The conflict between fisheries and the oil and gas industry with respect to the exploitation of common space is, in nature, a classic marine conflict. The position of the provincial government is a fair rendition of the view of socio-economic development. The viewpoint of the fischeries is discussed fruitfully. The position of the environmentalists towards the oil and gas industry is one of the avowed opposition with regards to the debatable theme Development versus Conservation. Environmental position is well discussed, with a sharp elaboration of the alliance between environmental and fisheries interests; the probable divisions within the general public are well discussed. Analysis and recommendations pull together some of the major axes of conflict and point out some of the particular difficulties to be dealt with. The excessively sectoral approach of many agencies, even presumably connected ones, leads into suggestion of ICM principles as a basis for resolution.

4. Rapporteur's Summary of the Workshop - Roger Green

Major themes from the workshop:

1. The Atlantic Canada offshore oil and gas scene – similarities and differences with respect to other areas

2. We can learn from areas that differ

3. How far out do effects go?

4. Questions of monitoring design with respect to replication, error and testing

5. Modelling versus monitoring

6. Importance of long-time series

7. Measures of biological response

8. There is a need to fund field manipulative studies

9. Some ideas, recommendations, and thoughts for the future

1. The Atlantic Canada offshore oil and gas scene – similarities and differences with respect to other areas

The weather and exposed nature of both the Sable offshore and the Grand Banks causes high winds and strong currents that frequently disturb the bottom sediments. Thus, the sediments are coarse and well sorted, with little organic matter. The fauna are characteristic of such an environment, with little meiofauna and macrofauna mostly as epifauna, for example sand dollars and demersal fishes. The coastal currents are generally northerly and therefore cold, with Grand Banks platforms at risk from icebergs. Some fields, which have received much environmental scrutiny, are quite different from areas such as the Gulf of Mexico, whereas others, like the North Sea are not very different in these regards.

A more discretionary difference among offshore oil and gas fields is the type of drilling mud used. This has varied both geographically and temporally. The types of muds used off Canada have generally mirrored that of the North Sea through time (oil-based muds (OBM) to low-toxicity mineral oil (LTMO) to synthetic-based mud (SBM) and water-based mud (WBM)). Less OBM has been used off Canada than the North Sea because major developments were started later.

2. We can learn from areas that differ

Important lessons can be learned from different areas. We heard two presentations that described the experience from developing and applying pulp and paper environmental effects monitoring (EEM) and mining EEM. These environments differed greatly from that of the usual offshore oil and gas EEM, but useful experiences in monitoring protocols were provided. Differing offshore oil and gas environments also provide a larger context for review and planning of the Atlantic Canada offshore scene. Such differences include water depth, closeness to shore, exposure to winds and waves and consequent sorting of bottom sediments and current regimes, temperature, salinity, etc. For example, the Gulf of Mexico differs in several important ways, and yet it was often cited as a useful and relevant experience. Even more different was the monitoring experience at Brunei (tropical latitudes), and yet it provided useful information for us. Modifications are often needed to study designs (reflecting stronger more unidirectional currents and perhaps different drilling muds), biomonitoring (use of different taxa), and logistics (difficulty of sampling with some kinds of gear in some seasons).

3. How far out do effects go?

The consensus seems to be that the detection of biological effects is usually "not very far"; effects are detectable at 250 m, rarely detectable at 500 m, and seldom observed at 1000 m. There is evidence for contaminant detection further out, perhaps as far as 10 000 m. Some sublethal effects may be detected at 1000 m and beyond using new tools. Of course, currents and selection of drilling mud are also factors. Finally, one might comment that the public perception of the impacts of offshore oil and gas exploration and extraction typically exaggerates them. In my opinion, the environmental "footprint" of a platform is small, and the dangers (e.g. of a leak or a blowout) are slight under a modern regulatory framework, while other impacts that the public is largely unaware (e.g. trawling and dredging) may be much greater and affect larger areas. Perhaps it is the sight of the platforms on the horizon that is disliked the most.

4. Questions of monitoring design with respect to replication, error, and testing

Should there be replication at the sampling level (e.g. replicate boxcores)? Such replication does not provide error for testing impact-related hypotheses. It is what Hurlbert called pseudo-replication, and would be useful only for testing whether two sites differed (e.g. two locations at the same distance or two distances on the same radius). Neither is likely to be of interest. There are usually other ways to design the study to get error for testing impact-related hypotheses, as for example in the Gulf of Mexico Offshore Operations Monitoring Experiment (GOOMEX) where radii were considered random and that main effect and all interactions including it were random effects. Another approach, exemplified by Paul Montagna at this workshop, is to repeat the observational experiment several times, thus creating a randomised complete block design. It is important to note that the study area should be homogenous with respect to anything that might interact with the treatment levels, but it can be heterogeneous with respect to anything that doesn't.

In summary, for testing hypotheses there is usually no reason to replicate at the sampling level. Also, optimum survey power for a given number of samples is generally obtained by taking one sample per site thus maximising the number of sites and the coverage. However, one might want to take >1 sample per site in order to increase the area sampled at each site and get a better estimate of the site mean.

5. Modelling versus monitoring

In my opinion, modelling is often set in opposition to field monitoring and this workshop has been no exception. Often the model becomes the reality with an attitude that if the model doesn't fit then the data are bad. It should be emphasised that nature is always right and if there is a bad fit of model to data then it is most likely that the model is wrong! Modelling and collecting field data from monitoring should go together in an integrated approach, typically alternating – baseline survey to creation of a simple tentative model, then sampling another time to "ground-truthing" the model, followed by adjusting the model, and sampling again to validate it, and so on. Choosing one (modelling or field monitoring) and setting it in opposition to the other is like asking, "Which leg should we use, the right or the left?"

When modelling we should get away from simple-minded deterministic predictive (but not explanatory) models. Probabilistic models predict a range of outcomes that can be compared to data. Alternative models based on different parameter values and differing linear or nonlinear functions are useful in model exploration. Sensitivity analysis (evaluating change in predicted response as a function of small changes in given parameters) can be valuable. Most important, models should attempt to describe the process that connects the predictor variables with the response variable. Mindless, brute-force models ("curve-fitting") are a waste of time, even if they predict adequately in a particular case.

6. Importance of long-time series

Several examples of long, monitoring time series were presented: 1979 to near present at the Shetlands oil terminal, 15 years at Brunei, and 16 years of monitoring drilling waste in the North Sea. It is not possible or necessary for every monitoring study to turn into a long-term study, but it is valuable to have a long-time series for each kind of environment and encompassing the various stages of drilling activities including pre-operation, throughout the operation, and post-operation (recovery).

7. Measures of biological response

Biological response "endpoints" can be categorised in several ways. There are different hierarchical levels: community, population, physiology, growth, tissue and cellular, enzyme level, genetic. Examples of these levels were presented in this workshop, and in previously published work (e.g. GEEP, GOOMEX).

The data collection approach can vary. Observational field sampling is typical, but field experiments using cages, passive samplers (artificial substrates), transplants, and manipulations can be a valuable supplement.

For detection of community level response, to what taxonomic level should identification be done? Organism identification is one of the most time-consuming and costly steps in community analysis. There is evidence that species-level identification is not necessary and that class and family levels are often sufficient to show the same pattern (in a multivariate analysis) as species and genus level identification.

The potential confounding of contaminant effects (e.g. toxicity) with platform structure effects (e.g. organic enrichment by a rain of organic material from the biofouling community on the platform structure) should be kept in mind. Based on what Paul Montagna said at the workshop and the GOOMEX results, I wouldn't be surprised if the rain from the organisms on the platform structure is a greater source of organic enrichment than drilling wastes. Evidence presented in this workshop suggests that much of what has been described in the past as contaminant impacts near platforms may have been direct or indirect platform structure ("reef") effects. More studies are needed to assess this. More generally, impacts can be caused by any of several things: leakage or a sudden large release of hydrocarbon fluids (and any associated heavy metals), cuttings piles, loss of drilling muds, and organic enrichment related to the platform structure. When platforms are close together the effects of different platforms can be confounded. In any particular monitoring, it is important to think ahead about the kinds of impacts there may be, and to design the study accordingly.

A useful feeding-related endpoint is potential interference with the ciliary action that is part of the feeding mechanism of some filter-feeding bivalves (e.g. scallops) by suspensions of constituents of drilling muds, even for low concentrations.

What do elevated concentrations of contaminants in tissues, and enzyme and metabolite responses, actually mean? They may be monotonically related to toxicity, but this is not certain. In some cases, especially for organically bound metals in bivalve mollusks, elevated tissue levels may represent sequestering the metal either for use or for avoiding toxic effects. Similarly, enzyme and metabolite responses may serve the same function. A response means that the contaminant impinged on the organism, and that the organism reacted, but what else it means is less certain.

Regarding statistical issues in description of community level response, one must be careful with ratios or proportions as they behave badly in statistical analysis – especially within hypothesis testing. The same information (e.g. relative abundance of two indicator taxa) can be displayed by using a log-log plot. Description of change in a whole community has traditionally been through measures of diversity or other biotic indices or by using multivariate techniques such as ordination and clustering. Indices are not safely transferable among biotic regions, and tend to be poor descriptors of what is actually going on. Multivariate techniques are sensitive and useful, but subjectivity can creep in.

They need to be applied with caution and the results should be verified. Someone experienced in interpreting the results of multivariate analyses should be involved.

Some new and promising community composition description methods are:

- Bob Smith's Benthic Response Index (BRI) which derives a sensitive index for the actual community concerned. See: Smith 2002 J.Agr. Biol. Envir. Stat. 7(1):74-94; Bergen et al 2000
  Envir.Monit.Assessm. 64(1):421-434
  [I have to check the dates of these references – next week – and I can turn all of these into full citations at that time if you want]

- Clarke & Warwick's taxonomic distinctiveness/structure method describes a community's hierarchical taxonomic structure (within a chosen major taxon) as a subset of that for a larger geographic region – i.e. whether the subset is representative or biased (perhaps by anthropogenic impact).
  See: Warwick & Clarke 1995. Mar.Ecol.Progr.Ser. 129:301-305
  Clarke & Warwick 1998. Oecologia 113(2):278-298
  Clarke & Warwick 1998 J.Appl.Ecol. 35:523-531
  Warwick & Clarke 1998 J.Appl.Ecol. 35:532-543

- M.J. Anderson's multivariate control chart for monitoring
  This is submitted to the journal Ecological Applications. See her website on the University of Auckland (New Zealand) website.

8. There is a need to fund field manipulative studies

Too often the agencies that fund monitoring studies react negatively to any proposal that it includes "an experiment", or "manipulation", on the grounds that they are not into funding "research" or "science". Go to the National Sciences and Engineering Research Council of Canada or the National Science Foundation, is the implication. But important questions regarding offshore oil and gas monitoring cannot be answered without going beyond the usual observational study based on bullseye designs around operational (or to-be-operational) platforms. Purely observational studies have inherent limitations. Paul Montagna's study using platforms as "reefs", in a set of platforms replicated three times (blocks), is a case in point. The whole question of platform effects versus operation effects is of major importance, and yet he had trouble getting funding for a study designed to answer it. The point is that agencies should be open to a proposal in which the case is made for a manipulative/experimental study. Such studies will often be for the purpose of teasing apart confounded effects (see above). This fact is a "no-brainer" for scientists - confounding by definition indicates the inadequacy of observational data and suggests the need for some experimental manipulation to answer the question, "which of the confounded explanations is the correct one", or if it is not an "all or none" situation, "what is the contribution of each"?

9. Some ideas, recommendations, thoughts for the future

It would be nice to say that we have done all the offshore oil and gas EEM that is needed, and that there are no important, unanswered questions remaining, but such is not the case. Based on what we know, monitoring can be designed to be more efficient, cost-effective, and uniform across different locations, but it can not be "designed out" and probably won't ever be.

Where does this workshop fit into the long-term process of improving offshore oil and gas EEM? This workshop is broader than the one at BIO three years ago, which focused mostly on the local scene. I think that the timing of the workshop is good and the publication of this workshop will also increase its impact. Offshore oil and gas EEM has reached a stage of maturity based on diverse experience and many published results, and this workshop has been able to reflect that and tie much of it together, for a broader audience as well as that represented by the attendees.

I suggest another workshop along these lines perhaps in three to four years' time, but I think the diversity of participation could increase. We had attendees from South America and Asia, but they did not present, and some major players were not represented (Australia, Indonesia). Perhaps they could be next time. The overall theme of this workshop is quite serviceable for a subsequent one, but perhaps the themes within it could change or be expanded.

5. Friday Forum Transcription

Forum Chair: Ted Potter, Fisheries and Oceans Canada, Oceans and Environment

Keynote Speaker: Kathleen Hadley, Manager, National EEM Office, National Water Research Institute, Environment Canada

Title: ***EEM Under the Fisheries Act: Lessons Learned and Future Directions***

The goal of the *Fisheries Act* is to protect fish, fish habitat and the use of fisheries resources. The Act prohibits the release of 'deleterious substances' into Canadian fisheries waters, but also provides the authority to regulate the release of substances under specified conditions.

There are two sets of regulations under the *Act* through which environmental effects monitoring at regulated facilities is mandated: the *Pulp and Paper Effluent Regulations (1992)* and the *Metal Mining Effluent Regulations (2002).* The regulations are technology based, this means that the effluent discharge limits set for certain parameters are based on what can be achieved by the best available technology economically available. The monitoring then provides feedback on how the receiving environment is responding to the prescribed effluent discharge limits.

So, what is EEM? It is iterative scientific evaluation of the effects of effluent on fish, fish habitat and the use of fisheries resources. It is structured to include monitoring and interpretation phases over a 2-6 year span. The frequency and type of monitoring depends on the results. The industry is responsible for:

- Preparing study designs in accordance with guidance documents,
- Submitting them to government prior to undertaking field work, and
- Preparing and submitting interpretive reports after the field work has been completed.

Government then

- Reviews the report and makes sure that the requirements have been met,
- Updates the guidance documents as science evolves,
- Undertakes national and regional analysis,
- Undertakes supporting research,
- Ensures national consistency,
- Facilitates communications, and
- Maintains the database.

The objective of the EEM program is to determine whether a point source of effluent is causing an effect on fish, fish habitat or fish usability. The definition of 'effect' is *…a statistically significant difference between measurements taken from an exposure area and measurements taken from a reference area for fish, benthic invertebrates or fish usability.*

A series of key 'endpoints' have now been adopted for the fish population survey, the benthic survey, and the fish usability survey. They were the subjects of considerable debate, but have been confirmed and are now being used.

The objective of the pulp and paper EEM program has changed. When it first came out the objective was to assess the adequacy of the regulations, but in reality, the program monitored impacts. Once we have all the relevant information together, it will be used to assess the adequacy of the regulations.

What are the components of an EEM Program?

- For fish – a fish population survey is required
- For fish habitat – a benthic invertebrate community survey is used as an indicator
- For fisheries resources – fish tissue analysis and tainting studies are undertaken

Also, specific supporting information is required to help interpret the studies. This includes sub-lethal toxicology, effluent quality data outside of the regulated parameters, water quality, and sediment quality. The determination of when monitoring should be done, or of what needs to be done, is based on five fish, four benthic habitat and two fisheries usability endpoints. The other information is not used in the decision-making process.

How does the program work? First, the proponent must confirm whether there is an 'effect' for the three areas of concern. If two consecutive surveys show an effect, then the proponent must determine the magnitude, geographical extent, and possible causes. In the East Coast, it will probably take 15-20 years to collect all the information that is needed. If there is no evidence (or confirmation) of effect, then the proponent must repeat the monitoring every six years to check the results. The follow-up actions are determined in light of the results. This includes determining whether the regulations are adequate – from a site-specific, regional or national standpoint.

If effects are identified, the regulations define only the level of effort required for the next EEM study. An assessment of the 'significance' of effects, and the need for further action is determined on a site-specific basis and is not prescribed in the regulations. The goal of those actions, however, is always to achieve a sustainable use of fisheries resources.

Some of the other factors that are taken into consideration in determining whether the effects are a problem include:

- **Ecological considerations** – the magnitude and geographic extent of effect(s), temporal trends, and the sensitivity of the ecosystem.
- **Social considerations** – stakeholders must be informed about changes to their local environment, the cost of corrective action and the profitability of the company
- **Economic and technical considerations** – there may be an impact but the cost of correcting it may not be worth it to the stakeholders, or there may not be suitable technology available.

Once relevant information is available on the effects, extent, and possible causes, there are a number of potential follow-up actions.

- Continue the EEM to at least ensure that the effects are not getting worse
- Enhance the monitoring program to get more information
- Undertake detailed engineering

One of the difficulties with the Pulp and Paper program is that from the outset it was recognised that 20 years would be needed to assemble the information required to assess the adequacy of the regulations. Essentially, the EEM programs provide the data to support the next iteration of the regulations.

The Pulp and Paper industry had been under regulations since 1971, but in the late 1980s it came under intense international scrutiny. There was a lot of concern about dioxins and furans, which were not covered by the regulations, and there was pressure to boycott exports of Canadian pulp and paper. The Canadian government responded by developing a new regulatory framework that came into effect in 1992. There were two parts to the regulation – under the *CEPA* the release of dioxins and furans in effluent was regulated, and under the *Fisheries Act* it was required that the effluent not be acutely lethal. Limits were set for Biological oxygen demand (BOD), Total Suspended Solids (TSS) and it was required that the operator undertake environmental effects monitoring. The numbers were identified through an assessment of available technology.

Since then there has been a vast improvement in the effluent, and the response of the industry to the regulations has been excellent. There has been a 90% reduction in BOD, 60-70% in TSS, and virtual elimination of dioxins and furans. The regulations came out in 1992, but the improvement began before they were implemented, and many companies installed secondary technology before the regulations came into effect.

So, has the improvement in effluent quality done the whole job? The impact on the environment reflects not only the quality of the effluent but also the sensitivity of the receiving environment. The EEM requirement under the Pulp and Paper regulations was initiated in 1996. At first, it did not work very well. In the first cycle of monitoring, there was a lot of difficulty achieving what was believed to be possible. To combat the problem, an intensive consultation and review was undertaken from 1996 to 1998. Every aspect of the program was examined using technical committees and expert committees. It resulted in a better understanding of the requirements and improved technical guidance on how to conduct an EEM program.

Under the Pulp and Paper regulations, there is a three-year cycle of monitoring and reporting. In light of the delays caused by the review, an extra year was added to the second cycle of monitoring, and reports were received by April 1, 2002. These reports contained much improved data and confirmed that most mills were conducting successful EEM studies. The data has allowed Environment Canada to undertake a national analysis. It found a good correlation between fish and fish habitat results, and reports of visible improvements to fish habitat between the first and second monitoring cycles.

While the fish results are positive overall – the fish are larger, they have larger livers and are older and fatter when they get exposed to the improved effluent – their gonads are smaller which indicates that something is interfering with the reproductive system. For benthic invertebrates, the results are variable and depend on the receiving environment. River habitats show increasing abundance coupled with either no change or increases in the number of taxa. This result indicates a mild to moderate eutrophication response. In the marine environment, there are decreases in both abundance and the number of taxa suggesting a toxic type of response. Lake data falls in between the two.

The fish data and the benthic response correlate quite well, but the gonad findings indicate that an endocrine disruption mechanism is occurring. Research is continuing to determine the cause of the problem.

Overall, the Pulp and Paper regulations have transformed effluent quality and many of the reports noted improvements in fish habitat. However, almost all mills are having an impact on the environment and more data will be needed to determine the magnitude, extent, and causes. It will be 10-15 years before the adequacy of the regulations can be fully assessed.

The strengths of the program are that:

- The polluter is required to provide information on the resource they are using, in this case Canadian fisheries waters,
- It links the technology-based regulations back to environmental performance,
- It allows for joint decision-making with other regulatory agencies, and
- It provides the industry with an opportunity to provide some environmental stewardship. They are increasingly using local advisory committees to discuss the results with local stakeholders.

There are some inevitable difficulties with a regulatory program that is science-based and where a balance must be struck between a national agenda and what is needed at a site-specific level. Harmonisation with other regulatory monitoring programs is also a challenge since the quality of provincial regulations varies. There are also technical complexities and it is clear that training is required before the industry can be expected to implement the program successfully.

The challenge for the future is to continue to refine the science involved in this program, particularly with respect to understanding the significance of effects, and to make sure that there is a link between the measured effects and the long-term goal of sustainability. For example, what are the implications for a fish population where individuals are larger and fatter but have smaller gonads? At this point, we don't know. In addition, we want to promote environmental performance as an alternative to using control technology to meet risk management objectives. We are now examining how municipal wastewater could be managed. One option would be to make the management program technology-based – for instance requiring that all municipalities install secondary or tertiary treatment. This is likely to be unpopular and may be challenged. Another option is to link treatment to environmental performance, which may be seen as a fairer, more acceptable solution.

Further information on the programs, the findings and upcoming workshops and meetings can be found on the web site www.ec.gc.ca/eem.

Questions:

Jocelyne Hellou – Reduction in gonad size could mean smaller eggs or fewer eggs. Has a reduction in gonad size translated into measurable changes in adult fish?

Kathleen Hadley – The reduction in gonad size does not automatically mean the population is threatened. The loss of eggs can be balanced out by recruitment under certain circumstances. In some places such as Jack Fish Bay, 30 years of data show that although the gonads are smaller, there has been no reduction in the fish population at that site. So though modelling studies and intuition might lead to a conclusion that smaller gonads means a long-term change to the fish community, in fact it is not that clear cut.

Peter Wells – Could the whole EEM process for the pulp and paper industry have been speeded up, and if so, how? It seems like a very long time between sampling for sublethal effects, data analysis, reporting and action to ameliorate effects.

Kathleen Hadley – Right now we need the 2-year cycle. A six-month review period for the study design is required before the proponent undertakes the work. Then the monitoring, interpretation of results, and the review of the monitoring report all take time. In an ideal situation, the studies would be done each year, but right now, a quality assurance check is required. As time goes by and the users become more familiar with the program, the six-month review may not be necessary. The EEM program will continue to evolve over time.

Panel Discussion

Chair: Gary Sonnichsen, Petroleum Research Atlantic Canada (PRAC)

I am a geologist with Geological Survey Canada and have a keen interest in EEM. Through my work with PRAC, I have a strong interest in the research that is being undertaken into the impact of petroleum development on the natural environment, in particular with respect to local and regional effects.

The panel members today have each been asked to provide their perspective on EEM. After each speaker has given his or her perspective, there will be an open discussion.

Dr. Robert (Bob) Rangeley, World Wildlife Fund

Biographic Information
Dr. Rangeley is the Marine Program director for the World Wildlife Fund (WWF). He was educated at the University of Western Ontario, University of New Brunswick, and

McGill. He is a marine ecologist and has studied seaweed, invertebrates, fishes, and seabirds in the waters of the Bay of Fundy, Gulf of Maine and Bay of St. Lawrence. A recurring theme in his work has been the interaction of marine mammals with their environment, and it has focused strongly on habitat and conservation issues. WWF is working on priority conservation areas and on a network of marine protected areas to preserve diversity and healthy fisheries. Dr. Rangeley will offer an ENGO perspective.

Presentation

The central questions we have been asked to address are:

1. Are EEM programs giving us the information we need?
2. How can they be improved?

There are two points I'd like to make on the role of Environmental Effects Monitoring. The first is that EEM should be our last line of defence in protecting the marine environment. And two, EEM does not address large spatial and temporal effects, and this has consequences for current regulations and oceans management.

So, what does this mean? Well first, we have to look at the big picture. And that means to ensure effective conservation we must adequately protect important areas in the ocean while simultaneously adhering to best environmental practices everywhere else.

The role of EEM is to ensure that best practices are conducted. This is necessary but not sufficient. We can't ignore the fact that there will always be environmental costs to exploring for and extracting hydrocarbons. That's a price we all pay. At it's best EEM plays an important role in minimising the environmental footprint, and it can feed information from monitoring into responsive management. In other words, the codes of practice should change, as effects are better understood.

Most importantly, adhering to environmental best practices should not translate into licenses to practice everywhere. That's what I mean by necessary but not sufficient. We must accept the fact that all areas cannot be open for development -- some representative habitats and some distinctive places should be off limits.

Why is this relevant to current practices in EEM? I argue that there is an over-reliance on EEM methods and technology by the regulators. It appears as if industry, EEM practitioners and regulators believe that monitoring for some potential effects in the vicinity of operations is all that is needed. Yes, there need to be standards and they need to be monitored. But, in some areas there is no acceptable level of risk – the costs of being wrong are simply too high - and yet in many of these areas we exploit resources even though there is high uncertainty and worse, there is total ignorance, about the potential effects.

No one predicted the Exxon Valdez and Prestige oil spills, but the high environmental costs of these disasters could have been avoided. These spills were major environmental catastrophes because the ships broke up in highly sensitive areas – places they shouldn't have been in in the first place. We need to identify and protect high priority conservation

areas – they are our insurance policy against uncertainty, inevitable accidents, and management errors.

This leads me to my second point. EEM methods and technology are poorly suited to addressing industry-wide cumulative and spill-over effects at large spatial and temporal scales. Monitoring these effects is very difficult and prohibitively expensive. Since environmental monitoring cannot be done everywhere, we should take steps to minimise the interaction between industry activities and conservation areas.

To summarise, the first line of defence should be to link new development projects to adequate marine protection, as a regulatory requirement. This should be done strategically by directing available resources to protect, conserve, and restore habitats and species while the opportunity still exists. Failure to act strategically will mean lost opportunities and a country with irreversible damage to its seascapes and species. It is not too late to act. And it should happen soon, while our oil and gas industry is still relatively young.

Cal Ross, ExxonMobil Canada

Biographic Information
Mr. Ross is a Senior Environmental Advisor to ExxonMobil Canada in Nova Scotia. He worked on oil spill clean-up and monitoring for 10 years before joining the oil industry and Mobil in the early 1980s. Since then, he has been involved with environmental management in several companies. Mr. Ross will present an industry perspective.

Presentation
I have been impressed with the science that has been presented in this workshop. We have certainly come a long way. On the question of how to link scientific findings to the management of environmental effects, perhaps the next workshop should also be on Environmental Effects Management. We need to develop some mechanism to translate information into the management of environmental effects and risk.

I have two main points to make. First, in North America our regulatory control and compliance regime is basically input-based, and focuses on the concentrations of certain compounds. Europe, on the other hand, is moving towards an outcome-oriented control mechanism rather than end-of-pipe concentrations. Unfortunately, I don't believe, we in Canada, have the regulatory foundation to follow the trend from input-based compliance monitoring to output-based compliance monitoring. The second point relates to risk. The work that has been described here represents tens of millions of dollars per year spent on collecting data. If we took a risk-based approach we would be looking at the same geographical area of management that we are using to focus the EEM.

Andy Parker, Canada Nova Scotia Offshore Petroleum Board (CNSOPB)

Biographical Information
Mr. Parker graduated from Dalhousie University and TUNS, worked with Amoco Canada Petroleum in oil sands, he returned to Nova Scotia in 1982 and since 1990 has been the manager of environment and chief safety officer for CNSOPB. He will speak from a regulatory perspective.

Presentation
Before I respond to the comments of fellow panel members, I'd like to give some background on the petroleum boards in Eastern Canada. There are two agencies set up to regulate oil and gas in the Atlantic Provinces, one in Newfoundland and the other in Nova Scotia. Their mandate includes the environment, health and safety, benefits, and resource management. We have limited expertise on staff so we rely on our Memoranda of Understanding with Fisheries and Oceans Canada and Environment Canada to access environmental analysis and advice. We have developed a very good working relationship with these departments, and this workshop is a good example of our mutual co-operation.

With respect to EEM, there are no formal regulations. The industry is subject to the *Fisheries Act*, of course, and required to meet offshore waste discharge guidelines that are based on best available technology. EEM has been required for all offshore development projects undertaken so far as a condition of approval of the Environmental Assessments. The projects are subject to public scrutiny at several stages and the EEM program is one of those stages. Stakeholders are involved throughout the monitoring process as development proceeds.

Bob is correct in saying that we have been very project-specific with EEM and there has been a good deal of duplication. As we move forward, we should adopt a more regional perspective, but it will require a good deal of discussion to determine how that can be achieved. One of the most important things we need is for industry to make its information publicly available. Currently the legislation allows information to be kept confidential for five years unless we get permission to release it. Unfortunately, we have not been able to achieve that in all cases, but we hope this situation will change.

In addition to the regional perspective, we are taking a closer look at the impact of seismic exploration, which has emerged as one of the bigger issues for regulators. The critical issue in this case is to find out whether stakeholder concerns about seismic are real or perceived. Overall, these two issues indicate that EEM should be required for a broader range of activities than those associated with the development of individual projects.

There is no doubt that industry is making a significant contribution to the understanding of broader issues through the research work it sponsors under the Environmental Studies Research Fund. The Fund has supported workshops on seismic impact and cumulative effects, and is one of the key funders of this workshop.

Ian McLaren, Dalhousie University

Biographic Information
Dr. McLaren is Emeritus Professor of Biology at Dalhousie University. He graduated from McGill and Yale Universities, and has been employed at the Fisheries Research Board of Canada, McGill and Dalhousie University. He has published over 175 papers and his research has covered seals, marine plankton, and copepod growth, cod larval recruitment and birds, including those on Sable Island. He has been an advisor to federal and provincial panels and a consultant on several East Coast activities. Dr. McLaren will offer an academic perspective.

Presentation
At Dalhousie there is a wide range of scientific perspectives that are relevant to this discussion, however since they cannot all be represented here, I will speak from a personal point of view.

I was unfortunately unable to attend the conference, however I have noted from the presentations this morning a concern with chemistry and direct biological effects of various offshore activities. While this is important, I feel that to some extent mammals and birds are being overlooked. These animals arouse considerable public concern as the recipients of impacts, but the impacts themselves are often dismissed without any statistical rigour or much scientific depth. Andrew raised the topic of seismic exploration, and that seems to be the activity generating most concern among casual observers of the offshore, including many of my academic colleagues. It is also a serious concern among those with real expertise in that area. We need more attention to interactions with seismic activities, and also to the perception that catastrophic spills are a serious problem. EEM may cover these issues at some level, but they are usually dismissed fairly quickly as being less problematic than perceptions indicate. Something is missing in this picture. These issues may be dismissed but they are not going away, and people (including federal scientists) keep talking about the impact on seabirds of a potential hydrocarbon spill offshore.
Perhaps some very simple low cost experiments could be undertaken to see whether there are any impacts. Perhaps the EEM industry should spend less time on bacteria and amphipods and more time on larger species that are more central to public concern.

Moving to another issue, the sonic impact of the rigs is also repeatedly raised as a matter of concern. There may be no direct impact on mammals, but they say, the animals avoid it. So, what does this mean in terms of the marine mammal's well being? One of the papers in this workshop talked about how oil and gas exploration in the Beaufort Sea has had no impact on the Innuit's Beluga hunt. Those research findings may be accurate but are unlikely to counter broad and legitimate concerns about the welfare of these animals. I think that public pressure to examine these broader issues will continue, and I believe we should be paying more attention to it. There is an opportunity to lay them to rest by undertaking more careful effects monitoring.

Gary Sonnichsen:

To summarise some key points from our panel members. Bob Rangeley said that sensitive areas should be identified and protected prior to opening up blocks for exploration, and that EEM should come later as a second step in environmental protection.

Cal said that society would get more benefit for the money invested in EEM if there was a risk-based approach so that monitoring efforts is focused on areas where there is the greatest potential for impact.

Andy noted that there is a need to look at regional issues, but also that seismic exploration is arousing public concern, more perhaps than the point source emissions from rigs where most of the monitoring effort is focussed.

Ian noted that while the examination of indicator species may be important for determining the overall impact of offshore projects, the public's interest is focused on species higher up the food chain, particularly mammals and birds, and these are not getting much rigorous scientific attention.

I would now like to invite questions from members of the audience.

Roger Green

I just want to reinforce two things that Bob Rangeley spoke about. He said that EEM is operating on too small a scale – we need to look bigger – and he also talked about marine reserves. I have had some experience with those in the Caribbean and Asia. Apart from the conservation value, marine reserves also provide an excellent scientific opportunity. The best way to learn about something is to exclude outside influences and see if that makes a difference to the species being protected. In other words, marine protected areas area beneficial scientifically as well as in conservation terms.

Gary Sonnichsen

When you look at other exploration areas, particularly in Europe, it appears that the EEM work is jointly undertaken by the government and industry. In Atlantic Canada, we are dealing with a basin in which there are only one or two active producers. How can regional studies be undertaken in this situation? Who should assume the responsibility for undertaking this work?

Cal Ross

There are a number of mechanisms to fund those regional studies but it is in fact more of a challenge to decide what gets measured. If we can agree on the scope of the research, then a way can probably be found for the industry and government to fund the work. Unfortunately, it is likely to be difficult to get that basic agreement on scope.

In response to Andy's comment about industry not revealing its data. At least ten papers in the last four days have been based on industry data here on the Scotian Shelf. The challenge is to differentiate between the data that should be released for academic and scientific use and that which cannot not be released because of its commercial importance.

Gary Sonnichsen

Kathleen, how can the data provided from the national EEM from pulp and paper or mining be accessed?

Kathleen Hadley

It is available on our web site. It is not in a particularly user-friendly format, but all information is accessible down to individual observations.

Gary Sonnichsen

Is industry required in the regulations to make the data available?

Kathleen Hadley

In the regulations, it states that industry must provide the data in an electronic and paper format determined by the regulators. Once it has been received, it is posted on the web site. So far, there have been no concerns about proprietary information in the EEM work.

Peter Wells

Bob, you stated that there is an over-reliance on EEM by regulators, I think it is very important to understand the history of EEM. It has taken government a long time to build EEM into a regulatory framework. Thirty years ago we started examining end-of-pipe discharges knowing that we needed to start their looking at the problem of environmental contamination. Once lethality was eliminated from much of the effluent, we then needed to go into the field to check whether there was a suitable level of protection. There was no definitive plan for the monitoring; we just wanted to see what was happening. Kathleen's description this morning shows that the program has been very successful.

In the oil and gas context, we need waste guidelines, and we need EEM to determine safe levels of discharge and document any problems that are occurring. One of my personal concerns is that in ecotoxicology we now have a huge battery of biological and chemical procedures that we can use in EEM, but we do not have a well developed strategy for selecting the most appropriate ones in different contexts.

At this point I would like to ask you what your concerns are with EEM. We don't want to gut the program; it took us a long time to establish and maintain it, and there still are

many questions about how ecological systems are responding to chemical stressors. I believe we need to strengthen monitoring and use it appropriately. In this regard, I believe the regulatory approach that is now being used represents a strength and not a weakness.

Robert Rangeley

I want to be clear that my comment about over-reliance or over-confidence in EEM is to set it into a context. It should be applied as one prong in a two-prong approach. The first prong is to identify sensitive areas where oil and gas activities should not take place. Once we have set aside certain habitats as a representative sample of those areas, then in areas where activities are permitted, we must recognise that there will be impacts of some description. My comments are not a criticism of EEM per se, but rather a plea for a more appropriate balance. We can't just say that every location could be used but that we will counter the potential for impact with a good environmental monitoring program. That approach is irresponsible because it ignores the uncertainty and ignorance of effects, and that we are actually learning as we go along. We are on a trajectory from bucket science to something very sophisticated, as we have seen this week. I don't know where we will be in 10-15 years, but we are always discovering unexpected effects. So let's invest in a little insurance and set some areas aside from impact altogether.

Kathleen Hadley

My understanding is that the combination of EA and EEM procedures should address most of the issues that have just been raised. Sensitive or protected areas should not be affected by these activities. You start with the environmental assessment procedures, whether they are rigorous enough is another matter, and EEM provides a check or ground-truthing of your assessment and forecasts – in other words, did the impacts occur in the manner predicted and were they accurate. Are you not subject to EA procedures that would address those types of issues?

Gary Sonnichsen

Isn't it possible that the system is working back to front in that project-specific assessments have been completed in advance of regional assessment? Isn't this why we are now seeing interest in the broader regional effects? If a shift of emphasis towards regional assessment is required, who should assume responsibility for it?

Kathleen Hadley

There should not be too much reliance on EEM. Projects should be sited correctly, and the local environment should be taken into account prior to siting. That is an important function of the EA process.

Robert Rangeley

Unfortunately, that is not what happens. Oil and gas is one example and aquaculture is another example of how we site projects based on business needs and then go back and look at environmental impacts afterwards. What we have done at that point is to foreclose on certain options by entering into a licensing process. This does not mean that the activities are inappropriate, but rather it is the locations that are inappropriate in some cases. That situation cannot be recovered after the fact when the license has gone out.

Kathleen Hadley

I agree, but the EEM program was never intended to do that. If that is happening, then the EA process is not effective and not doing what it is supposed to do – which is to ensure that protected areas stay protected and sensitive areas remain untouched.

Andrew Parker

The discussion is moving away from EEM, but this issue comes down to a matter of defining policy as to which areas should be open for oil and gas and which should be closed. The *Oceans Act* can be used to do this, and in the interim, there can be discussion about how to use Strategic Environmental Assessments or Regional Environmental Assessments to address some of these issues.

Mark Butler

At present, there is really no EA or public comment at the licensing stage. We are starting to do it but it is far from what we need to do. There was a very good workshop last week that addressed this question. What emerged from the discussion is a sense that we should move towards the European model which is to identify areas deserving of protection before large blocks are opened up for exploration. Perhaps it would mean fewer assessments or less onerous EEM down the road if we did a better job up front.

My question here has to do with seismic impacts. I was not at the workshop for most of the week, but I note that there were only two papers on this subject. The relatively scant research that has been done on this topic shows that there are impacts, so, given the length of time that science takes and how long it takes to translate information into regulations, do we have to wait 15 years and have 15 years of seismic exploration before we get some answers and action? How can we make this happen faster? Could it figure more prominently in the next meeting?

Ian McLaren

I agree entirely. Having read a lot of the literature, I would say that the picture is muddy in terms of the impact of seismic activity, but it has also been getting little attention. The science that is required to study birds and mammals doesn't have to involve sophisticated

science – which can be challenging to do on mobile species which tend to group and thus make statistical analysis difficult.

I see that there was one paper here by Memorial University on the in-gathering effect of rigs on seabirds. Currently most of the data comes from observers, drawn largely from the fishing community, who are stationed on platforms. They may get some training but their output is a series of daily logs recording what they see. The scientific investigation of birds and mammals that should be undertaken does not have to be very sophisticated but requires more than a simple observer program of this type. Properly developed transects measuring the abundance of seabirds and some temporal information is required to determine the interaction of the birds and the rigs.

Gary Sonnichsen

Are noise effects from rigs included in EEM in other jurisdictions?

Ian McLaren

Yes, the noise can be measured but the effects are not well understood.

Diaisa Sanchez

I work for the oil industry in Venezuela. This week we heard about research by industry in countries that, for the most part, have regulations with respect to environmental quality. In countries like Venezuela, companies are starting to undertake oil and gas operations offshore, but there is no national structure of environmental legislation to regulate their activities. Can we trust the policies of big companies to deliver good development in the offshore until we can develop our own legal structure?

Cal Ross

Most oil companies have policies stating that if they are working in a country that does not have a complete regulatory framework, they will adopt a 'reasonable standard' for their operations. I'm not so sure what the oil industry in Venezuela would call a 'reasonable standard' and whether that would meet your expectations. There are a number of ways to do determine what it should be. The worst way is to import someone else's regulatory regime. The environmental performance of industries in different countries should be based on the social, economic and environmental needs of that region and to say that effective environmental regulation should be the same in very different countries around the world would in my view be a false approach. What you could do is to look at regulations around the world and put together a regime that would provide some level of protection. That could be done quite quickly.

Gary Sonnichsen

The ExxonMobil experience in the Caspian could be used as an example of a situation where regulations were adopted for a region that had not experienced exploration for some time and had no framework to deal with it.

Kevin Bill

I work in fisheries management in Inuvik. The Arctic faces different issues from the Scotian Shelf. In recent years, exploration for natural gas has increased once again along with renewed interest in building a pipeline down the Mackenzie Valley. In terms of research, there are three main issues that cause problems:

- There is a lack of baseline information, the logistics and costs are a big problem;
- The Inuvialuit are more dependent on the resources; and
- The Mackenzie delta is the largest drainage system in Canada and, since other activities are also being undertaken elsewhere in the basin, cumulative effects are a concern.

In light of this, I would like to ask if there are plans to develop regulations such as exist for Pulp and Paper or mineral mining. If so, how long would it take to put them in place? Right now, there is a proposal to get the pipeline into operation by 2008. Offshore development is also approaching quickly, and questions are arising about how land-fast and offshore ice packs, which will affect monitoring.

Andrew Parker

The National Energy Board is involved in the regulation of that area, and the Board works in collaboration with the CNSOPB and the CNOPB. At this time, there are no plans to develop comprehensive EEM guidelines or regulations. There are pros and cons to that position. On the one hand it gives a great deal of flexibility and allows each area to develop the requirements that best fit the local needs; on the other hand there may be differences and possibly inconsistencies in the requirements. Through workshops such as this there is a lot of interaction between the CNSOPB, other regulatory agencies, and national bodies such as DFO and Environment Canada. Hopefully that will ensure consistency from one location to another, but there are no plans to create national guidelines or regulations at this stage.

Kathleen Hadley

We do have regulations for the two existing sectors, and I would argue that the fundamental framework of what you monitor and why you monitor should not change substantially between sectors. We have gone through this for two sectors, and as we look at the requirements for a third one, municipal discharges, we find that we are coming up with similar lists. The special challenges that you face in the Arctic relate to the sampling that needs to be done in northern areas. We will be facing the same issues in environmental effects monitoring at northern metal mines.

We have tried to build flexibility into our guidance documents, and they now recognise that changes need to be made in certain areas of the country. We have little information to go on at present, but we'll be receiving the first studies in the next 12-18 months. I'm fully expecting that once more we will learn a great deal from that first round of monitoring. We recognise that metal mines are not pulp mills, and we can't apply the same kind on monitoring program to them. There will be sampling difficulties and we will learn from them. To sum up, the fundamental decisions regarding what you monitor and why would not change, but scientific sampling techniques would be selected in response to local challenges.

Don Gordon

I would like to offer some opinions about who should be doing what and who should be paying for what from the perspective of a government scientist. I certainly do support the ideas and concepts behind the EEM programs, but I feel strongly that the work should be funded by industry, while government scientist should provide advice on the best tools and techniques. Government scientists should be involved in research to develop methods but not in the EEM work itself. Government funds should be directed to baseline environmental studies and long-term zonal monitoring programs so that we have a better understanding of the huge offshore territory that we have responsibility for but know little about.

Most people know that there has been a concerted effort over the past few years to put in place a national seabed mapping program (SeaMap), and there are also other research programs underway at BIO to identify the type and distribution of sensitive habitats in the marine environment. The work with the deep-water corals is being funded by the oil and gas industry through the ESRF. Our role is to do general mapping and surveying so that we can better understand what is out there in the offshore. This information can be used to locate sensitive areas that are deserving of protection. We have limited resources, and should not dilute our efforts by getting involved in EEM. We should supply advice and guidance but EEM programs should always be funded by the industry.

Roger Green

We should remember that there are many spin-off benefits from EEM, even with all of its shortcomings. We learn a lot of new information about the species present, the variation of the natural habitat, the natural environment, and so on. There was little attention to northern research until the Mackenzie Valley Pipeline proposal came forward and it was realised that not much was known about the area. Much work has now been done on the basic fauna and flora in the Mackenzie Valley and the Porcupine River valley through monitoring. Similarly in California, monitoring led to an excellent series of scientific studies off the coast. For all of its faults, EEM brings many science and conservation benefits.

Ian McLaren

I want to support Don's view of the role of government science, it is absolutely correct. However, there is another role for government scientists in reviewing the assessment of effects, and particularly in reviewing EIS documents. Sometimes, looking at the review comments from the industry side, it is clear that the EIS work has not been critiqued by the right people and the resulting responses seem strange and off-base. Who manages this process and provides 'quality control' over the responses? Someone needs to ensure that the statistics or biology or physical oceanography has been fully understood by the reviewers. At times it has clearly not been understood and the response is confused.

Gary Sonnichsen

Once we have appropriate information compiled through EEM, how do we translate it into management requirements. What is the way forward?

Cal Ross

ExxonMobil is currently reviewing the successes and failures of the six-year Sable EEM program in order to prepare for the monitoring that will be undertaken as we bring on more fields in Phase 2 of the Project. Similarly, I'm sure many people in this room will take the accumulated information from the past week and examine their programs in a similar way. We will look at what has worked and what hasn't, and some of the solutions and innovative ideas.

In response to some of the comments made by Dr. Green about the value of long-term monitoring, it is very difficult to decide which programs should be kept in the interests of long-term data sets, and which should be replaced in order to get better information from better techniques. Some of the hydrocarbon information from sediments taken 15 years ago is probably not worth very much but it is better than nothing. It is very difficult to balance the need to stay on the cutting edge of what we measure and how we measure it with the need for a historical record of data. This dilemma makes it hard to tease out the learnings from our EEM work.

Andrew Parker

I think it is fair to say that from a regulatory perspective, there hasn't been a clear linkage between the EEM and a 'go-forward' management strategy, though, on the positive side, EEM is tied into the waste treatment guidelines and that linkage is likely to continue. One problems is that the issues are shifting, for instance, seismic is becoming more prominent and is likely to receive more attention with time.

The process of developing guidelines may offer an appropriate mechanism to link some aspects of EEM and management. As part of the guideline process stakeholders would be brought together to discuss the issues, including both the regional perspective and the project-specific work to date.

With respect to Don Gordon's comments, I would just like to reiterate that the ESRF is a very good mechanism for funding research.

Overall, this workshop has been very thought-provoking and timely and should provide some good ideas for moving forward.

Peter Wells

I would like to hear from the panel as to what you think we absolutely have to keep measuring with respect to point sources and the environments we are responsible for. As a scientist involved with ecotoxicology, I know that the science is outstripping the management applications many fold. We are developing hundreds of test procedures all over the world which are useful in the lab and in the field, but we are ending up with a grab bag of techniques that require sorting prior to use in environmental management. What do you feel are the valued ecosystem components that must be monitored in relation to this industry?

Robert Rangeley

I would like greater recognition of spatial and temporal scale effects. I realise that this is not necessarily under the purview of EEM and relies on basic research as well. We don't have a strategic view of the research and the monitoring needs that complement one another, including control areas and so forth. Specifically, we need much more information about the effects of seismic surveying. That topic keeps coming up and is very important with respect to some of the endangered marine mammals. We need to get a better understanding of its impact.

Kathleen Hadley

It is important to develop general guidelines for industry on what should be measured, and in fact it is the responsibility of government to do so. Government has the scientific authority and responsibility, and industry appreciates the information. Government also needs to ensure consistency in the monitoring activities.

Cal Ross

A checklist would make my life easier but I'm not sure it's possible. When you asked the question Peter, I wrote down fish, fish habitat and fish quality but it could also be shellfish, shellfish habitat and shellfish quality. I think it is a little simplistic for the oil and gas industry to work with a checklist, because if we focus on that, other subjects may be ignored. For instance, stakeholders might ask why there was only one paper on seabirds at this workshop and not much on marine mammals. There may be a wider range of stakeholders in the marine environment than elsewhere, and I'm not sure that we can narrow the issues down to a short critical list. Long ago the prevailing truism was that if the most vulnerable organism can be protected, then everything else would be taken care

of. That is a difficult concept to get across at public meetings, reviews and panel hearings. In the long term, monitoring programs need to focus on the sentinel, representative, and sensitive species and environments and keep faith that if we can look after those, we will also be looking after the others.

Roger Green

I deal with this matter of long-term monitoring and consistency all the time and have been forced on occasion to tell monitoring groups that the data they have been collecting for several years is of limited value because the methods they used were changed repeatedly. Apart from the question of what should be studied, it is important to ensure that there is consistency and comparability in the long term. If a new and better method emerges, keep applying the old one for a while to provide some overlap and calibration. Most of the cost of monitoring lies in the sampling, and the additional cost of continuing the old approach may not be large. This overlap provides a core of consistency that goes through the whole time sequence.

Gary Sonnichsen

At this point, I would like to thank the panel members and ask Don Gordon to provide some final thoughts to close this forum.

Don Gordon

In March 2000, there was a workshop here at BIO to look specifically at EEM but it had a more regional focus. The workshop was hosted by the Sable Environmental Effects Monitoring Advisory Group (SEEMAG) which is an advisory body to the Sable Offshore Gas Project. At that time we wanted to bring together the regional community to review what was being done under the Sable EEM program and compare it with the earlier experience at Panuke-Cohasset, the current activity at Hibernia, and what was planned for Terra Nova.

The purpose was to review what had been done, what had been learned, and how we should move forward. The feeling that emerged from the workshop, and which is summarised in the report included in your kit (Canadian Technical Report of Fisheries and Aquatic Sciences 2311), was that the program had been designed properly and was working well. There also did not seem to be any major effects from waste generated at the offshore platforms.

Now, three years later, this week's workshop has broadened the examination to include the international perspective, and we have been presented with a great deal of new information, new approaches, and new methods. Overall, it seems to me that there is still a general feeling of comfort that the results are positive and the effects we do see are being held close to the platform. Though it seems that there has been little change over the three years in terms of the general conclusions, there are obviously ways in which we can improve the methods we use and be more efficient in our use of money.

Looking ahead, and recognising that the industry may be expanding even further, we need to stay on top of the issues. The biggest one to emerge, which has nothing to do with the offshore EEM, is the impact of seismic exploration. Another matter, I submit, is the impact of other human activities in the offshore environment, particularly fishing. There are already initiatives underway to address these issues in Atlantic Canada.

In May 2002, there was a workshop in St. John's funded by ESRF on cumulative effects (ESRF Report 137). There is also a program called the Eastern Scotian Shelf Integrated Management Program (ESSIM) that is looking at integrated management of all offshore activities in this part of the world. I believe that these are two good examples of the direction we should be going in.

As with any type of monitoring program, it must be recognised that we are looking at the impact of human activities on a natural environment that has very pronounced spatial and temporal variation. As I said before, I believe government scientists should take a leading role in defining the baseline conditions in the offshore environment.

6. Student Competition Results

A student competition was included in the workshop to encourage the next generation of scientists to present their research in a public forum. Participants in the competition had a valuable opportunity to enhance their communication skills, to obtain comments on their research, and to make contacts with established researchers. EnCana and Petro-Canada each contributed $500 in prize money for platform and poster presentation categories. Members of the Workshop Organising Committee evaluated student platform and poster presentations. Thanyamnta Worakanok and Nui Haibo, both students of the Faculty of Engineering at Memorial University of Newfoundland, were awarded prises for best poster presentation and platform presentation, respectively.

Student award ceremony. Left to right: Urban Williams (Petro-Canada), Peter Cranford (DFO), Thanyamnta Worakanok (student award winner, MUN), Lori MacLean (EnCana), Geoffrey Hurley (EnCana), Ken Lee (COOGER). Missing: Nui Haibo (student award winner, MUN).

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