

Final report of the 1998 Annual Meeting of the
Fisheries Oceanography Committee

February 24-26, 1998
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

Ken Drinkwater, Chairman

April 1999

Atlantic Zone

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of the

Fisheries Oceanography Committee

Held on February 24-26, 1998

**At the Bedford Institute of Oceanography
Dartmouth, Nova Scotia**

K.F. Drinkwater, Chairman

Executive Summary of the 1998 FOC Annual Meeting

The Fisheries Oceanography Committee (FOC) of the Department of Fisheries and Oceans (DFO) met in Dartmouth, Nova Scotia at the Bedford Institute of Oceanography on 24-26 February 1998. The Committee reviewed environmental conditions in the Northwest Atlantic during 1997, held a special theme session on the Relative Importance of the Environment on Growth and Reproduction and reviewed several additional papers of a more general nature.

1. As part of the overview of environmental conditions in 1997, four papers were reviewed on the meteorological and physical oceanographic conditions and an additional four on nekton and plankton. For the second consecutive year, relatively warm conditions were observed off Labrador and northern Newfoundland, although they were cooler than in 1996. A below normal North Atlantic Oscillation (NAO) resulted in warmer air and sea temperatures and less ice than usual. In the waters off southern Newfoundland, within the cold intermediate layer (CIL) in the Gulf of St. Lawrence and in the subsurface waters on the northeastern Scotian Shelf and off southwest Nova Scotia, temperatures were cooler-than-normal. Temperatures have been moderating in these areas, however, with the exception of St. Pierre Bank where temperatures have remained relatively steady. In the deep basins on the Scotian Shelf and Gulf of Maine temperatures throughout 1997 continued to be above normal and near record highs. Beginning in December, these warm waters were being replaced by cold offshore waters. These cold waters were first observed during the autumn along the continental slope of the Scotian Shelf.

2. Off Newfoundland, the juvenile fish survey in 1997 showed higher zooplankton biomass but no significant difference in nekton, relative to surveys in 1994 through 1996. Abundance of Arctic capelin nekton decreased over the four years of survey. Pelagic 0-group Atlantic cod increased slightly in 1997 for the first time in four years but is still at very low values. Zooplankton surveys during 1997 in the Lower St. Lawrence Estuary suggested an increase in 1997 of mesozooplankton, *Calanus* and krill abundance. All increased relative to 1995 and 1996 but tended to be below values recorded in 1994. On the Scotian Shelf, the geographical distribution of zooplankton and krill in 1997 resembled that observed in 1996. However, there was similar zooplankton biomass along transects taken on the central and northeastern Scotian Shelf, whereas in past years there was higher biomass in the central shelf region. A paper analyzing zooplankton data collected in 1997 proposed the hypothesis that the offshore regions are the source of *Calanus finmarchicus* to the mid- and western regions of the Shelf. This conflicts with the conclusions from earlier studies that the primary source was from the Gulf of St. Lawrence.

3. Five papers were reviewed during the general environmental session. Two papers dealt with physical oceanographic conditions, one presented time series of satellite derived sea-surface temperatures from the Northwest Atlantic and the other described recent salinity changes in the Gulf of Maine and their possible mechanisms. Three papers examined the response of fish to environmental change, one examining environment-recruitment correlations (these tend to be stronger at the limits of the range of the species), another on water temperatures and the catchability

of cod during the groundfish survey in the southern Gulf of St. Lawrence, and the third on the distribution of northern cod with respect to bottom temperature and estimation of cod biomass using potential mapping using SPANS. In addition, there was a presentation on the CPR data followed by a general discussion on the CPR. The FOC noted that the CPR data represent one of the few long-term plankton time series in Canadian waters and recommended that it should be continued.

4. The theme session on Growth and Reproduction of Fish and Shellfish and the Relative Importance of Environmental Forcing attracted a total of 9 papers and 3 additional presentations. These covered four species including cod, haddock, lobster and snow crab and regionally covered areas of Newfoundland, the Gulf of St. Lawrence and the Scotian Shelf. Temperature was identified as an important factor in determining both differences in growth rates between regions and interannual variability within a region. However, effects of density dependence on growth were also found for some cod stocks, especially those in the southern Gulf of St. Lawrence.

5. Presentations were made which updated the FOC on ongoing activities as part of large-scale national and international programs. Participants of Canadian GLOBEC, the U.S. GLOBEC, JGOFS and CLIVAR (Climate Variability) gave separate talks.

6. Reports from the two FOC Working Groups formed in 1997 were presented. A Cod Growth Working Group (CGWG) was established under the chairmanship of K. Drinkwater to investigate the effects of temperature and density dependence on the growth of cod in all major Canadian east coast stocks. Many of the results arising from their work were presented during the Theme Session. The CGWG will continue working through 1998 including undertaking a statistical comparison of changes in growth rates between different Canadian cod stocks. The Environmental Indices Working Group (EIWG) had been asked to document the main physical oceanographic indices presented in the annual overviews and how they are calculated. The EIWG was also asked to recommend standard methods of calculation and analysis. Due to other commitments, this working group did not meet during the past year. The FOC felt that the original mandate needed to be completed. The EIWG was asked to begin the work during the coming year and appointed E. Colbourne as its new chair.

7. The Committee also established a new Working Group on Cod Distribution under the chairmanship of M. Castonguay. This WG will investigate the relative role of temperature and abundance on the distribution of cod in the NW Atlantic including comparative analyses between different stocks.

8. Next year's annual meeting is to be held at the Maurice Lamontagne Institute during the last week of February 1999. The Committee discussed several possible topics for the theme session. The Chairman was requested to make a decision later in the year after further consultations with the committee core-members and the research community at large.

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1. Introduction

The Fisheries Oceanography Committee (FOC) of the Department of Fisheries and Oceans (DFO) met in Dartmouth, Nova Scotia at the Bedford Institute of Oceanography on 24-26 February, 1998, to (1) review the environmental conditions in the Northwest Atlantic during 1997, (2) examine the role of the environmental and other factors on the growth and reproduction of vertebrate and invertebrate fish stocks, (3) review other relevant papers on the environment or fisheries-environment linkages and (4) discuss the research being undertaken in large national and international programs. This report provides a summary of the working papers, discussions during the meeting and recommendations. The approved agenda, list of working papers and meeting participants appear in Appendices 1, 2 and 3, respectively.

2. FOC Core-Membership

While participation in the activities of the FOC are open to all, the Committee formally consists of a number of core-members whose responsibilities are to disseminate information in their respective laboratories and to provide a leadership role within the committee. Since our last meeting, we have had one new member added to the committee. Eugene Colbourne from the Newfoundland Region has joined while Savi Narayanan, formerly a Newfoundland core-member, remains but now represents MEDS in Ottawa. At the time of 1998 annual meeting, the FOC core-members were:

<u>Name</u>	<u>Region</u>	<u>Location</u>
John Anderson	Newfoundland Region	NAFC
Denis D'Amours	DFO Headquarters	Ottawa
Eugene Colbourne	Newfoundland Region	NAFC
Ken Drinkwater, Chairman	Maritimes Region	BIO
Ken Frank	Maritimes Region	BIO
Jacques Gagné	Laurentian Region	IML
Denis Gilbert	Laurentian Region	IML
Glen Harrison	Maritimes Region	BIO
Savi Narayanan	MEDS, DFO Headquarters	Ottawa
Patrick Ouellet	Laurentian Region	IML
Fred Page	Maritimes Region	SABS
Dave Reddin	Newfoundland Region	NAFC
Doug Swain	Maritimes Region	Moncton
John Tremblay	Maritimes Region	Halifax Lab

3. 1997 Environmental Overviews

As part of the FOC mandate, the Committee provides an annual review of environmental conditions in the Northwest Atlantic. A total of 6 papers were reviewed and 3 additional papers were tabled. Two presentations were made without accompanying papers. The tabled papers were

presented at previous RAP meetings and are listed in Appendix 2. As last year, each environmental overview paper was assigned two reviewers to improve the quality of the manuscripts by providing detailed comments, ensuring editorial correctness and possible suggestions for next year's overview papers. Reviewers delivered their comments to the senior authors before the end of the meeting or made arrangements to provide them shortly thereafter. In appliance with recommendations made last year, a physical environmental "scorecard" was introduced and is included below.

3.1 Meteorological and Sea Ice Conditions (*K. Drinkwater et al.*)

Annual air temperatures in the NW Atlantic in 1997 generally cooled relative to 1996. In the northern Labrador Sea, temperatures remained above their long-term means, while those on the southern Labrador coast and in the Gulf of St. Lawrence they were near normal. Along the Atlantic coast from Newfoundland to Cape Hatteras annual air temperatures were below normal (Fig. 1). From the Gulf of St. Lawrence north, temperatures went from extremely warm during the first past of the winter to very cold in the latter half.

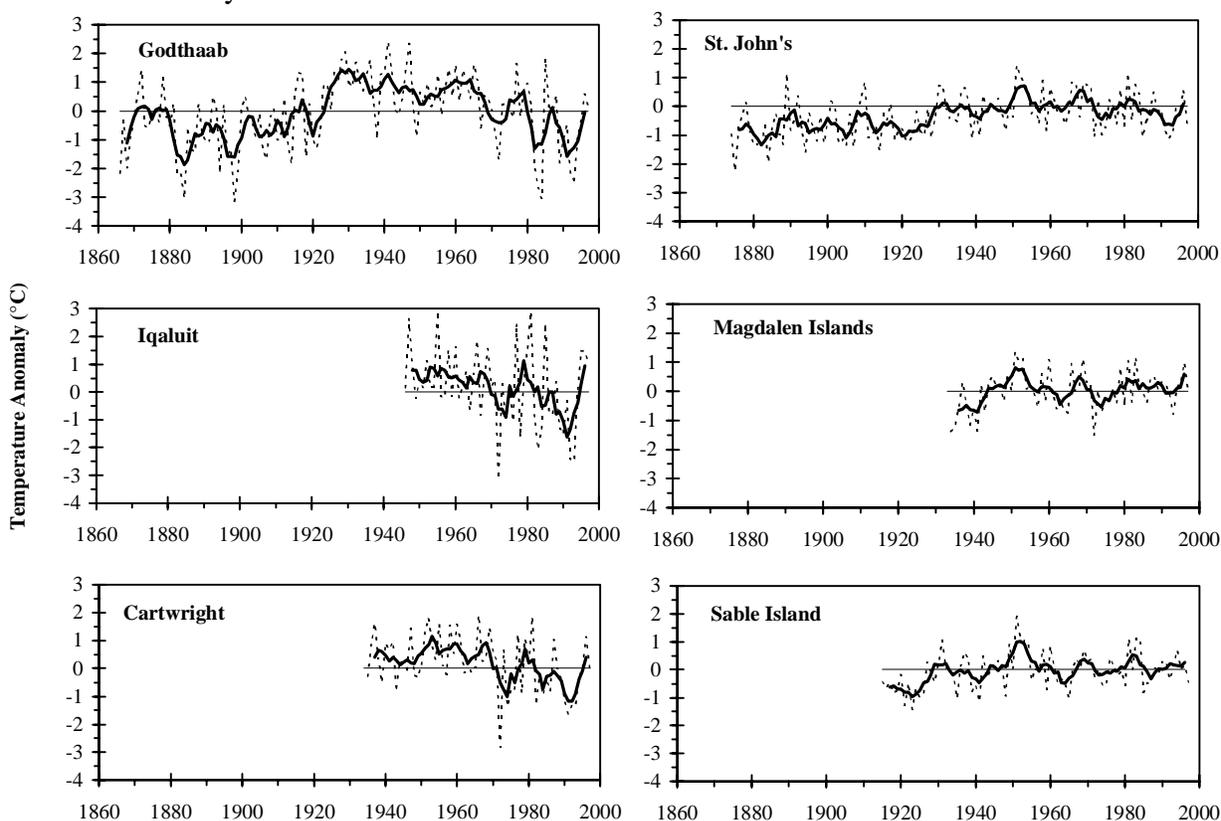


Fig. 1. Annual (dashed) and 5-yr running means (solid) of air temperature anomalies relative to 1961-1990 means at selected sites.

The North Atlantic Oscillation (NAO) index in 1997 was below normal for the second consecutive year but above that recorded in 1996 (Fig. 2). Although the sea ice on the southern Labrador and Newfoundland appeared late and left early, resulting in a shorter duration than usual, the areal

extent in 1997 was greater than in 1996 (Fig. 3). In addition, the numbers of icebergs reaching the Grand Banks increased over 1996 by about 60% but still remained well below the large number of icebergs reported in the early 1990s. In the Gulf of St. Lawrence, the ice in 1997 typically appeared late but remained longer than expected. While the ice also lasted longer than normal on the Scotian Shelf and seaward of Cabot Strait, its areal coverage was lower than normal.

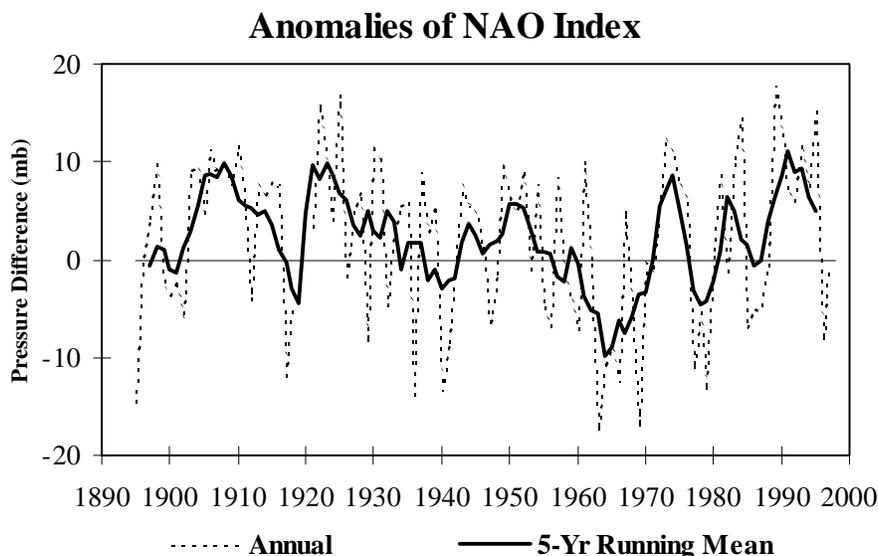


Fig. 2. Annual (dashed) and 5-y running means (solid) of anomalies of the North Atlantic Oscillation (NAO) index.

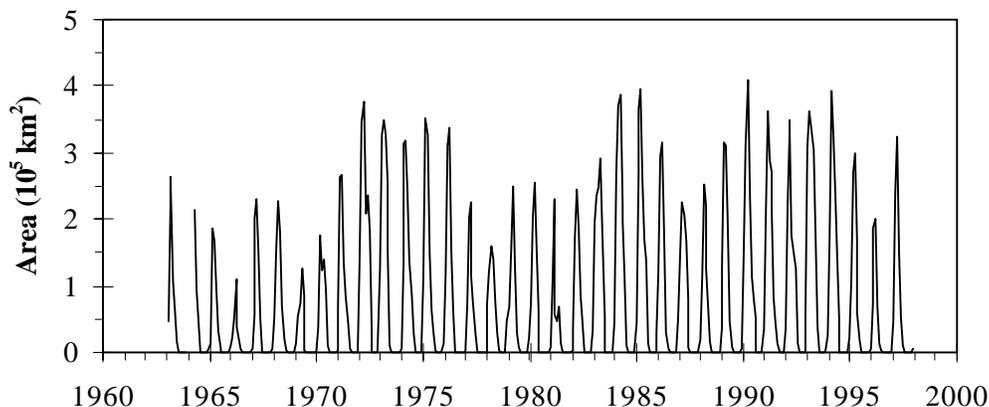


Fig. 3. The time series of the monthly mean area of sea ice off southern Labrador and northern Newfoundland between 45°N and 55°N.

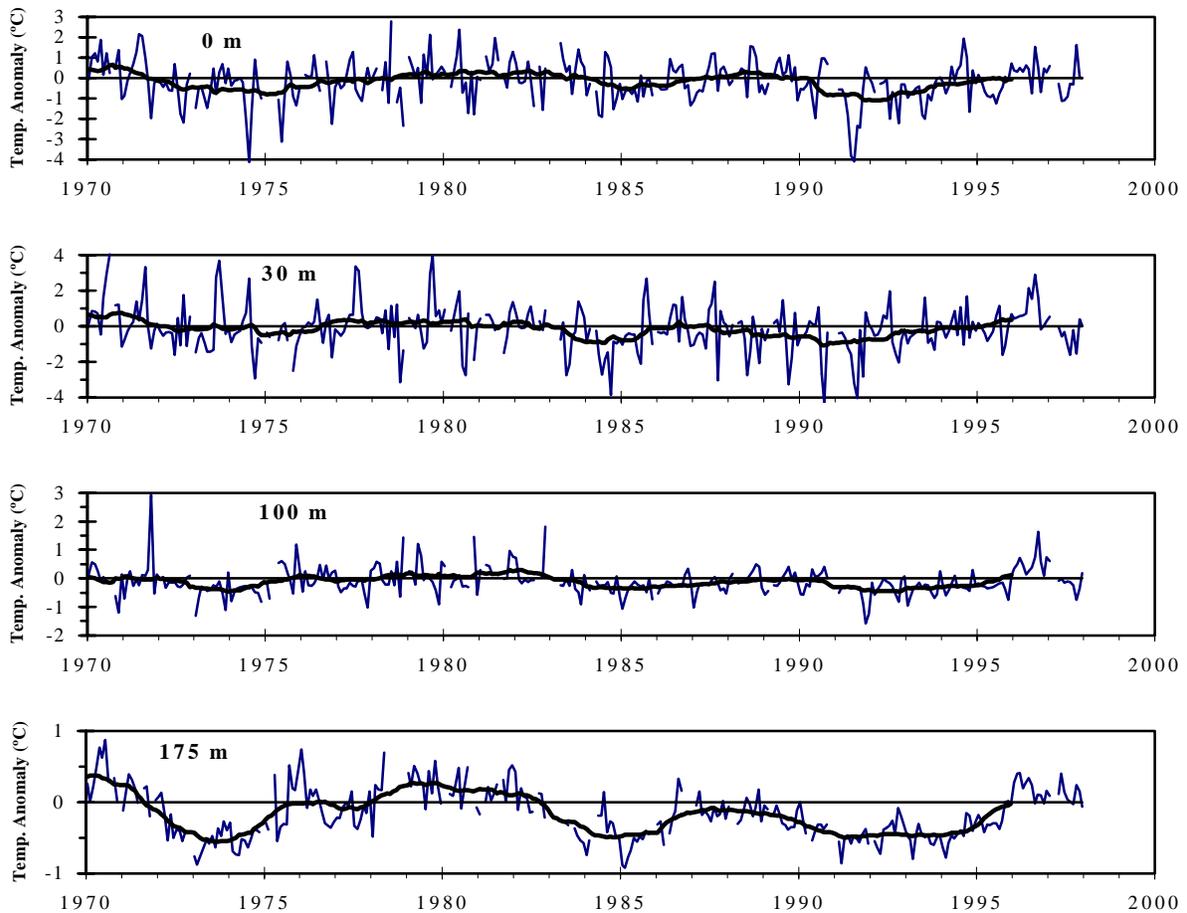


Fig. 4. Monthly and 25-month running means of temperature anomalies at Stn. 27.

3.2 Physical Oceanographic Conditions

3.2.1 *Newfoundland/Southern Labrador (E. Colbourne)*

Water temperatures over many areas of Newfoundland and southern Labrador were slightly above or near normal through 1997, having warmed significantly in 1996 relative to the cold conditions of the early 1990s. This is most evident at 175 m at Stn. 27 off St. John's (Fig. 4). Salinities were fresher-than-normal in 1997 but less so than in 1996. These relatively fresh conditions have dominated through most of the 1990s. There was a smaller amount of cold intermediate layer (CIL) water over the shelves (Fig. 5) although the minimum temperature in the CIL decreased relative to 1996. Bottom temperatures recorded during the groundfish surveys were above normal in most areas. In contrast, temperatures at depths below 50 m off southern Newfoundland in the vicinity of St. Pierre Bank remained cold, and unlike 1996 showed no evidence of moderation during 1997.

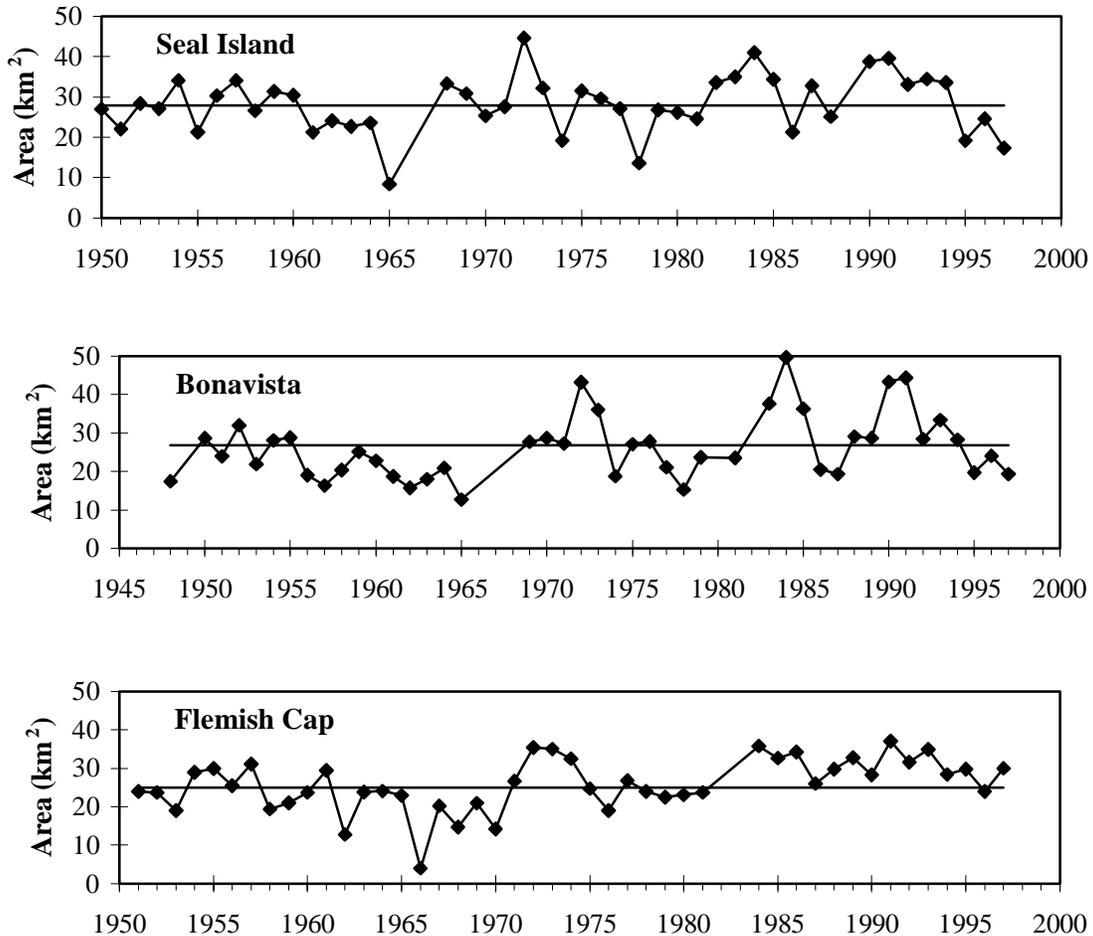


Fig. 5. The CIL area along selected transects. The horizontal lines represents the 1961-1990 mean.

3.2.2 *Gulf of St. Lawrence* (D. Gilbert et al.)

During 1997, colder-than-normal temperatures were observed for the 14th consecutive year in the CIL waters in the Gulf of St. Lawrence. Similar to last year, the minimum CIL temperature during mid-summer did rise slightly compared to the very cold conditions of the earlier 1990s (Fig. 6). The thickness of the CIL throughout the Gulf, as defined by waters $<0^{\circ}\text{C}$, decreased by approximately 5 to 20 m compared to 1996 throughout most of the Gulf and for waters $<3^{\circ}\text{C}$ by between 10 and 50 m. Large areas of the Magdalen Shallows continue to be covered by cold bottom waters during the September annual groundfish surveys although there was evidence of moderating conditions as the area covered by temperatures of $<0^{\circ}\text{C}$ and $<1^{\circ}\text{C}$ decreased for the second straight year (Fig. 7). Deep-water temperatures (200-300 m) at Cabot Strait (Fig. 8) and throughout the Gulf were above normal and rose relative to 1996 conditions.

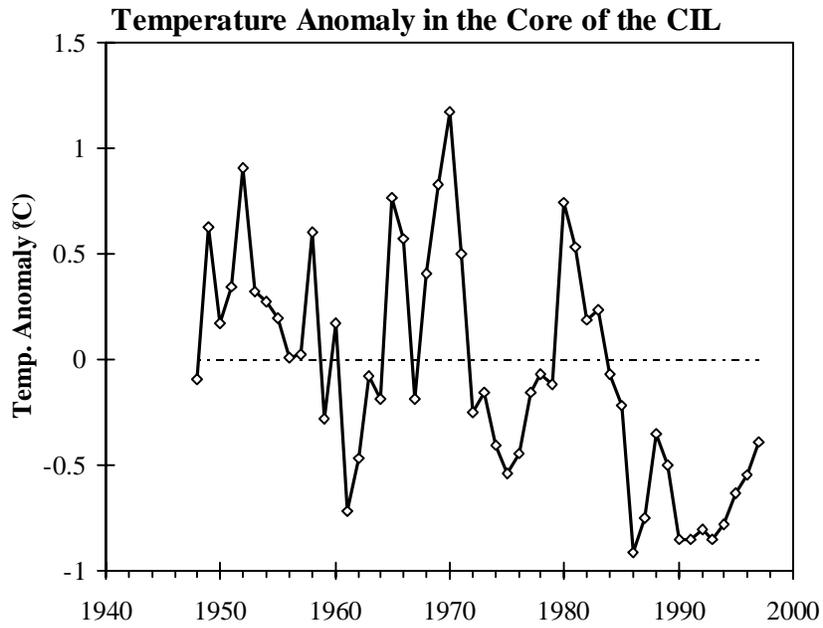


Fig. 6. Mid-summer composite index of CIL core temperature in the Gulf of St. Lawrence.

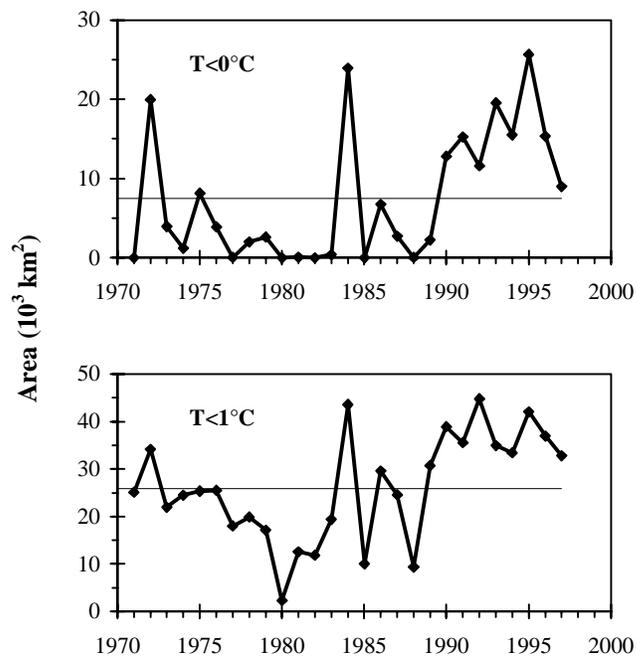


Fig. 7. Area of the Magdalen Shallows with bottom temperatures below 0° and 1°C in September.

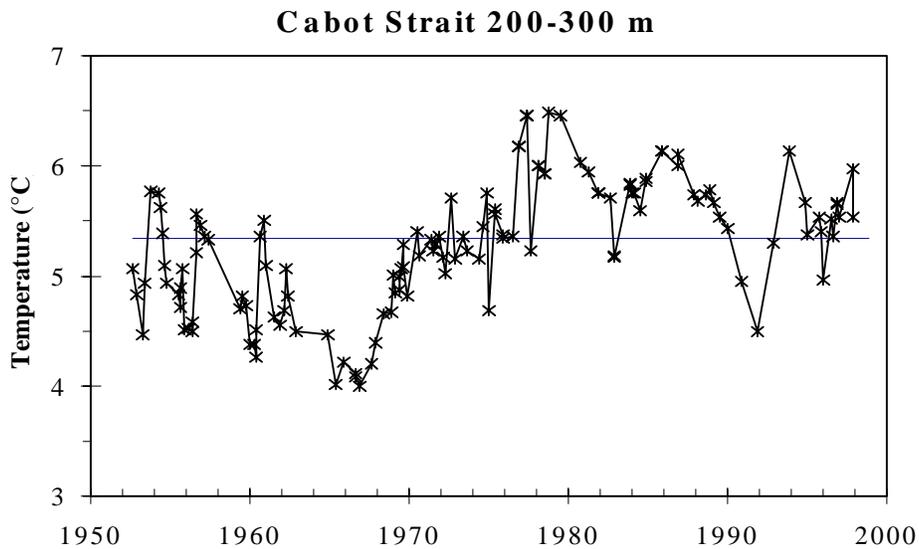


Fig. 8. Average temperature of 200-300 depth layer in Cabot Strait.

3.2.3 Scotian Shelf/Gulf of Maine (*F. Page et al.*; *K. Drinkwater et al.*)

Subsurface waters (>50 m) on the northeastern Scotian Shelf remained cold, continuing a trend that has persisted since the mid-1980s (Fig. 9). Colder-than-normal water was also observed at 50 m over much of the remainder of the Scotian Shelf but less there was less cold water at 100 m and even less near bottom (Fig. 10). In the vicinity of Emerald Basin, warm slope water transported from offshore continued to keep near-bottom temperatures higher-than-average and near the warmest on record (Fig. 10, 11). The waters in the central Gulf of Maine were also found to be warmer-than-average in 1997. For the third consecutive year, sea surface temperatures at Boothbay Harbor and St. Andrews were generally above normal whereas at Halifax they tended to be below normal.

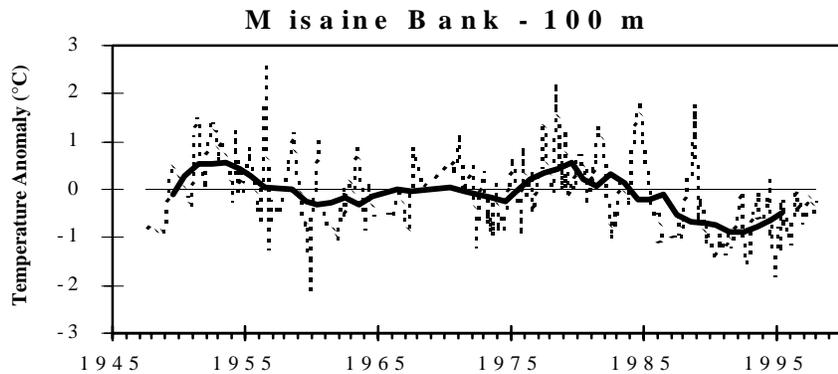


Fig. 9. Temperature anomalies (relative to 1961-90 mean) at 100 m on Misaine Bank.

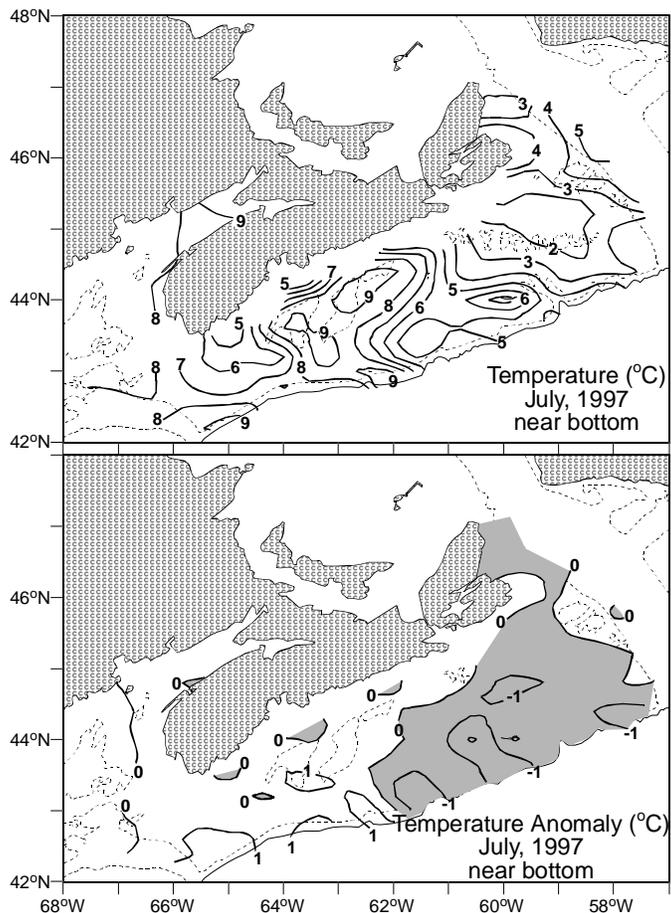


Fig. 10. Near bottom temperature and temperature anomalies (relative to 1961-90 mean) during the July groundfish survey. Negative anomalies are shaded.

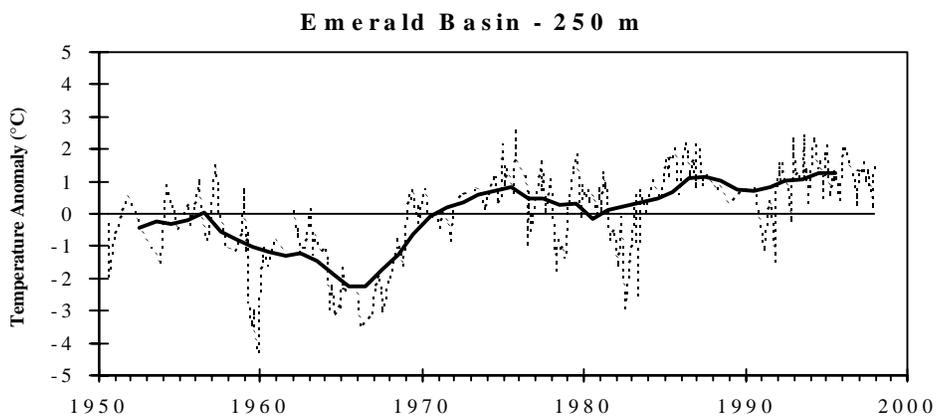


Fig. 11. Temperature anomalies (relative to 1961-90 mean) at 250 m in Emerald Basin.

Table 1. 1998 environmental scorecard. The third column is the sign of the anomaly in the index for 1997 relative to the long-term mean. A + means the index was above normal and - means below normal. The fourth column is the difference relative to the previous year, 1996 and the fifth column relative to the previous five years. A + indicates the index rose and a - that it declined. If there was no change then it was labelled as the same. Conditions associated with warm years are positioned on the left side of the column, cold years on the right and normal conditions in the center.

Index	Area	1997	Compared to 1996	Relative to 1992-1996
NAO		-	+ -	
Air Temperature	Lab/Nfld	+	- +	
	Gulf St. Lawrence	Normal	- +	
	Scotian Shelf	-	- -	
	Gulf of Maine	-	- -	
Sea Ice	Lab/Nfld	-	+ -	
	Gulf St. Lawrence	-	+ -	
	Scotian Shelf	-	+ -	
Near-Bottom Temp	Nfld. Shelf Nov.	+	- +	
	St. Pierre Bank	-	-	Same
	Magdalen Sept	- +		+
	NE Scotian Shelf	- +		+
	Emerald Basin	+	-	-
	Georges Basin	+	-	-
	Bay of Fundy (P5)			
CIL	Nfld	-	Same	-
	Gulf St. Lawrence	+	-	-
Integrated Temp	Stn 27	Normal	- +	
	Cabot Strait	+	Same	Same
Surface Temp	Stn 27	-	- +	
	Gulf St. Lawrence	+	Same	
	Halifax	-	Same	-
	Bay of Fundy	+	Same	+
	Gulf of Maine	+	Same	+
Salinity	Stn 27	Normal	+ +	
	Prince 5	- +		-

3.2.4 Tabled Papers

Three papers on the temperature data collected during the 1997 groundfish surveys from the Scotian Shelf and Georges Bank were tabled but not presented. This was in agreement with a decision made by the committee last year. At the 1997 FOC meeting, the person responsible for these analyses, Fred Page, had suggested, since they are generally presented at the groundfish RAP meetings during the autumn prior to the FOC and the primary results are incorporated within the broader based annual environmental overviews, that these papers need not be presented to the FOC. The FOC agreed but it was conditional on obtaining the agreement of the Marine Fish Division in the Maritimes Region. The Chairman, discussed the matter with Mike Sinclair and Bob O'Boyle during 1997, and both agreed that these papers did not have to be reviewed by the FOC.

3.2.5 Physical Environment Scorecard

In keeping with another recommendation at the 1997 FOC meeting, a physical oceanographic "scorecard" was instituted to help participants keep track of changes in the many standard environmental indices (Table 1). Members felt that while this scorecard helped in summarizing the environmental changes that took place and providing an overall view of conditions, it could be improved. Suggestions included incorporating quantitative information such as the whether the index was in the top 10%, 25%, etc. of their time series. Those involved with the presentations (Colbourne, Drinkwater and Gilbert) were asked to consider possible improvements for next year.

3.2.6 Questions and Discussion

Questions were raised regarding the difference between the warming of the waters over the northern and eastern Newfoundland Shelves and the continued cold waters off southern Newfoundland. The warming appears related to changes in the large-scale atmospheric circulation as reflected in the NAO index. The lower NAO index of the last two years has been accompanied by weaker northwest winds over the Labrador Sea, warmer air masses, less ice and warmer sea temperatures. It was pointed out that the colder-than-normal conditions to those off southern Newfoundland are similar to those experienced in the Gulf of St. Lawrence and on northeastern Scotian Shelf. The mechanisms causing and maintaining these cold conditions, which began around the mid-1980s, are to be investigated as part of DFO's climate program. Both advection and local atmospheric cooling are to be considered.

It was suggested that an overall environmental index using the NAO, air and sea temperatures, the CIL, ice, etc. be constructed for the Newfoundland region. This could be undertaken in other regions as well. It needs to be done from the physical oceanographic perspective since, from the fisheries perspective, the importance of both the relative ranking of the variables and their absolute values will be species dependent.

A new index of the river discharge from the St. Lawrence River system was presented. Statistical comparisons between this new index and the older (RIVSUM) were suggested.

3.3 *Biological Oceanographic Conditions*

3.3.1 *Newfoundland/Southern Labrador (E. Dalley and J. Anderson)*

Plankton and nekton distribution and abundance were described based upon a 1997 late summer pelagic fish survey covering an area from southern Labrador to the Tail of the Banks. Results were compared to 1994-1996 surveys. Surface temperatures increased southward, as is typical for this time of the year, and were higher than those encountered during the 1995 survey but lower than in 1994 and 1996. Mean temperatures at 50 m in 1997 were lower than in 1995 and 1996 but higher than in 1994. The mean total plankton biomass and that of the smallest size fraction of the catch in the bongo nets was significantly higher in 1997 than in the other 3 years. The mean wet nekton biomass (including or excluding jellyfish) ranked second to, but was not significantly different from that recorded in 1995. Capelin was the most abundant species (86% of the total numbers caught in 1997) but its absolute abundance was the second highest after 1994. Mean catches of pelagic 0-group Arctic cod declined steadily since 1994 and in 1997 made up only 3% of the total abundance of all species. In comparison, during 1996 Arctic cod made up 72% of the total abundance from the survey. Larval and juvenile Atlantic cod abundances remained low, although they increased slightly compared to 1996 but remain significantly lower than in 1994.

3.3.2 *Gulf of St. Lawrence (J. Runge)*

Since 1994, an annual zooplankton survey has been conducted in September in order to estimate biomass for an exploratory fishery for *Calanus* species and euphausiids in the Lower St. Lawrence Estuary. The biomass of *Calanus* and total plankton generally increases with depth. Krill biomass is lower than *Calanus* and not dependent upon depth. Zooplankton biomass in 1997 increased over 1996 and 1995 but remained lower than in 1994. Similar trends were observed in krill biomass and *Calanus* biomass. The percentage of the total plankton biomass was over 50% *Calanus*, and less than 10% for each of gelatinous zooplankton and fish larvae. The later two showed no change in percent of the total biomass between 1996 and 1997.

3.3.3 *Scotian Shelf*

Doug Sameoto discussed zooplankton data collected on the Scotian Shelf during 1997. The general pattern of zooplankton distributions and krill biomass concentrations were similar to those seen in 1996 with the western half of the shelf having a higher biomass of krill. In 1997, the total zooplankton biomass was not significantly different between the Halifax Line and the Louisbourg Line and was relatively low. This had not been seen in previous years and is believed to be due to the low biomass levels observed in Emerald Basin during the spring of 1997. The October composition of the dominant copepod species on the Halifax line was dominated by herbivores while on the Louisbourg Line it was dominated by omnivores. Few fish larvae were collected during the April and October sampling and those that were captured were dominated by sand lance and herring larvae. A large mass of cold water observed along the slope edge in October was noted as being unusual.

E. Head discussed the offshore regions as a springtime source of *Calanus finmarchicus* to the mid- and western areas of the Scotian Shelf based upon data collected during 1997 and 1995. In April of 1997, *Calanus finmarchicus* concentrations were high at the shelf break and on the Shelf

along the Halifax Line but low along the entire Louisbourg Line. In contrast, in 1995, the concentrations at the shelf break on both the Louisbourg and Halifax Lines were high while they were low on both lines over the shelf. It was suggested that the high abundance of *Calanus* at the shelf break are associated with the presence of relatively warm, salty water and that they derive from a population which overwinters in the deep offshore waters to the south and east. Slope water intrudes onto the shelf during the winter in the area of the Halifax Line but it appears that the degree of penetration or timing differed between 1995 and 1997, such that shelf population was greater in 1997. Hydrographic properties in the upper 50 m showed higher percentage of warmer, salty waters supporting a greater offshore influence in 1997. In the past, the primary hypothesis was that the *Calanus* came from the Gulf of St. Lawrence.

3.3.4 Questions and Discussion

Inquires were made into whether there were day/night differences in the catch rates during the juvenile fish survey off Newfoundland. Differences between day and night tows were observed in the nekton. Further examination of these differences and their influence upon the results and conclusions are underway.

The committee was reminded that the southern Gulf of St. Lawrence mackerel survey in late June to early July has been collecting zooplankton data since the early 1980s. Jeff Runge noted the strong correlation ($r=0.59$) between mackerel recruitment and zooplankton biomass and RIVSUM that he reported on in detail at the 1995 FOC meeting. This is a potential source of zooplankton data for monitoring purposes. It was also suggested that perhaps other fisheries surveys could be used to collect plankton samples. One problem in this regard is finding available time during the surveys without increasing the number of ship days.

One of the constant concerns regarding most of the plankton surveys is year-to-year uncertainty of funding. This reflects the lack of commitment from DFO for this type of monitoring although there may be some changes in this through the zonal monitoring proposal. The FOC acknowledged the importance of such surveys and fully supports their continuation.

3.4 Environmental Summaries

As in past years, a brief environmental summary was written following the meeting and sent together with the working papers to the Regional Assessment Process co-ordinators for each of the regions. A copy of that summary is provided in Appendix 4. A second summary of the physical environment was assembled and presented in early June to the North Atlantic Fisheries Organization (NAFO) Standing Committee on Fisheries and the Environment (STACFIN) as a research document (*Overview of environmental conditions in the Northwest Atlantic in 1997*, co-authored by Drinkwater, Colbourne and Gilbert, NAFO Res. Doc. 98/38).

4. 1998 Theme Session: Growth and Reproduction of Fish and Shellfish and the Relative Importance of Environmental Forcing

4.1 Introduction

During the past decade or more significant reductions were observed in the growth rates of several fish species off Atlantic Canada. Recent studies suggest that this may, in part, be linked to the presence of extensive cold water. In view of these findings the FOC convened a special theme session on the topic of growth and reproduction. While the FOC was particularly interested in the influence of the environment on growth and reproduction, we encouraged comparisons between the relative importance of the environment with other possible controlling mechanisms such as density dependence and size-selective fishing. Papers were requested on the following and related topics.

- * Evidence of environmental effects on growth and reproduction in fish and shellfish.
- * The relative importance of environment, density dependence and fishing on growth and reproduction.
- * Comparative studies among stocks inhabiting different environmental conditions.
- * Incorporation of environmental factors in marine fish and shellfish growth models.
- * Did (environmentally-driven) changes in growth and reproduction played a role in the collapse of some groundfish stocks?
- * Need to incorporate environmentally-induced growth/mortality rates into assessments.

A total of 11 presentations were given, 9 of which were accompanied by working papers.

4.2 Presentations

S. Campana lead off with a presentation of published results describing the effects of temperature on the growth of cod. Lengths-at-age of cod vary up to 3-fold between Georges Bank and the Gulf of St. Lawrence and have been attributed to differences in bottom temperature. A polynomial expansion of a temperature-based von Bertalanffy growth model appeared to fit the data well, with no residual patterns across most ages, lengths, temperatures, or years. Declines in bottom water temperature since the mid-1980s appear to be responsible for approximately 50% of the observed declines in size at age of the cod stock on the eastern Scotian Shelf.

A. Sinclair described the changes in growth of southern Gulf of St. Lawrence cod between 1971 and 1996 from the groundfish survey data. While there was little variation in the mean lengths at ages 1-3, at age 4 the mean lengths were above 40 cm from 1971-1981 and between 35-40 cm after 1981. For ages 5-7, the mean lengths increased from 1971-1977, then declined in the late 1970s and early 1980s, reaching a minimum in 1985-1987. A similar pattern was observed for ages 8-12, except the time of the maxima and minima occurred slightly later than the earlier ages. The most recently analyzed lengths-at-age are well below the average of the complete time series. The trends in lengths-at-age suggested that changes occurred more by year-class than by year. The estimated von Bertalanffy growth parameters indicated a shift in growth characteristics. The 1973-

1984 year classes had lower L_{∞} (maximum asymptotic length) and higher k values (growth rate) than the 1970-1972 year-classes. The former year-classes thus grew more quickly but achieved a smaller size at older ages than in previous years.

D. Swain tested the effects of abundance and temperature in explaining the observed variability in the size-at-age of southern Gulf of St. Lawrence cod. Using a modified von Bertalanffy growth curve for length following the Miller and Myers method, k and L_{∞} were modelled as functions of temperature and abundance of cod. The results showed both factors induced variations in the growth of southern Gulf cod. The single variable providing the most substantial improvement in model fit was cod-occupied temperature.

A. Sinclair examined evidence for size-selective mortality to explain the reduction in mean length-at-age of southern Gulf of St. Lawrence cod. Regression of back-calculated length-at-age 3 from otoliths versus age of capture indicated size-selective mortality of large and small fish as well as neutral selection. For the 1968-72 year-classes, for example, the back-calculated lengths increased with age suggesting that larger fish had a higher probability of surviving to older ages than smaller fish. On the other hand, for the 1979-81 year-classes, the smaller fish had a higher probability of surviving, while for the 1973-78 year classes there was no trend. The conclusion was that the population mean length-at-age of southern Gulf cod has been influenced by size selective mortality but that care must be taken in its interpretation.

A. Sinclair discussed an investigation of the range of individual size-at-age and growth trajectories of southern Gulf of St. Lawrence cod in relation to changes in population mean size-at-age. Lengths-at-age of individual fish collected during the September groundfish surveys over the period 1971-97 showed two different growth rates or "morphs". The 1966-69 year-classes had relatively linear growth patterns, reaching average lengths of approximately 100 cm by age 15. For the 1970-1978 year classes, the spread of lengths at ages 7+ increased and in several cases there was a bi-modal distribution of size at age 10+. Comparison with the 1966-69 year-classes indicated overlap of the larger individuals, but the later year-classes had smaller individuals than the earlier year-classes. By the 1979 year-class, the population was dominated by smaller individuals at age. In the year-classes after 1982, corresponding to the year-classes since the imposition of the moratorium, there has been an increase in the range of size-at-age. The study went on to examine what would happen in the case of 2 growth morphs subjected to size selective commercial fishing. The effects of fishing on the abundance of the 2 morphs differed according to their age and thus the relative proportion of their populations varied through time. The result was that the population mean length reflected neither of the two morphs, but rather jumped from the slow growing to the fast growing at older ages.

M. Castonguay presented the results from a study examining possible causes of the cod collapse in the Gulf of St. Lawrence. The Gulf cod have the smallest size-at-age of any of the Canadian stocks. Study results suggest that the fishery in the northern Gulf removed fast-growing fish at age 4 and slow growing fish at age 8, with no selection at age 6. The size and condition declines in the 1980s and 1990s were not driven by the fishery, however, since back calculations of

cod lengths-at-age failed to show evidence of higher fishing mortality (F) in the fast growing fish. The changes in size-at-age did coincide with changes in the distribution of cod and followed closely changes in the CIL temperatures. The latter indicated below normal temperatures from the mid-1980s to at least the mid-1990s. It has been well documented that cod living in cold water are characterized by smaller size-at-age and inferior condition, however, they also realize an increasing percentage of the maximum growth rate. With low growth rates and poorer condition fish more fish were needed to reach the TACs. The study thus concluded that although the primary cause for the collapses of cod stocks in Canada was the excess fishing pressure, environmental conditions explained why some stocks collapsed while others did not. Future work will examine whether the collapse can be attributed to a sudden increase in natural mortality. This may be linked to the environment through the lower growth rates and subsequently lower survival.

G. Lilly provided a brief overview of studies in size-at-age and condition of cod from southern Labrador to the Grand Bank. Length-at-age data generally show declines for cod ages 3 and older from the late 1970s through to the 1990s with the largest declines in the north (2J) and the least in the south (3L). Fulton's condition index for cod ages 3-6 showed low values during 1990-1993 in both 2J and 3K but not in 3L. The liver index showed different trends with low values from 1990 to the present in 2J but high values in 3L. The liver index in 3K was intermediate between the two. A review of studies that have shown the effect of temperature, density dependence and the stock size of capelin on the growth and condition of cod was then presented. All three factors appear to influence cod growth and condition but their relative importance varies by division. Some of the difficulties in developing better relationships with capelin and feeding in general include the need for a composite index of capelin biomass, better understanding of changes in distribution of capelin and a measure of the duration of the feeding period for cod.

C. Taggart (no working paper) presented results from studies Dalhousie University are conducting on Western Bank. The presentation focussed upon whether Atlantic cod have been spawning on Western Bank in spite of the very low spawning stock biomass. This low biomass lead to the present moratorium on the fishery. The study, undertaken as part of the Canadian GLOBEC program, has been ongoing over the past few years. Results indicate that the cod have been spawning on the Bank. Similar to findings during the late 1980s, the spawning has been concentrated during the fall.

K. Frank (no working paper) discussed the length-at-age variation of eastern Scotian Shelf haddock. The haddock have recently been re-aged to correct ageing errors that persisted over a number of years. In past analyses, the 4VW and 4X haddock stocks were linked together but examination of the new length-at-age from the two areas show distinct differences that would argue against any such connection. The lengths-at-age for 4VW fish older than 2 years show a distinct decline during the mid-1980s. The timing of the decline matches closely the decrease in bottom temperatures in the northeastern Scotian Shelf. Also, the length-at-age for the older fish has remained low through the 1990s, corresponding to a time period of continued cold temperatures.

B. Sainte-Marie presented a paper on the possible effects of changes in the temperature and thickness of the cold intermediate layer (CIL) on the population of snow crab in the Gulf of St.

Lawrence. Since the mid-1980s, the CIL in the Gulf has been thicker and colder than normal. This cold period has lasted for more than one generation of snow crab and may have had major effects on the distribution and population dynamics of the species. Spatial distribution of snow crab may have increased during the cold period, while egg production declined owing to a shift from a 1-yr to a 2-yr duration for egg incubation. Maturation and size for terminal molt in both sexes are apparently, in part, temperature-dependent. Cohorts with immature individuals subject to the recent cold period express earlier maturity, and a large fraction of males are undergoing terminal molt at sublegal sizes. These changes may have important consequences for reproductive processes and may directly affect fishery performance.

M. Comeau examined the growth increments of lobsters from the southern Gulf of St. Lawrence using streamer tags. Lobsters ranging in size from 56 to 87 mm of cephalothorax length (C_1) were separated into 5 groups: premolt males, females and berried females and postmolt males and females. Significant differences were observed between growth increments of pre and postmolt lobster of the same gender. The lower average growth of the premolts is believed to be related to tagging trauma. A significant difference was also observed between genders in the same molting condition. The lowest average growth increment was observed for berried females. Furthermore, a decrease in growth increments in relation to C_1 was observed for female lobster tagged in postmolt and both male and female lobsters tagged in premolt. A constant relationship was observed for male lobsters tagged in postmolt and berried female tagged in premolt. This reduction in the percentage of growth increment with increased C_1 seems to be related to maturity for females and tagging trauma for males.

J. Tremblay discussed molt timing and growth of lobster off northeastern Cape Breton Island. Seasonal changes in molt condition together with mark-recapture data were used to estimate molt timing and growth of adolescent and adult lobsters in the St. Ann's Bay area during 1993 and 1994. In both years, most molting occurred between late July and early September. Within the larger sizes (>70 mm carapace length), males molted earlier than females, but there was extensive overlap in their molting periods. Annual differences in molting time were apparent and were linked to bottom temperature. Double molting was rare and limited mainly to pre-recruit lobsters. From spring to autumn, there were substantial changes in trap catch rate, size composition and sex ration. Males dominated the catch in late summer and fall, probably because they molted earlier than females. Within-season and between-year changes in catchability associated with molting need to be accounted for if trap catch rates are to be used as indices of lobster abundance and for estimation of exploitation rates.

3.3 Questions and Discussion

During and following the presentations, many questions were asked concerning the details of the models, their assumptions and the data that were used to test them or from which various parameters were derived. It was clear, however, that temperature is an important influence on the interannual changes in growth of several species (cod, haddock, snow crab, lobster). Other factors such as density dependence and size-selective fishing also had effects but the relative importance of the various influences were generally not established.

A number of general suggestions were put forward. It was noted that back calculations of lengths-at-age (for example, Atlantic cod) have shown important results but the methods used by different groups need to be standardized. Comparison of results between stocks is often hampered by differences in data and the analyses used. It was suggested that a comparative study using similar analysis be carried out on cod, for example. This will be undertaken within the Cod Growth Working Group (see section 7). Several factors need to be included in the analyses, where possible, in order to establish the relative importance of environment and other mechanisms. It was recognized that changes in growth are linked to changes in reproduction and age-at-maturity but that these two effects were generally not considered in most of the papers. Further analyses on the growth of invertebrates and their links with environmental change was encouraged.

For the slow and fast growing fish identified in the Gulf of St. Lawrence, it was suggested that an examination of their spatial distributions be carried out. Although a cursory view indicated no obvious differences in distribution between these fish, it was felt to warrant a further look.

5. General Environmental Session

Each year the FOC receives several papers on topics unrelated to the major theme session. This year the committee reviewed 5 papers in this category and had one additional presentation.

5.1 Presentations

C. Mason presented monthly climatologies and surface temperature anomaly maps for four regions in the Northwest Atlantic (Scotian Shelf, Gulf of St. Lawrence, Newfoundland Shelf and the World Ocean Circulation Experiment (WOCE) region at 35-67°N, 35-77°W. The dataset covers the period October, 1981 to December 1996 and is derived from the Jet Propulsion Laboratory (JPL) weekly global satellite imagery 18 km gridded multi-channel sea-surface temperature (MCSST) from the daytime NOAA Advance Very High Resolution Radiometer (AVHRR). Comparisons of in situ and satellite-derived temperatures over a range of -1.7° to 17.8°C indicate that the two datasets agree to within 1.45°C. This error represents the largest standard deviation of the temperature differences. The MCSST dataset was found to be useful in determining the annual temperature cycle over the northwest Atlantic.

P. Smith analyzed 3 years (Oct. 1993-Sept. 1996) of monthly mean current, temperature and salinity data from moorings in the Gulf of Maine inflows off southwest Nova Scotia and in the Northeast Channel. They revealed (1) a peak inflow near-surface in spring versus late summer at depth, (2) a maximum near-surface cross-channel flow toward Georges Bank in late winter and (3) the absence of a significant salinity cycle anywhere in the water column. It was found that increased (decreased) inflow in the Northeast Channel was associated with positive (negative) temperature and salinity anomalies in the Gulf and reduced (increased) inflow off southwest Nova Scotia. Freshening in 1995 and 1996 in the Gulf of Maine was due to a change of mixing ratios among the Maine Coastal, Warm Slope and Scotian Shelf Waters and not a change in the character of these water masses. This was consistent with increased inflow from off southwest Nova Scotia that is believed to be due to advection from the Newfoundland shelves.

R. Myers reviewed the role of environmental variability in the survival of juvenile fish and shellfish by examining the success of previously published environment-recruitment correlations when tested with new data. The proportion of published correlations that have been verified upon retest is low. One generalization stood out; correlations for populations at the limit of a species geographic range have often remained statistically significant when re-examined. An examination of previous relationships also showed that only 1 out of 47 studies is currently used in the estimation of recruitment in routine assessments.

D. Sameoto (no working paper) gave an up-date on results from the CPR data. The CPR survey is the only biological monitoring program that operates on an ocean basin scale. It is unique in that the methodology and plankton analysis procedures have been maintained with little change for more than 50 years. The CPR data have been shown positive and negative linear trends from 1948 to 1995 in the northeast Atlantic and the North Sea where the program has been operating the longest. The spreading of anomalously cold waters from the Arctic may have contributed to the decline in phytoplankton north of 59°N while to the south of this latitude the phytoplankton season length and abundance has increased. Decadal variability of the zooplankton abundance of some species in certain areas shows statistical relationships with environmental variables such as the NAO index and the inflow into the North Sea. Up dates on the CPR collections from the northwest Atlantic were also presented. The concentration of *Calanus finmarchicus* generally increases from east to west over the Scotian Shelf and Gulf of Maine. There tends to be large interannual fluctuations in the concentration of *C. finmarchicus*, the causes of which are unknown. There is little year-to-year persistence in the concentrations, however, such that one cannot predict the size of next year's population from the current year's values. The levels of *C. finmarchicus* stage 5-6 on the northeastern Scotian Shelf were lowest during the period 1991-1994 compared to data collected in 1961-76 while levels of arctic species (*C. hyperboreus* and *C. glacialis*) were at their highest levels. Also since 1991, *C. finmarchicus* appears earlier in the spring compared to the previous period. The colour index from the CPR data was significantly higher during the 1991-1994 period and is positively correlated with the total amount of copepods, but only weakly.

D. Swain investigated the effects of water temperature on the catchability of cod by the bottom-trawl during the annual groundfish survey in the southern Gulf of St. Lawrence. Survey catch rates of southern Gulf cod were correlated with most indices of cod distribution and environmental conditions. Tests involving sequential population analysis (SPA) calibration or residuals from a multiplicative analysis of catch rates did not support the hypothesis that these correlations reflected effects of distribution or environmental conditions on catchability or availability to the survey. Catchability was unaffected by variation in cod distribution in relation to temperature or depth which supports an earlier conclusion that depth and temperature distributions of southern Gulf cod are density dependent. The apparent changes in catchability to the survey may actually reflect changes in natural mortality. Analysis provided support for an environmental effect on availability; however, this had a negligible effect on abundance indices from the survey.

G. Lilly presented a paper by D. Kulka on the spatial distribution of northern cod relative to bottom temperatures and the estimation of cod biomass from potential mapping using the software package SPANS. The technique interpolates data between point biomass estimates to produce a continuous stock density map. Results indicate that in the early 1980s the 2J3KL cod were aggregated into four areas during the autumn; a northern group stretching along the Labrador coast (51°N) to the shelf edge north of 54°30'N, a middle group along the shelf edge between 51°30'N and 53°N, a southern group along the northeast slope of the Grand Bank to 50°30'N and a group on the Grand Bank at the border of 3L and 3NO. Some of the interannual variation in distribution within these groups depended upon the relative timing of the survey to the inshore-offshore cod migration. This pattern started to change after 1985 as the northern group started to diminish. It was the largest concentration from 1983 to 1988 and was the first to disappear from the Labrador Shelf during the collapse of the stock. At the same time, the middle and southern groups first increased in the extent of the high-density areas and biomass but then rapidly declined until 1993 by which time only a small remnant of the southern group was left. During 1989 to 1991, the remaining cod aggregated, peaking in 1990 at 95% of the biomass concentrating in 20% of the area. Along the Labrador coast where the bottom temperature was more variable among years, the cod distribution appeared to vary somewhat independently with respect to temperature. There was no downturn in the fall bottom temperatures during the period of decline. Bottom temperature appeared not to change the behaviour of the migrating cod or directly drive the decline of the stock. On the other hand, the pattern of disappearance of the concentrations with respect to the pattern of fishing offshore suggests that fishing pressure was also not the primary cause of the decline.

5.2 Discussion

A long discussion followed the presentation on the CPR data. Given that these data have proved value in documenting long-term changes in the plankton community in the northeast Atlantic, and are beginning to be used to document apparent changes in the northwest Atlantic, *the FOC recommends (1) continuation of the CPR data collection in the northwest Atlantic including the Iceland to Newfoundland (Z) line and (2) further analysis to document how representative they are and to better quantify their seasonal and interannual variability.* Of particular note is the need for improved coverage in April and May during the period of the spring bloom. In many years there were no data for these months.

6. Reports on National and International Research Programs

At the 1997 FOC meeting it was noted that a number of important national and international oceanographic programs are presently ongoing. In order that the committee might keep up to date on the research that is being conducted and the results, the Chairman was asked to contact individuals from a number of these programs to make presentations to the FOC. Representatives of Canadian GLOBEC, US GLOBEC, JGOFFS and CLIVAR agreed to make presentations.

6.1 Canadian GLOBEC

J. Loder began by providing an overview of the work being undertaken under the Canadian Global Ocean Ecosystem Dynamics (GLOBEC) program. The objective of the international GLOBEC program is an understanding of how physical and biological processes affect the ecosystem in the ocean. The Canadian component of GLOBEC is divided into two components. On the Atlantic coast it focuses upon zooplankton and demersal fish (cod) whereas on the Pacific coast of Canada it emphasises zooplankton and pelagic fish, especially salmon. The program is a collaboration of university and government scientists and is funded for 1996-2000 by DFO and NSERC. The remainder of his talk highlighted the program underway on the east coast of Canada.

The Atlantic Canadian GLOBEC program seeks to determine the importance of environmental regulation of fish production, i.e. direct physical influences versus planktonic food supply to the early life stages. Work focuses upon fish nursery areas on the Scotian Shelf and in the Gulf of St. Lawrence and upon *Calanus* distributions on the NW Atlantic. The main program consists of 3 modelling projects and 4 field projects. The former includes (1) ecological modelling of *Calanus finmarchicus* in the Northwest Atlantic, (2) the effects of circulation on the seasonal and interannual variation in abundance and distribution of *Calanus* in eastern Canadian waters, and (3) hydrodynamic and lower trophic level influences on gadoid production and stock structure on the Scotian Shelf. The field studies include projects on (1) production, growth and retention of zooplankton and ichthyoplankton on Western Bank on the Scotian Shelf, (2) turbulent mixing and feeding ecology of larval fish, (3) relationship between growth rates of larval fish and zooplankton supply and production on banks of the Scotian Shelf, and (4) temperature, feeding success and interannual variations in pre-juvenile growth, linking climate, zooplankton dynamics and recruitment of commercial fishes. The field studies will be completed by early 1999.

J. Loder went on to provide further details of modelling project number (3). Its overall goal is to identify and develop quantitative linkages among the hydrodynamics regime, lower trophic levels and various life stages of gadoid populations on the western and central Scotian Shelf. Retrospective analysis of data from the Fisheries Ecology Project (FEP), the Scotian Shelf Ichthyoplankton Project (SSIP), GLOBEC and other sources are being carried out. Interpretation, exploration and synthesis of the data are being attempted using both a 3-d hydrodynamics model and an individual-based biological model. Initial results from the seasonal circulation model of the Scotian Shelf and the interannual variability in transport over the Shelf were presented.

J. Runge outlined modelling efforts to examine individual zooplankton behaviour. In these studies there is a close linkage between the physical characteristics (e.g. temperature and circulation) and the plankton. N. Shackell discussed briefly some of the results from the work on gadoid fish. This component included an examination of the spatial evolution of year classes and stock discreteness of cod, haddock and pollock. Of particular interest is relationship between Browns Bank haddock stocks and those in the Bay of Fundy.

Information on Canadian GLOBEC is available on the web at <http://www.globec-canada.mun.ca/globec/>.

6.2 U.S. GLOBEC

P. Smith gave an overview of the U.S. GLOBEC program. Its ultimate goal is to predict changes in the distribution and abundance of major commercial species as a result of changes in their physical and biotic environment, as well as to anticipate how fish populations might respond to climate change. The work has focussed upon the population dynamics of key species (cod, haddock and 2 species of zooplankton-*Calanus finmarchicus* and *Pseudocalanus*) on Georges Bank. Special attention is paid to the coupling of the dynamics to both the physical environment and the predator-prey fields. The main components include (1) a broad-scale, long-term study, (2) process-oriented field studies and (3) modelling and retrospective analyses. The broad-scale studies include at least annual occupation of 40-50 hydrographic and biological stations over the Bank and vicinity, current measurements using both moored instruments and drifters, and acquisition and analysis of satellite data. The process-oriented field program includes work on density stratification (1995), retention and exchange (1997) and cross-frontal exchange (1999). Also population studies to examine the distribution, survival, growth and abundance of various cohorts was carried out in all field years (odd-numbered years). The modelling has focussed upon development of regional models as well as process-oriented modelling. The models have been used to examine the transport of plankton and larvae to and from the bank at different times of the year. One of the unexpected results of the program has been the identification of hydroids as a prey of cod larvae. In addition, analysis of satellite data has revealed a number of "crossover" events, whereby cold surface waters from the Browns Bank area moves directly onto Georges Bank. These events may be one mechanism whereby cod, haddock or pollock larvae are transported from Browns to Georges.

6.3 The Canadian Joint Global Ocean Flux Study (JGOFS)

G. Harrison presented an up-date on JGOFS. This is a decade-long study of the natural and anthropogenic CO₂ cycles in the ocean aimed at reducing uncertainties in the understanding of atmosphere-ocean exchanges, transformations and transport in the water column and burial on the sea floor. A number of international programs have been completed during Phases 1 and 2 of JGOFS, including work in the North Atlantic, the Equatorial Pacific, the Arabian Sea and the Southern Ocean. Under Phase 3, the Canadian effort has been on carbon cycling and export in the Labrador Sea and runs from 1998 to 2002. It is a co-operative program between 4 DFO laboratories, 8 Canadian universities and 8 foreign universities. The central hypothesis to be tested is that in the Labrador Sea, the unique combination of physical and biological processes results in a large and regionally important export of carbon to the ocean interior. This export is believed to occur through deep convection in winter and in the form of particulate biogenic carbon such as phytodetritus, fecal pellets, etc. during periods of high biological activity in summer.

6.4. Climate Variability and Predictability (CLIVAR)

A. Clarke provided the FOC with an outline of a new climate program. CLIVAR is in the planning stage and input into the program is still being sought. Its aim is to increase our understanding of the climate, its variability, and the major forcing mechanisms. Another important

aspect of CLIVAR is to be their examination of the extent by which we can predict climate changes on seasonal to interannual time scales. The program is designed to increase data collection, undertake further analysis, and develop as well as apply models of the coupled climate system. The program is global in scope with 9 principal research areas. The two components of most interest to the FOC are those dealing with the North Atlantic Oscillation (NAO) and on the thermohaline circulation in the North Atlantic. The former will examine in detail the atmospheric processes that contribute to the formation of the NAO and determine what, if any feedback mechanisms may be operating between the atmosphere and the ocean. The latter component will examine oceanic heat transfers in the North Atlantic including the Gulf Stream and deep convection in the Labrador and Greenland Seas. It will attempt to determine the sensitivity of the thermohaline circulation to changes in the surface fluxes, to understand the critical physical processes, to determine the space-time characteristics of the variability that may be related to thermohaline circulation over the past 1000 years and establish the degree of predictability in the influence of the circulation pattern on the atmospheric climate. The CLIVAR implementation plan will be published soon and will include review chapters that should be of interest to FOC members. The CLIVAR website can be found at www.clivar.ucar.edu.

7. General Business

7.1 Stock Status Reports

During the meeting, the FOC was provided draft Stock Status Reports (SSRs) on the State of the Ocean for Newfoundland (by E. Colbourne), the Gulf of St. Lawrence (by D. Gilbert) and the Scotian Shelf (by K. Drinkwater). These were reviewed and some editorial suggestions were made to the authors, which they will incorporate into their SSRs. The zonal Stock Status Report encompassing the Northwest Atlantic was not in draft form as it includes information from the three regions. K. Drinkwater proposed some specific wordings based upon revisions on last year's SSRs. The authors are to produce the final versions of the SSRs and submit them through the regions and in the case of the zonal SSR to Ottawa directly.

7.2 FOC Working Groups

7.2.1 Cod Growth Working Group Report

Members-Martin Castonguay, Don Clarke, Ken Drinkwater (Chairman), Jean-Denis Dutil, Paul Fanning, Dominique Gascon, Joe Hunt, Allan Sinclair, and Doug Swain

The CGWG conducted two conference calls and one meeting during the past year. Topics discussed included objectives, available data, identification of which stocks to analyze (2J3KL, 3Ps, 4RS/3Pn, 4T/4Vn, 4VsW, 4X and 5Z), determination of the types of analysis that would be carried out and what progress, if any, had been made. It was agreed that initially working group members would investigate the relative effects of temperature, density dependence and size-selective fishing on their particular stocks using available information. The progress achieved during the year varied greatly amongst the members and some of the results were presented during the FOC special theme

session on Growth and Reproduction. At the last meeting of the working group held in St. John's, members agreed that they would like to continue the working group into 1999.

The FOC confirmed the continuation of the CGWG with the present membership for the 1998-1999 year with the following mandate:

1. To continue examination of the relative importance of temperature, density dependence and size-selectivity by fishing on the growth rates of the major cod stocks off eastern Canada.
2. To undertake comparative analyses between stocks using standardized methods.
3. To report to the FOC at the 1999 annual meeting.

7.2.2 Environmental Indices Working Group Report

Members: Eugene Colbourne, Ken Drinkwater, Denis Gilbert, Fred Page (Chair)

Due to other commitments the work that the FOC requested of this group was not carried out. The EIWG still felt that documentation of the data, their sources and methods of calculation was still needed. They, therefore, asked that the working group be maintained. Fred Page asked to be relieved of his duties as Chair and member of the working group due to other commitments.

The FOC felt that the work originally proposed for the EIWG should be carried out and agreed to extend the working group through the 1998-1999 year under the Chairmanship of E. Colbourne and members K. Drinkwater and D. Gilbert with the following mandate.

1. To list the major physical environmental indices used in the overviews and document both the sources of the data and, if required, how they are calculated.
2. To recommend standardized indices and methods of estimating similar types of indices.
3. To place the main indices on the worldwide web.
4. To report to the FOC at the 1999 annual meeting.

7.2.3 Formation of the Cod Distribution Working Group

The FOC was requested by the Maritimes Region (Mike Sinclair) that a working group be formed to investigate the relative roles of changes in temperature and abundance in determining shifts in the distribution of cod in the northwest Atlantic. At present there is no consensus but the interpretation is important in trying to sort out the causes of the declines in the diverse cod populations. Different methods are being used by different researchers. Some analyses have been

published and others have not. It would be very useful to determine if there a consensus can be reached on the degree to which the changes in bottom temperature have caused changes in cod distribution, and how the role of temperature may vary geographically. The FOC agreed to form the CDWG with the following members and mandate.

Members: Martin Castonguay (Chair), Fred Page, Doug Swain, Kees Zwanenburg

Mandate:

1. To investigate the different methodologies used to examine the relative roles of temperature and abundance on the distributional changes of cod.
2. To determine the relative usefulness of RV and commercial data to examine distributional changes.
3. To conduct comparative analyses of distributional changes in the major Canadian cod stocks.
4. To conduct a workshop in the autumn of 1998 where analyses would be presented. A report on the workshop results will be written.
5. To report to the FOC at the 1999 annual meeting.

7.2.4 Further Discussion on Working Groups

While the FOC discussed the possibility of forming additional working groups, it felt that none were needed at the present time. Concern was expressed over the formation of too many working groups, fearing that the heavy work schedules of most of the scientists might not result in the work being carried out. At the same time the FOC decided that more working groups could be formed in future years if important or pressing issues arose.

7.3 *Other Business*

No items were brought to the FOC under other business.

7.4 *Next Year's Meeting*

7.4.1 Possible Theme Sessions

The FOC discussed a number of possible theme sessions for the 1999 meeting. These included the following.

- a. The Recover of Atlantic Cod in the 1970s and early 1980s. Following the declaration of the 200-mile offshore limit by Canada, the cod stocks throughout Canadian waters immediately began to

recover from extremely low abundance levels prior to the declaration. Recruitment and survival was generally high and growth was good. It was generally thought that managerial decisions contributed to the quick recovery and decisions were made to increase fishing pressures. What were the differences between the 1970s and the 1990s when there has been no significant recovery to date after the declaration of the cod moratorium?

b. Biological-Physical Modelling. During the last decade there has been rapid development of shelf circulation models and of application of these models to biological problems. Initially, most of the applications were directed to advection of plankton and fish eggs and larvae but presently there has been work (e.g. within GLOBEC) on the dynamics of the plankton and/or larvae that includes information from the physical models. The FOC thought a general discussion of the models, their successes, their limitations and the future would be beneficial to the fisheries community.

c. Forecasting and Prediction. More and more, there are requests to forecast the environment on time scales of use to the fisheries managers, i.e. annual to decadal. It was felt that a theme session that address possible methods of prediction and forecasting environmental variables would be timely. This would include statistical analyses based on persistence (i.e. autocorrelation) of the particular variable in question or prediction from lagged correlations with other variables and dynamical modelling. Information on how reliable such predictions might be, would also be useful.

The FOC felt that further consultation with other core members not attending the business meeting, as well as the wider scientific community, was needed before a final decision should be made. It was left to the chairman to solicit advice and to make a decision on next year's theme session topic later in the year.

7.4.2 Date and Location

The next annual meeting will be held at the Institute Maurice-Lamontagne in Mont Joli, Quebec, during the last week of February, 1999.

Appendix 1: Agenda

FOC Annual Meeting, February 24-26, 1998 Ocean Sciences Boardroom, 4th Floor Bedford Institute of Oceanography, Dartmouth, N.S.

Tuesday, Feb. 24

- 9:00 Introduction and administrative details
- Chairman

1997 Environmental Overviews

Physical Environment

- 9:15 Ken Drinkwater, Roger Pettipas and Liam Petrie
- *Meteorological and Sea Ice Conditions off Eastern Canada in 1997.*
- 9:45 Eugene Colbourne
- *Oceanographic Conditions in the Newfoundland Region in 1997.*
- 10:15 Break
- 10:45 Denis Gilbert
- *Overview of oceanographic conditions in the Gulf of St. Lawrence in 1997.*
- 11:15 Ken Drinkwater, Roger Pettipas and Liam Petrie
- *Physical oceanographic conditions on the Scotian Shelf and in the Gulf of Maine during 1997.*
- 11:45 Lunch

Biological Environment

- 13:00 John Anderson and Edgar Dalley
- *Plankton and nekton of the northeast Newfoundland Shelf and Grand Banks in 1997.*
- 13:30 Jeff Runge and Patrick Ouellet
- *Zooplankton in the Lower St. Lawrence Estuary in 1997.*
- 14:00 Doug Sameoto, Mary Kennedy and Norman Cochrane
- *Zooplankton changes along the Halifax and Louisbourg Lines in 1997.*
- 14:30 Erica Head
- *The offshore as a spring-time source of Calanus finmarchicus to the mid and western regions of the Scotian Shelf*
- 15:00 Break

General Environmental Session-Part 1

- 15:30 Recommendations from and Discussion of Environmental Overviews
 16:00 Clive Mason, Brian Petrie, Brenda Topliss
 -*Time series of Satellite derived SSTs in the Northwest Atlantic*
 16:30 Peter Smith
 -*On the recent salinity changes in the Gulf of Maine.*
 17:00 Ram Myers (Dalhousie University)
 -*When do environment-recruitment correlations work?*

Wednesday, Feb. 25

Theme Session: Growth and Reproduction of Fish and Shellfish and the Relative Importance of Environmental Forcing

- 9:00 Introduction
 -Chairman
 9:15 Steve Campana, Bob Mohn, Steve Smith and Ghislain Chouinard
 -*Temperature as a Key Modifier of Cod Growth*
 9:45 Alan Sinclair, Doug Swain and Ghislain Chouinard.
 -*Changes in growth of southern Gulf cod.*

 10:15 Break

 10:45 Alan Sinclair, Doug Swain and Ghislain Chouinard.
 -*Tests of effects of abundance and temperature on growth of southern Gulf cod.*
 11:15 Alan Sinclair, Mark Hanson and L. Currie.
 -*Evidence of size-selective mortality of southern Gulf cod.*
 11:45 Alan Sinclair, Doug Swain and Mark Hanson.
 -*Evidence for two growth morphs of southern Gulf cod.*

 12:15 Lunch

 13:15 Martin Castonguay, Jean-Denis Dutil and Denis Gilbert.
 -*Did an environmentally-induced decline in growth and condition play a role in the collapse of northern Gulf of St. Lawrence cod?*
 13:45 George Lilly
 -*Progress in the study of growth and condition of cod in 2J3KL and 3Ps*
 14:15 Chris Taggart, Christian Reiss and others. (Dalhousie University)
 -*Cod are still spawning on the eastern Scotian Shelf and Western Bank: Are the observations and the data sufficient to reject this hypothesis?*
 14:45 Ken Frank and Jim Simon

-Length-at-age variation of eastern Scotian Shelf Haddock

15:15 Break

15:45 Bernard Sainte-Marie and Denis Gilbert

-Possible effects of changes in CIL temperature and thickness on population dynamics of snow crab, Chionoecetes opilio, in the Gulf of Saint Lawrence.

16:15 Michel Comeau

-Lobster growth in the southern Gulf of St. Lawrence

16:45 John Tremblay

- Lobster molt timing and growth off northeastern Cape Breton Island

17:15 Discussion and Recommendations

18:00 Refreshments

Thursday, Feb. 26

General Environmental Session-Part 2

8:30 Doug Sameoto

-CPR data-an update.

9:00 Discussion and recommendations on CPR

9:15 Doug Swain, G. Poirier and Alan Sinclair.

- Water temperature and catchability of cod to the bottom-trawl survey in the southern Gulf of St. Lawrence.

9:45 Dave Kulka (to be presented by George Lilly)

- Spatial analysis of northern Atlantic cod distribution with respect to bottom temperature and estimation of biomass using potential mapping in SPANS

10:15 Break

Reports on Research Programs

10:45 John Loder, Jeff Runge and Nancy Shackell

-Canadian GLOBEC

11:45 Peter Smith

-US GLOBEC

12:15 Lunch

13:15 Glen Harrison

13:45 Allyn Clarke
-*JGOFS*
-*CLIVAR*

FOC Business Meeting

- 14:15 General Business of the FOC
1. Stock Status Reports
 - Discussion and Approval of Environmental Overview SSRs
 2. FOC Working Groups
 - Cod Growth Working Group
 - Environmental Indices Working Group
 - Working Group on the relative role of temperature and abundance on the distribution of cod in the northwest Atlantic
 - Other possible Working Groups?
 3. Other Business
 4. Next year's Meeting
 - Possible Theme Sessions
 - Date and Location

Appendix 2: Working and Tabled Papers

Working Papers

- WP 98/01 *Overview of Meteorological and Sea Ice Conditions off Eastern Canada in 1997.*
-Ken Drinkwater, Roger Pettipas and Liam Petrie
- WP 98/02 *Oceanographic conditions in the Newfoundland Region during 1997 with comparisons to the 1961-1990 average.*
-Eugene Colbourne
- WP 98/03 *Physical oceanographic conditions on the Scotian Shelf and in the Gulf of Maine during 1997.*
-Ken Drinkwater, Roger Pettipas and Liam Petrie
- WP 98/04 *Plankton and nekton of the Northeast Newfoundland Shelf and Grand Banks in 1997*
-Edgar Dalley and John Anderson
- WP 98/05 *Zooplankton biomass in the Lower St. Lawrence Estuary, 1994-1997.*
-Jeff Runge and Pierre Joly
- WP 98/06 *State of Zooplankton on the Scotian Shelf, 1997.*
-Doug Sameoto, Norman Cochrane, Alex Herman, Erica Head and Mary Kennedy
- WP 98/07 *Satellite measurements of sea surface temperature and their application to regional ocean climate.*
-Clive Mason, Brian Petrie and Brenda Topliss
- WP 98/08 *Interannual variability of boundary fluxes and water mass properties in the Gulf of Maine and on Georges Bank: 1993-97.*
-Peter Smith, Robert Houghton, Richard Fairbanks and David Mountain
- WP 98/09 *When do environment-recruitment correlations work? A review with generalizations.*
-Ram Myers
- WP 98/10 *Changes in growth of southern Gulf of St. Lawrence cod.*
-Alan Sinclair, Doug Swain and Ghislain Chouinard
- WP 98/11 *Tests of effects of abundance and temperature on growth of southern Gulf of St. Lawrence cod.*
-Doug Swain, Alan Sinclair and Ghislain Chouinard

- WP 98/12 *Evidence for size selective mortality of southern Gulf of St. Lawrence cod.*
-Alan Sinclair, Doug Swain, Mark Hanson and Linda Currie.
- WP 98/13 *Evidence for two growth morphs of southern Gulf of St. Lawrence cod.*
-Alan Sinclair, Doug Swain and Mark Hanson
- WP 98/14 *Spatial implications of a temperature-based growth model for Atlantic cod (Gadus morhua) off the eastern coast of Canada.*
-Steve Campana, Bob Mohn, Steve Smith and Ghislain Chouinard
- WP 98/15 *Size-at-age and conditions of cod in Divisions 2J+3KL, 3NO and 3Ps.*
-George Lilly
- WP 98/16 *Possible effects of changes in CIL temperature and thickness on population dynamics of snow crab, Chionoecetes opilio, in the Gulf of Saint Lawrence.*
-Bernard Sainte-Marie and Denis Gilbert
- WP 98/17 *Lobster (Homarus americanus) growth in the southern Gulf of St. Lawrence.*
-Michel Comeau
- WP 98/18 *Molt timing and growth of Lobster, Homarus americanus, off northeastern Cape Breton Island, Nova Scotia*
-John Tremblay and Mike Eagles
- WP 98/19 *Water temperature and catchability of cod to the bottom-trawl survey in the southern Gulf of St. Lawrence.*
-Doug Swain, G. Poirier and Alan Sinclair
- WP 98/20 *Spatial analysis of northern Atlantic cod distribution with respect to bottom temperature and estimation of biomass using potential mapping in SPANS.*
-David Kulka

Tabled Papers

- WP *Overview of 1997 hydrographic sampling effort and near-bottom water temperature and salinity conditions during the Canadian research vessel groundfish surveys conducted during the spring on the eastern Scotian Shelf (4VsW) and Georges Bank (5Z)*
-Fred Page, Randy Losier and Jeff McRuer
- WP *Overview of 1997 hydrographic sampling effort and near-bottom water temperature and salinity conditions during the Canadian research vessel groundfish summer surveys conducted on the Scotian Shelf and in the Bay of Fundy (4VWX)*
-Fred Page, Randy Losier, Jeff McRuer and Michelle Ringuette

WP Overview of 1997 hydrographic sampling effort and near-50 meter water temperature and salinity conditions during the Canadian research vessel groundfish summer surveys conducted on the Scotian Shelf and in the Bay of Fundy (4VWX)
-Fred Page, Randy Losier, Jeff McRuer and Michelle Ringuette

Appendix 3: Meeting Participants (* denotes FOC Core-member)

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Appendix 4: Summary of Environmental Conditions off Eastern Canada in 1997

Atmospheric and Sea Ice Conditions

During 1997, the large-scale atmospheric circulation pattern as reflected in the North Atlantic Oscillation (NAO) index was weaker-than-normal for the second consecutive year but stronger than in 1996. Associated with this lower-than-normal NAO index was a weakened Icelandic Low, reduced northwest winds over the Labrador Sea, and warmer-than-normal air temperatures over the same region. Warmer air temperatures and weaker northwest winds resulted in later-than-normal ice formation, less areal extent of ice than normal and a shorter duration of ice, over much of the Labrador/Newfoundland shelves and in the Gulf of St. Lawrence/Scotian Shelf. In turn, the warm temperatures, weak winds and less ice all contributed towards a large reduction in the number of icebergs reaching the Grand Banks in 1996 relative to 1995 and the earlier years of the 1990s. During spring, air temperature anomalies continued to remain above normal, consistent with a weaker Icelandic Low and weaker northwest winds over the Labrador Sea. During the summer and autumn, air temperatures tended to fluctuate about their long-term means.

Hydrographic Conditions off Newfoundland

The anomalously cold-water temperatures in recent years along the east coast of Newfoundland finally were replaced by warmer-than-normal waters. Positive temperature anomalies were observed throughout the water column at Station 27 over most of the year with maximum anomalies of 2°C at mid-depths during the summer. This represents the warmest waters at Station 27 in over a decade. Salinities at Station 27 were generally below normal throughout the year with the greatest departures from the long-term mean appearing near 100 m in the late summer. The areal extent of the cold intermediate layer (CIL), as defined by temperatures less than 0°C, along the Bonavista Line in summer was below normal for the second consecutive year. The CIL area did, however, increase slightly relative to 1995. During the annual autumn groundfish survey, bottom temperatures increased significantly from the extensive cold temperatures observed during the 1991-1994 period. Observations south of Newfoundland in areas 3Ps and 3Pn indicate water temperatures there also moderated from the very cold period that began in the mid-1980s and extended into the 1990s. In 1996, near bottom temperatures in these areas had returned to near normal values.

Hydrographic Conditions in the Gulf of St. Lawrence

Colder-than-normal temperatures were observed for the 12th consecutive year in the depth range of 30-100 m, which corresponds to the CIL in the Gulf of St. Lawrence. The minimum temperature in the CIL in mid-summer was approximately -0.5°C, up slightly from 1995 but still below normal. Cold bottom waters continued to cover the Magdalen Shallows in September during the annual groundfish survey in the southern Gulf. The areal extent of the Shallows covered by waters less than 0°C and less than 1°C decreased relative to 1995 but remained high compared to most years during the 1970s and 1980s. The thickness of the CIL throughout the Gulf, as defined by waters less than 0°C, decreased by approximately 10 to 20 m on average compared to 1995. In

the 100-200 m depth layer, the temperature was below normal everywhere in the Gulf, similar to 1995. Deep waters (200-300 m) in the Gulf, including in and around Cabot Strait, ranged between 4 and 6°C and were near their long-term normals.

Hydrographic Conditions on the Scotian Shelf and in the Gulf of Maine

Waters below the upper mixed layer (>30 m) on the northeastern Scotian Shelf continued to be colder-than-normal, extending the trend that began around the mid-1980s. Similar cold conditions were observed along the Atlantic coast of Nova Scotia and off southwest Nova Scotia. The deep waters (>150 m) in Emerald Basin remained relatively high and are consistent with conditions found in the deep basins of the Gulf of Maine. These deep waters originate offshore and are transported onto the shelf through cross-shelf exchange processes. Bottom temperatures observed during the annual July groundfish survey support this pattern of colder-than-normal in the northeastern Shelf and off southwest Nova Scotia and warmer-than-normal in Emerald Basin and the deep basins of the Gulf of Maine. Compared to 1995, temperatures warmed in the northeast and off southwest Nova Scotia but cooled slightly in Emerald Basin. Warm bottom temperatures seen in the central Gulf of Maine in July were typical of deep water conditions in the Gulf of Maine through most of the year, based upon data collected at the hydrographic station at the mouth of the Bay of Fundy, Prince 5, and an XBT transect across the Gulf from Massachusetts Bay to Cape Sable. Warm waters were also seen from coastal sea surface temperatures at Boothbay Harbor in Maine and St. Andrew's, New Brunswick. Of significant note were the low salinities recorded throughout the year at Prince 5, the lowest on record in over 70 years. This parallels freshening events observed in the deep waters of the central Gulf of Maine. Cause of this freshening is unknown but may be related to an intrusion of offshore slope water.

Brief Summary of Meteorological and Hydrographic Conditions

Significant changes in the large-scale circulation pattern over the northern North Atlantic lead to a low NAO index and a weakened Icelandic Low. Over the Labrador Sea this resulted in weakened northwest winds in winter, warmer-than-normal air temperatures, less ice and warm sea temperatures. This represents a significant change from the cold conditions of the last decade. In contrast to the significant warming over the Labrador and Newfoundland waters, oceanographic conditions in the Gulf of St. Lawrence, the Scotian Shelf and the Gulf of Maine remained similar to recent years. This included colder-than-normal conditions at intermediate depths (30-200 m) in the Gulf of St. Lawrence, on the northwestern Scotian Shelf, along the Atlantic coast of Nova Scotia and off southwest Nova Scotia although temperatures in these areas are beginning to moderate. Relatively warm conditions continued in the deep basins of the Scotian Shelf and the Gulf of Maine.

Zooplankton Conditions

Zooplankton sampling along the Halifax and Louisbourg standard sections during 1996 show that macrozooplankton (euphasiid and to a lesser extent amphipod) levels tend to be higher along the Halifax Line. In Emerald Basin, *Calanus finmarchicus* populations during 1996 were

at their lowest levels since 1985 when data collection began. Both euphasiids and fish populations in the Basin gradually increased between 1984 and 1994, followed by a steep decline in 1995 and then a subsequent sharp increase in the euphasiid population during 1996 back to previously high levels.

A zooplankton survey in the Lower St. Lawrence Estuary undertaken since 1994 showed that zooplankton biomass in 1995 and 1996 was significantly lower than in 1994. Krill biomass was lower by a factor of 10 in 1996 relative to 1994 while total plankton biomass is down by a factor of 2 and *Calanus* biomass is lower by a factor of 3. No explanation for these decreases is available at this time.

During the past three years, an extensive survey for zooplankton and nekton was also carried out during August-September over the northern Newfoundland shelf and the Grand Banks. In 1996, the mean total zooplankton biomass collected in bongo tows was significantly higher than 1994 and similar to 1995. However, the mean wet nekton biomass, with or without jellyfish, was significantly lower in 1996 than other years. The mean catch of pelagic 0-group Arctic cod was significantly lower in 1996 than in 1994 but similar to 1995. The number of Atlantic cod decreased in 1996 from 1995, which in turn was down from 1994. The amount of biomass of squid also decreased but significantly more sculpins, seasnails and white hake were observed in 1996 compared to the past two years. It is not clear whether these changes are part of the natural year-to-year variability or if they represent a longer-term trend. Longer time series of the zooplankton biomass will help to answer such questions.