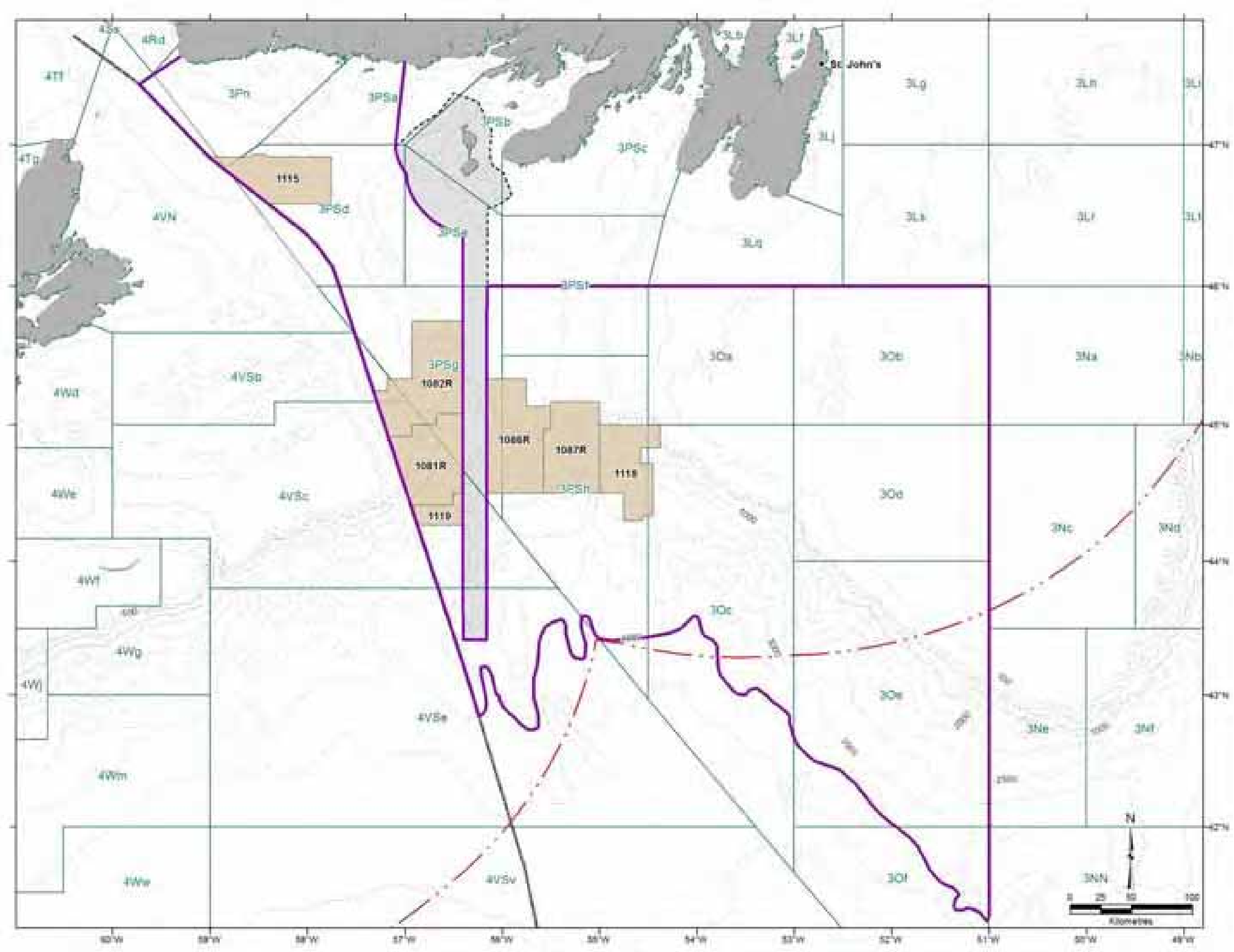
SOUTHERN NEWFOUNDLAND STRATEGIC ENVIRONMENTAL ASSESSMENT



Final Report

CANADA-NEWFOUNDLAND
and LABRADOR
OFFSHORE
PETROLEUM
BOARD

Southern Newfoundland
Strategic Environmental Assessment
Final Report

Prepared by

LGL Limited
environmental research associates
388 Kenmount Road, Box 13248, Stn. A., St. John's, NL A1B 4A5
Tel: 709-754-1992   Fax: 709-754-7718
rbuchanan@lgl.com
www.lgl.com

In Association With

Oceans Limited
65A LeMarchant Road
St. John's, NL A1C 2G9
709-753-5788

Canning & Pitt Associates, Inc.
Box 21461, St. John's, NL A1A 5G2
Tel: 709-738-0133   Fax: 709-753-4471
www.canpitt.ca

and

PAL Environmental Services
Box 29030. St John's, NL A1A 5B5
Tel: 709-576-1226 Fax: 709-576-1522
e-mail: esd@provair.com

Prepared for

Canada-Newfoundland and Labrador Offshore Petroleum Board
Fifth Floor, TD Place
140 Water Street
St. John's, NL
A1C 6H6

February 2010
SA1037

Suggested format for citation:

LGL Limited. 2010. Southern Newfoundland Strategic Environmental Assessment. LGL Rep. SA1037. Rep. by LGL Limited, St. John’s, NL, Oceans Limited, St. John’s, NL, Canning & Pitt Associates, Inc., St. John's, NL, and PAL Environmental Services, St. John’s, NL, for Canada-Newfoundland and Labrador Offshore Petroleum Board, St. John’s, NL. 333 p. + Appendix.

For more information, contact:
C-NLOPB
5th Floor, TD Place, 140 Water Street
St. John’s, NL, A1C 6H6
Tel: (709) 778-1400
Fax: (709) 778-1473

ISBN: 978-1-897101-79-7

Table of Contents

Page

Table of Contents ii
List of Figures ix
List of Tables xiii
List of Acronyms/Abbreviations xv
1.0 Introduction 1
  1.1 Objectives 2
  1.2 Scoping 3
  1.3 Offshore Licences 4
    1.3.1 Exploration Licence 4
    1.3.2 Significant Discovery Licence 4
    1.3.3 Production Licence 5
  1.4 History of Oil and Gas in the Southern Newfoundland SEA Area 5
  1.5 Current Oil and Gas Activities in the Newfoundland Offshore Area 5
  1.6 Call for Bids 5
  1.7 Focus and Organization of the SEA 5
2.0 Physical Environment 7
  2.1 Climatology 7
    2.1.1 Data Sources 8
    2.1.2 Wind Climatology 10
    2.1.3 Wave Climatology 11
    2.1.4 Air and Sea Temperature 13
    2.1.5 Visibility 15
    2.1.6 Precipitation 17
    2.1.7 Sea Spray Vessel Icing 19
    2.1.8 Tropical Systems 22
    2.1.9 Wind and Wave Extreme Value Analysis 26
  2.2 Physical Oceanography 27
    2.2.1 Currents 27
      2.2.1.1 Currents Outside St. Pierre Bank 29
      2.2.1.2 Currents Outside Whale Bank 31
    2.2.2 Water Properties 31
  2.3 Ice 37
    2.3.1 Databases 38
    2.3.2 Sea Ice 38
      2.3.2.1 Sea Ice Concentrations 38
    2.3.3 Icebergs 38
      2.3.3.1 Iceberg Distribution by Year 41
      2.3.3.2 Iceberg Distribution by Month 42
      2.3.3.3 Iceberg Size Distribution 42
      2.3.3.4 Iceberg Drift 43
      2.3.3.5 Iceberg Scour 43
  2.4 Bathymetry 43
  2.5 Geology 45
    2.5.1 Sediments 45
    2.5.2 Recent Geological Studies in the Area 46
    2.5.3 Seismicity 47
    2.5.4 Geohazards 48
  2.6 Unexploded Ordnance 49
  2.7 Planning Implications 49

2.7.1 Geology 49
2.7.2 Climatology 49
2.7.3 Physical Oceanography 50
2.7.4 Ice 50
2.7.5 Unexploded Ordnance 51
2.8 Data Gaps 51
3.0 Biological Environment 53
3.1 Fish Habitat 53
3.1.1 Bottom Substrate 53
3.1.2 Coastal Algal Communities 53
3.1.2.1 Marine Algae 53
3.1.2.2 Estuarine Algae 54
3.1.3 Plankton 54
3.1.4 Benthic Invertebrates 56
3.1.4.1 Continental Shelf 57
3.1.4.2 Slope/Abyssal 59
3.1.5 Planning Implications 61
3.1.6 Data Gaps 61
3.2 Fish 62
3.2.1 Commercially-harvested Species 62
3.2.1.1 Macroinvertebrates 62
3.2.1.2 Finfish 65
3.2.2 Important Species not Presently Commercially Harvested in the SEA Area 75
3.2.2.1 Cusk 75
3.2.2.2 Blue Shark 75
3.2.2.3 Capelin 75
3.2.2.4 Alewife 76
3.2.2.5 Spinytail Skate 76
3.2.2.6 Spiny Eel 76
3.2.2.7 Sandlance 77
3.2.2.8 Atlantic Salmon 77
3.2.2.9 Atlantic Saury 78
3.2.2.10 Shortfin Squid 78
3.2.2.11 Sharks 78
3.2.2.12 Hakes 79
3.2.3 Macroinvertebrate and Fish Spawning 80
3.2.4 DFO Research Vessel (RV) Surveys 80
3.2.4.1 Catch Weight 80
3.2.4.2 Catch Distribution 80
3.2.5 Planning Implications 80
3.2.6 Data Gaps 96
3.3 Fisheries 96
3.3.1 Commercial Fisheries 97
3.3.1.1 Commercial Fisheries Overview 98
3.3.1.2 SEA Area Commercial Harvest, 2000-2007 99
3.3.1.3 Emerging Fisheries/Under-utilized Species 143
3.3.2 Aquaculture 143
3.3.3 Recreational Fisheries 143
3.3.3.1 Brown Trout 143
3.3.3.2 Atlantic Mackerel 144
3.3.3.3 Shortfin Squid 144
3.3.3.4 Capelin 144
3.3.3.5 Atlantic Cod 144
3.3.3.6 Scallop 144

3.3.4 Aboriginal Fisheries ... 144
3.3.5 Planning Implications ... 145
3.3.6 Data Gaps ... 145
3.4 Marine-associated Birds ... 146
3.4.1 Seabirds ... 146
3.4.1.1 Nesting Populations and Breeding Biology ... 146
3.4.1.2 Prey and Foraging Habits ... 150
3.4.1.3 Geographic and Seasonal Distribution ... 155
3.4.1.4 Pelagic Seabird Abundance – Combined Species ... 155
3.4.2 Coastal Waterfowl, Loons, and Grebes ... 170
3.4.3 Shorebirds ... 173
3.4.4 Important Bird Areas (IBA) ... 173
3.4.4.1 Witless Bay Islands ... 174
3.4.4.2 Mistaken Point ... 174
3.4.4.3 Cape St. Mary's ... 174
3.4.4.4 Placentia Bay ... 174
3.4.4.5 Corbin Island ... 174
3.4.4.6 Middle Lawn Island ... 175
3.4.4.7 Green Island ... 175
3.4.4.8 Big Barasway ... 175
3.4.4.9 Codroy Valley Estuary ... 175
3.4.4.10 Grand Bay West to Cheeseman Provincial Park ... 175
3.4.4.11 Ingonish Island ... 175
3.4.4.12 Bird Islands ... 175
3.4.4.13 Northern Head and South Head ... 176
3.4.4.14 Portnova Islands ... 176
3.4.4.15 Forchu Head ... 176
3.4.4.16 Basque Island and Michaud Point ... 176
3.4.4.17 Sable Island ... 176
3.4.5 Other Important Habitat Areas ... 176
3.4.6 Bird Species at Risk ... 177
3.4.7 Rare Species ... 177
3.4.8 Planning Implications ... 177
3.4.9 Data Gaps ... 178
3.5 Marine Mammals ... 178
3.5.1 DFO Cetacean Sighting Database ... 179
3.5.2 Marine Mammal Monitoring in the Laurentian Sub-basin, 2005 ... 190
3.5.3 Baleen Whales (Mysticetes) ... 190
3.5.3.1 Humpback Whale ... 190
3.5.3.2 Sei Whale ... 191
3.5.3.3 Minke Whale ... 191
3.5.4 Toothed Whales (Odontocetes) ... 192
3.5.4.1 Common Bottlenose Dolphin ... 192
3.5.4.2 Long-finned Pilot Whale ... 192
3.5.4.3 Short-beaked Common Dolphin ... 193
3.5.4.4 Atlantic White-sided Dolphin ... 193
3.5.4.5 White-beaked Dolphin ... 194
3.5.4.6 Striped Dolphin ... 194
3.5.4.7 Risso's Dolphin ... 195
3.5.4.8 Sperm Whale ... 195
3.5.5 True Seals (Phocids) ... 196
3.5.5.1 Harbour Seal ... 196
3.5.5.2 Grey Seal ... 196
3.5.5.3 Hooded Seal ... 197

3.5.5.4 Harp Seal 197
3.5.6 Planning Implications 198
3.5.7 Data Gaps 198
3.6 Sea Turtles 198
3.6.1 Loggerhead Sea Turtle 199
3.6.2 Kemp's Ridley Sea Turtle 199
3.6.3 Planning Implications 199
3.6.4 Data Gaps 200
3.7 Species at Risk 200
3.7.1 Fishes 201
3.7.1.1 Atlantic Salmon (Inner Bay of Fundy Population) 201
3.7.1.2 Wolffishes 201
3.7.1.3 Banded Killifish 204
3.7.1.4 Atlantic Cod 204
3.7.1.5 Porbeagle Shark 205
3.7.1.6 White Shark 206
3.7.1.7 Roundnose Grenadier 206
3.7.1.8 Winter Skate 206
3.7.1.9 Cusk 207
3.7.1.10 Shortfin Mako Shark 207
3.7.1.11 American Plaice 207
3.7.1.12 Blue Shark 208
3.7.1.13 American Eel 208
3.7.1.14 Roughhead Grenadier 209
3.7.2 Marine-associated Birds 209
3.7.2.1 Piping Plover *Melodus* Subspecies 209
3.7.2.2 Roseate Tern 210
3.7.2.3 Ivory Gull 210
3.7.2.4 Harlequin Duck (Eastern Population) 210
3.7.2.5 Barrow's Goldeneye (Eastern Population) 210
3.7.2.6 Red Knot *Rufa* Subspecies 210
3.7.3 Marine Mammals 210
3.7.3.1 Blue Whale (Atlantic Population) 211
3.7.3.2 North Atlantic Right Whale 211
3.7.3.3 Northern Bottlenose Whale (Scotian Shelf Population) 212
3.7.3.4 Beluga Whale (St. Lawrence Estuary Population) 212
3.7.3.5 Fin Whale (Atlantic Population) 212
3.7.3.6 Sowerby's Beaked Whale 213
3.7.3.7 Harbour Porpoise 213
3.7.3.8 Killer Whale (NW Atlantic/Eastern Arctic Populations) 214
3.7.4 Sea Turtles 214
3.7.4.1 Leatherback Sea Turtle 214
3.7.5 Planning Implications 216
3.7.6 Data Gaps 217
3.8 Potentially Sensitive Areas 218
3.8.1 Integrated Management Areas 218
3.8.1.1 Placentia Bay Grand Banks Large Ocean Management Area 218
3.8.1.2 Eastern Scotian Shelf Integrated Management Initiative 219
3.8.1.3 Gulf of St. Lawrence Integrated Management Initiative 219
3.8.2 Ecologically and Biologically Significant Areas 220
3.8.3 CAD-NAFO Coral Protection Zone 226
3.8.4 CPAWS Special Marine Areas 226
3.8.5 Proposed National Marine Conservation Areas 226
3.8.5.1 Laurentian Channel Marine Region 228

3.8.5.2 Grand Banks Marine Region 229
3.8.6 Atlantic Salmon Rivers 229
3.8.7 Planning Implications 231
3.8.8 Data Gaps 231
4.0 Exploration/Production Activities and Associated Environmental Effects 232
4.1 Exploration Phase 232
4.1.1 Geophysical Surveys 232
4.1.2 Exploratory Drilling 235
4.1.3 Potential Issues 237
4.2 Production Phase 237
4.3 Decommissioning Phase 239
4.4 Potential Sources of Effects from Routine Activities 239
4.4.1 Underwater Sound 239
4.4.1.1 Source Levels 239
4.4.1.2 Path Component 241
4.4.1.3 Receiver Component 241
4.4.2 In-Air Sound 243
4.4.3 Ambient Sound 243
4.4.4 Industrial Sounds 243
4.4.4.1 Geophysical Surveys 243
4.4.4.2 Drilling Sounds 245
4.4.4.3 Production Sounds 245
4.4.5 Offshore Drilling 245
4.4.6 Construction Activities 250
4.4.7 Production Effluents and Emissions 251
4.4.8 Decommissioning Activities 252
4.5 Interactions and Potential Effects of Routine Activities 252
4.5.1 Effects of Sound 253
4.5.1.1 Fish Habitat 253
4.5.1.2 Fish and Invertebrates 253
4.5.1.3 Fisheries 261
4.5.1.4 Marine-associated Birds 261
4.5.1.5 Marine Mammals 262
4.5.1.6 Sea Turtles 268
4.5.1.7 Species at Risk and Potentially Sensitive Areas 269
4.5.1.8 Planning Implications 270
4.5.1.9 Data Gaps 270
4.5.2 Effects of Drilling Muds and Cuttings 271
4.5.2.1 Fish, Fish Habitat and Fisheries 271
4.5.2.2 Marine-associated Birds 271
4.5.2.3 Marine Mammals and Sea Turtles 272
4.5.2.4 Species at Risk and Potentially Sensitive Areas 272
4.5.2.5 Planning Implications 272
4.5.2.6 Data Gaps 272
4.5.3 Effects of Bottom Disturbance 272
4.5.3.1 Fish Habitat, Fish and Fisheries 273
4.5.3.2 Marine-associated Birds, Sea Turtles and Marine Mammals 273
4.5.3.3 Species at Risk and Potentially Sensitive Areas 273
4.5.3.4 Planning Implications 273
4.5.3.5 Data Gaps 274
4.5.4 Effects of Produced Water 274
4.5.4.1 Marine-associated Birds 274
4.5.4.2 Sea Turtles and Marine Mammals 274
4.5.4.3 Species-at-Risk and Potentially Sensitive Areas 274

4.5.4.4 Planning Implications 275
4.5.4.5 Data Gaps 275
4.5.5 Effects of Lights and Flaring 275
4.5.5.1 Fish Habitat, Fish and Fisheries 275
4.5.5.2 Marine-associated Birds 275
4.5.5.3 Marine Mammals and Sea Turtles 275
4.5.5.4 Species at Risk and Potentially Sensitive Areas 275
4.5.5.5 Planning Implications 276
4.5.5.6 Data Gaps 276
4.5.6 Effects of Presence of Structures 276
4.5.6.1 Fish Habitat, Fish and Fisheries 276
4.5.6.2 Marine-associated Birds 277
4.5.6.3 Marine Mammals and Sea Turtles 277
4.5.6.4 Species at Risk and Potentially Sensitive Areas 277
4.5.6.5 Planning Implications 277
4.5.6.6 Data Gaps 278
4.5.7 Effects of Liquid and Solid Wastes 278
4.5.7.1 Fish Habitat, Fish and Fisheries 278
4.5.7.2 Marine-associated Birds 278
4.5.7.3 Marine Mammals and Sea Turtles 279
4.5.7.4 Species at Risk and Potentially Sensitive Areas 279
4.5.7.5 Planning Implications 279
4.5.7.6 Data Gaps 279
4.5.8 Effects of Atmospheric Emissions 279
4.5.8.1 Fish, Fish Habitat and Fisheries 279
4.5.8.2 Marine-associated Birds, Sea Turtles and Marine Mammals 279
4.5.8.3 Species at Risk and Potentially Sensitive Areas 279
4.5.8.4 Planning Implications 279
4.5.8.5 Data Gaps 280
4.5.9 Effects of Marine Vessel Presence (non-acoustic effects) 280
4.5.9.1 Fish Habitat, Fish and Fisheries 280
4.5.9.2 Marine-associated Birds 280
4.5.9.3 Marine Mammals and Sea Turtles 280
4.5.9.4 Species at Risk and Potentially Sensitive Areas 281
4.5.9.5 Planning Implications 281
4.5.9.6 Data Gaps 281
4.6 Accidental Hydrocarbon Releases 281
4.6.1 Blowouts and Spills 282
4.6.2 Accidental Hydrocarbon Release Sizes 282
4.6.3 Fate and Behaviour 283
4.6.4 Interactions and Potential Effects of Accidental Hydrocarbon Releases 283
4.6.4.1 Fish Habitat 285
4.6.4.2 Fish 285
4.6.4.3 Fisheries 287
4.6.4.4 Marine-associated Birds 288
4.6.4.5 Marine Mammals 289
4.6.4.6 Sea Turtles 289
4.6.4.7 Species at Risk and Potentially Sensitive Areas 290
4.6.4.8 Planning Implications 290
4.6.4.9 Data Gaps 292
5.0 Cumulative Effects 293
5.1 Oil and Gas Activities 294
5.1.1 Seismic Surveys 294
5.1.2 Drilling 294

5.2 Commercial, Research and Recreational Fisheries and Aquaculture 294
5.3 Marine Transportation 295
5.4 Hunting 297
5.5 Tourism 297
5.6 Military Activities 297
5.7 Subsea Cables 298
6.0 Summary and Conclusions 299
6.1 Potential Issues 299
6.2 Planning Implications 299
6.2.1 Identified Potentially Sensitive Areas 299
6.2.2 Shallow Subtidal/Intertidal Areas 300
6.2.3 Mitigations 300
6.3 Data Gaps 301
6.4 Addressing Data Gaps 302
6.5 Conclusions 302
7.0 References 304
Appendix 1 - Report on Industry, Agency and Community Consultations 1

List of Figures

Page
Figure 1.1 Southern Newfoundland SEA Area, Including Locations of ELs, Study Areas Associated with Sydney Basin SEA (pink) and Laurentian Sub-basin SEA (aqua). 2
Figure 2.1. Data Sources for Wind and Waves. 9
Figure 2.2. Monthly and Annual Percentage Occurrence of Visibility for Region 1. 16
Figure 2.3. Monthly and Annual Percentage Occurrence of Visibility for Region 2. 16
Figure 2.4. Monthly and Annual Percentage Occurrence of Visibility for Region 3. 17
Figure 2.5. Percentage Frequency of Potential Spray Icing Conditions for Region 1. 20
Figure 2.6. Percentage Frequency of Potential Spray Icing Conditions for Region 2. 21
Figure 2.7. Percentage Frequency of Potential Spray Icing Conditions for Region 3. 21
Figure 2.8. Canadian Hurricane Centre Response Zone. 22
Figure 2.9. Storm Tracks of Tropical Systems Passing within 200 nm of 44.5°N 53.5°W, 1957 to 2007. 24
Figure 2.10. Frequency of Tropical Storm Development in the Atlantic Basin. 1958 – 2007. 25
Figure 2.11. 5-Year Average of the Number of Tropical Storms which Formed in the Atlantic Basin since 1960. 26
Figure 2.12. Schematic Diagram of the Main Features of the Surface Circulation in the Western Atlantic Ocean (cold shelf break waters are shown in blue while warm gulf stream waters are shown in red). 27
Figure 2.13. General Oceanic Circulation around the St. Pierre Bank. 28
Figure 2.14. Monthly Temperature and Salinity Profiles at Burgeo Bank. 32
Figure 2.15. Monthly Temperature and Salinity Profile in Hermitage Channel. 33
Figure 2.16. Monthly Temperature and Salinity Profile in Laurentian Channel 34
Figure 2.17. Monthly Temperature and Salinity Profile for the St. Pierre and Green Banks Shelf Region. 35
Figure 2.18. Monthly Temperature and Salinity Profile for the Laurentian Fan Slope Region. 36
Figure 2.19. Hydrographic Contours along the South East Grand Banks Transect during April 2008. 37
Figure 2.20. Study Area Sub-divided into Quadrants. 39
Figure 2.21. Probability of Sea Ice Cover by Subsection. [SW and SE quadrants were ice-free.] 39
Figure 2.22. Pack Ice Type by Month. 40
Figure 2.23. Iceberg Distribution by Year. 41
Figure 2.24. Sightings Per One Degree Block. 41
Figure 2.25. Monthly Occurrence of Icebergs as a Percentage of the Yearly Total. 42
Figure 2.26. Iceberg Size Distributions for the South Newfoundland Offshore Block. 43
Figure 2.27. General Iceberg Drift Patterns Surrounding the South Newfoundland Offshore Location. 44
Figure 2.28. Bathymetry and Physical Features of SEA Area. 44
Figure 2.29. Historical Seismicity in and near the Laurentian Sub-basin. 48
Figure 3.1. Newfoundland and Labrador Lobster Fishing Areas. 64
Figure 3.2. Distributions and Relative Catch Weights of DFO RV Survey Catches of Deepwater Redfish (top) and Thorny Skate (bottom) in SEA Area, 2006 and 2007 Combined. 86
Figure 3.3. Distributions and Relative Catch Weights of DFO RV Survey Catches of Yellowtail Flounder (top) and American Plaice (bottom) in SEA Area, 2006 and 2007 Combined. 87
Figure 3.4. Distributions and Relative Catch Weights of DFO RV Survey Catches of Atlantic Cod (top) and Sand Lance (bottom) in SEA Area, 2006 and 2007 Combined. 88
Figure 3.5. Distributions and Relative Catch Weights of DFO RV Survey Catches of Witch Flounder (top) and White Hake (bottom) in SEA Area, 2006 and 2007 Combined. 89
Figure 3.6. Distributions and Relative Catch Weights of DFO RV Survey Catches of Sea Cucumber (top) and Black Dogfish Shark (bottom) in SEA Area, 2006 and 2007 Combined. 90
Figure 3.7. Distributions and Relative Catch Weights of DFO RV Survey Catches of Longfin Hake (top) and Greenland Halibut (bottom) in SEA Area, 2006 and 2007 Combined. 91

Figure 3.8. Distribution and Relative Catch Weight of DFO RV Survey Catches of Haddock in SEA Area, 2006 and 2007 Combined. ... 92
Figure 3.9. Distribution, Number of Individuals (top, blue) and Relative Catch Weight (bottom, red) of DFO RV Survey Catches of Northern Wolffish in SEA Area, 2006 and 2007 Combined. ... 93
Figure 3.10. Distribution, Number of Individuals (top, blue) and Relative Catch Weight (bottom, red) of DFO RV Survey Catches of Spotted Wolffish in SEA Area, 2006 and 2007 Combined. ... 94
Figure 3.11. Distribution, Number of Individuals (top, blue) and Relative Catch Weight (bottom, red) of DFO RV Survey Catches of Atlantic Wolffish in SEA Area, 2006 and 2007 Combined. ... 95
Figure 3.12. SEA Area in Relation to Regional Fisheries Management Areas. ... 97
Figure 3.13. Domestic (upper) and Foreign (lower) Commercial Harvest from NAFO Div. 3O for All Species, Groundfish Species, and Invertebrate Species, 1988-2007. ... 100
Figure 3.14. Composition of the Domestic Harvest in 3O, 1988. ... 101
Figure 3.15. Composition of the Domestic Harvest in 3O, 2007. ... 101
Figure 3.16. Average Monthly Harvest, All Species, for the SEA Area, 2000-2007. ... 103
Figure 3.17. SEA Area Harvest by Month, All Species, 2006 (Black) and 2007 (Grey). ... 103
Figure 3.18. SEA Area Harvesting Locations, All Species, All Months, 2006 (upper) and 2007 (lower). ... 104
Figure 3.19. SEA Area Harvesting Locations, All Species, Mobile Gear 2006 (upper), Mobile Gear 2007 (lower). ... 106
Figure 3.20. SEA Area Harvesting Locations, All Species, Fixed Gear 2006 (upper), and Fixed Gear 2007 (lower). ... 107
Figure 3.21. SEA Area Harvesting Locations, Groundfish, All Months, 2006 (upper) and 2007 (lower). ... 111
Figure 3.22. Annual Atlantic Cod Harvest, 2000-2007. ... 112
Figure 3.23. Monthly Atlantic Cod Harvest, 2006 and 2007. ... 112
Figure 3.24. Atlantic Cod Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). ... 113
Figure 3.25. Annual Redfish Harvest, 2000-2007. ... 114
Figure 3.26. Monthly Redfish Harvest, 2006 and 2007. ... 114
Figure 3.27. Redfish Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). ... 115
Figure 3.28. Annual Yellowtail Flounder Harvest, 2000-2007. ... 116
Figure 3.29. Monthly Yellowtail Flounder Harvest, 2006-2007. ... 116
Figure 3.30. Yellowtail Flounder Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). ... 117
Figure 3.31. Annual White Hake Harvest, 2000-2007. ... 118
Figure 3.32. Monthly White Hake Harvest, 2006 and 2007. ... 118
Figure 3.33. White Hake Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). ... 119
Figure 3.34. Annual Atlantic Halibut Harvest, 2000-2007. ... 120
Figure 3.35. Monthly Atlantic Halibut Harvest, 2006 and 2007. ... 120
Figure 3.36. Atlantic Halibut Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). ... 121
Figure 3.37. Annual Skate Harvest, 2000-2007. ... 122
Figure 3.38. Monthly Skate Harvest, 2006 and 2007. ... 122
Figure 3.39. Skate Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). ... 123
Figure 3.40. Annual Monkfish Harvest, 2000-2007. ... 124
Figure 3.41. Monthly Monkfish Harvest, 2006 and 2007. ... 124
Figure 3.42. Monkfish Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). ... 125
Figure 3.43. Annual American Plaice Harvest, 2000-2007. ... 126
Figure 3.44. Monthly American Plaice Harvest, 2006 and 2007. ... 126
Figure 3.45. American Plaice Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). ... 127
Figure 3.46. Annual Pollock Harvest, 2000-2007. ... 128
Figure 3.47. Monthly Pollock Harvest, 2006 and 2007. ... 128
Figure 3.48. Pollock Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). ... 129
Figure 3.49. Annual Greenland Halibut Harvest, 2000-2007. ... 130
Figure 3.50. Monthly Greenland Halibut Harvest, 2006 and 2007. ... 130

Figure 3.51. Greenland Halibut Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). 131
Figure 3.52. Annual Hagfish Harvest, 2000-2007. 132
Figure 3.53. Monthly Hagfish Harvest, 2006 and 2007. 132
Figure 3.54. Hagfish Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). 133
Figure 3.55. Annual Snow Crab Harvest, 2000-2007. 134
Figure 3.56. Monthly Snow Crab Harvest, 2006 and 2007. 134
Figure 3.57. Snow Crab Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). 135
Figure 3.58. Annual Lobster Harvest, 2000-2007. 136
Figure 3.59. Monthly Lobster Harvest, 2006 and 2007. 136
Figure 3.60. Annual Whelk Harvest, 2000-2007. 137
Figure 3.61. Monthly Whelk Harvest, 2006 and 2007. 137
Figure 3.62. Whelk Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). 138
Figure 3.63. Annual Sea Scallop Harvest, 2000-2007. 139
Figure 3.64. Monthly Sea Scallop Harvest, 2006 and 2007. 139
Figure 3.65. Sea Scallop Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). 140
Figure 3.66. Annual Swordfish Harvest, 2000-2007. 141
Figure 3.67. Monthly Swordfish Harvest, 2006 and 2007. 141
Figure 3.68. Swordfish Harvesting Locations, All Months, 2006 (upper) and 2007 (lower). 142
Figure 3.69. Locations of Coastal Habitat Areas for Marine-associated Birds within and Adjacent to the SEA Area. 148
Figure 3.70. Average of Combined Species (nos. of indiv./km) by 15'N x 30'W (Jan-Mar top; Apr-Jun bottom; Jul-Sep next page top; Oct-Dec next page bottom). 156
Figure 3.71. Combined Seabird Species: Average Density per 10-minute Counts by Weekly Periods, 16 June to 29 September 2005, Laurentian Sub-basin. 158
Figure 3.72. Average Densities of Combined Seabird Species (number of individuals/km^2) by 15'N x 30'W blocks in the Laurentian Sub-basin, 16 June- 29 September 2005. 159
Figure 3.73. Average Densities of Northern Fulmar (number of individuals/km^2) by 30'N x 30'W Blocks During Feb-July, 2006 to 2008. 161
Figure 3.74. Average Densities (number of individuals/km^2) of Greater Shearwater by 15'N x 30'W Blocks in the Laurentian Sub-basin during 16 June- 29 September 2005. 162
Figure 3.75. Average Densities of Shearwater (number of individuals/km^2) by 30'N x 30'W Blocks During Feb-Jul, 2006 to 2008. 163
Figure 3.76. Average Densities of Storm-Petrel (number of individuals/km^2) by 30'N x 30'W Blocks During Feb-Jul, 2006 to 2008. 165
Figure 3.77. Average Densities (number of individuals/km^2) of Leach's Storm-Petrel by 15'N x 30'W Blocks in the Laurentian Sub-basin during 16 June-29 September 2005. 166
Figure 3.78. Average Densities of Black-legged Kittiwake (number of individuals/km^2) by 30'N x 30'W Blocks During Feb-Jul, 2006 to 2008. 168
Figure 3.79. Average Densities of Large Gulls (number of individuals/km^2) by 30'N x 30'W Blocks During Feb-Jul, 2006 to 2008. 169
Figure 3.80. Average Densities of combined auks (alcids) (number of individuals/km^2) by 30'N x 30'W Blocks During Feb-Jul, 2006 to 2008. 172
Figure 3.81. Distribution of Baleen Whale Sightings within the SEA Area (based on DFO sightings database 1975-2007). 185
Figure 3.82. Distribution of Large Toothed Whale Sightings within the SEA Area (based on DFO sightings database 1975-2007). 186
Figure 3.83. Distribution of Dolphin and Porpoise Sightings within the SEA Area (based on DFO database from 1975-2007). 187
Figure 3.84. Distribution of Unidentified Cetacean Sightings within the SEA Area (based on DFO database from 1975-2007). 188
Figure 3.85. Sightings and Entanglements of Leatherback Sea Turtles in the SEA Area, 1982-2007. 216
Figure 3.86. Potentially Sensitive Areas that Either Occur within or Abut the SEA Area. 221
Figure 3.87. DFO Scheduled Atlantic Salmon Rivers in the SEA Area. 230
Figure 4.1. Schematic of Seismic Survey Vessel. 233

Figure 4.2. Typical Configuration of a Seismic Air Gun Array and Streamers. 233
Figure 4.3. Typical CSEM Towed Gear. 234
Figure 4.4. Typical CSEM Dipole Antenna (Receiver) with Anchor. 234
Figure 4.5. Semi-submersible Drill Rig *Glomar Grand Banks*. 235
Figure 4.6. Rowan Gorilla Jack-up Rig. 236
Figure 4.7. A Typical Drillship. 236
Figure 4.8. Hibernia GBS. 238
Figure 4.9. Petro-Canada FPSO. Courtesy of Petro-Canada. 238
Figure 4.10. Terminology Used to Describe Sound Pressure Levels in an Acoustic Impulse (horizontal axis not drawn to scale). 240
Figure 4.11. Schematic Representation of Acoustic Spreading Loss from a Sound Source as a Function of Distance and Interaction with the Seafloor. 241
Figure 4.12. Schematic Representation of the Zones of Potential Influence of Anthropogenic Sounds on Marine Animals (vertical distances among the different effects are not drawn to scale). 242
Figure 5.1. Shipping Routes in Vicinity of SEA Area. 295
Figure 5.2. Cargo Vessels and Ferry Traffic. 296
Figure 5.3. Oil Tanker Traffic. 296

List of Tables

Page

Table 2.1. Location of MSC Nomad Weather Buoys. 8
Table 2.2. Monthly Mean Wind Speeds (m/s) for the SEA Area. 10
Table 2.3. Monthly Maximum Wind Speeds (m/s) for the SEA Area. 10
Table 2.4. Monthly Mean Significant Wave Height (m) for the SEA Area. 12
Table 2.5. Monthly Maximum Significant Wave Height (m) for the SEA Area. 12
Table 2.6. Air Temperature (°C) Statistics for Region 1. 13
Table 2.7. Air Temperature (°C) Statistics for Region 2. 13
Table 2.8. Air Temperature (°C) Statistics for Region 3. 14
Table 2.9. Sea Temperature (°C) Statistics for Region 1. 14
Table 2.10. Sea Temperature (°C) Statistics for Region 2. 14
Table 2.11. Sea Temperature (°C) Statistics for Region 3. 15
Table 2.12. Percentage Frequency (%) Distribution of Precipitation for Region 1. 18
Table 2.13. Percentage Frequency (%) Distribution of Precipitation for Region 2. 19
Table 2.14. Percentage Frequency (%) Distribution of Precipitation for Region 3. 19
Table 2.15. Tropical Systems Passing within 200 Nautical Miles of 44.5°N 53.5°W, 1957 to 2007. 23
Table 2.16. Extreme Wind Speed and Significant Wave Height Values using the Gumbel Distribution. 27
Table 2.17. Current Speed (m/s) Statistics for the Area outside St. Pierre Bank for June 1996 - April 2000. 30
Table 2.18 IIP Iceberg Size Classification. 42
Table 3.1. Key Invertebrate Species Associated with General Intertidal Habitat Types in the SEA Area. 57
Table 3.2. Spatial and Temporal Planktonic Egg and Larvae Occurrence in the SEA Area. 81
Table 3.3. Invertebrate and Fish Species Accounting for Most of the Catch Weight During DFO RV Surveys in the SEA Area, 2002-2007 Combined. 85
Table 3.4. Average Harvest for 2000-2007 in SEA Area, and Annual Harvests for 2006 and 2007. 102
Table 3.5. SEA Area Harvest by Gear Type, All Months, 2000-2007. 105
Table 3.6. Landed Value for the SEA Area in 2007. 108
Table 3.7. Georeferenced Harvest Within the SEA Area, Average 2000-2007. 110
Table 3.8. Monthly Relative Abundance of Bird Species that Likely Occur in the Pelagic Waters of the SEA Area. 147
Table 3.9. Estimated Pairs of Species at Risk and Colonial Seabirds Nesting at Important Bird Areas (IBAs) along Newfoundland's South Coast. 149
Table 3.10. Estimated Numbers of Pairs of Seabirds Nesting at IBAs Located on Coastal Nova Scotia near the SEA Area. 151
Table 3.11. Reproductive Parameters of Seabirds Nesting in the SEA Area. 152
Table 3.12. Seabird Nesting Phenology in the SEA Area. 153
Table 3.13. Foraging Strategy and Prey Types of Pelagic Seabirds that Frequent the SEA Area. 154
Table 3.14. Average Densities of Pelagic Seabirds (number of individuals/km^2) by Month (derived from 10-minute seabird counts in the Laurentian Sub-basin, 16 June to 29 September 2005). 158
Table 3.15. Marine Mammals Likely to Occur within the SEA Area. 180
Table 3.16. Population Estimates of Marine Mammals Likely to Occur within the SEA Area. 182
Table 3.17. Number of Cetacean Sightings and Individuals within the SEA Area by Season, 1975-2007. 183
Table 3.18. Number of Cetacean Sightings by Depth within the SEA Area, 1975-2007. 184
Table 3.19. Sea Turtles Known to Occur within the SEA Area (adapted from Table 3.15 *in* JWEL (2003)). 198

Table 3.20. *SARA* Schedule 1 and COSEWIC-listed Marine Species that Potentially Occur in the SEA Area. 202
Table 3.21. Leatherback Sea Turtle Sightings and Entanglements in the SEA Area, 1982-2007. 215
Table 3.22. Specifics of Placentia Bay-Grand Banks LOMA EBSAs that Occur within the SEA Area. 222
Table 3.23. Specifics of Eastern Scotian Shelf Proposed EBSAs that Occur within the SEA Area. 225
Table 3.24. Specifics of CPAWS Special Marine Areas that Occur within or Proximate to SEA Area. 227
Table 4.1. Typical Mud Components and Cuttings Discharge Volume for a Grand Banks Exploration Well. 246
Table 4.2. Composition of the SBM PARADRIL-IA. 248
Table 4.3. Chemical Composition of Produced Water from Norwegian North Sea Platforms. 251
Table 4.4. Potential Interactions of Oil and Gas Exploration and Production Routine Activities and Valued Ecosystem Components. 253
Table 4.5. Accidental Hydrocarbon Release Size Categories. 282
Table 4.6. Oil Spill (>1 Litre) Data Pertaining to the Newfoundland and Labrador Offshore Area, 1997-2009. 284

List of Acronyms/Abbreviations

ABR	auditory brainstem response
ADW	approval to drill a well
AOIs	Areas of Interest
AZMP	Atlantic Zone Monitoring Program
bbl	barrels
brt	below rotary table
BDDB	Burgeo Diversification Development Board
BIO	Institute of Oceanography
BOP	Blowout preventer
CAPP	Association of Petroleum Producers
CEAA	*Canadian Environmental Assessment Act*
CEA Agency	Canadian Environmental Assessment Agency
CHC	Canadian Hurricane Centre
CIS	Canadian Ice Services
CMAs	Coastal Management Areas
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
C-NLOPB	The Canada-Newfoundland and Labrador Offshore Petroleum Board
COB	Coast of Bays
COB CPC	Coast of Bays Coastal Planning Committee
CPAWS	Canadian Parks and Wilderness Society
CPUE	catch per unit effort
CSEM	Controlled source electromagnetic surveys
CWS	Canadian Wildlife Service
dB	decibels
DFA	Department of Fisheries and Aquaculture
DFO	Fisheries and Oceans Canada
DND	Department of National Defence
DP	dynamically-positioned
DUs	Designatable Units or
EA	Environmental Assessment
EBSAs	Ecologically and Biologically Significant Areas
ELs	Exploration Licences
ESA	*Endangered Species Act*
ESRF	Environmental Studies Research Fund
ESS	Eastern Scotian Shelf
ESSIM	Eastern Scotian Shelf Integrated Management
FEZ	fisheries exclusion zone
FFAWU	Fish, Food and Allied Workers Union
FLOs	fisheries liaison officers
FPSO	floating production, storage and offloading vessel
GEAC	Groundfish Enterprise Allocation Council
GOM	Gulf of Mexico
GOSLIM	Gulf of St. Lawrence Integrated Management
GPS	Global Positioning Systems
HADD	Harmful Alteration, Disruption or Destruction
HOTO	Health of the Oceans
IBA	Important Bird Area
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
IIP	International Ice Patrol
IM	Integrated Management
LFA	Lobster Fishing Areas

LOMA	Large Ocean Management Area
MPA	Marine Protected Area
NAFO	Northwest Atlantic Fisheries Organization
NAO	North Atlantic Oscillation
NL	Newfoundland and Labrador
NLOA	Newfoundland and Labrador Offshore Area
nm	nautical miles
NMCA	National Marine Conservation Area
NOAA	National Oceanic and Atmospheric Administration
OBC	on-bottom-cable
OBS	ocean bottom seismometers
OCS	Outer Continental Shelf
OLABS	Offshore Labrador Biological Studies Program
OWTG	*Offshore Waste Treatment Guidelines*
P	sound pressure
Pa	Pascals
PAHs	polycyclic aromatic hydrocarbons
PERD	Program of Energy Research and Development
PB	Placentia Bay
PBGB LOMA	Placentia Bay/Grand Banks Large Ocean Management Area
PBIMPC	Placentia Bay Integrated Management Planning Committee
PEMEX	Petróleos Mexicanos
PIROP	Programme intégré de recherches sur les oiseaux pélagiques
ppm	parts per million
PTS	permanent threshold shifts
RED	Regional Economic Development
rms	root mean square
RV	Research Vessel
SAR	Species at Risk
SARA	*Species at Risk Act*
SBM	synthetic-based muds
SDL	Significant Discovery Licence
SEA	Strategic Environmental Assessment
SEL	Sound Exposure Level
SFAs	salmon fishing areas
SG	Southern Gulf
SMA	Special Marine Areas
SPL	Sound Pressure Level
TTS	temporary threshold shift
UXO	Unexploded Ordnance
VECs	Valued Ecosystem Components
VSP	Vertical Seismic Profiling
WBM	water-based drilling muds
YOY	young of the year

1.0 Introduction

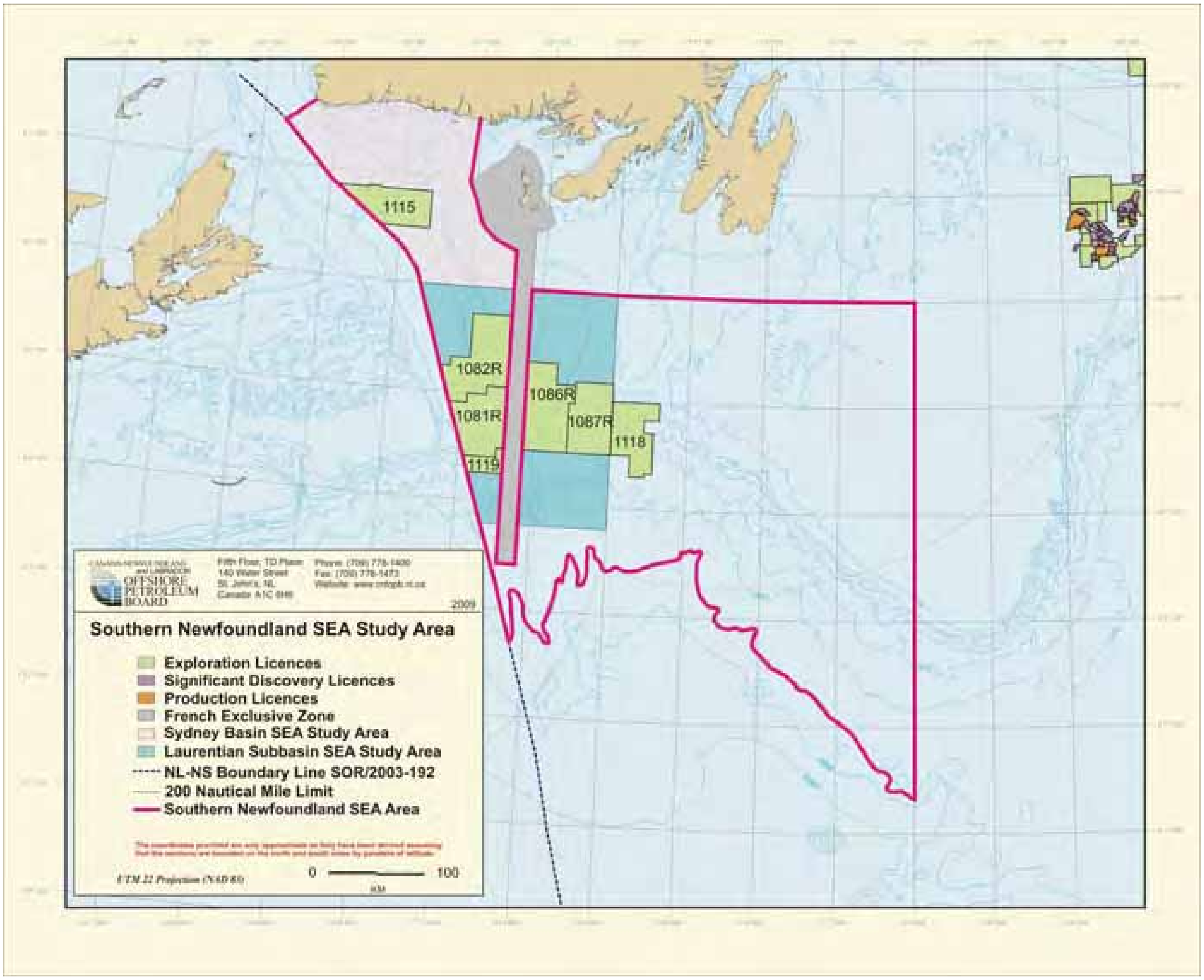
The Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) is responsible, on behalf of the Government of Canada and the Government of Newfoundland and Labrador, for petroleum resource management in the Newfoundland and Labrador Offshore Area. The *Canada-Newfoundland Atlantic Accord Implementation Act* and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* (the *Accord Acts*), administered by the C-NLOPB, govern all petroleum operations in the Newfoundland and Labrador offshore area. The C-NLOPB's mandate is to interpret and apply the provisions of the *Accord Acts* to all activities of operators in the Newfoundland and Labrador Offshore Area; and to oversee operator compliance with those statutory provisions. In the implementation of its mandate, the role of the C-NLOPB is to facilitate the exploration for and development of the hydrocarbon resources in the Newfoundland and Labrador Offshore Area in a manner that conforms to the statutory provisions for:

- worker safety;
- environmental protection and safety;
- effective management of land tenure;
- maximum hydrocarbon recovery and value; and
- Canada/Newfoundland and Labrador benefits.

While the legislation does not prioritize these mandates, worker safety and environmental protection will be paramount in all Board decisions.

This document provides a Strategic Environmental Assessment (SEA) of potential exploration and production activities that could occur in the Southern Newfoundland SEA Study Area (hereafter referred to as "SEA Area" except where full title is required for clarity) (Figure 1.1). The SEA serves as a planning document to assist the C-NLOPB in their decision process with respect to areas, which may or may not be suitable to offshore exploration, and/or areas, which may require special mitigations. This SEA provides: an overview of the existing environment; discusses, in broad terms, the potential environmental effects associated with offshore oil and gas activities in the SEA Area; identifies knowledge and data constraints; highlights issues of concerns; and offers recommendations for mitigation and planning. The SEA provides a broad-scale environmental assessment (EA) considering larger ecological settings. As such, the SEA is not intended, in part or in whole, to preclude the requirements for a project –specific environmental assessment. This SEA provides an update for two previous SEAs for the area (Laurentian Sub-basin and Sydney Basin).

Seven Exploration Licences (ELs) (ELs 1081R, 1082R 1086R, 1087R , 1118 and 1119 held by ConocoPhillips Canada Resources Corp. and EL 1115 held by Husky Oil Operations Limited have been issued in the SEA Area (Figure 1.1). ELs 1118 and 1119 were issued in January 2010 in accordance with the terms and conditions of Call for Bids NL09-02.



Source: C-NLOPB (2009).

Figure 1.1 Southern Newfoundland SEA Area, Including Locations of ELs, Study Areas Associated with Sydney Basin SEA (pink) and Laurentian Sub-basin SEA (aqua).

1.1 Objectives

The SEA represents a broader, more proactive approach to assessing and managing environmental effects than traditional project-specific environmental assessments. An SEA:

- allows environmental issues to be identified and addressed at the earliest stages of planning and typically focuses on "regional-scale" environmental concerns;
- can facilitate the consideration of stakeholder issues and concerns early in the planning process, and demonstrates accountability and due diligence in decision-making; and
- can also help to define the environmental components and potential effects which may require consideration in subsequent project-specific environmental assessments by identifying the key environmental issues associated with a particular sector and/or region.

In this particular case, information from the SEA will assist the C-NLOPB to:

- determine whether or not an EL should be offered in whole or in part within the SEA Area;
- determine what mitigative measures or restrictions should be applied to offshore oil and gas exploration activities in the SEA Area; and
- determine whether or not to issue an EL (pursuant to the *Accord Acts*) in whole or in part within the SEA Area.

An EL confers (C-NLOPB 2006):

- The right to explore for, and the exclusive right to drill and test for, petroleum;
- The exclusive right to develop those portions of the offshore area in order to produce petroleum; and
- The exclusive right, subject to compliance with the other provisions of the *Accord Acts*, to apply for a Production Licence.

Activities that may be associated with ELs include:

- Seismic and other geophysical surveys;
- Drilling of wells (either exploration or delineation); and
- Well abandonment.

If one or more exploratory drilling programs are successful in the identification of petroleum deposits with commercial potential, production activities may follow. Production activities may include:

- Drilling of wells (delineation, development/production and injection wells);
- Installation and operation of subsea equipment;
- Installation and operation of production facilities; and
- Production abandonment activities.

Each of the exploration and production activities requires specific approval of the Board, including a project specific assessment of its associated environmental effects in accordance with the *Canadian Environmental Assessment Act* (*CEAA*). The Southern Newfoundland SEA will not replace the requirement for project-specific environmental assessments.

1.2 Scoping

The C-NLOPB has the responsibility pursuant to the *Accord Acts* to ensure that offshore oil and gas activities proceed in an environmentally responsible manner. The C-NLOPB decided in 2002 to conduct a series of SEAs for portions of the Newfoundland and Labrador Offshore Area that may have the potential of offshore oil and gas exploration activity but that were not subject to recent SEAs and not to recent and substantial site-specific assessments.

The exploration activities considered within the scope of this SEA include: exploratory and delineation drilling; seismic surveys, including two-dimensional (2-D), three-dimensional (3-D), vertical seismic profiling (VSP) and geohazards surveys; and wellsite abandonment. Generic types of potential production facilities that could be employed for the SEA Area have been identified and their project-environment interactions discussed. The spatial boundary for the SEA Area is shown in Figure 1.1. The temporal boundary is for oil and gas activities as listed above which may occur in the SEA Area within the next 10 years. The report will be reviewed in five years to determine if updates are required.

The C-NLOPB identified a requirement for an SEA for an area offshore known as the Southern Newfoundland Offshore Area. As part of the preparation of an SEA, a scoping document was drafted by the C-NLOPB staff with the assistance of a Working Group.

Scoping for the SEA was conducted as follows:

- Input was provided by a Working Group consisting of representatives from federal and provincial government departments and agencies, local Regional Economic Development (RED) Boards, the Fish, Food and Allied Workers Union (FFAWU), and non-governmental organizations;
- The C-NLOPB prepared a Draft Scoping Document in January 2009;
- Previous SEAs for southern Newfoundland (e.g., Laurentian Sub-basin, Sydney Basin Offshore Area) were reviewed; and
- A series of consultations were held during May to June 2009.

Consultations were held with Environment Canada (EC), Fisheries and Oceans Canada (DFO), Department of Fisheries and Aquaculture (DFA), fish harvesters (Port aux Basques, Burgeo, Marystown, St. Brides, St. John's), Town of Burgeo, Marine Mountain Zone Corporation, Schooner Regional Development Corporation, Conne River Band, FFAWU, Natural History Society, Association of Seafood Producers, Ocean Choice International, and others. The consultation report is provided in Appendix 1.

1.3 Offshore Licences

There are three types of licences: exploration (EL); significant discovery (SDL); and production licences (PL) issued by the C-NLOPB. A general overview of the requirements for each licence is provided in the following sections.

1.3.1 Exploration Licence

The term of an EL shall not exceed nine years and shall not be extended or renewed thereafter. In the offshore area, ELs have the maximum nine-year term, typically consisting of two consecutive periods of five years (Period I) and four years (Period II). The interest owner is required to drill or spud and diligently pursue one exploratory well on or before the expiry date of Period I as a condition precedent to obtaining tenure to Period II. Failure to drill or spud a well will result in reversion to Crown reserve of the licence. If the EL requirement for Period I is fulfilled, the interest owner is entitled to obtain tenure to Period II. The only requirement applicable to Period II is the payment, in advance, of annual rentals.

1.3.2 Significant Discovery Licence

A drilling program that has resulted in a significant discovery entitles the interest owner to an SDL (C-NLOPB 2006). A significant discovery is defined in the *Accord Acts* as: a discovery indicated by the first well on a geological feature that demonstrates by flow testing the existence of hydrocarbons in that feature and, having regard to geological and engineering factors, suggests the existence of an accumulation of hydrocarbons that has potential for sustained production.

An SDL is the document of "title" by which an interested owner can continue to hold rights to a discovery area while the extent of that discovery is determined and, if it has potential, to be brought into commercial production in the future. An SDL is effective from the application date and remains in force for as long as the relevant declaration of significant discovery is in force, or until a Production Licence is issued for the relevant lands.

1.3.3 Production Licence

The interest owner is entitled to a PL once a commercial discovery has been declared (C-NLOPB 2006). A commercial discovery is defined as: a discovery of petroleum that has been demonstrated to contain petroleum reserves that justify the investment of capital and effort to bring the discovery to production.

A PL confers: the right to explore for, and the exclusive right to drill and test for, petroleum; the exclusive right to develop those portions of the offshore area in order to produce petroleum; the exclusive right to produce petroleum from those portions of the offshore area; and title to the petroleum so produced. A PL is effective from the date it is issued for a term of 25 years or for such period during which commercial production continues.

1.4 History of Oil and Gas in the Southern Newfoundland SEA Area

Presently, there are seven offshore ELs in the SEA Area, totaling about 2.13 million hectares. Past exploration activity in the SEA Area has included the drilling of 28 offshore wells (C-NLOPB website) and the collection of about 265,000 kilometres of seismic data (~110,000 2D; ~155,000 km 3D) (C-NLOPB, pers. comm., 2010). The last drilling of a well (i.e., 2007, Lewis Hill G-85) in the SEA Area was conducted by Husky Oil on the continental shelf in the eastern part of the SEA Area.

1.5 Current Oil and Gas Activities in the Newfoundland Offshore Area

Currently in the Newfoundland and Labrador Offshore Area there are 38 ELs (25 on the Grand Banks, nine off western Newfoundland in the Gulf of St. Lawrence, and four in the Labrador offshore), 50 SDLs (45 on the Grand Banks and five in the Labrador offshore), and eight PLs, all on the Grand Banks. Hibernia, Terra Nova, and White Rose are producing developments and Hebron is in the design and development application phase.

1.6 Call for Bids

The C-NLOPB normally issues an official call for nominations for exploration annually, in the fall. This call is a preliminary step prior to a competitive call for bids by allowing interested parties the opportunity to nominate lands of interest to be included in a subsequent call for bids. The C-NLOPB is not bound to proceed with a call for bids in respect of any lands nominated, nor is a nominee obligated to bid on lands nominated and included in a subsequent call for bids. The C-NLOPB also has the right to nominate lands on its own initiative for inclusion in a call for bids.

The C-NLOPB submits a plan annually to the provincial and federal Ministers outlining the anticipated decisions of the C-NLOPB during that year respecting calls for bids for approval. Lands that are nominated may be considered for inclusion in the plan for interests. The C-NLOPB initiates a call for bids upon receipt of Ministerial approval, normally commencing in early March and closing in late November. In this case, the call for bids closed November 19, 2009. Exploration licences were issued to successful bidders following the close of the call for bids.

This SEA provided support for the bid process on parcels NL09-02-01 and NL09-02-02 and will do so any future parcels within the Southern Newfoundland SEA Area.

1.7 Focus and Organization of the SEA

This SEA presents an overview of the SEA Area's ecosystem with emphasis on valued ecosystem components (VECs). A VEC in Canadian environmental assessment parlance is a key part of the environment that is recognized by society as important ecologically, scientifically, economically, recreationally, or culturally. A VEC may be of local, national, or international interest. A VEC may be a species or group of species, or valued human activity that has at least some potential to be affected by a proposed project. Typical VECs on the east coast of

Canada include fish habitat, fish, fisheries (aboriginal, commercial, recreational, aquaculture), marine birds, marine mammals, sea turtles, Species at Risk (SAR) as listed in legislation, and sensitive areas.

The SEA is organized according to the following major sections:

- Introduction;
- Physical Environment;
- Biological Environment;
- Exploration/Production Activities and Associated Environmental Effects;
- Cumulative Effects;
- Summary and Conclusions; and
- References.

As noted above, the Southern Newfoundland SEA ("the SEA") Study Area is hereafter referred to as "SEA Area" unless the full name is required for clarity.

2.0 Physical Environment

The climatology, physical oceanography, ice conditions, geology and bathymetry of the SEA Area are described in this section. Some of the information presented includes summaries of physical environment information provided in the Laurentian Sub-basin SEA (JWEL 2003) and the Sydney Basin Offshore Area SEA (JW 2007). Relevant information not provided for these areas in their respective SEAs are presented in this SEA. New physical environment information is presented for the eastern portion of the SEA Area (i.e., NAFO Div. 3O) and the area due south of the Laurentian Sub-basin SEA Area (i.e., NAFO Unit Area 4VSe). NAFO Divisions, Sub-divisions and Unit Areas are shown in Figure 3.3 in Section 3.3 Commercial Fisheries.

2.1 Climatology

The area south of Newfoundland experiences weather conditions typical of a marine environment with the surrounding waters having a moderating effect on temperature. In general, marine climates experience cooler summers and milder winters than continental climates and have a much smaller annual temperature range. Furthermore, a marine climate tends to be fairly humid, resulting in reduced visibilities, low cloud heights, and receives significant amounts of precipitation.

The SEA Area covers a large area and encompasses the Sydney Basin, the C-NLOPB portion of the Laurentian Sub-basin as well as a large area to the east. The climate of this area is very dynamic, being largely governed by the passage of high and low pressure circulation systems. These circulation systems are embedded in, and steered by, the prevailing westerly flow that typifies the upper levels of the atmosphere in the mid-latitudes, which arises because of the normal tropical to polar temperature gradient. The mean strength of the westerly flow is a function of the intensity of this gradient, and as a consequence is considerably stronger in the winter months than during the summer months, due to an increase in the south to north temperature gradient [Meteorological convention defines seasons by quarters; e.g., winter is December, January, February, etc.]. At any given time, the upper level flow is a wave-like pattern of large and small amplitude ridges and troughs. These ridges and troughs tend to act as a steering mechanism for surface features and therefore their positions in the upper atmosphere determine the weather at the earth's surface. Upper ridges tend to support areas of high pressure at the surface, while upper troughs lend support to low pressure developments. The amplitude of the upper flow pattern tends to be higher in winter than summer, which is conducive to the development of more intense storm systems. During the winter months, an upper level trough tends to lie over Central Canada and an upper ridge over the North Atlantic resulting in three main storm tracks affecting the region south of Newfoundland: one from the Great Lakes Basin, one from Cape Hatteras, North Carolina and one from the Gulf of Mexico. These storm tracks, on average, bring eight low pressure systems per month over the area. Frequently, intense low pressure systems become 'captured' and slow down or stall off the coast of Newfoundland and Labrador. This may result in an extended period of little change in conditions that may range, depending on the position, overall intensity and size of the system, from the relatively benign to heavy weather conditions. Rapidly deepening storms are a problem south of Newfoundland in the vicinity of the warm water of the Gulf Stream. Sometimes these explosively deepening oceanic cyclones develop into a "weather bomb"; defined as a storm that undergoes central pressure falls greater than 24 mb over 24 hours. Hurricane force winds near the center, the outbreak of convective clouds to the north and east of the center during the explosive stage, and the presence of a clear area near the center in its mature stage (Rogers and Bosart 1986) are typical of weather bombs. After development, these systems will either move across Newfoundland or near the southeast coast producing gale to hurricane force winds from the southwest to south over the area.

There is a general warming of the atmosphere during spring due to increasing heat from the sun. This spring warming results in a decrease in the north-south temperature gradient. By summer, the main storm tracks have moved further north than in winter; hence low-pressure systems are less frequent and much weaker. With the low pressure systems passing to the north of the region, the prevailing wind direction during the summer months is from the southwest to south. As a result, the incidences of gale or storm force winds are relatively infrequent over Newfoundland during the summer.

In addition to extratropical cyclones, tropical cyclones often retain their tropical characteristics as they enter the SEA Area. Tropical cyclones account for the strongest sustained surface winds observed anywhere on earth. The hurricane season in the North Atlantic basin normally extends from June through November, although tropical storm systems occasionally occur outside this period. Once formed, a tropical storm or hurricane will maintain its energy as long as a sufficient supply of warm, moist air is available. Tropical storms and hurricanes obtain their energy from the latent heat of vapourization that is released during the condensation process. These systems typically move east to west over the warm water of the tropics; however, some of these systems turn northward and make their way towards Newfoundland. Since the capacity of the air to hold water vapour is dependent on temperature, as the hurricanes move northward over the colder ocean waters they begin to lose their tropical characteristics. By the time these weakening cyclones reach Newfoundland, they are usually embedded into a mid-latitude low and their tropical characteristics are usually lost. A significant number of tropical cyclones that move into the midlatitudes transitions into extratropical cyclones. On average, 46% of tropical cyclones which formed in the Atlantic transition into extratropical cyclones. During this transformation, the system loses tropical characteristics and becomes more extratropical in nature. These systems frequently produce large waves, gale to hurricane force winds and intense rainfall. The likelihood of a tropical cyclone transitioning increases toward the second half of the tropical season, with October having the highest probability of transition. In the Atlantic, extratropical transition occurs at lower altitudes in the early and late hurricane season and at higher latitudes during the peak of the season (Hart and Evans 2001).

2.1.1 Data Sources

Wind and wave climate statistics for the area were extracted from the MSC50 North Atlantic wind and wave database compiled by Oceanweather Inc. under contract to Environment Canada. The MSC50 database consists of continuous wind and wave hindcast data in 1-hour time steps from January 1954 to December 2005, on a 0.1° latitude by 0.1° longitude grid. Winds from the MSC50 data set are 1-hour averages of the effective neutral wind at a height of 10 metres (Harris 2007). Three grid points from this dataset were chosen to represent conditions within the SEA Area. These are grid point 3869 located at 43.00°N 53.00°W, grid point 7986 located at 45.00°N 54.00°W and grid point 11537 located at 47.00°N 58.00°W.

In addition to the MSC50 wind and wave climate database, statistics were also computed using data from four MSC Nomad Weather Buoys located throughout the SEA area. This data was obtained from the Department of Fisheries and Oceans Integrated Science Data Management (ISDM) website. ISDM performs a subjective quality inspection (QC) of each observed wave spectra prior to update into the database. Flags are assigned to the observed and derived parameters reflecting data quality. Quality control is performed by examining the energy distribution of the power spectrum and comparing relative values of significant wave height and peak period between neighbouring buoys (ISDM, 2010). These buoys and the period of data collection are presented in Table 2.1. The buoys had two RM Young propeller-vane anemometers installed at 5.25 and 4.45 metres above sea level and reported 10 minute vector mean winds until mid 1997; subsequently they reported 10 minute scalar means. Studies have shown that winds speeds measured by these anemometers may be as much as 8% lower than winds measured at the standard 10-m height; however, this value is dependant on the stability of the atmosphere. Rough seas may also have an impact on buoy measured winds due to the motion of the buoy and the probability of winds being measured below the wave crest; however, these errors are believed to be small (Taylor et al. 2002). Waves were measured with a wave accelerometer. Studies have shown, that when compared with satellite-based radar altimeters and U.S. buoys, the MSC wave buoys systematically report 10% too low. This error is independent of location, type of buoy and magnitude of wave height (Durrant et al. 2009).

Table 2.1. Location of MSC Nomad Weather Buoys.

	Latitude	Longitude	Start Date	End Date
Buoy 44138	44°16'0" N	53°38'0" W	11/30/1988	07/13/2009
Buoy 44139	44°16'0" N	57°5'1" W	12/02/1988	07/13/2009
Buoy 44140	43°45'0" N	51°44'1" W	09/05/1990	04/22/2009
Buoy 44255	47°16'7" N	57°21'9" W	07/25/1998	07/01/2009

Prior to 1962, mean monthly ice statistics were used when calculating the wave heights in the MSC50 data. As a result, if the mean monthly ice coverage for a particular grid point is greater than 50% for a particular month, the whole month (from the 1st to the 31st) gets "iced out"; meaning that no forecast wave data have been generated for that month. This sometimes results in gaps in the wave data. Since 1962, weekly ice data supplied by the Canadian Ice Service were used allowing the MSC50 hindcast to better represent the changing ice conditions (Swail et al. 2006).

Air temperature, sea surface temperature, precipitation, visibility, freezing spray and thunderstorm statistics for the area were compiled using data from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) covering the period from January 1950 to December 2006. Due to the large extent of the SEA Area, this data set was divided into three subsets to give a better representation of conditions over the region. Region 1 is bounded to the north by 47.5°N, south by 46.5°N, east by 57°W and west by 59.5°W. Region 2 is bounded to the north by 46.0°N, south by 44.0°N, east by 51°W and west by 57.5°W. Region 3 is bounded to the north by 44.0°N, south by 43.5°N, east by 51°W and west by 56.5°W. The ICOADS data set has certain inherent limitations in that the observations are not spatially or temporally consistent. In addition, even though the data used in this report were subjected to standard quality control procedures, the data set is somewhat prone to observation and coding errors, resulting in some erroneous observations within the data set. The errors were minimized by using the standard filtering system using source exclusion flags, composite QC flags and an outlier trimming level of 3.5 standard deviations. The ICOADS data set is also suspected to contain a fair-weather bias, due to the fact that ships tend to avoid severe weather or simply do not transmit weather observations during storm situations.

Tropical cyclone climatology statistics were calculated from the National Hurricane Centre's (NHC) best-track dataset (Neumann et al. 1993; Jarvinen et al. 1984). This dataset provides positions and intensities at 6-hour intervals for every Atlantic tropical cyclone since 1886. In this report, a subset of the NHC dataset consisting of all storms of tropical origin from 1957 to 2007 which have tracked within 200 nm of 44.5°N 53.5°W (denoted "Hurricane Track" in Figure 2.1) was used. This subset was obtained from the National Oceanic and Atmospheric Administration's Coastal Services Center Historical Hurricane Tracks website.

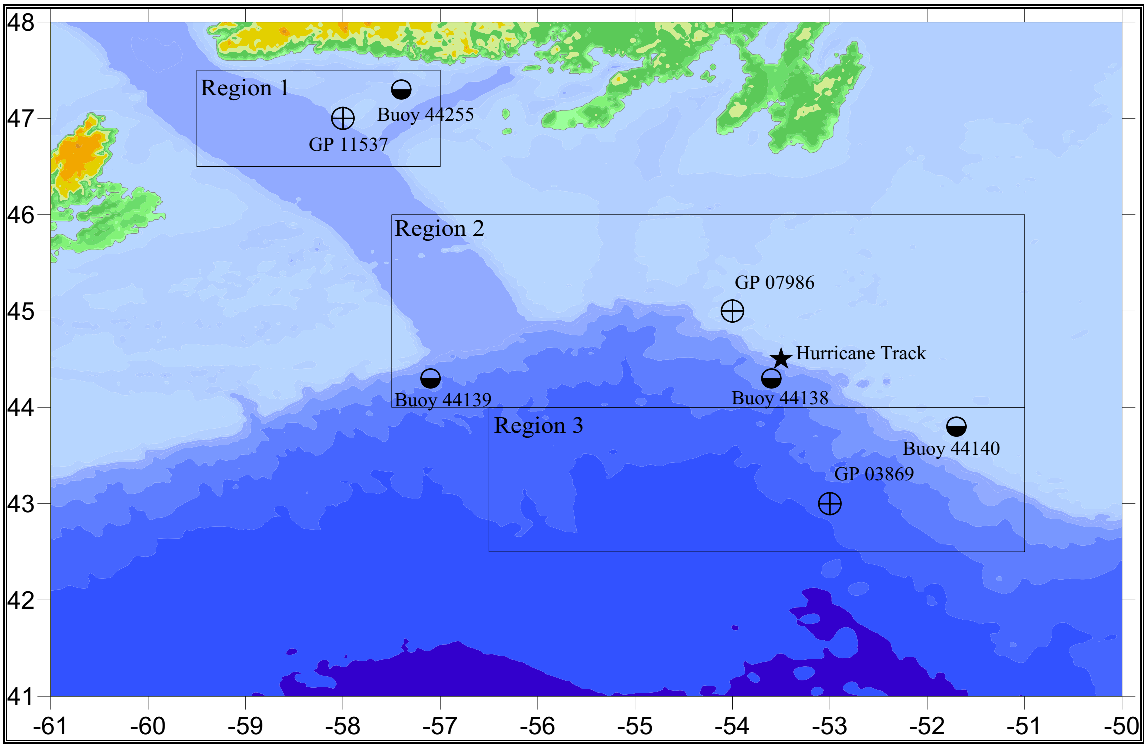


Figure 2.1. Data Sources for Wind and Waves.

2.1.2 Wind Climatology

The area south of Newfoundland experiences predominantly southwest to west flow throughout the year. West to northwest winds which are prevalent during the winter months begin to shift counter-clockwise during March and April resulting in predominant southwest winds by the summer months. As autumn approaches, the tropical-to-polar temperature gradient strengthens and the winds shift slightly, becoming predominantly westerly again by late fall and into winter. Low pressure systems crossing the area are more intense during the winter months. As a result, mean wind speeds tend to peak during this season. Mean wind speeds for the three MSC50 grid points and the four MSC Buoys used in this study are presented in Table 2.2.

Table 2.2. Monthly Mean Wind Speeds (m/s) for the SEA Area.

	MSC50			MSC Buoys			
	3869	**7986**	**11537**	**44138**	**44139**	**44140**	**44255**
January	10.7	10.9	10.7	7.1	8.0	6.6	7.1
February	10.7	10.8	9.9	6.0	7.8	6.0	8.3
March	9.9	10.0	9.2	5.4	7.4	5.5	7.6
April	8.8	8.7	7.8	5.2	4.4	4.1	6.2
May	7.3	7.0	6.2	4.1	4.4	2.9	4.4
June	6.6	6.4	5.7	3.6	4.5	2.6	3.7
July	6.1	6.0	5.5	3.5	4.1	2.9	4.0
August	6.4	6.4	6.0	4.7	5.3	3.6	5.2
September	7.6	7.6	7.2	5.4	6.4	4.8	5.9
October	8.6	8.8	8.6	6.9	7.5	5.7	7.1
November	9.7	9.8	9.6	7.7	7.9	6.2	6.8
December	10.6	10.8	10.4	8.0	8.8	6.8	7.3

Intense mid-latitude low pressure systems occur frequently from early autumn to late spring. In addition, storms of tropical origin including their remnants and those transitioning into extratropical cyclones have passed near Newfoundland between spring and late fall. Tropical cyclones, including hurricanes, and transitioning cyclones do occasionally track over Newfoundland and surrounding waters. Recent examples include Hurricane Michael in 2000, which made landfall on the south coast of Newfoundland as a Category 1 hurricane, and Tropical Cyclone Florence in 2006. Therefore, while mean wind speeds tend to peak during the winter months, maximum wind speeds may occur at anytime during the year. Maximum wind speeds for the three MSC50 grid points and the four MSC Buoys used in this study are presented in Table 2.3.

Table 2.3. Monthly Maximum Wind Speeds (m/s) for the SEA Area.

	MSC50			MSC Buoys			
	3869	**7986**	**11537**	**44138**	**44139**	**44140**	**44255**
January	27.9	33.4	26.2	21.6	30.0	27.5	20.5
February	29.9	28.0	26.5	22.5	22.2	24.2	21.2
March	28.8	29.0	24.8	21.3	24.5	19.6	21.2
April	26.4	24.2	24.9	19.6	19.7	16.7	17.8
May	22.0	22.3	24.0	19.1	16.1	14.4	16.2
June	22.3	22.1	20.3	13.7	19.5	13.9	16.5
July	23.6	21.5	22.0	18.9	13.9	17.3	12.5
August	29.9	23.8	20.2	21.1	20.2	18.0	14.3
September	28.7	34.0	28.2	23.1	26.3	19.2	20.4
October	23.3	29.8	26.2	22.9	23.3	21.0	24.5
November	27.9	29.6	24.4	21.5	21.9	24.0	21.4
December	28.9	27.7	25.8	23.9	27.7	22.5	22.2

Rapidly deepening storm systems known as weather bombs frequently pass south of Newfoundland. These storm systems typically develop in the warm waters off Cape Hatteras and move northeast across the region. While mid-latitude low pressure systems account for the majority of the peak wind events on the Grand Banks, storms of tropical origin can also on occasion pass over the region.

2.1.3 Wave Climatology

The wave climate south of Newfoundland is dominated by extra-tropical storms, primarily during October through March; however, severe storms may, on occasion, occur outside these months. Storms of tropical origin may occur during the early summer and early winter, but most often from late August through October. Hurricanes are usually reduced to tropical storm strength or evolve into extra-tropical storms by the time they reach the area; however, they are still capable of producing hurricane force winds and high waves.

The main parameters for describing wave conditions are the significant wave height, the maximum wave height, the peak spectral period, and the characteristic period. The significant wave height is defined as the average height of the 1/3 highest waves, and its value roughly approximates the characteristic height observed visually. The maximum height is the greatest vertical distance between a wave crest and adjacent trough. The spectral peak period is the period of the waves with the largest energy levels, and the characteristic period is the period of the 1/3 highest waves. The characteristic period is the wave period reported in ship observations, and the spectral period is reported in the MSC50 and MSC wave buoy data sets.

A sea state may be composed of the wind wave alone, swell alone, or the wind wave in combination with one or more swell groups. A swell is a wave system not produced by the local wind blowing at the time of observation and may have been generated within the local weather system, or from within distant weather systems. The former situation typically arises when a front, trough, or ridge crosses the point of concern, resulting in a marked shift in wind direction. Swells generated in this manner are usually of low period. Swells generated by distant weather systems may propagate in the direction of the winds that originally formed, toward the vicinity of the observation area. These swells may travel for thousands of miles before dying away. As the swell advances, its crest becomes rounded and its surface smooth. As a result of the latter process, swell energy may propagate through a point from more than one direction at a particular time.

The wave climate south of Newfoundland is dominated by extra-tropical storms, primarily during October through March; however, severe storms may, on occasion, occur outside these months. Storms of tropical origin may occur during the early summer and early winter, but most often from late August through October. Hurricanes are usually reduced to tropical storm strength or evolve into extra-tropical storms by the time they reach the area; however, they are still capable of producing hurricane force winds and high waves.

Fetch is an important factor in the formation and size of wind waves for the area south of Newfoundland. Since wind waves are dependant on the length of area over which the wind is interacting with the ocean, parts of the SEA Area closest to the island will experience significantly lower wind waves than parts further offshore when the wind is blowing from the north. Similarly, fetch will be limited for westerly winds with respect to Nova Scotia. The majority of wave energy (over one-third of the total wave energy) for the area comes from the west-southwest to south-southwest. During autumn and winter, the dominant direction of the combined significant wave height is from the west. Since swell energy from the west is fetch limited, this would suggest that during the late fall and winter, the wind wave is the main contributor to the combined significant wave height. During the months of March and April, the wind wave remains predominantly westerly, while the swell begins to back to a generally southerly direction. A mean southwesterly direction for the combined significant wave heights during the summer months is a result of a mainly southwesterly wind wave and a southwesterly swell. As winter approaches again, during the months of September and October, the wind wave will veer to westerly and become the more dominant component of the combined significant wave height. This will result in the frequency of occurrence of the combined significant wave heights veering to westerly once again.

The proximity of the region to the Island of Newfoundland and the mainland has a significant impact on the direction of swells propagating into the area. For the most part, swells originating from the west to north are limited to local wind waves dying out after the passage of a system. These swells would be of short period and short duration. One exception to this, however, is the most eastern part of the region. Since this region extends further east than the Island of Newfoundland, long period northerly swells generated from systems off Labrador are possible within this region.

Significant wave heights in the region peak during the winter months while the lowest significant wave heights occur in the summer. Table 2.4 presents the monthly mean significant wave height values for each of the three grid points used in this study as well as the four MSC Buoys. The effects of fetch limiting are noticeable during the winter months with Grid Point 11537 and Buoy 44255 when winds are typically out of the northwest. Significant wave heights are also lower at Grid Point 7986 when compared with Grid Point 3869. This may also be attributed to fetch limiting. The effects of fetch limiting can be seen in each month; however, it is most noticeable during the winter months. The effects of fetch limiting can also be seen in the maximum wave heights presented in Table 2.5. Maximum wave heights are much higher at Grid Point 3869 than at Grid Point 11537. While maximum wave heights tend to be greater during the winter months, they may occur at any time of the year due to the presence of tropical systems during the summer months.

Table 2.4. Monthly Mean Significant Wave Height (m) for the SEA Area.

	Mean			**MSC Buoys**			
	3869	**7986**	**11537**	**44138**	**44139**	**44140**	**44255**
January	4.1	3.6	2.4	3.6	3.2	3.7	1.5
February	3.9	3.2	1.9	3.4	3.2	3.5	2.0
March	3.5	3.0	1.6	3.1	2.9	3.1	1.8
April	2.9	2.6	1.6	2.5	2.2	2.4	1.8
May	2.2	2.1	1.4	1.9	1.8	1.9	1.4
June	1.9	1.8	1.3	1.6	1.5	1.7	1.2
July	1.7	1.6	1.3	1.5	1.4	1.5	1.2
August	1.8	1.7	1.4	1.6	1.6	1.5	0.9
September	2.3	2.2	1.7	2.0	1.9	2.1	1.0
October	2.8	2.6	2.1	2.6	2.4	2.6	1.3
November	3.4	3.1	2.4	3.0	2.6	3.0	1.4
December	4.0	3.6	2.8	3.6	3.0	3.4	1.3

Table 2.5. Monthly Maximum Significant Wave Height (m) for the SEA Area.

	Maximum			**MSC Buoys**			
	3869	**7986**	**11537**	**44138**	**44139**	**44140**	**44255**
January	13.4	12.2	9.3	13.7	10.1	13.0	10.0
February	13.0	11.5	9.4	10.6	10.1	12.9	8.3
March	13.7	11.2	8.3	12.3	11.9	11.2	7.4
April	11.2	9.0	6.8	9.9	7.6	7.6	7.0
May	9.3	8.4	6.2	6.4	6.6	7.1	7.8
June	9.8	6.9	6.7	4.8	9.8	7.0	7.2
July	8.7	6.5	7.3	4.6	4.4	5.9	6.2
August	11.1	7.2	8.5	10.7	8.4	6.5	3.3
September	13.4	10.4	9.3	9.7	9.0	9.1	6.7
October	10.5	11.9	7.9	12.1	10.9	9.9	6.1
November	12.2	11.0	8.8	10.9	9.5	9.9	7.3
December	12.9	11.9	8.9	14.3	12.8	11.6	12.0

2.1.4 Air and Sea Temperature

The moderating influence of the ocean serves to limit both the diurnal and the annual temperature variation in the SEA Area. Diurnal temperature variations due to the day/night cycles are very small. Short-term, random temperature changes are due mainly to a change of air mass following a warm or cold frontal passage. In general, air mass temperature contrasts across frontal zones are greater during the winter than during the summer season.

Of the three regions, Region 1 which is closest to the Island of Newfoundland is typically colder, while Region 3 which is closest to the Gulf Stream is typically the warmest. Annually, atmospheric temperature is warmest during the month of August with a mean temperature ranging from 16.50°C in Region 1 to 18.78°C in Region 3, and coldest during the month of February with a mean temperature ranging from -3.28°C in Region 1 to 2.36°C in Region 3. Similarly, the sea surface temperature is warmest in August with a mean temperature ranging from 15.93°C in Region 1 to 18.05°C in Region 3, and coldest in February and March with a mean temperature ranging from 0.13°C in Region 1 to 3.96°C in Region 2. A summary of the air and sea surface temperature statistics is provided in Tables 2.6 to 2.11.

Table 2.6. Air Temperature (°C) Statistics for Region 1.

	Mean	Maximum	Minimum	Standard Deviation	Mean Daily Maximum	Mean Daily Minimum
January	-2.34	12.80	-16.00	4.37	-1.05	-3.10
February	-3.28	11.00	-16.50	4.53	-1.75	-4.60
March	-1.39	10.00	-12.10	3.78	0.11	-2.29
April	1.64	10.40	-5.90	2.36	2.66	0.85
May	4.83	13.80	-2.20	2.36	5.97	4.05
June	9.12	19.00	0.90	2.70	10.30	8.33
July	14.29	23.30	7.00	2.62	15.17	13.39
August	16.50	23.30	8.00	2.28	17.36	15.75
September	13.84	22.20	5.00	2.71	14.70	12.95
October	8.92	20.00	-1.00	3.10	10.06	8.30
November	4.60	16.30	-7.00	3.34	5.62	3.89
December	0.69	15.00	-10.60	3.90	1.90	0.10

Table 2.7. Air Temperature (°C) Statistics for Region 2.

	Mean	Maximum	Minimum	Standard Deviation	Mean Daily Maximum	Mean Daily Minimum
January	0.93	14.50	-14.00	3.62	3.54	-1.12
February	0.06	12.50	-13.00	3.79	2.90	-2.19
March	1.06	12.20	-9.30	3.06	3.72	-0.98
April	3.00	13.00	-5.60	2.56	5.56	1.17
May	5.65	15.60	-2.80	2.80	8.64	3.47
June	9.62	19.90	0.50	3.11	12.43	7.43
July	14.60	24.20	5.00	2.93	17.17	12.54
August	17.01	24.60	5.50	2.51	19.37	15.06
September	14.96	24.60	4.80	2.72	17.47	12.99
October	11.12	22.10	0.50	3.21	13.55	8.99
November	7.22	19.50	-4.00	3.42	9.91	5.17
December	3.42	17.00	-8.00	3.69	5.91	1.27

Table 2.8. **Air Temperature (°C) Statistics for Region 3.**

	Mean	Maximum	Minimum	Standard Deviation	Mean Daily Maximum	Mean Daily Minimum
January	3.12	20.00	-7.30	3.65	4.04	2.62
February	2.36	19.00	-8.30	3.64	3.31	1.57
March	3.09	18.10	-8.60	3.22	4.18	2.29
April	4.75	19.30	-4.00	2.99	6.06	4.26
May	7.68	21.00	0.00	2.98	9.05	6.71
June	11.35	25.20	0.90	3.15	12.85	10.28
July	16.32	27.00	6.00	3.27	17.65	15.61
August	18.78	28.00	8.00	2.78	19.64	18.08
September	16.65	27.00	6.00	2.96	17.54	15.93
October	12.73	26.20	1.00	3.40	13.92	12.21
November	8.71	23.30	-1.00	3.61	10.17	8.46
December	5.81	22.30	-4.50	3.75	6.79	5.24

Table 2.9. **Sea Temperature (°C) Statistics for Region 1.**

	Mean	Maximum	Minimum	Standard Deviation	Mean Daily Maximum	Mean Daily Minimum
January	1.43	7.00	-2.80	1.73	1.81	1.18
February	0.13	5.50	-2.30	1.32	0.78	0.01
March	0.18	5.20	-2.50	1.55	0.76	-0.02
April	1.23	7.00	-2.40	1.68	1.76	0.90
May	3.66	10.00	-1.50	1.98	4.41	3.31
June	7.43	15.30	0.40	2.24	8.08	7.07
July	13.05	20.20	5.60	2.56	13.51	12.53
August	15.93	20.80	6.00	2.25	16.29	15.35
September	13.74	20.00	6.00	2.36	14.14	13.37
October	9.76	17.00	3.00	2.31	10.50	9.35
November	6.46	13.50	0.00	2.02	6.85	5.93
December	3.80	10.00	-1.50	1.98	4.12	3.43

Table 2.10. **Sea Temperature (°C) Statistics for Region 2.**

	Mean	Maximum	Minimum	Standard Deviation	Mean Daily Maximum	Mean Daily Minimum
January	2.89	11.50	-2.80	2.26	4.80	1.52
February	1.77	10.00	-2.80	2.10	3.62	0.40
March	1.62	9.00	-2.80	2.03	3.56	0.25
April	2.45	10.50	-2.80	2.04	4.44	1.03
May	4.39	14.00	-2.00	2.36	6.71	2.72
June	7.75	17.40	-0.40	2.77	10.07	6.06
July	13.03	22.00	4.40	2.83	15.07	11.18
August	16.13	23.30	6.00	2.41	18.23	14.28
September	15.01	23.00	6.00	2.30	17.07	13.08
October	11.89	21.00	3.00	2.57	13.98	9.95
November	8.36	17.00	0.00	2.59	10.38	6.38
December	5.36	14.20	-2.00	2.54	7.14	3.48

Table 2.11. Sea Temperature (°C) Statistics for Region 3.

	Mean	Maximum	Minimum	Standard Deviation	Mean Daily Maximum	Mean Daily Minimum
January	5.01	16.20	-1.00	2.51	5.74	4.64
February	3.99	16.00	-2.70	2.47	4.86	3.47
March	3.96	16.00	-2.20	2.53	4.95	3.19
April	4.47	16.10	-2.20	2.42	5.49	3.92
May	6.20	18.50	-1.00	2.56	7.63	5.62
June	9.42	23.00	0.00	2.83	10.95	8.71
July	14.59	27.00	5.00	3.19	15.98	14.19
August	18.05	26.10	8.40	2.70	18.87	17.49
September	16.83	26.00	8.80	2.67	17.69	16.15
October	13.54	24.00	5.60	2.97	14.83	13.28
November	10.14	23.00	1.20	2.93	11.51	9.98
December	7.73	18.00	0.00	3.03	8.48	6.98

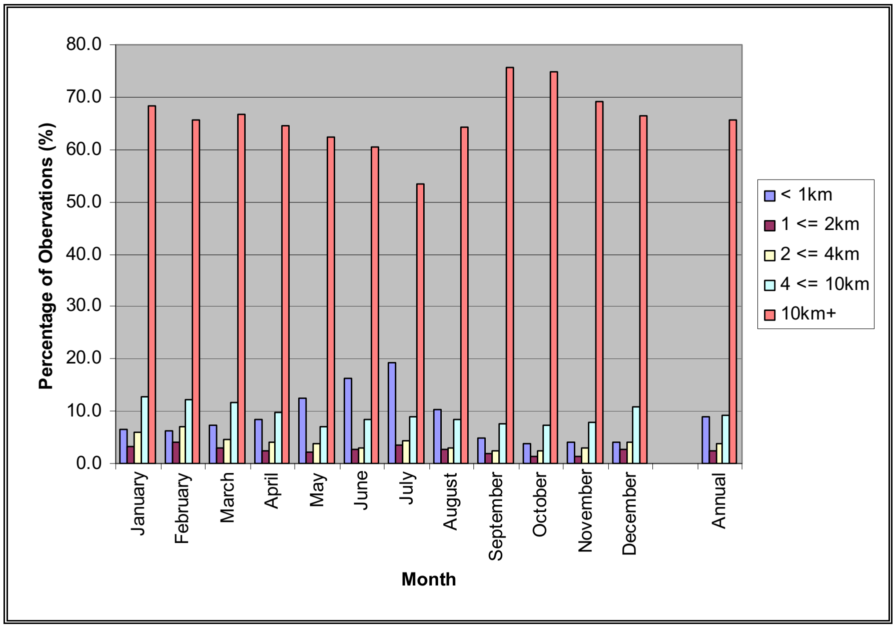
From April to August, the mean sea surface temperature is colder than the mean air temperature, with the greatest air-sea temperature difference occurring in the month of June. From October to March, sea surface temperatures are warmer than the mean air temperature. The colder sea surface temperatures from April to August have a cooling effect on the atmosphere which results in the formation of advection fog.

2.1.5 Visibility

Visibility is defined as the greatest distance at which objects of suitable dimensions can be seen and identified. Horizontal visibility may be reduced by any of the following phenomena, either alone or in combination:

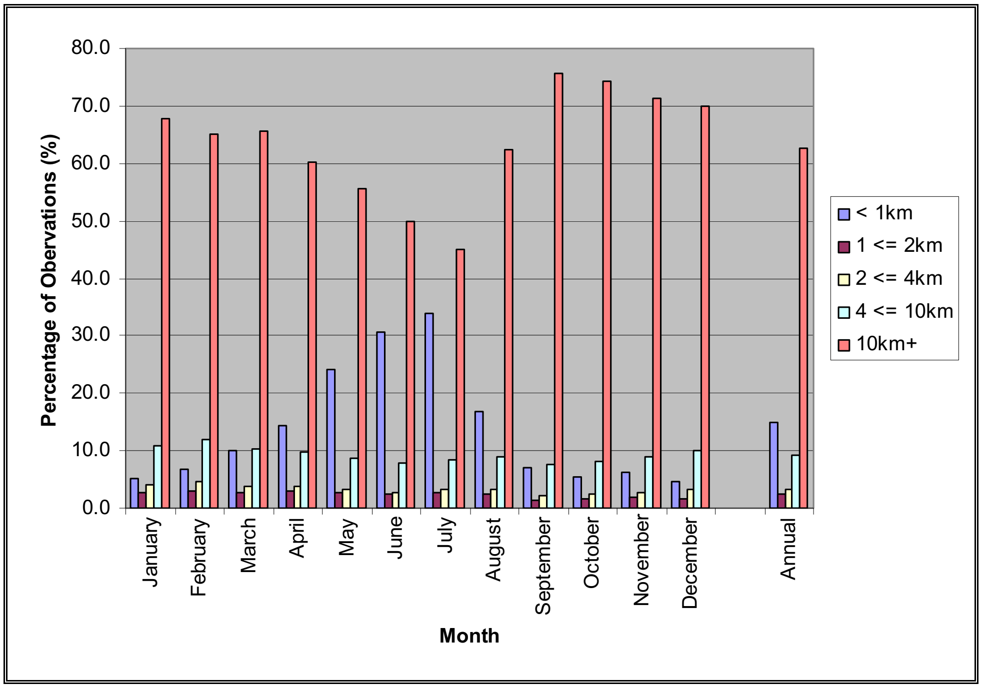
- Fog;
- Mist;
- Haze;
- Smoke;
- Liquid Precipitation (e.g., drizzle);
- Freezing Precipitation (e.g., freezing rain);
- Frozen Precipitation (e.g., snow); and
- Blowing Snow.

During the winter months, the main obstruction is snow; however, mist and fog may also reduce visibilities at times. As spring approaches, the amount of visibility reduction attributed to snow decreases. As the air temperature increases, so does the occurrence of advection fog. Advection fog forms when warm moist air moves over cooler waters. By April, the sea surface temperature south of Newfoundland is cooler than the surrounding air. As warm moist air from the south moves over the colder sea surface, the air cools and its ability to hold moisture decreases. The air will continue to cool until it becomes saturated and the moisture condenses to form fog. The presence of advection fog increases from April through July. The month of July has the highest percentage of obscuration to visibility, most of which is in the form of advection fog, although frontal fog can also contribute to the reduction in visibility. In August, the temperature difference between the air and the sea begins to narrow and by September, the air temperature begins to fall below the sea surface temperature. As the air temperature drops, the occurrence of fog decreases. Reduction in visibility during autumn and winter is relatively low and is mainly attributed to the passage of low-pressure systems. Fog is the main cause of the reduced visibilities in autumn and snow is the main cause of reduced visibilities in the winter. September and October have the lowest occurrence of reduced visibility since the air temperature has, on average, decreased below the sea surface temperature and it is not yet cold enough for snow. A plot of the typical frequency distribution of visibility derived from the ICOADS data set for each region is presented in Figures 2.2 to 2.4. These figures show that obstructions to visibility can occur in any month.



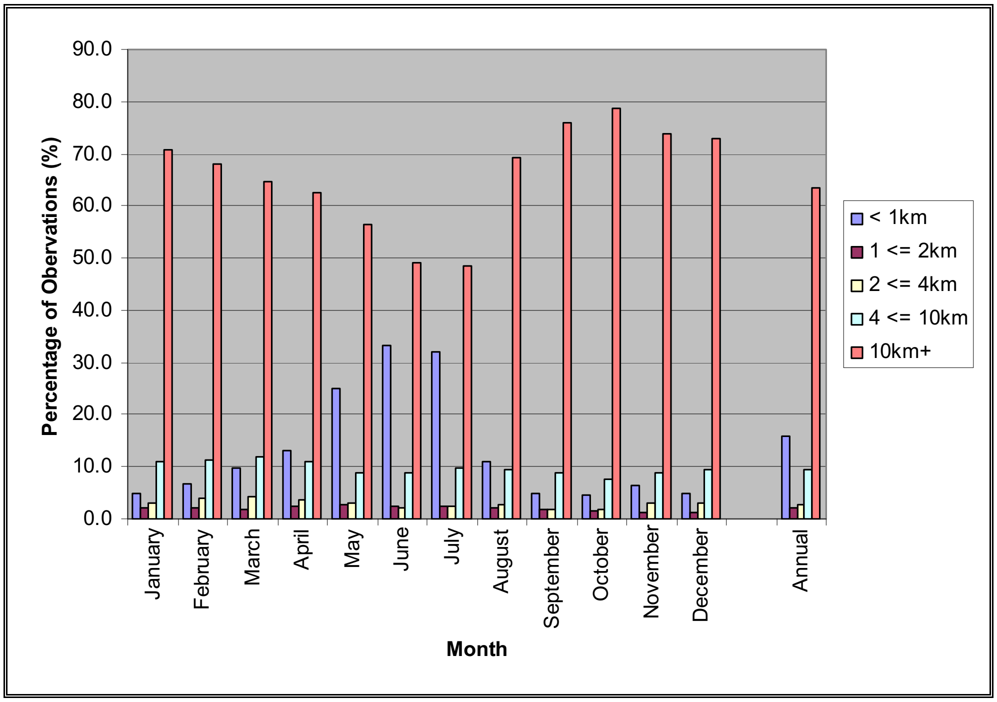
Source: ICOADS Data Set (1950 to 2006).

Figure 2.2. Monthly and Annual Percentage Occurrence of Visibility for Region 1.



Source: ICOADS Data Set (1950 to 2006).

Figure 2.3. Monthly and Annual Percentage Occurrence of Visibility for Region 2.



Source: ICOADS Data Set (1950-2006).

Figure 2.4. Monthly and Annual Percentage Occurrence of Visibility for Region 3.

Annually, over the three regions, there is little difference with the percentage of time that visibilities are reduced below 10 km with Region 1 having the lowest percentage of reduced visibilities (34.3%) and Region 2 having the highest percentage of reduced visibilities (37.4%). When visibilities are reduced, however, Regions 2 and 3 have a larger percentage of time with visibilities below one km than Region 1.

2.1.6 Precipitation

Precipitation can come in three forms and are classified as liquid, freezing or frozen. Included in the three classifications are:

(1) Liquid Precipitation
  - Drizzle
  - Rain

(2) Freezing Precipitation
  - Freezing Drizzle
  - Freezing Rain

(3) Frozen Precipitation
  - Snow
  - Snow Pellets
  - Snow Grains
  - Ice Pellets
  - Hail
  - Ice Crystals

The frequency of precipitation type for each region was calculated using data from the ICOADS data set, with each occurrence counting as one event. Precipitation statistics for these regions may be low due to a fair weather bias. Ships tend to either avoid regions of inclement weather, or simply do not report during these events.

The frequency of precipitation type (Tables 2.12 to 2.14) shows that annually, precipitation occurs more often in Region 1 and least in Region 3. This may be attributed to Region 1's proximity to the Island of Newfoundland and the effects of onshore and offshore flow on precipitation. Winter has the highest frequency of precipitation with snow accounting for the majority of precipitation during these months. Summer has the lowest frequency of precipitation. While the percentage frequency of snow is 0.0% in each region for August and for Regions 2 and 3 for July, there has been snow reported in every month with the exception of August in Region 3.

Freezing precipitation occurs when rain or drizzle aloft enters negative air temperatures near the surface and becomes super-cooled so that the droplets freeze upon impact with the surface. This situation typically arises ahead of a warm front extending from low pressure systems passing west of the area. The percentage of occurrences of freezing precipitation data was also calculated from the ICOADS data set. The frequency of freezing precipitation was slightly higher in the winter months than during the spring. No freezing precipitation occurred during summer and autumn.

Thunderstorms occur relatively infrequently over the SEA Area, although they may occur in any month of the year. Spring consistently shows the least number of thunderstorms occurring only 0.1% of the time in all three regions. It should be noted that hail only occurs in the presence of severe thunderstorms, yet in Tables 2.13 and 2.14, the frequency of hail is often higher than the frequency of thunderstorms. This may be due to observer inexperience, classifying what should be ice pellets (formed through entirely different atmospheric processes) as hail or mistyping what should have been "Thunderstorm without Hail – Code 95" as "Thunderstorm with Hail – Code 96" in the original Manmar data.

Table 2.12. Percentage Frequency (%) Distribution of Precipitation for Region 1.

	Rain / Drizzle	Freezing Rain / Drizzle	Rain / Snow Mixed	Snow	Hail	Thunder storm	Total
January	5.8	0.3	1.6	29.1	0.1	0.2	37.0
February	5.8	0.6	1.0	25.7	0.0	0.0	33.1
March	7.5	1.2	0.9	18.3	0.0	0.1	27.9
April	8.6	0.4	1.1	8.1	0.0	0.1	18.1
May	11.5	0.1	0.3	0.9	0.0	0.2	12.9
June	9.3	0.0	0.1	0.1	0.0	0.2	9.5
July	8.2	0.1	0.1	0.1	0.0	0.5	8.5
August	9.3	0.0	0.0	0.0	0.0	0.4	9.4
September	13.2	0.0	0.0	0.1	0.0	0.8	13.4
October	14.1	0.1	0.4	1.1	0.3	0.3	15.9
November	12.3	0.1	1.0	8.3	0.1	0.1	21.8
December	7.4	0.5	1.4	21.0	0.1	0.2	30.4
Winter	6.3	0.5	1.3	25.2	0.1	0.3	33.4
Spring	9.3	0.5	0.7	8.5	0.0	0.1	19.1
Summer	9.0	0.0	0.1	0.1	0.0	0.4	9.1
Autumn	13.2	0.1	0.5	3.3	0.1	0.4	17.2
Total	9.5	0.3	0.6	8.4	0.1	0.3	18.9

Table 2.13. Percentage Frequency (%) Distribution of Precipitation for Region 2.

	Rain / Drizzle	Freezing Rain / Drizzle	Rain / Snow Mixed	Snow	Hail	Thunder storm	Total
January	10.4	0.4	1.3	18.6	0.3	0.2	31.0
February	8.3	0.4	1.4	18.5	0.2	0.2	28.7
March	8.6	0.3	1.0	11.8	0.2	0.1	21.8
April	11.1	0.2	0.7	4.1	0.1	0.3	16.1
May	9.2	0.0	0.2	0.6	0.0	0.1	10.1
June	7.9	0.0	0.0	0.1	0.0	0.2	8.0
July	7.1	0.0	0.0	0.0	0.0	0.3	7.1
August	10.0	0.0	0.0	0.0	0.0	0.5	10.1
September	11.3	0.0	0.0	0.1	0.0	0.3	11.5
October	14.4	0.0	0.1	0.3	0.1	0.2	14.9
November	15.6	0.1	0.5	2.7	0.4	0.2	19.3
December	11.8	0.2	1.2	11.3	0.3	0.1	24.8
Winter	10.2	0.3	1.3	16.1	0.3	0.2	28.1
Spring	9.6	0.2	0.5	4.8	0.1	0.1	15.1
Summer	8.3	0.0	0.0	0.0	0.0	0.3	8.4
Autumn	13.6	0.0	0.2	0.9	0.2	0.2	14.9
Total	10.2	0.1	0.5	4.9	0.1	0.2	15.9

Table 2.14. Percentage Frequency (%) Distribution of Precipitation for Region 3.

	Rain / Drizzle	Freezing Rain / Drizzle	Rain / Snow Mixed	Snow	Hail	Thunder storm	Total
January	13.7	0.2	1.5	12.8	0.5	0.5	28.7
February	11.9	0.6	1.4	11.9	0.2	0.2	25.9
March	11.8	0.2	1.0	8.1	0.4	0.2	21.4
April	12.4	0.0	0.5	3.0	0.2	0.2	16.1
May	9.5	0.1	0.1	0.5	0.0	0.1	10.2
June	8.4	0.0	0.0	0.1	0.0	0.1	8.5
July	7.3	0.1	0.0	0.0	0.0	0.2	7.4
August	9.4	0.0	0.1	0.0	0.0	0.7	9.6
September	11.3	0.0	0.0	0.1	0.0	0.3	11.4
October	14.0	0.0	0.0	0.3	0.0	0.3	14.4
November	14.0	0.1	0.9	1.1	0.6	0.3	16.7
December	15.9	0.4	0.9	6.2	0.5	0.3	23.8
Winter	13.8	0.4	1.2	10.2	0.4	0.3	26.0
Spring	11.0	0.1	0.5	3.5	0.2	0.1	15.2
Summer	8.3	0.0	0.0	0.0	0.0	0.3	8.4
Autumn	13.1	0.0	0.3	0.5	0.2	0.3	14.1
Total	11.0	0.1	0.4	2.8	0.2	0.3	14.5

2.1.7 Sea Spray Vessel Icing

Sea spray icing can accumulate on vessels and shore structures when air temperatures are below the freezing temperature of water and there is potential for spray generation. In addition to air temperature, icing severity depends on water temperature, wave conditions, and wind. A review of the sea spray icing hazard is provided by

Minsk (1977). The frequency of potential icing conditions and its severity was estimated from the algorithm proposed by Overland et al. (1986) and subsequently updated by Overland (1990). The algorithm generates an icing predictor based on air temperature, wind speed, and sea surface temperature which was empirically related to observed icing rates of fishing vessels in the Gulf of Alaska. This method will provide conservative estimates of icing severity in the study region as winter sea surface temperatures are colder and wave conditions are lower in the SEA Area compared to the Gulf of Alaska where the algorithm was calibrated (Makkonen et al. 1991). Potential icing rates were computed using wind speed, air and sea surface temperature observations from the ICOADS data set.

The greatest potential for sea spray vessel icing occurs in Region 1 with a frequency of occurrence of 14.9%, while the least potential occurs in Region 3 with a frequency of occurrence of only 2.2% (Figures 2.5 to 2.7). This corresponds with the air and sea surface temperature statistics provided earlier. Potential sea spray icing conditions start in all three regions during the month of November. As temperatures cool throughout the winter, the frequency of icing potential increases, reaching its peak in the month of February. Extreme sea spray icing conditions were calculated to occur 6.81% of the time in Region 1 during February, while it does not occur at all in Region 3. Icing potential decreases rapidly after February in response to warming air and sea surface temperatures, and by June, the frequency of icing conditions is 0% in all three regions.

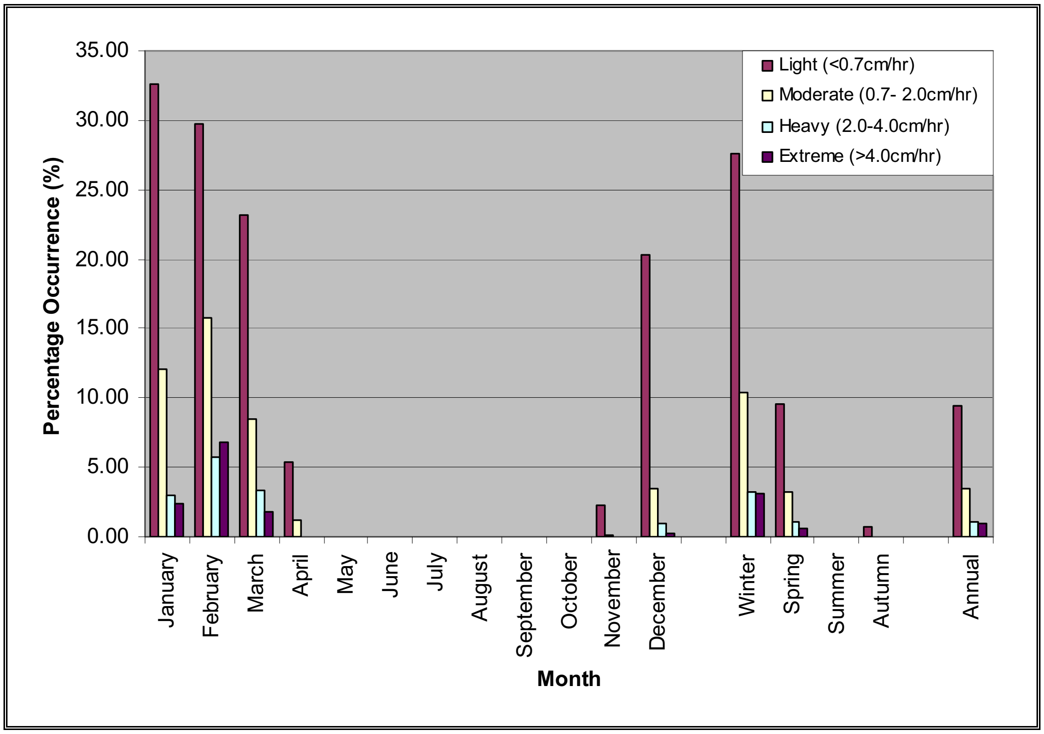


Figure 2.5. **Percentage Frequency of Potential Spray Icing Conditions for Region 1.**

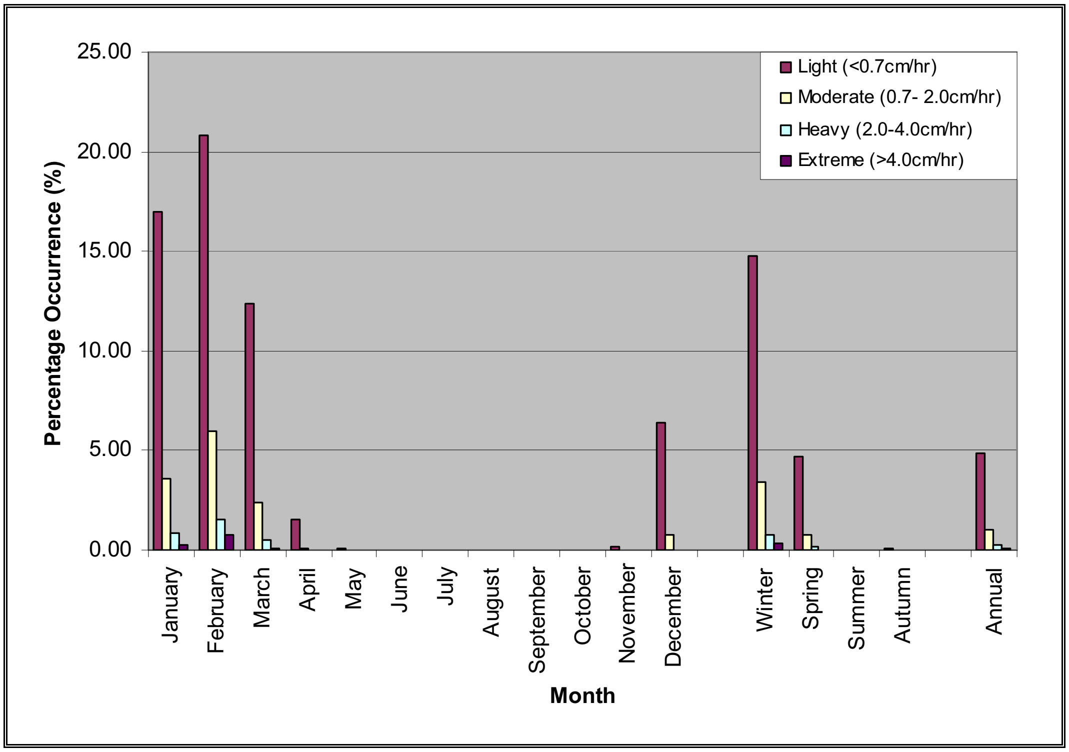


Figure 2.6. Percentage Frequency of Potential Spray Icing Conditions for Region 2.

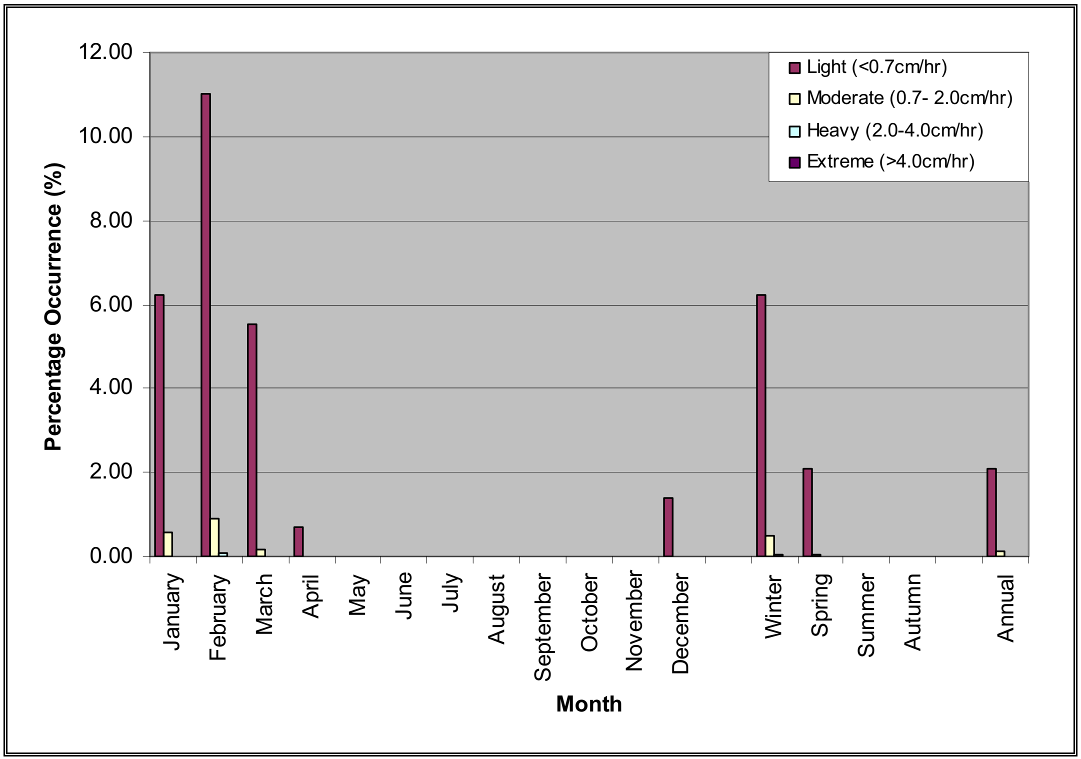


Figure 2.7. Percentage Frequency of Potential Spray Icing Conditions for Region 3.

2.1.8 Tropical Systems

Since 1995, the number of hurricanes that have developed within the Atlantic Basin has been increasing. This increase in activity has been attributed to naturally occurring cycles in tropical climate patterns near the equator called the tropical multi-decadal signal and typically lasts 20 to 30 years (Bell and Chelliah 2006). As a result of the increase in tropical activity in the Atlantic Basin, there has also been an increase in storms of tropical origin entering the Canadian Hurricane Centre Response Zone (Figure 2.8), and consequently, a slight increase in the number of tropical storms entering the SEA Area. The CHC Response Zone can be found by joining the following latitude/longitude coordinates, beginning with the north westernmost coordinate pair: 60.0N 95.0W; 45.0N 95.0W; 38.0N 85.0W; 38.0N 75.0W; 36.0N 65.0W; 40.0N 45.0W; 45.0N 41.0W; 60.0N 41.0W. This can be seen in Figure 2.8.

A position within the SEA Area, located at 44.5°N 53.5°W (Figure 2.1) was used for this study. During the 50-year period from 1957 to 2007, 72 tropical systems have passed within 200 nautical miles (nm) of this location. The names of each cyclone are given in Table 2.15 and the tracks over the SEA Area are shown in Figure 2.9. It must be noted that the values in the table are the maximum 1-minute mean wind speeds occurring within the tropical system at the 10-m reference level as it passed.

The dominant features of the mean sea level pressure pattern in the North Atlantic are the semi-permanent area of relatively low pressure in the vicinity of Iceland and the sub-tropical high pressure region near the Azores. The relative strengths of these two systems control the strength and direction of westerly winds and storm tracks in the North Atlantic and therefore play a significant role in the climate of the North Atlantic. The fluctuating pressure difference between these two features is known as the North Atlantic Oscillation (NAO).

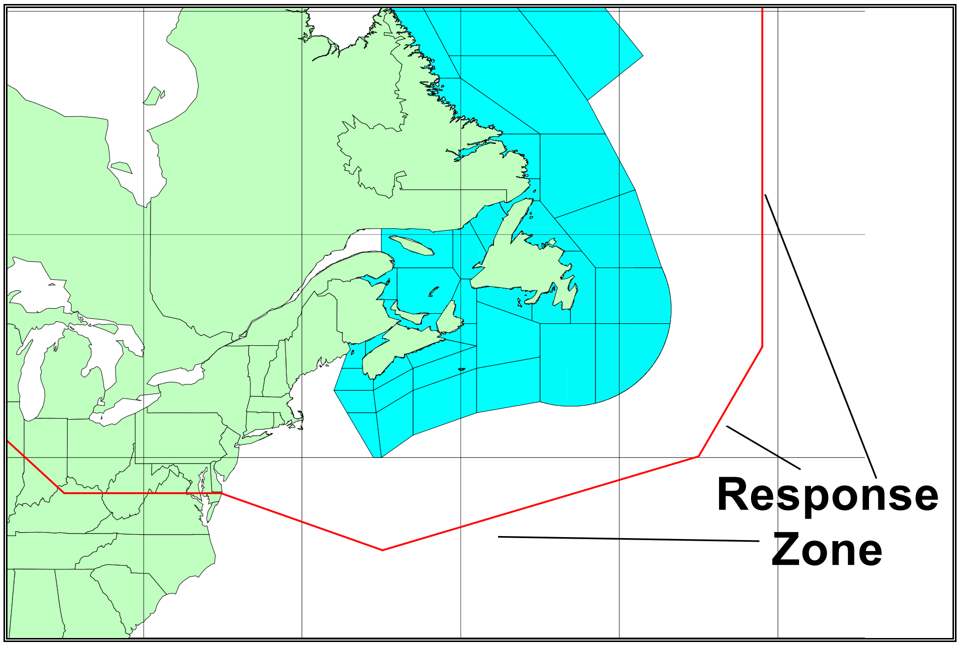


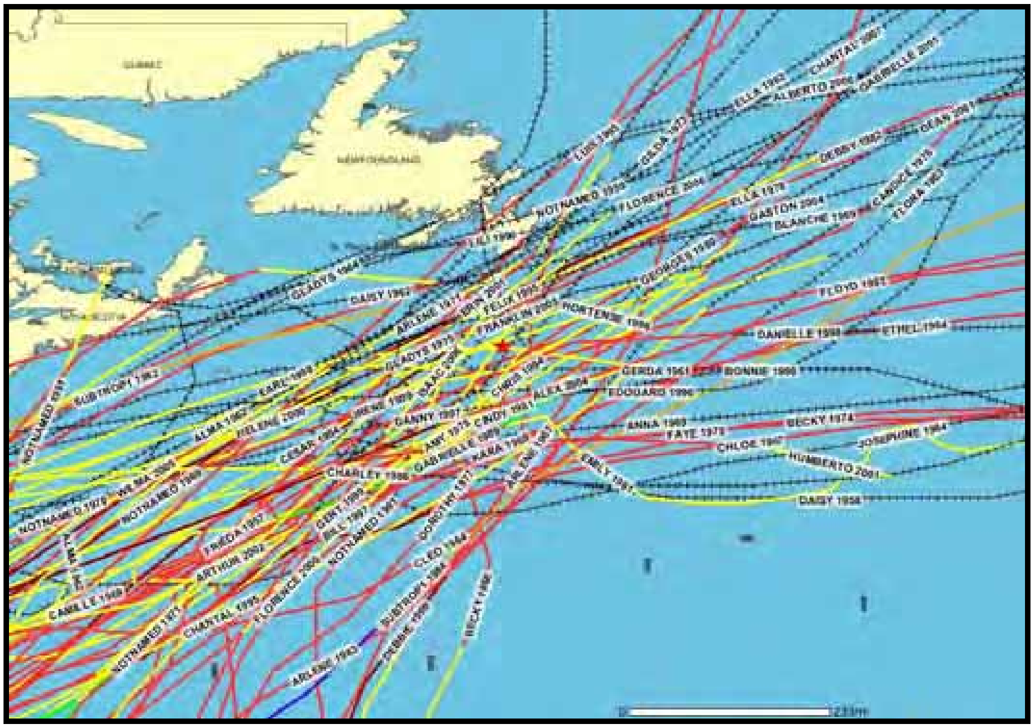
Figure 2.8. Canadian Hurricane Centre Response Zone.

Table 2.15. Tropical Systems Passing within 200 Nautical Miles of 44.5°N 53.5°W, 1957 to 2007.

Year	Month	Day	Name	Wind (kts)	Pressure (mb)	Category
1957	9	27	Frieda	45	N/A	Post-Tropical
1958	8	30	Daisy	50	N/A	Post-Tropical
1959	6	21	Not Named	45	N/A	Post-Tropical
1961	10	22	Gerda	30	N/A	Post-Tropical
1962	9	2	Alma	15	N/A	Post-Tropical
1962	10	9	Daisy	50	N/A	Post-Tropical
1962	10	22	Ella	60	N/A	Post-Tropical
1963	8	11	Arlene	65	N/A	Post-Tropical
1963	10	12	Flora	75	N/A	Category 1
1964	9	4	Cleo	75	970	Category 1
1964	9	14	Ethel	75	969	Category 1
1966	7	3	Becky	55	N/A	Tropical Storm
1967	9	3	Arlene	75	N/A	Category 1
1967	9	17	Chloe	80	967	Category 1
1969	8	4	Anna	45	N/A	Post-Tropical
1969	8	22	Camille	55	N/A	Tropical Storm
1969	8	24	Debbie	90	N/A	Category 2
1969	9	25	Not Named	65	N/A	Category 1
1969	10	18	Kara	90	N/A	Category 2
1970	8	18	Not Named	60	992	Tropical Storm
1970	10	17	Not Named	70	980	Category 1
1971	7	7	Arlene	45	N/A	Tropical Storm
1971	8	6	Not Named	60	N/A	Tropical Storm
1973	10	28	Gilda	55	N/A	Post-Tropical
1974	9	1	Becky	90	N/A	Category 2
1975	7	4	Amy	50	986	Tropical Storm
1975	9	28	Faye	75	977	Category 1
1975	10	3	Gladys	85	960	Category 2
1976	8	23	Candice	80	N/A	Category 1
1977	9	29	Dorothy	60	990	Post-Tropical
1978	9	5	Ella	105	960	Category 3
1980	9	8	Georges	70	993	Category 1
1981	8	5	Cindy	40	1006	Tropical Storm
1981	9	8	Emily	60	984	Tropical Storm
1982	6	20	Sub-Tropical 1	60	984	Sub-Tropical
1982	9	19	Debby	90	970	Category 2
1984	8	20	Sub-Tropical 1	45	1000	Sub-Tropical
1984	9	1	Cesar	40	998	Tropical Storm
1984	10	17	Josephine	55	993	Tropical Storm
1986	8	21	Charley	40	992	Post-Tropical
1989	9	13	Gabrielle	30	1010	Tropical Depression
1990	10	15	Lili	40	994	Post-Tropical
1991	10	29	Not Named	45	992	Post-Tropical
1993	9	10	Floyd	65	990	Category 1
1994	8	23	Chris	45	1003	Tropical Storm
1995	7	20	Chantal	50	1000	Tropical Storm
1995	8	22	Felix	50	986	Tropical Storm

Year	Month	Day	Name	Wind (kts)	Pressure (mb)	Category
1995	9	11	Luis	80	965	Category 1
1996	9	4	Edouard	50	995	Post-Tropical
1996	9	16	Hortense	40	998	Post-Tropical
1997	7	13	Bill	60	990	Tropical Storm
1997	7	27	Danny	40	1004	Post-Tropical
1998	8	30	Bonnie	45	1000	Tropical Storm
1998	9	3	Danielle	70	965	Category 1
1998	9	5	Earl	50	986	Post-Tropical
1999	9	23	Gert	60	968	Tropical Storm
1999	10	19	Irene	80	968	Post-Tropical
2000	9	17	Florence	50	1000	Tropical Storm
2000	9	25	Helene	55	988	Tropical Storm
2001	8	28	Dean	50	997	Tropical Storm
2001	9	14	Erin	65	984	Category 1
2001	9	19	Gabrielle	60	978	Post-Tropical
2001	9	27	Humberto	70	987	Category 1
2002	7	17	Arthur	50	998	Post-Tropical
2004	8	5	Alex	90	970	Category 2
2004	9	1	Gaston	45	998	Post-Tropical
2005	7	30	Franklin	45	1003	Post-Tropical
2005	10	26	Wilma	50	986	Post-Tropical
2006	6	16	Alberto	50	972	Post-Tropical
2006	9	13	Florence	70	967	Post-Tropical
2006	10	2	Isaac	55	995	Tropical Storm
2007	8	1	Chantal	45	992	Post-Tropical

Source: National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center Archive.



Source: NOAA Coastal Services Center Archive.

Figure 2.9. Storm Tracks of Tropical Systems Passing within 200 nm of 44.5°N 53.5°W, 1957 to 2007.

A measure of the North Atlantic Oscillation (NAO) is the NAO Index, which is the normalized difference in pressure between the Icelandic low and the Azores high. A large difference in pressure results in a positive NAO Index and can be the result of a stronger than normal subtropical high, a deeper than normal sub-polar low, or a combination of both (http://www.cpc.noaa.gov/products/precip/CWlink/pna/nao_index.html).

During the summer months, the NAO has a less direct effect on the climate of Eastern Canada; however, studies have shown that the NAO has an effect on the track of hurricanes in the North Atlantic. During seasons with a negative NAO index, hurricanes tend to favour a track that parallels lines of latitude often ending up in the Gulf of Mexico and the Caribbean (Elsner 2003), while during seasons with a positive NAO index, hurricanes tend to curve northward (Elsner and Bosak 2004) along the United States' Eastern Seaboard. An analysis of the number of tropical storms entering the Canadian Hurricane Centre Response Zone as well as the number of tropical storms coming within 200 nm of 44.5°N 53.5°W shows little or no correlation between NAO Index and Tropical Cyclone frequency (Figure 2.10). An analysis of other factors that may contribute to the decrease in tropical cyclone frequency is outside the scope of this document.

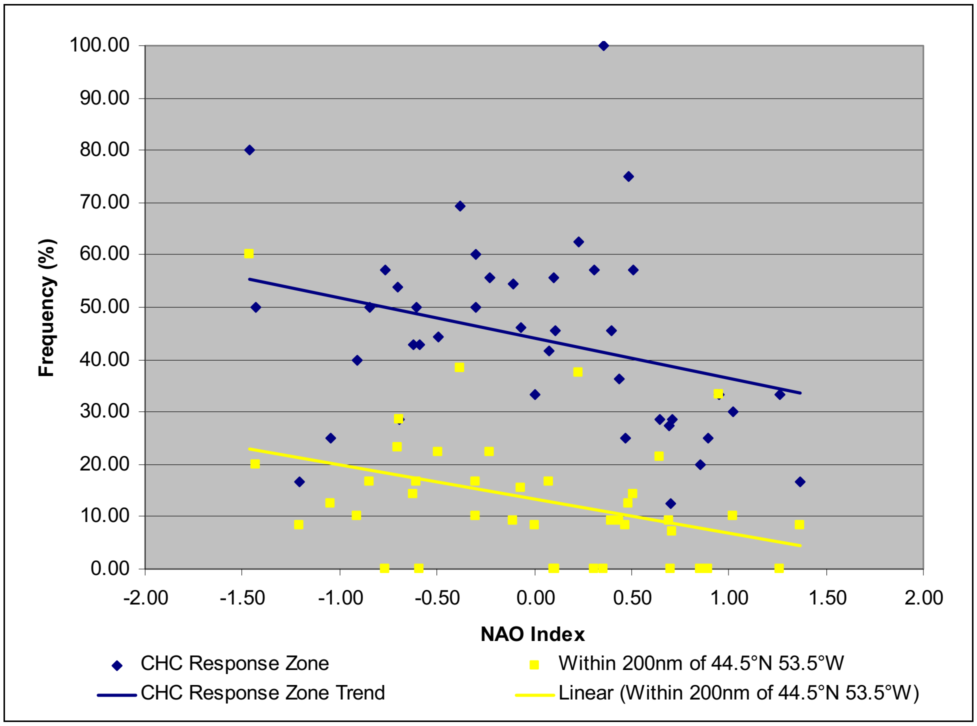


Figure 2.10. Frequency of Tropical Storm Development in the Atlantic Basin. 1958 – 2007.

Tropical cyclones usually lose their strength before reaching the SEA Area; however, on occasion; these systems still maintain their tropical characteristics when they reach Newfoundland. On September 05, 1978, Hurricane Ella, crossed the region as a Category 3 hurricane with 54.0 m/s winds and a central pressure of 960 mb. Hurricane Ella maintained hurricane strength winds until it moved northeast of the Grand Banks later the same day.

There has been a significant increase in the number of hurricanes that have developed within the Atlantic Basin within the last 15 years. Figure 2.11 shows the 5-year average (Note: 2005 to 2008 is only a 4-year average) of tropical storms which have developed within the Atlantic Basin since 1960. This increase in activity has been attributed to naturally occurring cycles in tropical climate patterns near the equator called the tropical multi-decadal signal and typically lasts 20 to 30 years (Bell and Chelliah 2006). As a result of the increase in tropical activity in the Atlantic Basin, there has also been an increase in tropical storms or their remnants entering the CHC Response Zone, and consequently, a slight increase in the number of tropical storms entering the SEA Area. It should be noted that the unusually high number of tropical storms in 2005 may be skewing the results for the

2005 to 2008 season. The average number of storms for the 3-year period of 2006 – 2008 is only 14.7 opposed to 18.5 storms for the 4-year period of 2005 to 2008.

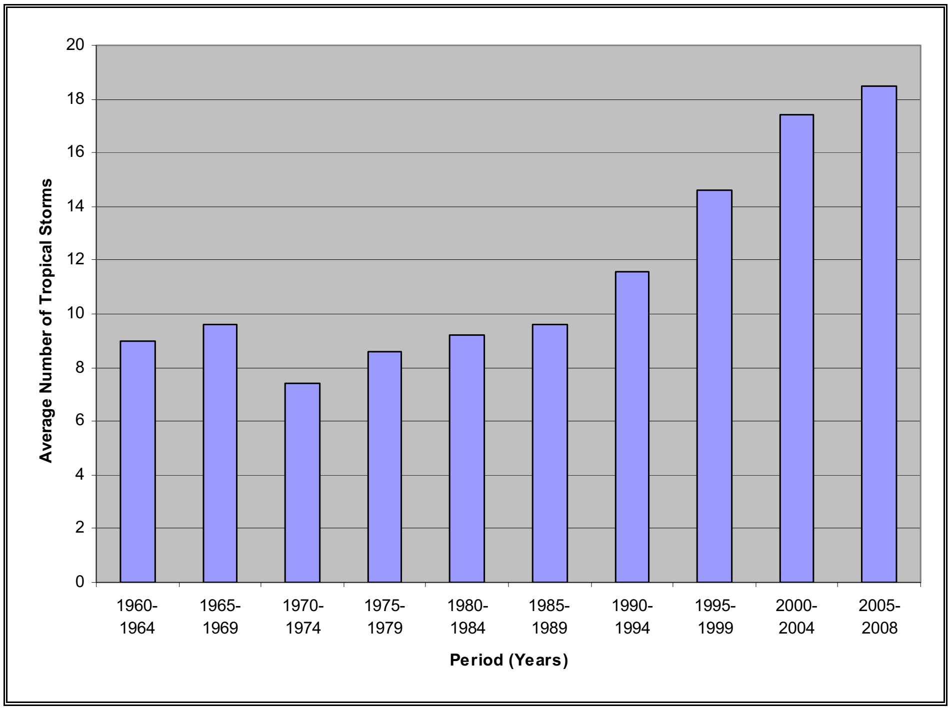


Figure 2.11. 5-Year Average of the Number of Tropical Storms which Formed in the Atlantic Basin since 1960.

2.1.9 Wind and Wave Extreme Value Analysis

An analysis of extreme wind and waves was performed by Oceanweather for Environment Canada with the MSC50 wind and wave data set using the peak over threshold method. This data set provides a continuous 52-year period of 1-hourly data for the SEA Area on a 0.1°x0.1° grid.

The analysis used the top 52 peaks to produce a fit at each of the three grid points (Figure 2.1) in the MSC50 data set using two distributions, Gumbel and Weibull. Five return periods were computed: 10; 25; 50; 75; and 100 years for each of the following six variables: Significant Wave Height; Maximum Wave; Maximum Crest; Associated Peak Period; Associated Wind Speed; and Maximum Wind Speed (Swail et al. 2006).

The Gumbel 5; 10; 50; 75; and 100 year return period values for both wind speed and significant wave height for each grid point are presented in Table 2.16. Wind speed values have been converted from 1-hour averages to 10-min averages to correspond with the sampling period of the observed data from the MSC Buoys (U.S. Geological Survey 1979). Still, a direct comparison cannot be done in the context of this report without adjusting the buoy wind speed from 5 m/s to 10 m/s which is outside the scope of this SEA.

Maximum significant wave heights measured by Buoy 44255, which is in the vicinity of Grid Point 11537, recorded a maximum significant wave height of 11.99 m on December 21, 1999 over its 10 years of operation. However, this is significantly higher than the estimated 100-year extreme wave height of 10.26 m from the values in the extremal analysis presented in Table 2.16. Similarly, the maximum wave height of 14.29 m measured by Buoy 44138 is significantly higher than the value from the 100-year extremal analysis for nearby grid point 7986. However, Buoy 44140 recorded a maximum significant wave height of 13.04 m which is similar to the 10-year extreme value estimate for nearby grid point 3869. It is uncertain why the measured values are higher than the extreme values calculated by Oceanweather and an analysis into the discrepancy is outside the scope of this document.

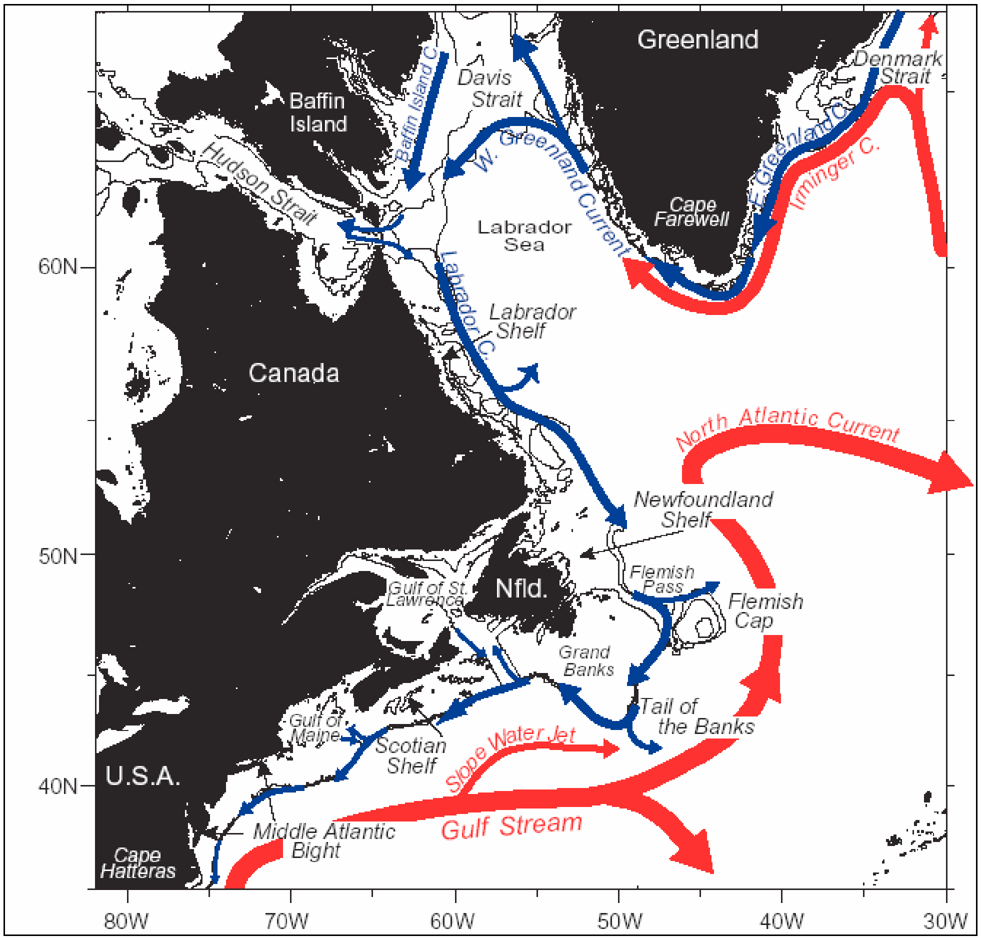
Table 2.16. Extreme Wind Speed and Significant Wave Height Values using the Gumbel Distribution.

	Maximum Wind Speed (m/s)			Maximum Significant Wave Height (m)		
	3869	**7986**	**11537**	**3869**	**7986**	**11537**
5	29.36	29.78	26.50	12.69	11.12	8.55
10	30.52	31.29	27.17	13.11	11.57	8.87
25	32.29	33.63	28.27	13.67	12.16	9.33
50	34.04	35.88	29.66	14.13	12.62	9.74
75	35.28	37.42	30.87	14.42	12.90	10.03
100	36.25	38.59	31.84	14.64	13.11	10.26

2.2 Physical Oceanography

2.2.1 Currents

The ocean circulation in the SEA Area is influenced by the Labrador Current, the Gulf Stream, the Slope Water Jet, and the water exchange with the Gulf of St. Lawrence through the Laurentian Channel. The main current pattern in the NW Atlantic is shown in Figure 2.12.

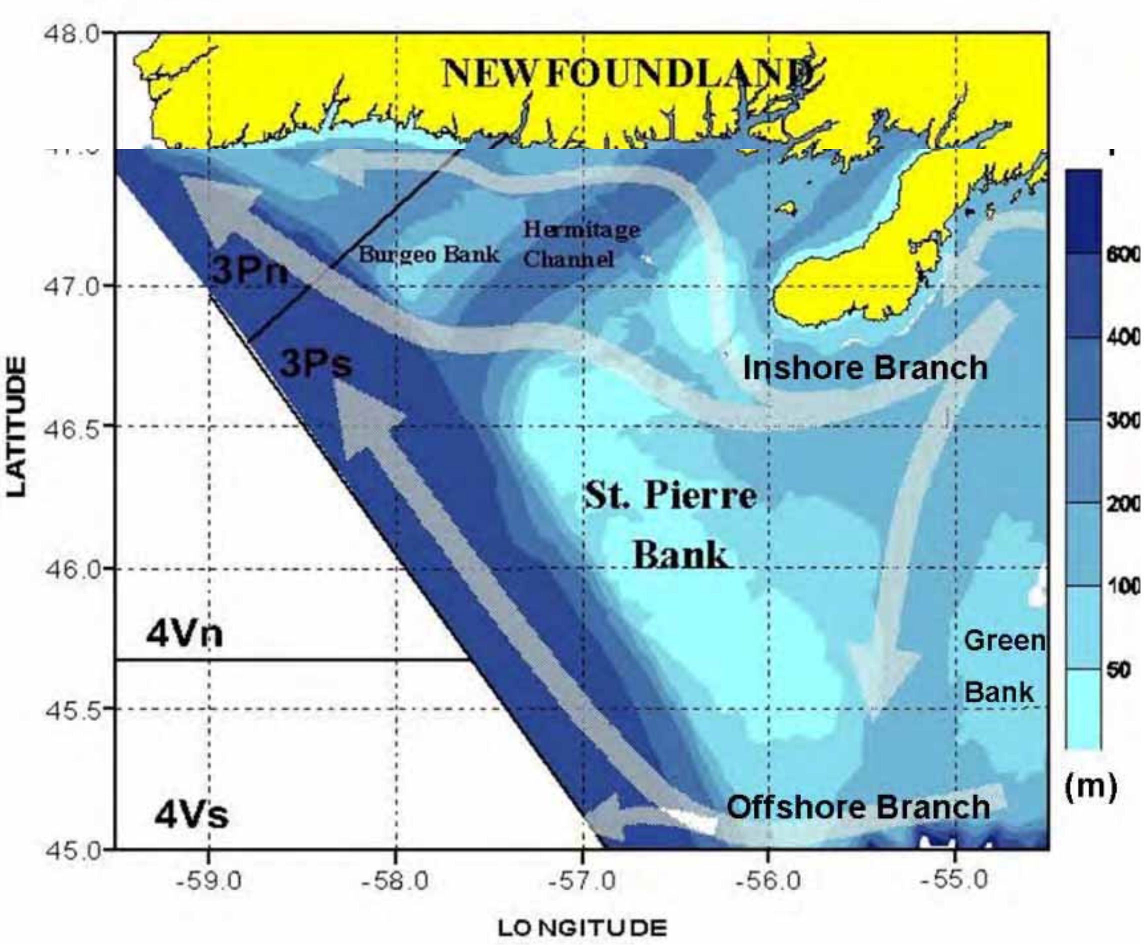


Source: Fratantoni and Pickart (2007).

Figure 2.12. Schematic Diagram of the Main Features of the Surface Circulation in the Western Atlantic Ocean (cold shelf break waters are shown in blue while warm gulf stream waters are shown in red).

The Labrador Current is a cold, relatively fresh, buoyancy-driven current that flows southward along the Continental Slope. The Labrador Current consists of two major branches. The inshore branch is located on the inner part of the shelf and its core is steered by the local topography through the Avalon Channel and then continues to follow the bathymetry around the Avalon Peninsula and southern Newfoundland.

Petrie and Anderson (1983) estimated that approximately 10 percent of the Labrador Current follows the inshore route. After the current exits the Avalon Channel it becomes a westward flowing current and reported to have speeds of 5 to 20 cm/s (Petrie and Anderson 1983). This branch then divides into two parts, one flowing west and around the north side of St. Pierre Bank and the other flowing south in Haddock Channel between Green Bank and Whale Bank (Figure 2.13). The stream to the north of St. Pierre Bank has been reported by Colbourne and Murphy (2005) to further divide, flowing along both sides of Burgeo Bank (Figure 2.13). They also report a southward flow in Halibut Channel between St. Pierre Bank and Green Bank.



Source: Colbourne and Murphy (2005).

Figure 2.13. General Oceanic Circulation around the St. Pierre Bank.

The stronger offshore branch flows along the shelf break over the upper portion of the Continental Slope. This branch of the Labrador Current flows around the eastern edge of the Grand Banks and through the Flemish Pass. Characteristic current speeds on the Slope are in the order of 30 cm/s to 50 cm/s (Colbourne 2000), while those on the central part of the Grand Banks are generally much lower, averaging between 5 and 15 cm/s. The offshore branch of the Labrador Current flows around the tail of the Grand Banks and continues to follow the bathymetric contours flowing north-westward along the Continental Slope. At approximately 55° W the Labrador Current turns to the southwest to flow along the slope region of the Scotian Shelf.

The Gulf Stream and its associated eddies play an important part in the southern region of the SEA Area. Between 65°W and 50°W the Gulf Stream flows eastward. The Gulf Stream is usually located south of 40°N but the meanders can sometimes extend north of 40°N. These meanders can become separated from the main stream and become rings or eddies, which move independently from the Gulf Stream flow. Once eddies are formed, they drift in different directions and can be sustained for a considerable period of time. Their size may be 200 to 399 km in diameter and can reach considerable depths. Their interaction with the bathymetry of the Continental Slope and other current flows influence the dynamics along the Shelf Break and Slope of the SEA Area. The eddies contain a warm water core that makes them easily identifiable in sea surface temperature satellite images.

There is a third major current between the eastward flowing Gulf Stream and the westward flowing Labrador Current, referred to as the Slope Water Jet (Fratantoni and Pickart 2007). This current, according to Pickart et al. (1999), separates from the Gulf Stream somewhere around 60°W and continues flowing eastward. In Laurentian Channel, the currents flow into the Gulf of St. Lawrence along the east side of the channel and out of the Gulf along the west side. Han et al. (1999) numerically computed the associated circulation fields from temperature and salinity across the Cabot Strait and reported the flow into the Gulf of St. Lawrence on the eastern side of Cabot Strait was mainly barotropic with a speed of 20 cm/s. The largest portion of the flow out of the Gulf of St. Lawrence on the western side of Cabot Strait flows along the western side of Laurentian Channel. A smaller portion flows along the inner Nova Scotian Shelf and onto the midshelf (Han 2003).

Current, particularly the surface flow, frequently does not make it around the tail of the bank – sea surface current statistics for this region from satellite altimetry that are described in various publications (e.g., Han 2004a,b; Han 2006) to address and highlight this interannual variability of the offshore branch of the Labrador Current within the SEA Area.

At all location in the SEA Area the currents will vary on different time scales related to tides, wind stress and atmospheric pressure changes from the passage of storm systems, volume transport of the Labrador current, seasonal temperature changes, salinity variations, etc. The current variability in the Slope Region is influenced by the relative position of the northern boundary of the Gulf Stream and any intermittent presence of Gulf Stream rings. Han (2004a,b) calculated from current model information combined with altimeter data that the geostorphic current anomalies associated with Gulf Stream rings offshore Nova Scotia can be over 1 m/s.

Lazier and Wright (1993) showed that the volume transport of the Labrador Current was lowest in summer and highest in winter. On an interannual scale the baroclinic transport component of the Labrador Current is negatively correlated with the NAO index (Han 2006). The relative strength of the two pressure systems control the strength and direction of westerly winds and the position of storm tracks in the North Atlantic; which in turn impacts the volume transport of the Labrador Current. Similarly, the current variability on a synoptic scale is directly linked to the passage of low pressure systems.

Han (2006) used current model information and altimeter data between 1992 and 2002 to investigate the current variability over the Grand Banks and Continental Slope. He found that the current variability increased in an offshore direction towards the Gulf Stream and North Atlantic Current. He calculated the current anomalies to have magnitudes of 10 to 20 cm/s over most of the Grand Banks and ~50 cm/s over the Slope.

2.2.1.1 Currents Outside St. Pierre Bank

Currents were measured near the Shelf Break outside St. Pierre Bank by the Bedford Institute of Oceanography (BIO) during a 5-year period between June 1996 and April 2000. The instruments were placed at a depth of 56 m, 153 m, 400 m and 680 m. The westward flow is most likely due to the Labrador Current waters flowing along the shelf break. The north-westward flow near the bottom appears to be part of the circulatory system of the Laurentian Channel, where waters enter the Gulf of St. Laurence along the east margin of the channel and leaves the Gulf along the west margin. The difference in current directions between the upper layers of the water column and the near-bottom depths may be evidence of a deep-water topographic steering of the flows contributing to the mass balance of the Gulf of St. Lawrence.

Statistics on the current are presented in Table 2.17. The maximum currents were observed in January at 56 m (86.8 cm/s), April at 153 m (55.2 cm/s), December at 400 m (44.1 cm/s), and October at 680 m (30.2 cm/s). The average current speeds were 23.9 cm/s at 56 m, 14.7 cm/s at 153 m, 9.9 cm/s at 400 m, and 4.8 cm/s at 680 m.

Table 2.17. Current Speed (m/s) Statistics for the Area outside St. Pierre Bank for June 1996 - April 2000.

Speed Statistics 56 M					
Month	**Mean**	**Std**	**Minimum**	**Maximum**	**N.Obs.**
January	27.85	14.61	1.40	86.83	2976
February	25.28	13.75	1.68	71.70	2712
March	25.61	12.08	1.40	68.80	2976
April	20.97	11.83	1.10	60.40	2844
May	19.16	10.41	1.10	53.70	2232
June	21.91	11.75	1.39	69.39	2283
July	22.48	11.21	1.10	70.26	2976
August	23.82	10.50	1.10	65.61	2976
September	23.10	13.07	1.39	62.71	2881
October	25.29	12.38	1.10	77.50	2976
November	24.03	11.58	1.70	67.94	2880
December	25.98	13.85	1.40	82.18	2976
Total	**23.93**	**12.56**	**1.10**	**86.83**	**33688**
Speed Statistics 153 M					
Month	**Mean**	**Std**	**Minimum**	**Maximum**	**N.Obs.**
January	16.95	11.69	1.10	53.12	2976
February	16.10	9.52	1.10	51.08	2712
March	15.83	9.54	1.10	48.18	2976
April	15.10	9.39	1.10	55.20	2880
May	12.48	8.05	1.10	38.30	2976
June	14.38	8.00	1.10	44.98	3004
July	12.83	7.76	1.10	46.14	3720
August	13.51	8.37	1.10	48.76	3720
September	12.45	7.74	1.10	53.12	3600
October	17.11	10.05	1.10	52.54	3720
November	15.05	8.70	1.10	52.00	3332
December	15.43	9.51	1.10	50.21	2976
Total	**14.71**	**9.19**	**1.10**	**55.20**	**38592**
Speed Statistics 400 M					
Month	**Mean**	**Std**	**Minimum**	**Maximum**	**N.Obs.**
January	11.32	6.86	1.10	39.50	2976
February	11.46	7.47	1.10	41.78	2712
March	10.04	5.72	1.10	38.30	2976
April	10.92	6.93	1.10	35.70	2844
May	8.01	4.48	1.10	23.19	1526
June	8.00	4.68	1.10	24.64	1563
July	8.47	5.41	1.10	25.80	2232
August	7.37	5.20	1.10	27.54	2232
September	8.51	5.26	1.10	40.33	2161
October	9.76	6.24	1.10	34.52	2232
November	9.17	5.62	1.10	32.80	2160
December	9.58	5.87	1.10	44.11	2746
Total	**9.59**	**6.15**	**1.10**	**44.11**	**28360**
Speed Statistics 680 M					
Month	**Mean**	**Std**	**Minimum**	**Maximum**	**N.Obs.**
January	5.70	4.09	1.00	24.93	2976
February	5.25	3.92	1.00	25.22	2712
March	5.96	4.33	1.00	29.29	2976
April	4.89	3.56	1.00	20.57	2844
May	3.88	2.92	1.00	16.79	2232
June	4.05	3.10	1.10	21.73	2283
July	3.60	2.61	1.10	16.50	2976

Speed Statistics 56 M					
Month	**Mean**	**Std**	**Minimum**	**Maximum**	**N.Obs.**
August	3.74	2.68	1.10	14.18	2976
September	4.55	3.40	1.10	27.25	2881
October	4.80	3.61	1.10	30.20	2976
November	5.26	3.81	1.00	26.67	2880
December	5.36	3.76	1.00	22.00	2976
Total	**4.78**	**3.62**	**1.00**	**30.20**	**33688**

2.2.1.2 Currents Outside Whale Bank

Currents were measured on the Continental Slope outside Whale Bank between August 5 and September 19, 1987. The instruments were placed at depths of 88 m, 828 m, and 1546 m. The maximum current speeds were 42.0 cm/s, 13.0 cm/s and 12.0 cm/s at depths of 88 m, 828 m, and 1546 m, respectively. The mean speeds were 15.8 cm/s, 4.3 cm/s and 3.0 at depths of 88 m, 828 m, and 1546 m, respectively.

2.2.2 Water Properties

Temperature and salinity profiles on Burgeo Bank, in the Hermitage Channel and in the Laurentian Channel, are presented in Figures 2.14 to 2.16. These figures show blank areas when there were no data available. These figures were extracted from the Sydney Basin SEA and were produced from hydrographic data archived at BIO. Temperature and salinity profiles for the shelf region encompassing St. Pierre and Green Banks are presented in Figure 2.17 and those for the Laurentian Fan are presented in Figure 2.18.

The waters on the southern Newfoundland Shelf are mixed waters from different sources and show some seasonal changes. From May to December the water structure has three layers, warm surface stratified layer (in summer) overlaying a colder intermediate layer, below which is a warmer, saltier layer (Figure 2.17). The stratified layer extends to a depth of about 50 m. In winter, with colder air temperatures and intense wave action, the surface layer mixes and deepens to the level of the bottom of the intermediate cold layer such that the water column becomes uniform with little stratification. The cold layer has a temperature ranging from just below 0° to just above 2°C. Between 150 m and 200 m, the water is slightly warmer and more saline which indicates that the bottom water originates from the warmer, more saline waters of the Continental Slope.

Figure 2.18 shows that in spring, summer and fall, the water structure on the slope is in layers; a warm surface stratified layer, an intermediate cold water layer, a warm stratified higher salinity layer, a deep warm layer and a colder bottom layer. The monthly mean temperature data show that there is a distinct upper surface layer to about 50 m and an intermediate cold layer from about 50 m to 125 m during April to December (Figure 2.18). These two layers vary seasonally while the lower layers show little, if any, seasonal variation. In autumn, the surface layer extends to the level of the intermediate layer forming a four-layer stratification; the surface layer, the stratified salinity layer, the deep warm layer and the bottom cold layer.

The water structure on the southeast part of the Grand Banks is shown in Figure 2.19 which presents temperature and salinity contours between Station 27 and the tail of the Grand Bank for April 2008. The temperature contour plot suggests the positions of the two branches of the Labrador Current by the presence of the colder water (-1°C) in the Avalon Channel and at the Shelf Break. In the central part of the Grand Banks the temperature is 4°C and the salinity is 32.5 psu in April.

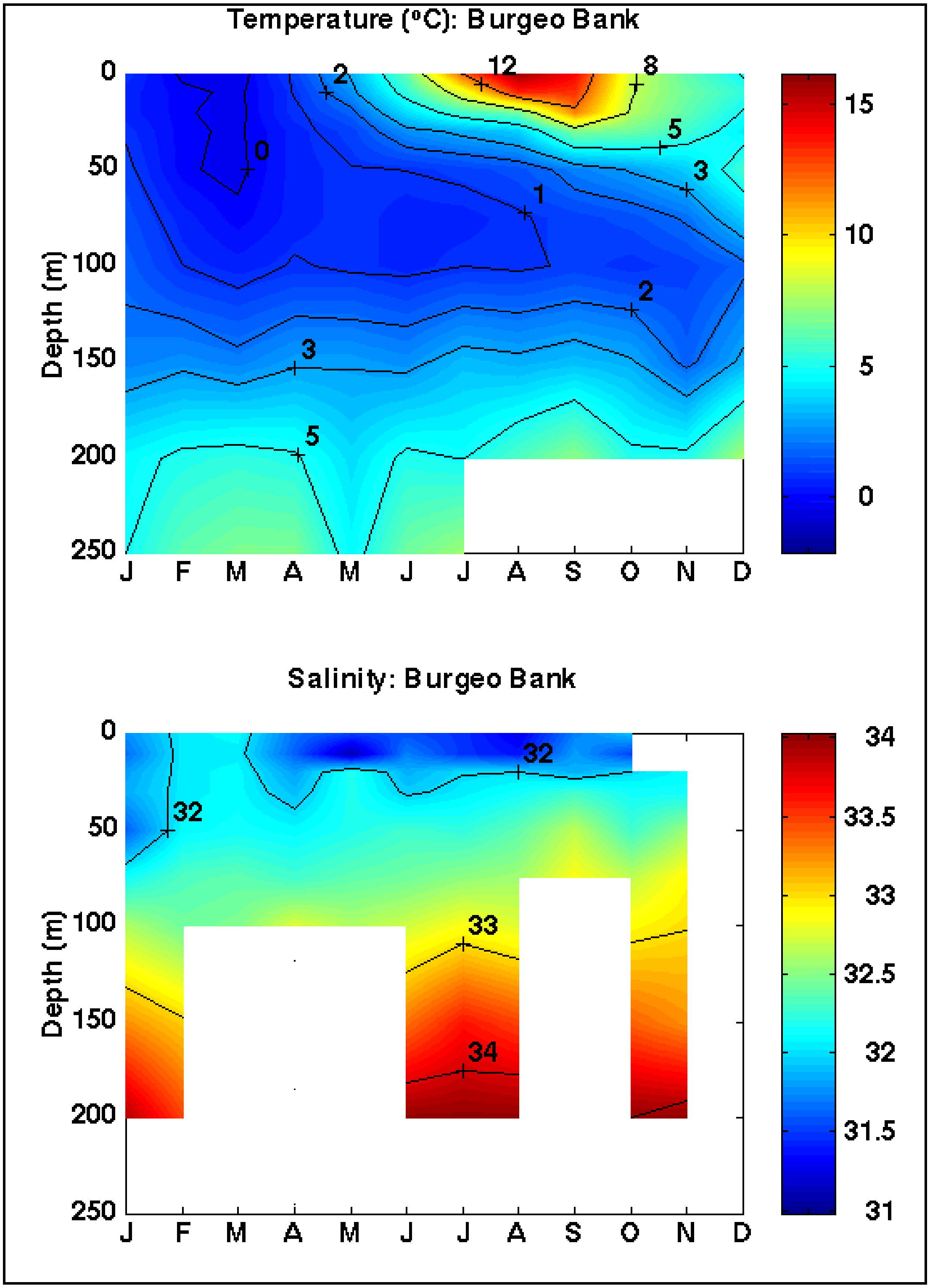


Figure 2.14. **Monthly Temperature and Salinity Profiles at Burgeo Bank.**

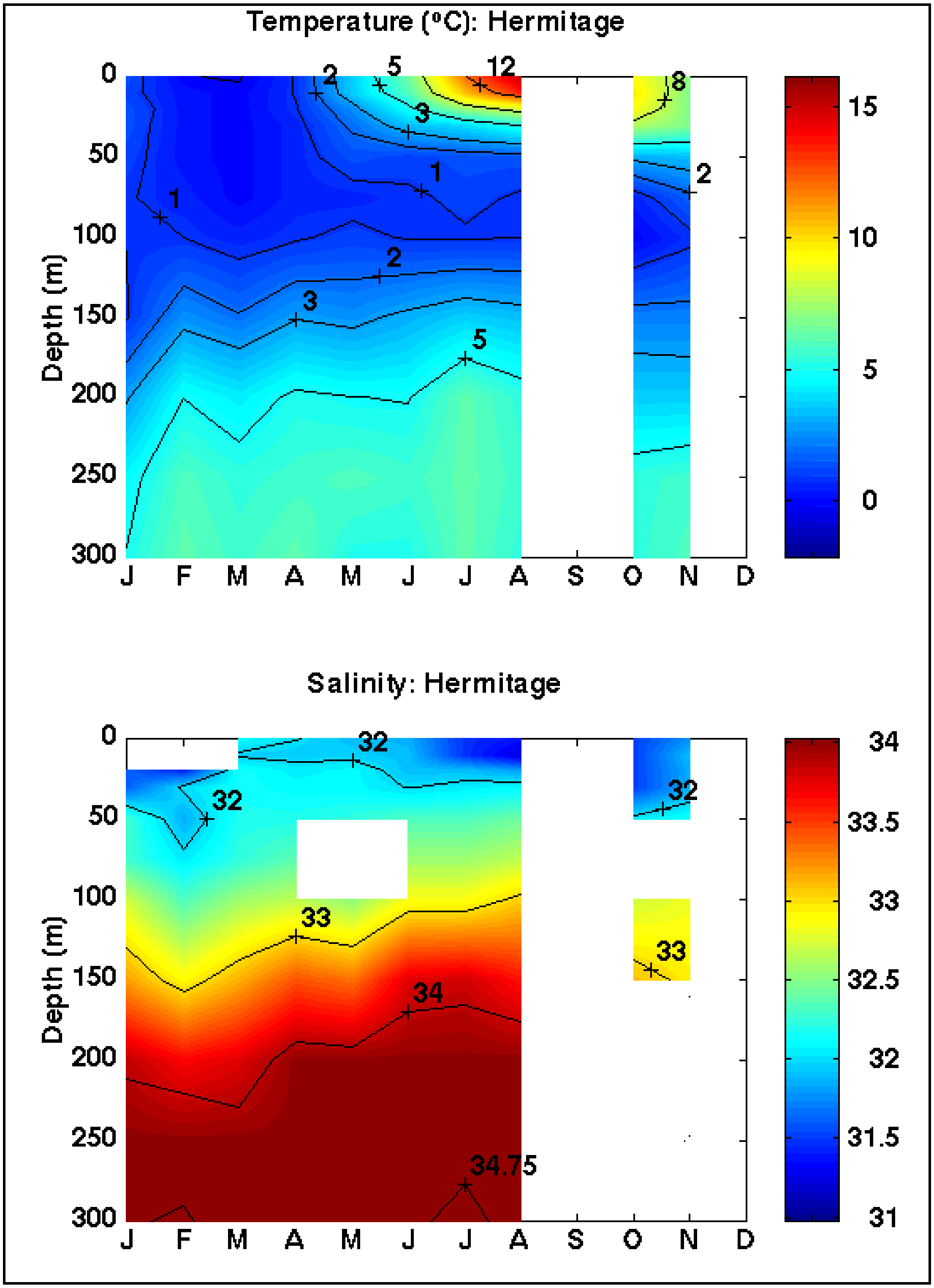
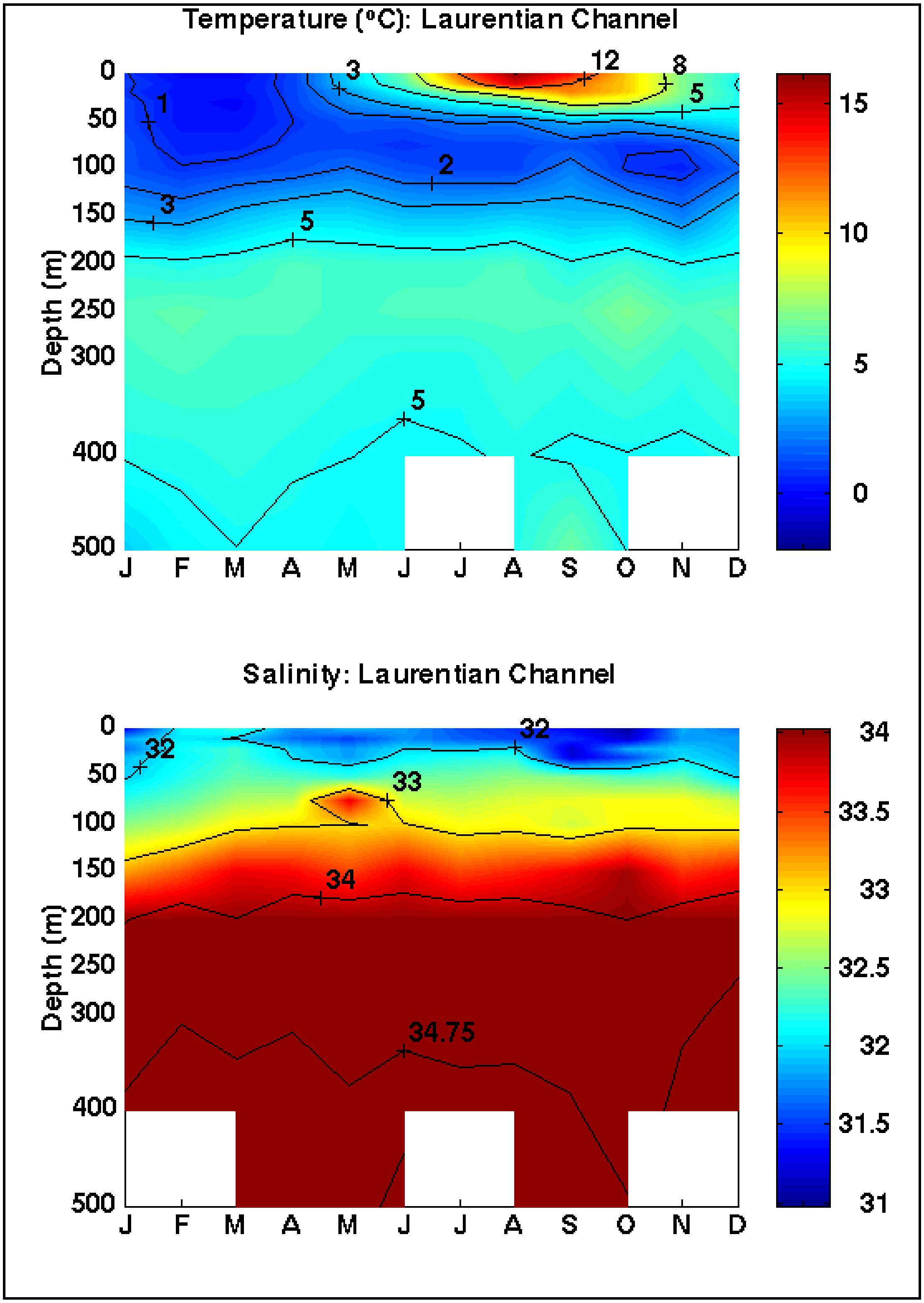


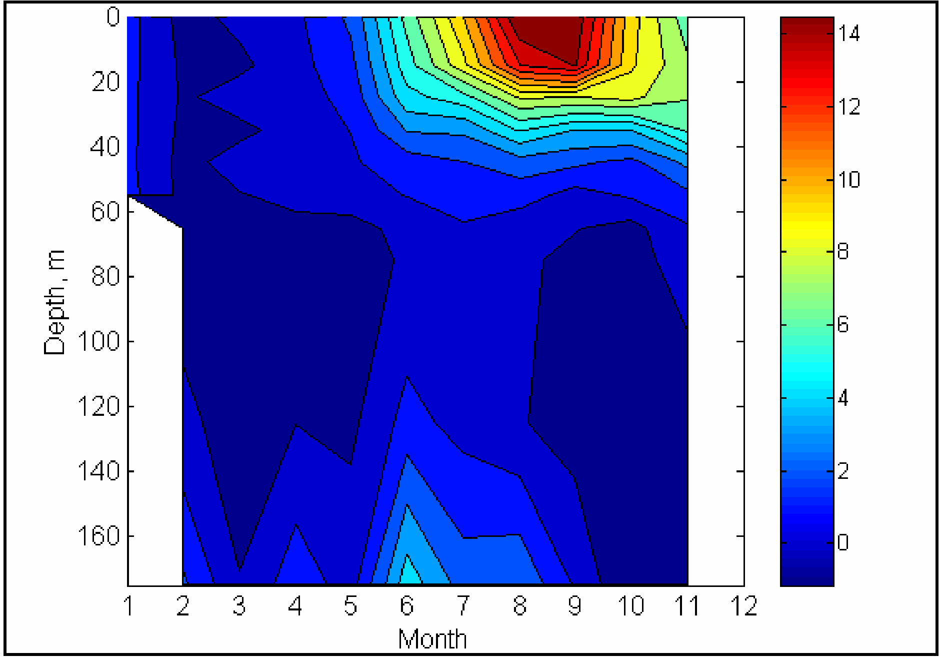
Figure 2.15. **Monthly Temperature and Salinity Profile in Hermitage Channel.**


Temperature (°C): Laurentian Channel

Salinity: Laurentian Channel

Figure 2.16. Monthly Temperature and Salinity Profile in Laurentian Channel

Temperature (°C)



Salinity (psu)

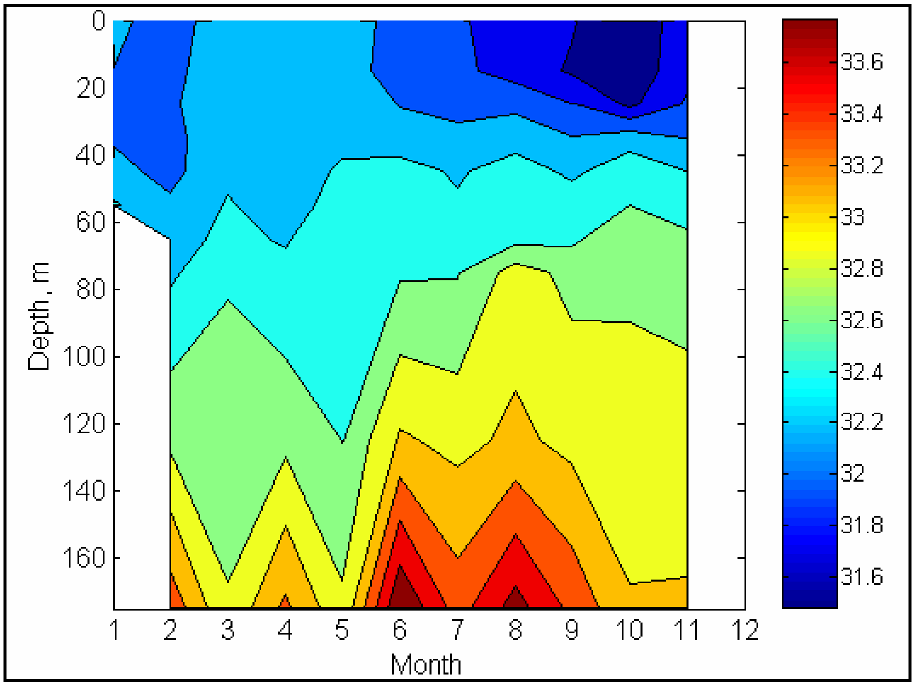
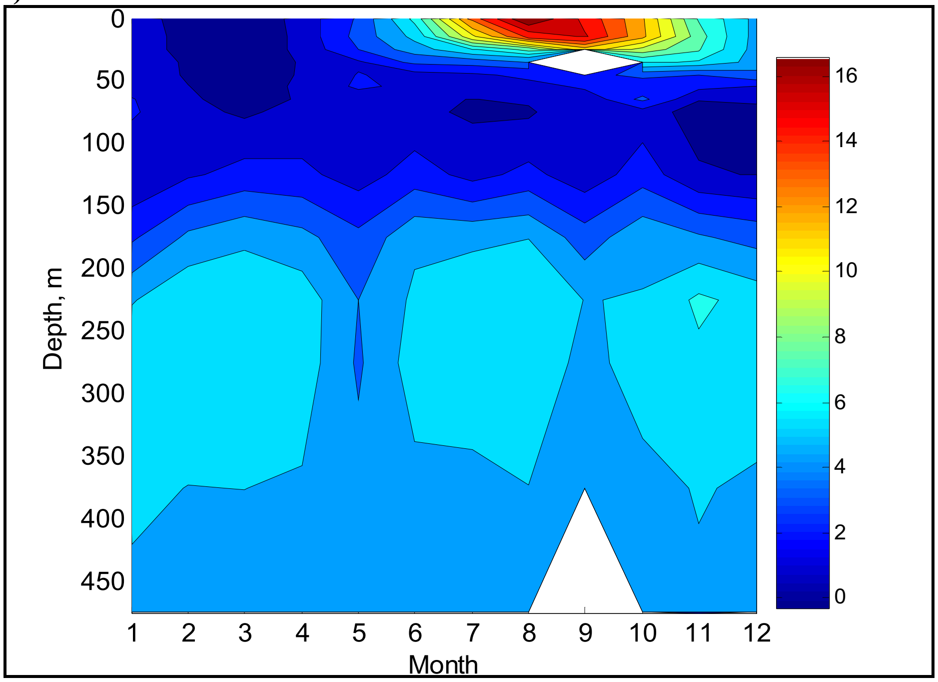


Figure 2.17. **Monthly Temperature and Salinity Profile for the St. Pierre and Green Banks Shelf Region.**

Temperature (°C)



Salinity (psu)

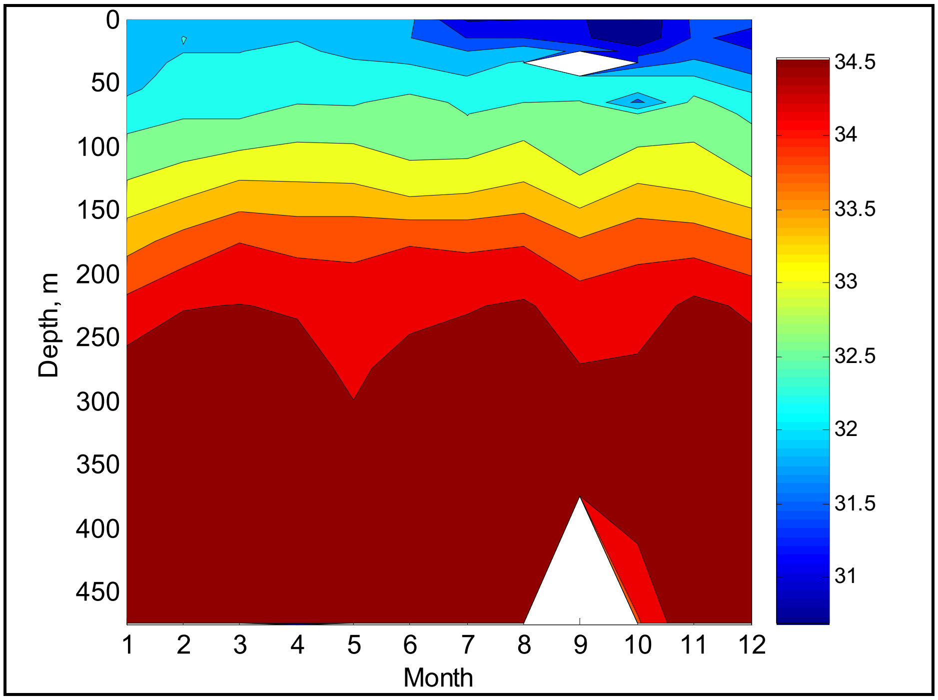
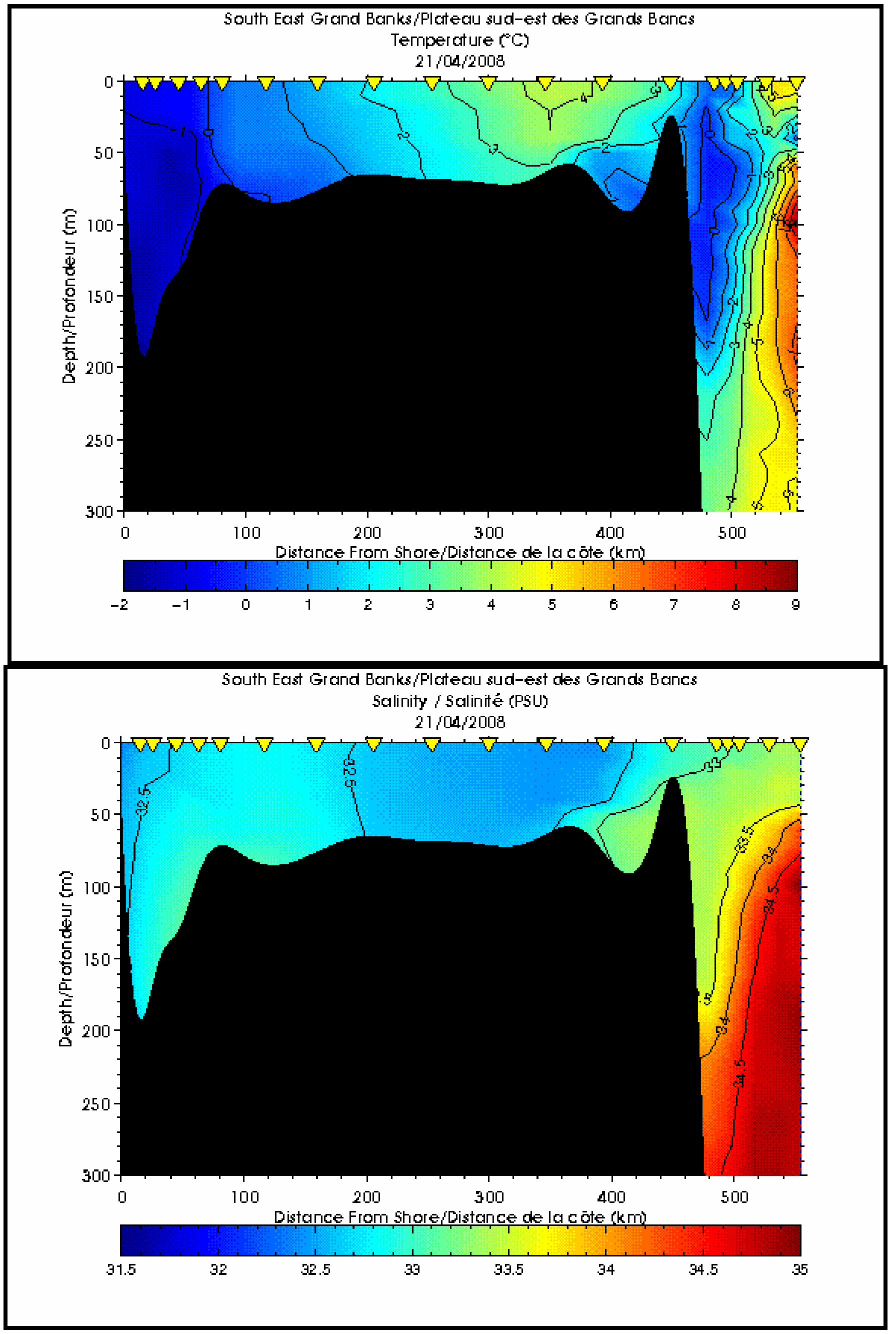


Figure 2.18. Monthly Temperature and Salinity Profile for the Laurentian Fan Slope Region.



Source: DFO Marine Environmental Data Service Website.

Figure 2.19. Hydrographic Contours along the South East Grand Banks Transect during April 2008.

2.3 Ice

The SEA Area is susceptible to seasonal incursions of ice from several directions and in two different forms, sea ice and icebergs. While iceberg encroachment is generally from the northeast and consists of icebergs that have been carried south down the Avalon Channel, there have been occasions when icebergs have drifted into the area from the southeast. These icebergs carry south down the Flemish Pass then round the Tail of the Banks following the northwesterly current along the southern side of the continental shelf. Sea ice encroachment into the area is primarily a result of the East Coast pack ice drifting south round Cape Race and easterly moving sea ice from the Gulf of St. Lawrence.

2.3.1 Databases

Regional sea ice data were compiled from approximately 30 years of ice observations conducted by the Canadian Ice Service (CIS). Beginning in the 1970s, satellite images supplemented airborne observations, but eventually replaced them as the principal sources of data by the mid-1990s. The data used for this report were extracted from the Sea Ice Climate Atlas, East Coast Canada (CIS 2000), which represents a compilation of weekly composite ice charts produced by the CIS. Data on icebergs were compiled from approximately 20 years of iceberg sightings from the Program of Energy Research and Development (PERD) Iceberg Sighting Database: 2007 (PERD 2007) which contains iceberg sightings from the International Ice Patrol (IIP). The IIP data have been used in most efforts to quantify and understand iceberg behaviour off eastern Canada. The database accessed for this report contains iceberg sightings and detections that, for the most part, come from aerial ice reconnaissance flights.

2.3.2 Sea Ice

The monthly probability of sea ice cover is different depending on which sector of the area is being considered. For the purpose of this SEA, the area was divided by the 55° W longitude into eastern and western sections. One could further subdivide these along 44°N latitude to give a more accurate assessment of probable incursions of sea ice, if required for operational purposes (Figure 2.20).

The major source of sea ice cover is from the Gulf pack and affects the NW quadrant of the area, peaking in March. The NE sector has a constant 15 percent probability of ice cover between February and May, restricted to a small area close to the northern boundary in February and March and just grazing the northern boundary in April and May (Figure 2.21). The SW and SE sections of the area remain free of sea ice all year.

2.3.2.1 Sea Ice Concentrations

Sea ice concentrations ranged widely from a low of 30 percent to a high of 80 percent. Mean concentrations when ice was present were just over 60 percent.

Pack Ice Composition

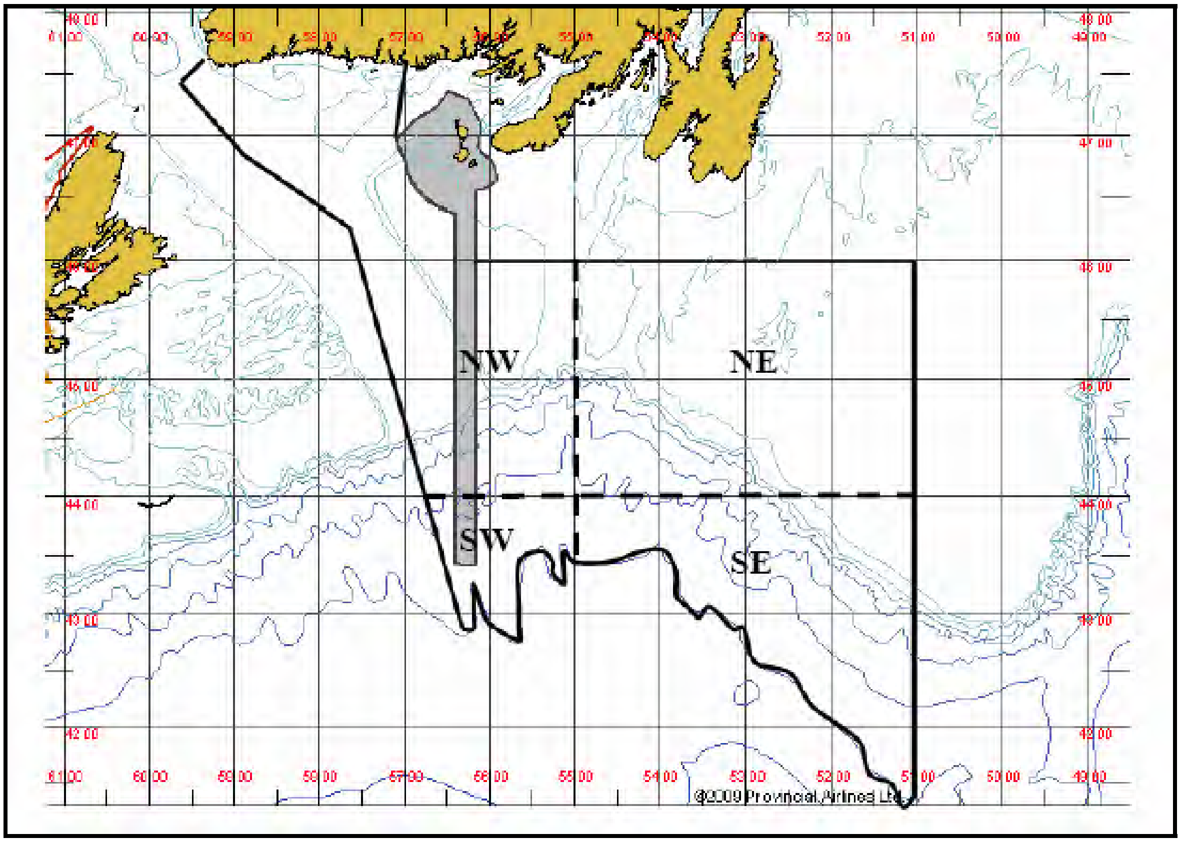
Composition data for the area show that the pack composition across the marginal ice zone is composed of primarily first-year ice (70 to 120 cm thick) in small floes. The CIS Ice Atlas shows that, in mid February, when pack ice is present, the NW section is initially mostly covered by grey-white ice. This then changes to first-year ice by month's end. First-year ice then remains the primary ice type through the months of March and April (Figure 2.22).

Pack Drift

Detailed drift data were not available from the databases consulted. However, analysis of weekly distributions shows that the pack ice edge advances out of the Gulf of St. Lawrence towards the South Newfoundland Offshore. In years of extreme sea ice distributions, additional ice may advance from the main pack that has rounded Cape Race, on the southern tip of Newfoundland, and join up with the Gulf pack.

2.3.3 Icebergs

Iceberg sightings made within the latitudes 46.00N to 41.30N and the longitudes 51.00W and 59.00W were extracted from the PERD Iceberg Sighting database. All sightings were sourced from IIP. Query of the database found 221 sightings during the 1987 to 2003 period.



Note: the shaded area represents the territorial waters of St Pierre and Miquelon

Figure 2.20. Study Area Sub-divided into Quadrants.

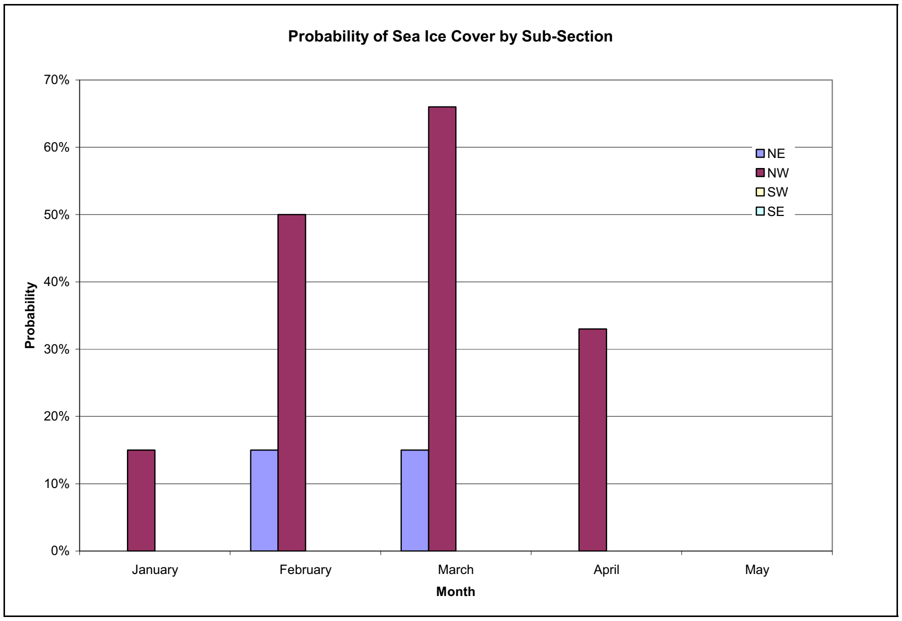
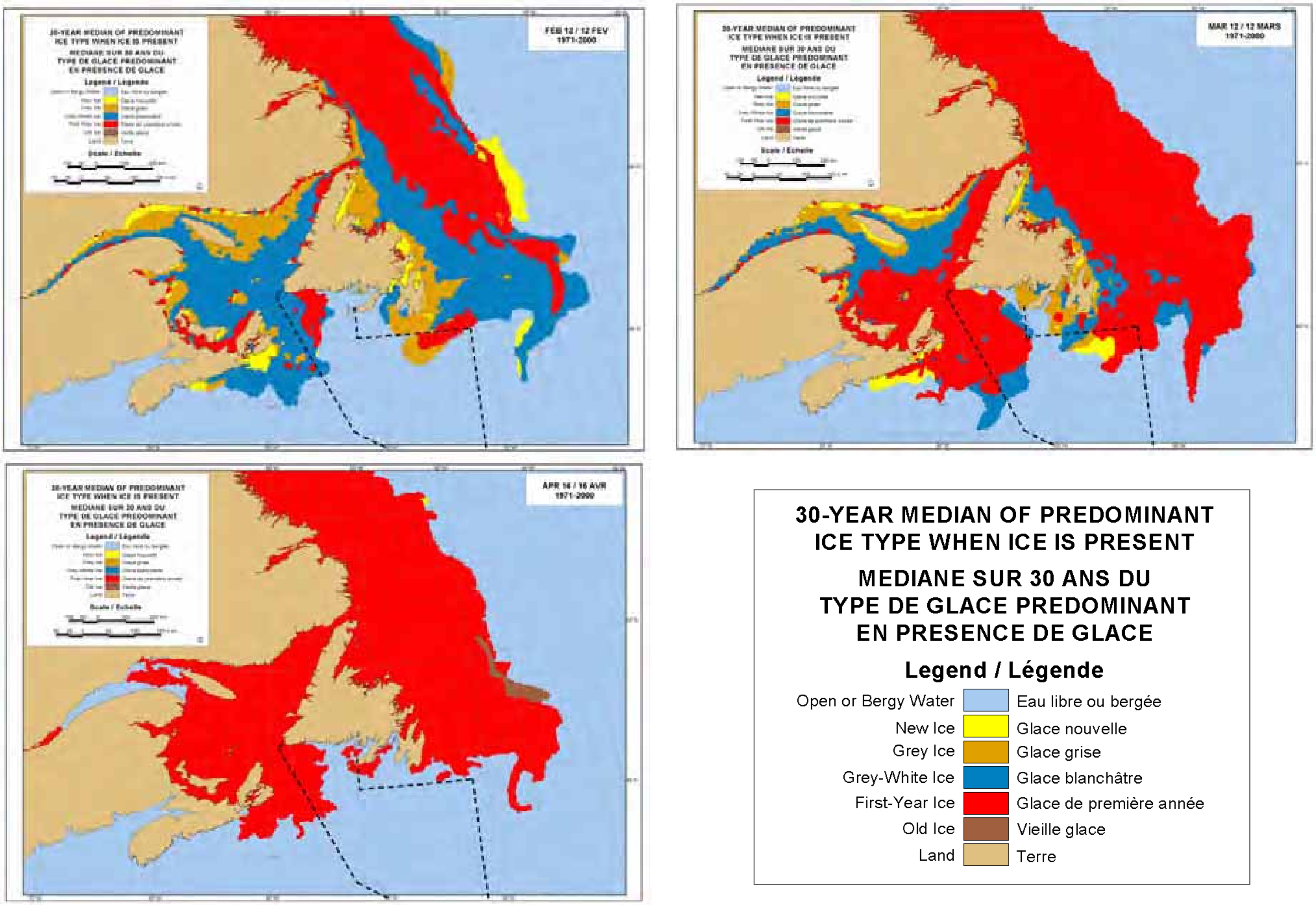


Figure 2.21. Probability of Sea Ice Cover by Subsection. [SW and SE quadrants were ice-free.]



Source: CIS Ice Atlas.

Figure 2.22. Pack Ice Type by Month.

2.3.3.1 Iceberg Distribution by Year

The confirmed sightings in the PERD database were then analyzed by year, and considerable fluctuations in the yearly iceberg distribution were evident (Figure 2.23). The same proved to be true when considering any single one-degree block off Canada's East Coast. The distribution of icebergs within the SEA Area is heavily weighted towards the eastern edge with over 75 percent of all iceberg sightings lying east of 54.00W.

The distribution is consistent with known iceberg drift patterns, confirming that most icebergs enter the area at the northeast corner and work their way slowly towards the southwest. Figure 2.24 shows the number of sightings per individual one degree block of latitude and longitude.

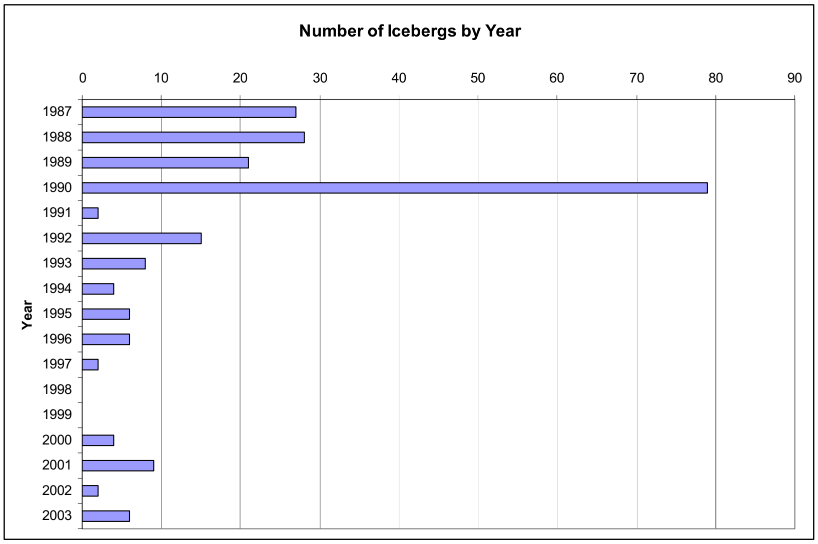


Figure 2.23. Iceberg Distribution by Year.

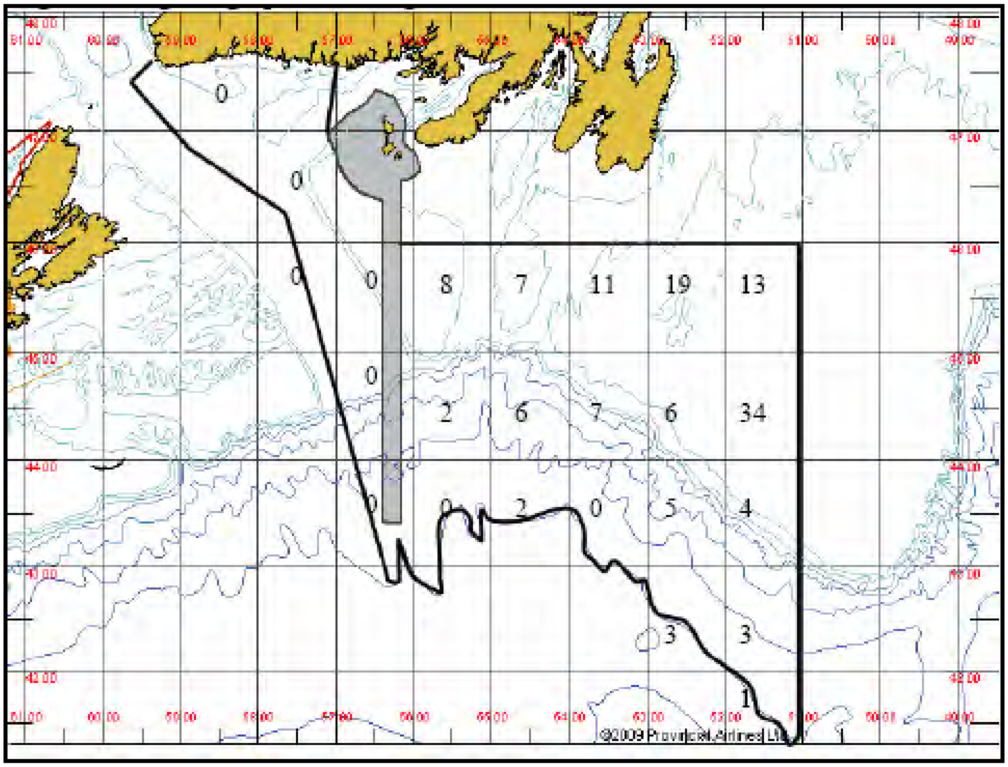


Figure 2.24. Sightings Per One Degree Block.

2.3.3.2 Iceberg Distribution by Month

Data on monthly iceberg distribution for the SEA Area were compiled from the IIP database. The spatial distribution is consistent with known iceberg drift patterns, confirming that most icebergs enter the area at the northeast corner and work their way slowly towards the southwest. Figure 2.24 shows the number of sightings per individual one degree block of latitude and longitude. Figure 2.25 shows the monthly occurrence of icebergs in the SEA Area as a percentage of the yearly total.

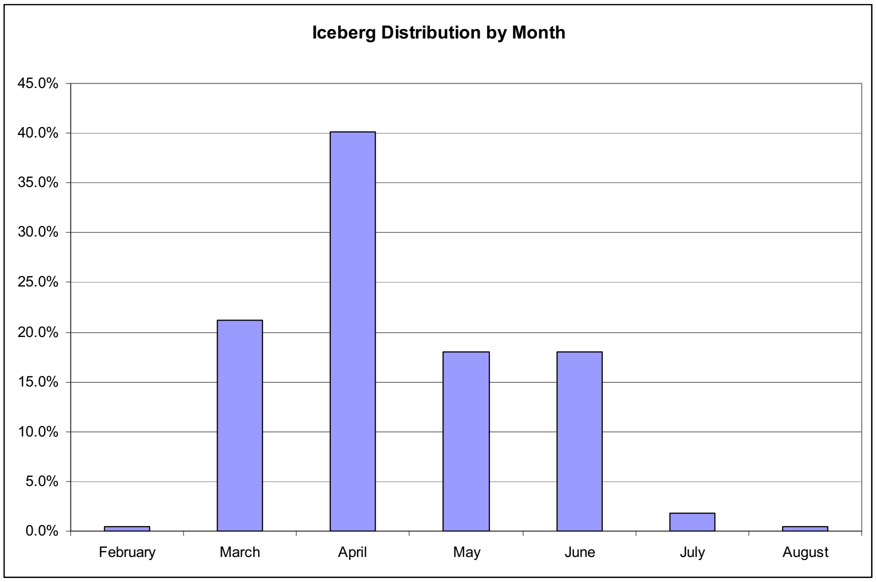


Figure 2.25. Monthly Occurrence of Icebergs as a Percentage of the Yearly Total.

2.3.3.3 Iceberg Size Distribution

Of the 121 icebergs extracted from the IIP database, 20 icebergs had associated size classifications. The IIP visually classifies icebergs according to Table 2.18.

Table 2.18 IIP Iceberg Size Classification.

Category	Height (m)	Length (m)	Approx. Mass (t)
Very Large	>75	>200	<10 Million
Large	45 -75	120 - 200	2 - 10 Million
Medium	15 - 45	60 - 120	100,000 - <2 Million
Small	5 - 15	15 - 60	100,000
Bergy Bit	1.0 - 5	5 - 15	10,000
Growler	<1.0	<5	1000

The accuracy of size distributions extracted from the IIP database is questionable because most data are based on visual estimations and unspecified selection criteria. However, these data have been used in many previous studies and reports and are the only data available for the SEA Area.

The iceberg size distribution for the SEA Area is shown in Figure 2.26. In general terms, this distribution is very similar to other areas studied; however, as the SEA Area is on the extreme southern range for icebergs there is a noticeable absence of large icebergs in the distribution. While the database does contain one report of a large iceberg, it was likely over-estimated. If this was a large iceberg, additional sightings would have been made either in the same area or upstream and there were no additional reports in the databases searched.

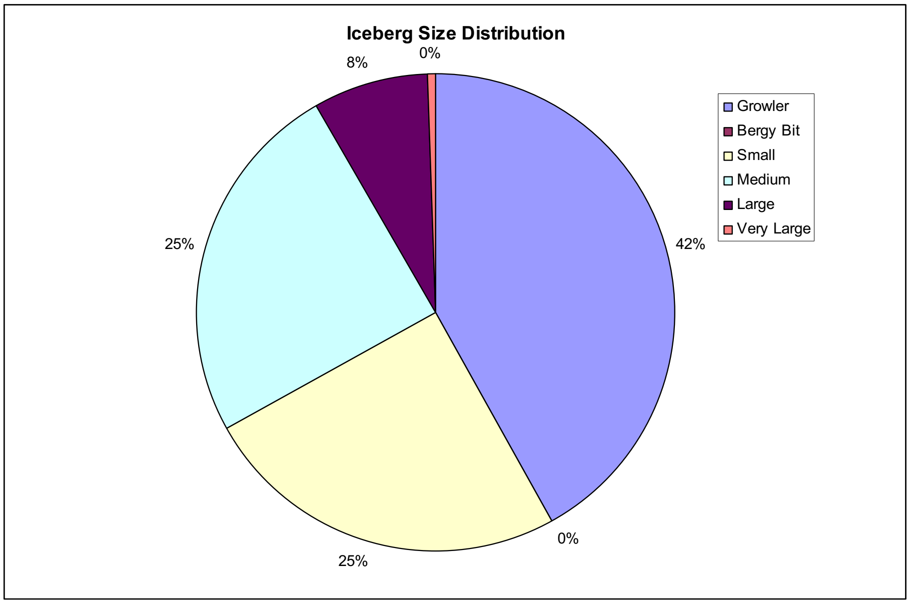


Figure 2.26. Iceberg Size Distributions for the South Newfoundland Offshore Block.

2.3.3.4 Iceberg Drift

Local winds and currents largely determine the movements of free-floating icebergs. There are few quantative data on iceberg drift in the Study Area. Therefore, only general iceberg drift information based on regional drift patterns and known distribution data from adjacent blocks can be presented.

Regional iceberg drift generally follows two basic patterns. The first is from the main inshore flow down through the Avalon Channel, turning south of Cape Race and drifting across the Saint Pierre Bank while the second approaches from the south and east following the bathymetry (Figure 2.27).

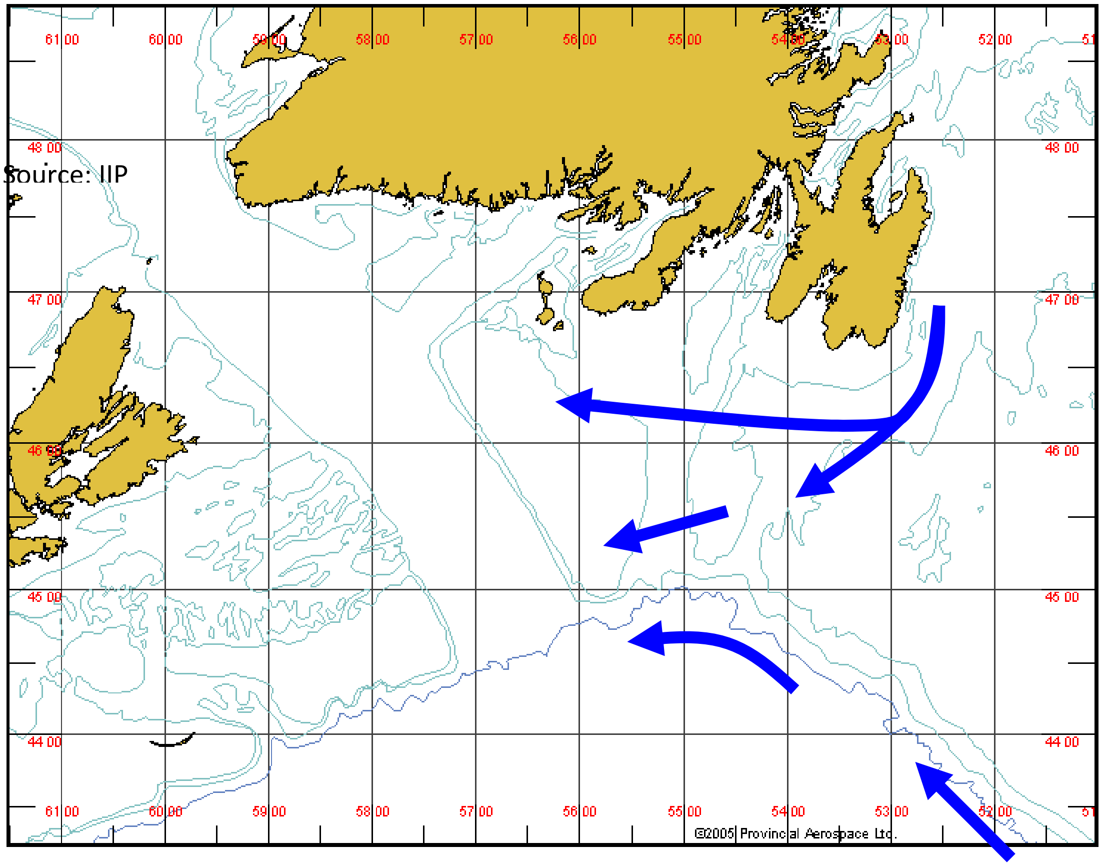
2.3.3.5 Iceberg Scour

When large icebergs drift into relatively shallow water they can come into contact with the sea floor resulting in a scour. Of the reported icebergs in this area, none have a size sufficient that could scour the sea floor. This area is close to the extreme limit for ice of glacial origin and any icebergs crossing the area are nearing the end of their melt cycle.

2.4 Bathymetry

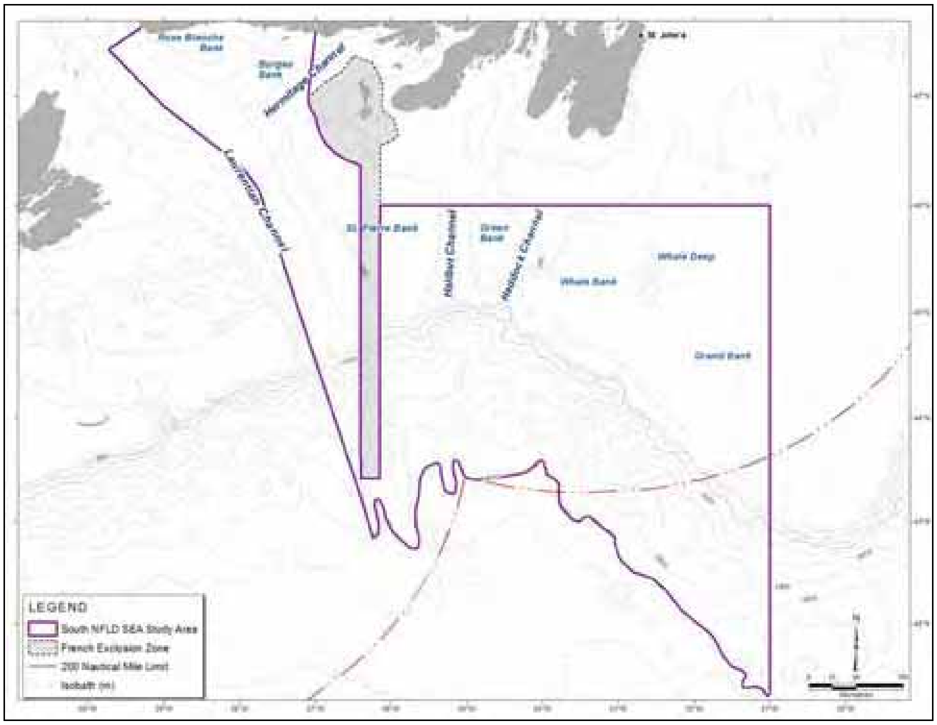
Bathymetry in the SEA Area is complex and depths vary widely from shallow shelf areas, steep slopes, deep troughs and abyssal basins (Figure 2.28). The area includes a series of banks from Burgeo Bank in the west to SW Grand Bank in the east. The Laurentian Channel bisects the area from NW to SE and is entered from the north by several deep channels such as Hermitage Channel and Halibut Channel.

The water depths within the SEA Area range from intertidal to 4000 m. Approximately 40 to 50% of the Study Area is accounted for by continental shelf (<200 m) and the remainder is continental slope/rise area (200- to 4000-m depths). Bathymetry and some place names relevant to the geology and biology of the area are discussed further in the following sections (see also Figure 2.29 in Subsection 2.5). Approximately 200 km of the SW coast is included in the Study Area, the only part of the Study Area in which the intertidal and shallow subtidal (i.e., ≤30-m water depth) zones are considered in this SEA.



Source: IIP

Figure 2.27. General Iceberg Drift Patterns Surrounding the South Newfoundland Offshore Location.



Source of bathymetry: GEBCO (2009)

Figure 2.28. Bathymetry and Physical Features of SEA Area.

The continental shelf west of the French waters associated with St. Pierre and Miquelon is limited, comprised of a relatively narrow coastal strip extending along most of the SEA Area coastline (e.g., Rose Blanche Bank, Burgeo Bank and part of St. Pierre Bank).

2.5 Geology

The geology of the SEA Area is described in detail in the previous SEAs for Sydney Basin and the Laurentian Sub-basin, and the site-specific EA for the existing ELs in the Laurentian Sub-basin (Buchanan et al. 2006, 2007). Some of the key points relevant to environmental assessments are discussed in this section. Emphasis is on the offshore because that is where the petroleum exploration interest lies. Nonetheless, it is of interest to note that the south coast from Cabot Strait to Fortune Bay is low to moderately steep and bedrock-dominated. There are numerous fjords with small estuaries, tidal flats or beaches at their heads. Coastal dunes, beaches, barriers and eroding bluffs of unconsolidated glacial material are found near Burgeo and around Hermitage Bay (Meltzer 1996).

Some potential petroleum-bearing basins from west to east are Sydney Basin, Laurentian Sub-basin, SW Whale Basin and Whale Basin. These basins and others like them were formed along the east coast of North America by geological processes of tectonic plate movements, thermal contraction of the lithosphere accompanied by subsidence and rapid sedimentation along the margin which produced exceptionally thick Mesozoic-Cenozoic sedimentary basins.

2.5.1 Sediments

A brief summary of surficial sediments based on previous SEAs and EAs for the area is provided below. The material concerns primarily sediments in water depths above 500 m. New information on deepwater sediments as obtained by BIO and others is described in the following section.

Unconsolidated Quaternary sediments deposited during and subsequent to the Wisconsinian glaciations lie above the Tertiary and older bedrock. Five surficial sedimentary formations are recognized within the SEA Area: (1) Grand Banks Drift, (2) Downing Silt, (3) Adolphus Sand, (4) Placentia Clay, and (5) Grand Banks Sand and Gravel. These units consist of glacial tills, proglacial silts, sublittoral sands, recent mud, and basal transgressive sand and gravel. Descriptions of these sediment types are provided below (from Fader et al. 1982; Piper et al. 1990; and Brown 1990).

Grand Banks Drift consists of till deposited at the base of a grounded ice sheet, generally in contact with bedrock surfaces. This unit is less than 60 m thick and found at water depths up to 500 m, as encountered on the upper continental slope. It is an olive-grey to reddish-brown, poorly sorted till, composed of sand, silt, and clay with various amounts of pebbles, cobbles, and boulders. Where this unit is exposed at the seabed it appears as protruding cobbles and boulders within a matrix of sandy mud. It occurs as a thin veneer or ground moraine, as infillings in old subaerial erosional channels in underlying bedrock, or in thick morainal ridges.

Downing Silt is a unit that overlies and locally intertwines with Grand Banks Drift. It is typically less than 90 m thick and is interpreted to have been deposited at the front of a grounded ice sheet, beneath an ice shelf, or as a proglacial deposit. Downing Silt is a dark greyish-brown to greenish-brown, clayey and sandy silt that locally grades to silty and clayey sand with minor angular gravel. In the SEA Area, Downing Silt is exposed primarily at the base of the Laurentian Channel and in isolated depressions of the Halibut Channel. Below the seabed, this unit occurs in the northeastern St Pierre Bank and over most of the Laurentian Channel. Where exposed, the surface of this unit is smooth with gentle undulations. In areas where this formation is thin and overlies rough glacial till, its surface mimics that of the underlying till. This unit is extensively furrowed by icebergs. Furrows can be up to 10 m deep.

Adolphus Sand is a formation found below the post-Wisconsinian low sea level at 115 to 120 m water depths. It is a dark, greyish-brown, fine to coarse-grained sand containing some silt and clay-sized fractions and gravel that generally is found as a thin veneer less than 10 m thick. Foraminiferal tests, sponge spicules, radiolaria, and broken shell fragments occur in abundance within this formation. In the SEA Area, this unit is found along the flanks of the Laurentian Channel and at the base of the Halibut Channel. Iceberg furrows occur across many areas of Adolphus Sand, particularly along the edges of the Laurentian Channel. In the Halibut Channel, the seabed is characterized by numerous sand waves with maximum heights of 8 m and wavelengths of 305 m.

Placentia Clay is a dark greyish-brown to dark olive, homogeneous silty clay to clayey silt formation. It is less than 30 m thick and its generally flat surface comprises most of the seabed of the Laurentian Channel within the SEA Area. This unit originates primarily from reworking of Downing Silt and glacial tills during the marine transgression of the Holocene.

Grand Banks Sand and Gravel is a basal marine transgressive sand and gravel deposit that occurs in water depths of less than 115 to 120 m and is generally less than 20 m thick. This unit consists of reddish to greyish-brown, fine to coarse grained, well sorted sand that grades locally to coarse, well rounded gravel with large boulders. The fine silt and clay-sized fraction characteristic of the Adolphus Sand is absent in this unit. Grand Banks Sand and Gravel is exposed at the seabed over most of St Pierre Bank as sand waves and megaripples with wavelengths of between one and 200 m.

2.5.2 Recent Geological Studies in the Area

New information on the geologic processes of the Laurentian Fan and the southwest slope of the Grand Banks has become available since the preparation of the previous SEAs and the site-specific EA for the Laurentian Sub-basin (Buchanan et al. 2006, 2007), including the following recently published information:

- Five major phases describe the late Cenozoic evolution of the Laurentian Fan, as outlined in Skene and Piper (2006). This paper suggests that coarse-grained bedload flowed down the Eastern Valley as hyperpycnal inflows due to ice margin flow separation as opposed to the Western Valley that was fed by finer-grained sediment from meltwater plumes;
- Stratigraphic and sedimentological evidence for late Wisconsonian sub-glacial outburst floods to the Laurentian Fan (Piper et al. 2007). Large scale meltwater discharge caused large-scale catastrophic erosion and the transport of coarse sediments to the abyssl plain while smaller scale discharges created principally muddy sediment. At least one major sediment transport event, presumably pre-dating the 1929 “Grand Banks” turbidity current and dated to 16.5 ^{14}C ka, eroded the upper slope and major fan valleys of the Laurentian Fan; a gravel bed at least three metres thick was deposited in the wide fan valleys and thick sand of the Sohm Abyssal Plain. This event may have also created giant flute-like scours;
- Ledger-Piercy and Piper (2007) described a reconnaissance survey of late Quaternary stratigraphy and geohazards on the deep continental margin seaward of Green Bank, Haddock Channel, and Whale Bank. Hunter Sparker lines were used to show that five regional reflections were correlated throughout these regions and map the distribution of major mass-transport deposits, evacuation surfaces, and headscarps. Using piston cores, mostly mud was recovered, although cores adjacent to Haddock Valley contained abundant thin sand bed layers. There is evidence for active salt tectonics in the area, but the frequency of seabed sediment failures is similar to other areas of the southeastern Canadian margin and indicates that there are no unusual geohazards in these regions; and
- Mosher and Piper (2007) interpreted multibeam bathymetric sonar data of the 1929 landslide area as showing canyons, valleys, and gullies typical of the continental slope in the region, with no major headscarp. It appeared to be a relatively shallow (top 5 to 100 m) landslide but laterally extensive and presumably changing into turbidity currents flowing along the existing canyon and valleys, supporting earlier theories that the landslide was thin-skinned and dispersed over a large area.

Unpublished research has also been made available for summary purposes in this SEA (David Piper, Geological Survey of Canada, BIO, pers. comm., 2009), and include:

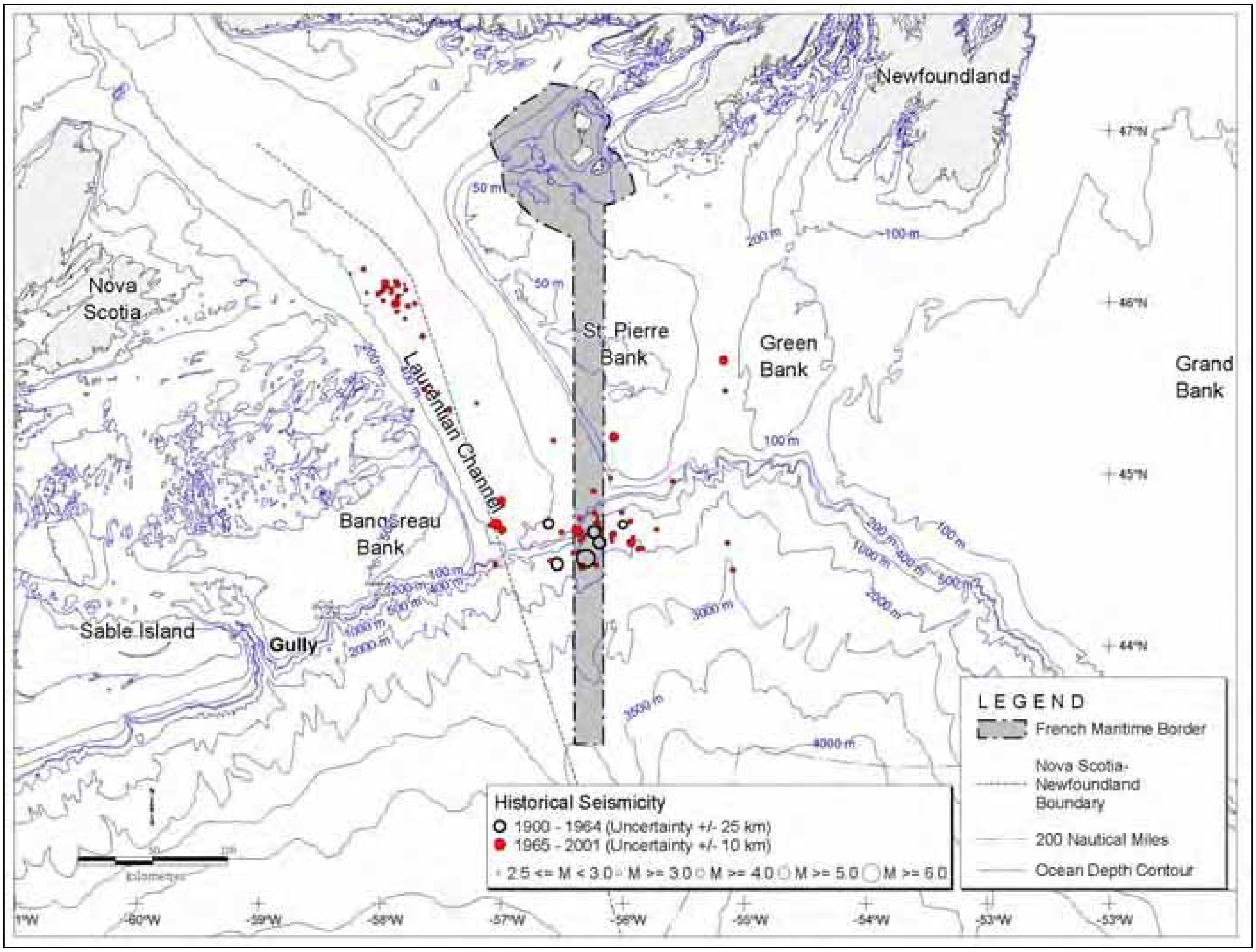
- A description of erosional and depositional features of glacial meltwater discharges on the eastern Canadian continental margin. From the Hudson Strait to the Scotian margin, there is evidence of important glacial meltwater processes seaward of all transverse troughs on the continental shelf. Glacigenic debris flows, turbidity current deposition of channel-levee complexes, and blocky mass-transport deposits resulting from debris avalanches are identified as three major end-member processes on submarine fans seaward of the transverse troughs. It appears that glacigenic debris flows are dependent on gradient and the importance of meltwater appears to be greater at lower latitudes;
- Armitage et al. (in press) investigated the development of canyons and intercanyon ridges as well as the sedimentary processes affecting glacially influenced slopes in the southwest Grand Banks slope region. Canyons apparently resulted from Quaternary ice-related processes along the continental margin (e.g., ice stream outwash and proglacial plume fallout). Near the shelf break, levee-like deposits occur. The authors suggest that the principal turbidity current generating mechanism in the region is likely turbulent subglacial outwash from tunnel valleys; these currents are important to the amount of upper slope sedimentation, slope morphology, and distribution of coarse-grained materials; and
- Mosher et al. (in prep.) discuss the near-surface geology of the Halibut Channel region of the southwest Newfoundland slope. In the eastern Laurentian area in particular, sedimentation appears to be predominantly pro-glacial above Q50 and has steep local gradients, suggesting that this area may be subject to failure. However, large-scale failures (such as that of the 1929 landslide) do not seem more frequent in this area than other regions of the eastern Canadian margin and are likely rare.

2.5.3 Seismicity

Each year about 300 earthquakes occur in eastern Canada. Along Canada's eastern continental margin, instrument-recorded earthquake epicentres are concentrated in a few "source zones" of relatively intense seismic activity such as at Baffin Island, northern Baffin Bay, the northern Labrador Sea and the Laurentian Slope. Eastern Canada is located in a stable continental region of the North American plate and, as a consequence, has a relatively low rate of seismic activity typical of "passive" continental margins relative to other areas such as the west coast of Canada. Nevertheless, numerous earthquakes have been recorded along the eastern continental margin including the devastating Laurentian Slope, or "Grand Banks", earthquake of November 1929 (epicentre at 44.69° N latitude, 56.00° W) which ripped apart numerous transatlantic cables and caused a tsunami that, coupled with a storm surge, resulted in a death toll of 27 people along the Burin Peninsula of Newfoundland. This magnitude 7.2 event could be felt as far away as New York, Ottawa, and Montreal, and also damaged structures in northeastern Nova Scotia (NRCan 2006).

A single earthquake has been recorded since 2006 in Newfoundland and areas of Atlantic Canada near the Laurentian Sub-basin. On 28 April 2009, an earthquake of 3.3 magnitude occurred 28 km southwest of Bay Roberts, Newfoundland at 47.4ºN, 53.5ºW (NRCan 2009).

In simple terms, the SEA Area, with at least one major exception, is believed to be in a zone of relatively low seismic hazard (NRCan 2006). This exception is the seaward entrance to the Laurentian Sub-basin where the above-described event originated (Figure 2.29).



Source of bathymetry: GEBCO (2009)

Figure 2.29. Historical Seismicity in and near the Laurentian Sub-basin.

2.5.4 Geohazards

Geohazards relevant to petroleum development in the Study Area (from Lewis and Keen 1990) include:

- Overpressure—abnormally high formation pressures that may threaten well control;
- Gas hydrates—may be present in deep water areas (>200 m); thawing produces rapid release of gas which may affect integrity of the well;
- Shallow gas—may occur in areas of fine-grained sediments when setting the well casing;
- Seabed instabilities—pock marks, steep slopes, erosion, etc.;
- Seismicity and earthquakes—may trigger liquefaction, slides, slumps, turbidity currents, and tsunamis; and
- Ice scour—from icebergs in shallow water (<200 m).

All of the above geohazards are normally taken under consideration when planning and designing exploration and production facilities in Canadian offshore waters.

2.6 Unexploded Ordnance

There are several potential sites within the SEA Area for which there may be unexploded ordnances (UXO). One potential UXO site is the wreck of the HMCS *Shawinigan*. The exact position for this site is unknown, as historical review and site survey to date have not yet located the wreck. This ship was a Flower Class corvette used to escort convoys across the Atlantic during World War II. After safely completing a routine escort of the Newfoundland ferry, the MV *Burgeo*, from Nova Scotia to Port Aux Basques on November 24, 1944, HMCS *Shawinigan* returned to regular patrol duties and was torpedoed by U-1228. The position where the ship sank is thought to be in the Cabot Strait, near Port Aux Basques, at approximately 47°34"N 59°11"W. Additional ordnance may be "the presence of a Second World War torpedoed merchant ship (*Empire Sailor*) within EL 1087 at a location of 43° 53' N and 55° 12' W. The ship, when sunk, was known to have been carrying explosives and chemicals which included 270 tons of phosgene bombs and 26 tons of concentrated mustard gas in 68 drums.

According to the *Grand Banks of Newfoundland: Atlas of Human Activities* (DFO 2007a), there are two potential warfare agent disposal sites located off the continental shelf south of the Halibut Channel. One is classified as an 'explosives and chemical restricted area' and its approximate coordinates are 44°N, 55.25°W at a water depth >3000 m. The other is classified as an 'explosives restricted area' and its approximate location coordinates are 44.75°N, 55°W at water depths of 1000 to 2000 m. This latter site is located in the easternmost EL shown in Figure 1.1. Known UXO sites are illustrated in the sensitive areas map (Figure 3.86) contained in Subsection 3.8. Another area to note, as a potential UXO, site is the Sydney Disposal Area, which is located at the western edge of the SEA in position 46.08N, 058 W.

Note that DND maintains a database of potential unexploded ordnance sites.

2.7 Planning Implications

This subsection describes some of the physical environment-associated planning implications related to operations in the SEA Area.

2.7.1 Geology

While the potential for geohazards may not be greater than in other areas of the eastern Canadian margin, an assessment of geohazards must be done prior to any drilling program. Surveys may require sediment sampling by core and/or grab, geophysical surveys using seismic and/or sonar, visual surveys by ROV or drop camera, or others.

2.7.2 Climatology

The climate offshore southern Newfoundland will impact the drilling activities. It is essential that a drilling platform is chosen which is suitable for operating in the weather conditions which may be present during the drilling season. Proponents are advised to consider climate change issues in project assessments and design.

High winds, high waves, icing due to freezing spray or precipitation, or low visibility in fog or snow, can impose serious constraints on operations. Operations during severe weather conditions are managed by having site-specific weather forecasts available. Drilling operators are required to contract a weather forecasting service to support the offshore activities for the duration of the drilling program. The requirements are outlined in the C-NLOPB *Offshore Physical Environmental Guidelines September 2008.*

High sea states may have an impact on drilling time. For planning purposes during the approach of a storm, it is important to know how the drilling platform will respond to the forecasted sea state. Forecasts of the motion of the drilling platform can be included with the weather forecasts provided that the "response amplitude operators" for the platform are known and provided to the weather forecasting contractor in advance. The current weather conditions are observed on the platforms and sent to the weather forecasting office every three hours to assist with weather forecasting. The wave heights are also measured by a wave buoy.

Storm surge as an important factor in tropical and extratropical cyclones, should be considered in planning and design for some locations and platforms.

2.7.3 Physical Oceanography

The currents are variable in both space and time. For any proposed drilling location, the currents are probably unknown. The currents on the Grand Banks have not presented any problems with regard to drilling activities. The currents on the banks offshore southern Newfoundland are expected to have similar characteristics. In general, currents are stronger on bathymetric slopes and in the boundaries between different water masses. It would be advantageous to have prior current measurements in those types of areas.

The C-NLOPB *Offshore Physical Environmental Guidelines September 2008* require current measurements to be made at a minimum of three levels in the water column during the drilling program period. There is also a requirement for real-time current measurements. The real-time currents are usually measured with instruments on the platforms. The technology is now available for real-time measurements to be transferred from a moored instrument to the platform by wireless communications. The oceanography program should also include measurements of the temperature and salinity of the water column to assist with the current analysis and to provide information on the water masses in the area and density stratification at the site.

The metocean data collected by operators are entered into government databases (e.g., BIO oceanographic database) and thus are available for use in spill modeling, if appropriate. There are no effects monitoring (EEM) requirements for exploratory wells. Production developments are required to conduct an EEM program that typically includes monitoring of mud and cuttings fate and effects.

2.7.4 Ice

Sea ice and icebergs can create serious constraints on operations off the Newfoundland and Labrador coasts. In general, there are fewer constraints off the south coast of Newfoundland than there are on the Grand Banks (where most of the offshore activity presently occurs). This section provides an overview of ice management practices that can be employed on a project to provide a safe environment and minimize operational disruptions. Current ice management practices on the East Coast include:

- Detection;
- Monitoring and assessment; and
- Physical management.

Detecting small floating targets in open seas is a well-understood and documented process. Technological advances in the preceding two decades have improved ice detection capabilities to a point where both sea ice and icebergs can be detected and positioned over a large area with great accuracy. Ice detection uses a combination of radar technologies and procedures to quantify and monitor ice distribution. Between government (both Canadian and U.S.) and private industry there are over 5000 hours of airborne reconnaissance conducted annually over the Canadian East Coast. In addition to these radar-equipped aircraft, the areas off the East Coast are swept daily by an assortment of satellite-based sensors and long-range, shore-based radars. Data from all these sources are integrated into a daily summary of ice distribution. The sequential ice distribution data are then used to monitor growth and movement. Using these procedures, the operator will be able to detect and monitor ice conditions, allowing for long-term resource and operational ice management planning.

Once detected, ice is monitored to establish the speed and direction of its movement (drift) and, when enough information has been obtained, assess its potential threat to the project. Typically this is accomplished in stages. The initial detection is usually accompanied by a general classification of the type of ice or iceberg. As successive detections are made over an area, a general drift track is established. At this stage the available data allow for general assumptions to be made. As ice closes on the project area, more detailed information is acquired.

The components of detailed ice assessment data include:

- Physical dimensions of sea ice and/or icebergs;
- Depth measurements of icebergs (draft); and
- Accurate drift (direction and speed).

Standard methods for obtaining physical dimensions comprise a mix of measurement, calculation and in some cases estimation, depending on the operational significance of the ice in question. Smaller icebergs and ice floes are usually estimated because their masses are well within the capabilities of ice management vessels. These methods are described in detail in an Operators' Ice Management Plan.

Obtaining accurate drift information is a simple process of measuring distance over time. The widespread use of the Global Positioning Systems (GPS) now provides very accurate positions, permitting accurate tracks, even over short distances and time spans. Once these baseline data have been collected, a reasonable assessment of the risk posed by the ice will be made. Typical risk assessment considers the following questions:

- Is the drift of the ice likely to pose a collision risk or disrupt operations?
- Is the ice in excess of the design criteria of the facility?
- Is the ice/iceberg within manageable parameters?
- Is the drift acceptable within the time frame required to move the rig if required?

If the answer to these simple questions is, 'no' then the ice need only be monitored for any drift changes. However, if the answer is 'yes' then either a physical ice management procedure will be initiated or the facility will be secured and prepared for a possible move.

In general terms, most physical sea ice management consists of towing or deflecting an iceberg off its free drifting track or breaking up ice floes to a size acceptable to the design of the facility. Sea ice management procedures are well documented. For example, breaking up sea ice to assist shipping is a commonplace occurrence in Canadian waters. The exact procedures for detection, monitoring and mitigation will be described in a Proponent's Ice Management Plan, which must be submitted for regulatory approval prior to the commencement of drilling.

2.7.5 Unexploded Ordnance

DND maintains a database on locations of unexploded ordnance. Proponents may be required to undertake additional surveys for hazards if there is potential for unexploded ordnance in their area of interest.

2.8 Data Gaps

Data gaps relating to the physical environment of the SEA Area include:

- Detailed metocean data at specific sites is usually lacking. This gap is typically filled just prior to or during a project's operational phase by installation of site-specific instrumentation;
- There are uncertainties about how best to use short term metocean measurements, near-surface measurements, or satellite data, in comparison to long-term modelled MSC50 wind and wave data, when describing marine climate;
- Some uncertainties arise from the different measurement heights and averaging intervals inherent in the data. Analysis of existing detailed metocean measurements at specific sites including sustained winds and gusts, in comparison to boundary layer models and empirical conversion factors, would help to resolve some of these uncertainties;

- There are uncertainties about the nature of recent trends in winds, waves, and extra-tropical and tropical cyclone storm tracks and frequencies in Canadian waters. There are uncertainties about how to factor short term trends, inter-annual variability, and climate change projections into extreme value analysis and design. Further research in these areas should be reviewed as it becomes available;
- Type and location of potential geohazards are usually unknown. Again, this deficiency is typically addressed prior to drilling;
- Detailed substrate information is often lacking. This is important from both a structural stability perspective but also from the detailed environmental assessment and monitoring perspectives, especially in regard to benthic communities; and
- Specific type, condition and locations of UXOs may be unknown.