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Ocean Productivity Trends in the Northwest Atlantic During 2014

by

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Abstract

Biological and chemical variables collected in 2014 from coastal high frequency monitoring stations, semi-annual oceanographic transects, and ships of opportunity ranging from the Labrador-Newfoundland and Grand Banks Shelf (Subareas 2 and 3), extending west into the Gulf of St. Lawrence (Subarea 4) and further south along the Scotian Shelf and the Bay of Fundy (Subarea 4) and into the Gulf of Maine (Subarea 5) are presented and referenced to previous information from earlier periods when available. We review the interannual variations in inventories of nitrate, chlorophyll *a* and indices of the spring bloom inferred from satellite ocean colour imagery, as well as the abundance of major functional taxa of zooplankton collected as part of the 2014 Atlantic Zone Monitoring Program (AZMP) and Continuous Plankton Recorder (CPR) Survey to 2013. In general, nitrate inventories in the upper (0-50m) water-column were near normal (within ± 0.5 standard deviation (SD) units) of the 1999-2010 climatology throughout the northwest Atlantic in 2014. The deeper (50-150m) nitrate inventories continue to remain well below normal with levels approaching 4-5 SD units lower along the northern transects, an ongoing decline that began in 2008. In contrast, deep nitrate levels have recovered from lower levels observed in 2010-2011 across the Gulf of St. Lawrence and near-normal along the Scotian Shelf in recent years (2012-2014). The chlorophyll *a* inventories inferred from the seasonal AZMP oceanographic surveys and fixed stations were variable throughout the Subareas with below normal conditions over the northern transects (2J to 3LNO), generally above average in the Gulf of St. Lawrence, and near-normal throughout the Scotian Shelf. Satellite ocean colour imagery indicated lower biomass and weaker spring blooms over the NW Atlantic in 2014. The initiation and duration of the spring bloom was later on average and limited in 2014 with predominately positive (delayed) and negative (reduced) anomalies respectively. Peak timing of the spring bloom varied across the different Subarea's with earlier production cycles in the northern regions while delayed on the Newfoundland and Scotian Shelf in 2014. The zooplankton abundance anomalies for a dominant small grazing copepod were generally positive over many of the survey transects and fixed stations with the highest abundance levels observed over the Grand Bank (3LM) and Gulf of St. Lawrence. In contrast, the abundance for a dominant large grazing copepod was lower throughout the Subareas with the largest decline observed over the eastern Scotian Shelf in 2014. In general, the total number of copepod taxa increased from 2013 levels throughout the northwest Atlantic in 2014. The non-copepod taxa, characterized by carnivorous zooplankton, gelatinous invertebrates, and meroplankton, have increased substantially in recent years throughout the northeast Newfoundland Shelf and eastern Gulf of St. Lawrence.

Introduction

We review biological and chemical oceanographic conditions on the Newfoundland (NL) and Labrador (LB) Shelves, Grand Bank (GB), Gulf of St. Lawrence (GSL), Scotian Shelf (SS), and in the Bay of Fundy (BoF) and Gulf of Maine (GoM) during 2014, and reference earlier periods when data are available. More frequent directed sampling from research vessels on oceanographic transects and ships of opportunity at coastal fixed stations by the Atlantic Zone Monitoring Program (AZMP[1]) and the completion of seasonal oceanographic surveys during 2014 provided good spatial and temporal series coverage of standard variables which affords a foundation for comparison with previous years. Additional details regarding physical, biological and chemical oceanographic conditions in the Northwest Atlantic in 2014 and earlier years can be found in Colbourne *et al.* (2014), Devine *et al.* (2015), and DFO (2014), Galbraith *et al.* (2014), Hebert *et al.* (2014), Johnson *et al*. (2014, 2014), Pepin *et al*. (2015), Plourde *et al.* (2014), Yashayaev *et al.* (2014).

Methods

Collections of standard AZMP variables are based on sampling protocols outlined by Mitchell *et al*. (2002). Observations for 2014 and earlier years presented in this document are based on seasonal surveys conducted during the spring through the autumn (typically March through December). The coastal stations are typically sampled at twice monthly to monthly intervals during ice-free conditions. The location of the standard oceanographic transects and coastal stations are shown in Figure 1.

Phytoplankton biomass was estimated from ocean colour data collected by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS; http://seawifs.gsfc.nasa.gov/SEAWIFS.html) and Moderate Resolution Imaging Spectroradiometer (MODIS) "Aqua" sensor (http://modis.gsfc.nasa.gov/). The SeaWiFS time series began in the September of 1997 and MODIS data stream began in July, 2002. Satellite data do not provide information on the vertical structure of chlorophyll *a* (chl*a*) in the water column but do provide highly resolved (~1.5 km) data on their geographical distribution in surface waters at the large scale. Two week composite images of chl*a* for the entire NW Atlantic (39-62.5° N Latitude 42-71° W Longitude) were routinely produced from SeaWiFS/MODIS data[2]. Basic statistics (mean, range, standard deviation, etc.) were extracted from the composites for selected statistical sub-regions as shown in Figure 1. We constructed an ocean colour time series from 1998 to 2014 using data from both satellite sensors and averaging during the overlap period from 2002 to 2010.

The Continuous Plankton Recorder (CPR) survey[3] provides an assessment of long-term changes in abundance and geographic distribution of planktonic organisms ranging from small phytoplankton cells to larger macrozooplankton (Warner and Hays 1994, Richardson et *al*. 2006). CPR collections in the northwest Atlantic began in the early 1960's and continued with some interruptions during the latter period through till 1986. Collections were renewed in 1991 and continue to present. The recorder is towed by commercial cargo transport vessels along a number of standard routes throughout the North Atlantic. The CPR device collects plankton at a nominal depth of 7m through an aperature and organisms are retained on a moving band of silk material and preserved. Sections of silk representing 18.5 km tow distance and ca. $3m^3$ of water filtered are analyzed microscopically using standard methods since the inception of the program thereby allowing valid comparisons between years. Every second section is analyzed providing a horizontal scale of ca. 37 km. The sampling distribution for CPR taxa was uneven for both spatial and temporal scales due to the nature of opportunistic sampling with ships of opportunity, variation in shipping routes, and funding. We used seasonally-adjusted annual mean and decadal estimates of the relative abundance of various dominant CPR taxa (phytoplankton colour index; total diatoms; total dinoflagellates, *Calanus* copepodite I-IV and *C. finmarchicus* V-VI stages; *C. glacialis*; *C. hyperboreus*; copepod nauplii; Parapseudocalanus spp.; Oithona spp.; Hyperidea and Euphausicea) from four regions based on a previous analysis (Head and Pepin 2010) and use

[1] http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html
[2] (http://www.bio.gc.ca/science/newtech-technouvelles/sensing-teledetection/index-eng.php)
[3] See SAFHOS web site at (http://192.171.163.165/) for a description of the CPR Program collected for The Sir Alister Hardy Foundation for Ocean Science of Plymouth, England.

of general linear models to account for variation in sampling (see Pepin et. al 2011 for a complete description of models).

Scorecard indices were developed as a method of summarizing the many variables used to represent the state of lower trophic levels. To simplify the information, the time-series of the annual estimate of inventory or abundance for each summary variable was standardized to a mean of zero (for the period 1999 – 2010) and unit standard deviation ([observation – mean]/SD). The standard deviation provides a measure of the variability of an index. The result of this standardization yields a series of anomalies. The scorecards serve to illustrate departures from the long term mean across the range of variables by colour coding anomalies as either being above/later than (red) or below/earlier than (blue) the long term average, with darkening shades serving to represent the increasing magnitude of that departure. For the chemical-biological observations, the key variables selected were: (1) near surface (0-50 m) and deep (50-150 m) nitrate inventories, and (2) 0-100m integrated chl*a*, satellite indices of background chl*a*, magnitude and amplitude, initiation, peak timing and duration of the spring bloom (Zhai *et al*. 2011), and zooplankton abundance for different functional zooplankton taxa (*Pseudocalanus spp*., *Calanus finmarchicus,* total copepods, and total non-copepod zooplankton) for the AZMP fixed stations and seasonal transects.

Annual Variability in Nutrient, Phytoplankton, and Zooplankton Conditions in NAFO Subareas

Based on the available data, the upper water-column (0-50m integral) nitrate inventories were generally near normal throughout the northwest Atlantic with anomalies ranging within ± 0.5 SD units in 2014 (Figure 2). The only exception occurred in the deep Avalon Channel at the fixed sampling station with below normal levels approaching – 1.5 SD. The deep inventories of nitrate, an index of nutrient availability to fuel the base of the marine food chain in the subsequent spring bloom, were consistently negative across the northern Subareas down to the southern Grand Bank (GB), while above normal conditions prevailed across the GSL and near-normal levels on the SS in 2014 (Figure 2). In general, the annual anomaly trends in nitrate inventories in the upper 50m layer have remained below normal since 2008 across the northern Subareas (2J to 4RS including the northeast GSL) while inventories along the western and southern GSL have increased back to near the climatology (1999-2010) in recent years (Figure 3). Upper water-column nitrate inventories along the SS are more variable with some years showing strong coherent signals across the zone (e.g. 2008, 2013; Figure 3). A significant reduction in deep nitrate inventories initiated in 2008-2009 remains ongoing along the northern Subareas into 2014 (Figure 3). Deep inventories continue to remain well below normal over southern LB and NL Shelf and GB while levels have increased back to normal or above the long-term mean throughout the GSL and SS Subareas and ongoing since 2012 (Figure 3). The chl*a* inventories inferred from the seasonal oceanographic surveys, which provides an index of phytoplankton biomass throughout the water-column, were generally near-normal throughout the NW Atlantic in 2014 (Figure 4). Trends in chl*a* inventories remain lower in northern Subareas since 2011 with gradual increasing levels into 2014 but still below the long-term climatology (Figure 5). Inventories in the GSL and SS have remained mostly above average in recent years compared to the pattern observed northwards (Figure 5). We also examined the trends in composite summed anomalies across the NL-LB Shelf, GB, GSL, and SS transects and fixed stations during the 16-year time series. The composite index for the upper water-column nitrate inventories tended to show a negative trend along the northern Subareas (2J to 3LNO) while interannual variability dominated the trends throughout the GSL and SS (Figure 6). We observed large amplitude changes and high interannual variability in deep nitrate inventories that appear to be strongly coupled between the GSL and SS but largely decoupled from the northern Subareas (Figure 6). A clear downward trend in deep inventories over the NL-LB Shelves and GB has been ongoing since 2008 (Figure 6). The composite chla inventories across the different Subareas have remained relatively stable over time with no distinct trend (Figure 6).

Annual anomalies were computed for each ocean colour metric during 2014 to evaluate spatial patterns across the different statistical sub-regions. Overall, background chl*a* concentration were generally lower across the northern regions with mostly negative anomalies while the southern regions showed mixed conditions in 2014 (Figure 7). The magnitude (integral of chl*a* biomass) and amplitude (peak intensity) of the spring bloom were typically below normal across most of the northwest Atlantic with 18/19 of 24 sub-regions showing negative anomalies respectively (Figure 7). The initiation and duration of the spring bloom was delayed and reduced in 2014 across the 24 sub-regions with only a few exceptions (Figure 7). Peak

timing of the spring bloom also showed mixed conditions with earlier timing in the northern regions while delays in the production cycle were evident in the northeast NL Shelf and SS (Figure 7).

Although large positive annual anomalies in background chla were observed in 2010-2011, levels have since returned to near-normal conditions in recent years across the sub-regions (Figure 8). The magnitude and amplitude of the spring bloom have been in decline, particularly in northern sub-regions in recent years but the frequency of negative anomalies has also increased in southern areas as well (Figure 9, 10). Although initiation and peak timing of the spring bloom has shifted earlier in recent years, this trend was reversed in 2014 with a large number (ca. 50 %) of positive anomalies indicating delayed production across the NL-GB Shelf and SS sub-regions (Figures11, 13). Since 2011, the frequency of shorter duration spring blooms has increased across the northwest Atlantic. The intensity of these short duration blooms were more notable in the northern and LB-NL-GB Shelf from Subarea 0B to 3K but, also apparent in the GSL in 2014 (Figure 12).

We developed composite indices for each of the ocean colour metrics by summing all of the annual SeaWiFS/MODIS anomalies across the sub-regions located in the subarctic, NL-LB Shelf, GSL, GB, and SS-GoM to evaluate trends during the 17-year series. Overall, no strong temporal trends in any of the composite anomalies were detected (Figure 14). The main changes in the composite anomalies were often dominated by large changes in internannual variability, often observed in the southern areas (Subarea 4) in magnitude and amplitude of the spring bloom while the GB-FC and GSL showed the largest annual variability in timing indices. The composite timing indices (initiation and peak timing) have tended to shift to earlier timing over the time series, particularly for the GB and GSL sub-regions (Figure 14).

The pattern of annual anomalies for the different functional zooplankton groups showed strong coherent patterns and spatial gradients across the entire survey area in 2014. The zooplankton abundance anomalies for a key small grazer and dominant copepod in the survey area, *Pseudocalanus spp*., were substantially higher again in 2014 similar to the pattern observed in the previous year with the largest changes observed over the Flemish Cap (3LM) and the northwest GSL including the fixed sampling stations (Figure 15). These small epipelagic, subarctic copepods represent an important preferred prey to many early life stages of fish. The abundance anomalies for the larger grazing copepod, *Calanus finmarchicus,* another dominant species and important prey item to higher trophic levels and energy transfer, were consistently below normal across the entire area with the largest decline observed over the eastern SS in 2014 (Figure 15). In general, total copepod taxa remained mostly at higher levels throughout the entire area but approached nearly 4 SD units above normal at the fixed sampling station in the GSL in 2014 (Figure 15). The non-copepod (mostly larval stages of benthic invertebrates, gelatinous and carnivorous zooplankton) taxa continued to increase in abundance throughout the northeast NL Shelf and eastern GSL in 2014 with remarkable positive anomalies in some cases reaching near 5-20 SD above normal (Figure 15).

The scorecard indices for the small grazing copepod *Pseudocalanus* has increased dramatically in recent years (2013-2014) along the northern transects and into the GSL although not previously observed during the time series (Figure 16). In contrast, the decline in another subarctic copepod, *Calanus finmarchicus* is ongoing in recent years throughout the northwest Atlantic although most prominently along the eastern SS since 2011 (Figure 16). In general, abundance levels increased from below normal levels in 2011-2013, particularly in the GSL and SS transects in 2014 (Figure 17). The non-copepod group, which consists of gelatinous forms, meroplankton, and carnivorous zooplankton, also continue to show substantial increased abundance and some of the highest levels observed in the time series along the northern transects and into the GSL with more mixed levels approaching near normal along the SS transects in recent years (Figure 17).

The composite indices summing each of the zooplankton abundance indices across the NL-LB Shelf, GB, GSL and SS Subareas revealed some contrasting patterns during the time series. The summed composite abundance anomalies for the small copepod *Pseudocalanus* spp. showed relatively consistent near-normal levels on the NL-LB Shelf and GB, high variability over the GSL and SS ongoing since 2010 (Figure 18). Composite abundance anomalies for the large grazing copepod *Calanus finmarchicus* were relatively stable over the extent of the time series on the NL-LB Shelf and GB in contrast to a negative trend along the GSL and SS transects since 2010 (Figure 18). The composite anomalies for total copepods and non-copepods were also

relatively stable without an overall trend during the time series with the exception of substantial increased levels observed in recent years along the GSL transects and fixed stations (Figure 18).

The pattern of decadal anomalies for the CPR phytoplankton taxa were highly coherent across the standard tow tracks from the NL down to the Scotian Shelf. Lower abundance of phytoplankton indices including the colour index (PCI), diatoms and dinoflagellates characterized the early 1960-1970's decades compared to higher abundance observed throughout the 1990-2000's (Figure 19). In general, CPR phytoplankton indices in recent years (2010-2013) were near or slightly above the long-term 1960-2009 climatology. The trend in dominant calanoid copepods, both early and late developmental stages, shows similar pattern among the decadal time series between the southern NL and SS compared to the abundance on the Grand Bank (Figure 20). The time series for early calanoid copepodite stages has been relatively stable over the past 4 decades with no apparent trend. Similairly, no trend was detected in adult stages of Calanus finmarchicus southwards from SNL Shelf but, a noticeable sequential decline was observed along the NL Shelf during the past two decades (1990-2000's) into recent years (2010-2012). The 2013 abundance levels recovered from low levels observed in recent years (Figure 20). The largest Arctic/Subarctic copepods (*C. glacialis* and *C. hyperboreus*) have generally increased in abundance during the past four decades but have subsequently declined from record-high levels observed during the 1990's (NL) and 2000's (SNL, ESS, WSS) in recent years (2010-2013). The CPR copepod nauplii index, a proxy for secondary productivity, increased from relatively low levels during the 1960-1970's reaching record-high abundance in the 1990's on SNL and southwards, while nauplii standing stocks has increased consecutively in NL since the start of monitoring in the 1960's (Figure 21). No clear decadal temporal trends were evident in the abundance of small grazing copepods (*Parapseudocalanus* and *Oithona* spp.) although differences were noted between the Grand Bank and southern areas in recent years (2010-2013). The temporal changes in abundance of the small grazers, particularly in the case of Oithona spp., were highly variable and coherent across the NW Atlantic during all four decades and recent years (Figure 21). CPR time series for two abundant macrozooplankton taxa (Euphausiacea and Hyperiidea) show coherent and reciprocal trends over time among the four sub-regions (Figure 22). Juvenile and adult stages of euphausiids have declined from the 1970's until recent years (2010-2012). The reverse pattern was observed for hyperiid amphipods with gradual increasing abundance over the time series with large positive anomalies noted on the ESS in 2013 (Figure 22). We summed the annual anomalies of the various dominant phyto- and zooplankton CPR taxa from the NL Shelf to derive a lower trophic level composite time series index during 1991-2013. The early 1990's period was characterized by positive anomalies, with higher abundance of calanoid copepods and small grazers along with macrozooplankton (euphausiids and hyperiid amphipods) while the late 1990's and much of the 2000's experienced lower abundance of these same taxa (Figure 23). Peak low abundance occurred in 2003 while the peak high in the time series was observed in 2010. The CPR time series is the only data available that permits an examination of the relative abundance of lower trophic levels back further in time prior to the inception of the AZMP in 1998. The AZMP has largely occurred during the last extensive warming period that began in the late 1990's and remains largely ongoing. The last extensive cold period occurred back in the early 1990's with below normal water temperatures and extensive ice extent over the northwest Atlantic. We evaluated the relationship between the composite CPR trophic index constructed on the Grand Bank (Subarea 3) with an environmental composite index derived from a variety of oceanographic and meteorological time series in the same general area and same time period (see Colbourne et al. 2014). The relative influence of ocean climate on the CPR composite trophic index indicated a weak negative relationship but suggested that further warming (i.e. strong positive anomalies) may be detrimental to plankton populations in the northwest Atlantic that are typically composed of a variety of cold-water temperate and sub-arctic taxa.

Ocean Productivity Highlights in 2014

- Nitrate inventories within the upper 50m were generally near normal of the 1999-2010 climatology throughout the northwest Atlantic from Subarea 2 to 4 in 2014.

- Deep (>50m) nitrate inventories continue to remain well below average over the northern transects approaching 4-5 standard deviations below normal in 2014. In contrast, deep nitrate inventories have increased in the Gulf of St. Lawrence and near-normal along the Scotian Shelf in recent years.

- The chlorophyll *a* inventories inferred from the seasonal AZMP oceanographic surveys and fixed stations were variable throughout the Subareas in 2014 with below normal conditions over the northern transects (2J to 3LNO), generally above average in the Gulf of St. Lawrence, and near-normal throughout the Scotian Shelf.

- The magnitude (integral of chl*a* biomass) and amplitude (peak intensity) of the spring bloom inferred from remote sensing was typically below normal across most of the northwest Atlantic in 2014 with 18/19 of 24 sub-regions showing negative anomalies respectively.

- The initiation and duration of the spring bloom was later on average and limited in 2014 with predominately positive (delayed) and negative (reduced) anomalies.

- The zooplankton abundance anomalies for a dominant small grazing copepod were generally positive over much of the survey transects and fixed stations in 2014 with the highest abundance levels observed over the Grand Bank (3LM) and Gulf of St. Lawrence.

- In contrast, the abundance for a dominant large grazing copepod were lower throughout the Subareas with the largest decline observed over the eastern Scotian Shelf.

- In general, the total number of copepod taxa increased from 2013 levels but, approached nearly 4 standard deviation units above normal at the fixed sampling station in the Gulf of St. Lawrence in 2014.

- The non-copepod taxa, characterized by carnivorous zooplankton, gelatinous invertebrates, and meroplankton, have increased substantially in recent years throughout the northeast Newfoundland Shelf and eastern Gulf of St. Lawrence in some cases approaching 5-20 standard deviation units above normal.

- Further warming of ocean climate conditions may be detrimental to plankton populations in the northwest Atlantic.

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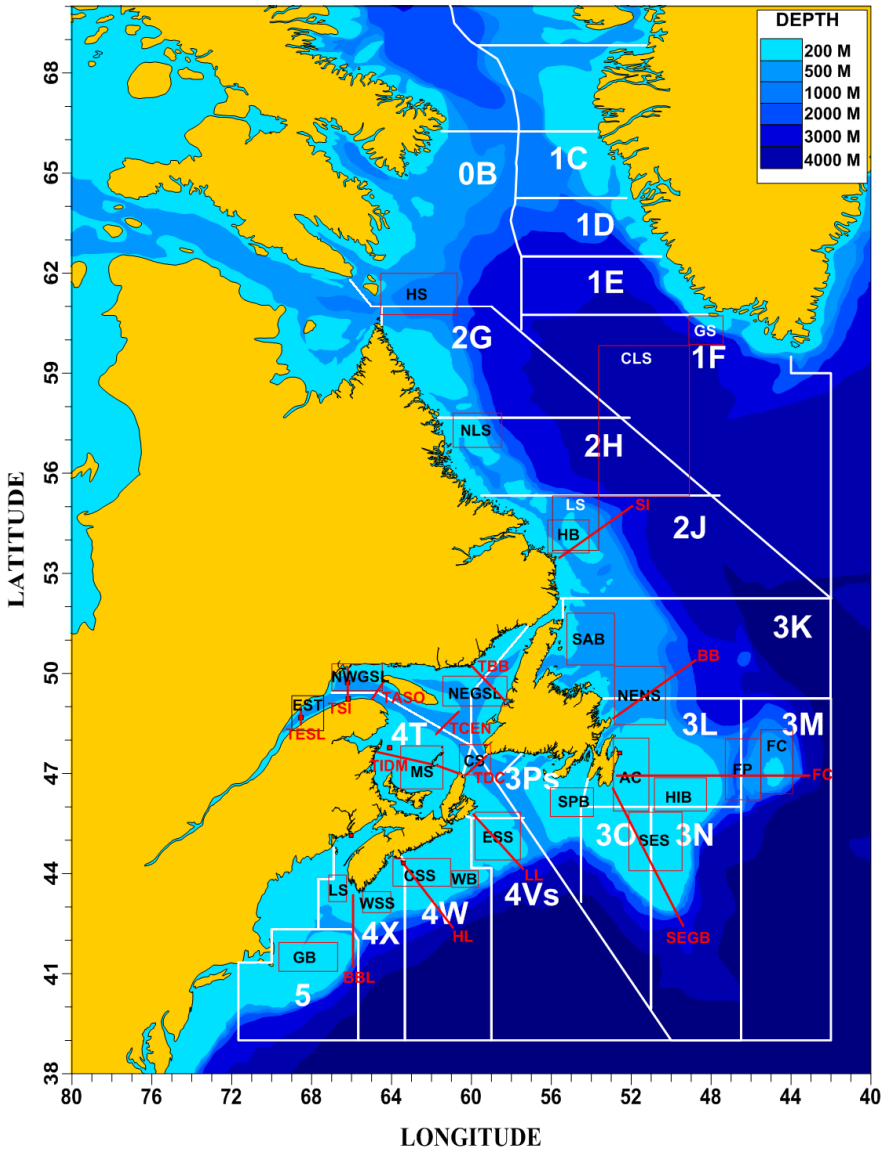

Figure 1. Location of the NAFO Regulatory Areas (white boxes) and standard Atlantic Zone Monitoring Program (AZMP) fixed coastal stations (closed red squares) and oceanographic transects (red lines). The statistical sub-regions (Petrie Boxes) shown by the open red boxes (HS=Hudson Strait, GS=Greenland Shelf, CLS=central Labrador Sea, NLS=northern Labrador Shelf, LS=Labrador Shelf, HB=Hamilton Bank (Seal Island), SAB=St. Anthony Basin, NENS=northeast Newfoundland Shelf, AC=Avalon Channel, FP=Flemish Pass, FC=Flemish Cap, HIB=Hibernia, SPB=St. Pierre Bank, SES=southeast Shoal, CS=Cabot Strait, MS=Magdalen Shallows, NEGSL=northeast Gulf of St. Lawrence, NWGSL=northwest Gulf of St. Lawrence, EST = Estuary, ESS=eastern Scotian Shelf, WB=Western Bank, CSS=central Scotian Shelf, WSS=western Scotian Shelf, LS=Lurcher Shoal, GB=Georges Bank. The standard AZMP transects are SI=Seal Island, BB=Bonavista Bay, FC=Flemish Cap, SEGB=southeast Grand Bank, TESL=Lower St. Lawrence Estuary, TSI=northwest Gulf of St. Lawrence, TASO=southwest Anticosti, TBB=Bonne Bay (northeast Gulf of St. Lawrence), TCEN=Centre Gulf of St. Lawrence, TIDM=Magdalen Shallows, TDC=Cabot Strait, LL=Louisbourg Line, HL=Halifax Line, BBL=Browns Bank Line, and fixed stations (Station 27, Rimouski, Anticosti Gyre, Gaspé Current, Shediac Valley, Halifax-2, and Prince-5).

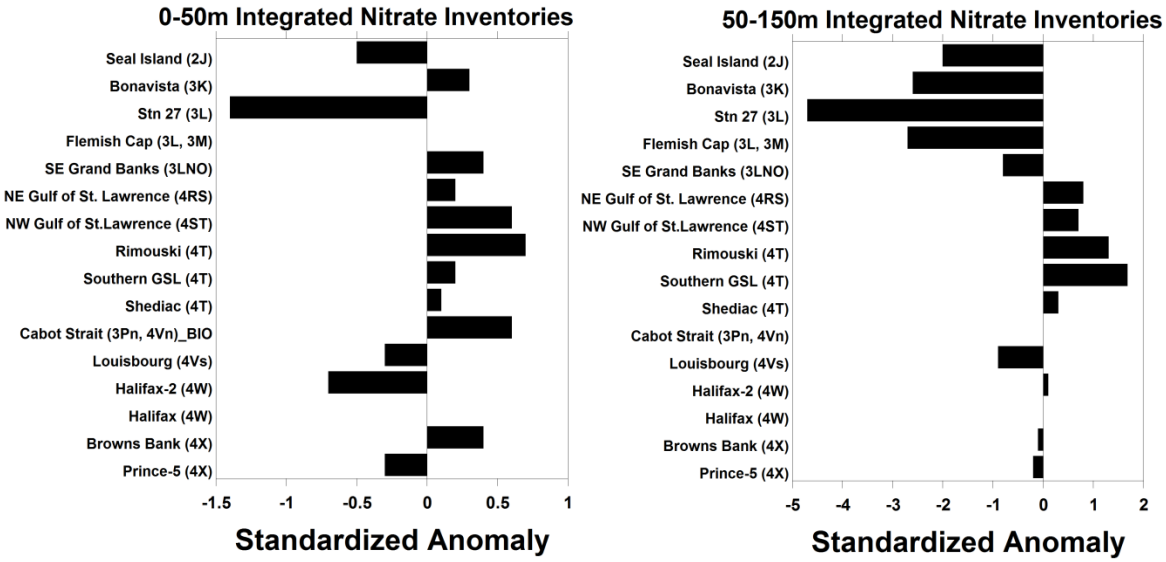

Figure 2. Summary of nitrate (combined nitrate and nitrite which represents the principal limiting nutrient in the system) from different oceanographic transects and fixed stations from the Atlantic Zone Monitoring Program during 2014. The standardized anomalies are the differences between the annual average for a given year and the long-term mean (1999-2010) divided by the standard deviation. The nutrient anomalies for transects were calculated using a general linear model using station, season, and year while the fixed stations only used season and year as inputs and were based on all available seasonal data. The NAFO Subareas are sorted by latitude from north (top) to south (bottom) regions.

Nitrate (0-50m)	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Seal Island (2J)	-0.1	0.2	0.6	1.0		2.0	0.8	-1.7	0.3	-1.2	-0.1	0.4	0.1	-0.2	-1.9	-0.5
Bonavista (3K)	-0.1	-0.2	-0.4	1.6	1.6	0.3	-0.6	-1.5	1.2	-0.5	-0.4	-1.1	0.1	-0.5	-0.6	0.3
Stn 27 (3L)		-0.1	1.8	-0.5	0.6	0.6	0.1	-0.7	0.7	0.2	-0.6	-2.1	-0.6	-1.2	-0.6	-1.4
Flemish Cap (3L, 3M)	-0.1	-0.8	0.3	1.2	2.1	0.6	-0.4	-0.5	0.6	-0.7	-0.7	-1.6	1.5	-0.8	-0.6	0.0
SE Grand Banks (3LNO)	0.1	-0.5	-0.1	0.2	2.5	0.7	0.2	-0.9	0.3	-0.5	-0.4	-1.6	-0.8	0.2	-1.4	0.4
NE Gulf of St. Lawrence (4RS)	1.3	1.4	-0.2	0.5	1.0	-1.6	-0.8	-0.9	0.9	-0.3	-0.5	-0.9	-2.2	-1.6	-0.7	0.2
NW Gulf of St.Lawrence (4ST)	1.0	-0.3	1.4	2.0	0.3	-1.1	-0.6	0.2	-0.8	-0.5	-0.9	-0.7	-1.2	0.7	0.9	0.6
Rimouski (4T)	-0.2	1.1	0.0	1.8	-0.6	0.9	-0.2	0.0	-0.5	0.7	-1.1	-1.8	-0.7	-0.5	0.0	0.7
Southern GSL (4T)	-1.4	0.8	0.1	0.5	-0.4	0.5	0.1	2.2	-0.6	0.3	-0.5	-1.6	-2.1	-1.2	0.2	0.2
Shediac (4T)	0.3	1.2	-0.8	0.4	-0.4	0.9	-0.5	1.0	-1.6	0.4	0.9	-1.7	-1.4	-0.2	-0.1	0.1
Cabot Strait (3Pn, 4Vn)_BIO	1.3	0.3	-0.3			-0.8	0.2	-0.5	0.9	1.1	-0.2	-2.0	1.4	0.8	2.2	0.6
Louisbourg (4Vs)	1.2	1.0	-1.1	-2.1	0.6	-0.8	-0.5	0.1	0.3	1.1	-0.2	0.5	-0.2	-0.5	0.7	-0.3
Halifax-2 (4W)	-1.9	1.1	0.9	-1.2	0.9	-0.1	-0.3	0.1	0.2	1.4	-0.2	-0.9	-0.6	-2.7	0.8	-0.7
Halifax (4W)	2.0	0.6	0.3	-0.8	-0.8	-1.2	-0.5	-0.2	-0.9	1.7	-0.4	0.2	0.7	1.4	1.8	0.0
Browns Bank (4X)	0.0	1.7	0.0	0.2	-1.4	-0.4	0.1	0.1	-1.8	1.5	0.4	-0.4	0.9	-0.3	0.7	0.4
Prince-5 (4X)	-1.5	-0.5	-0.8	0.9	0.9	0.0	-0.3	1.4	-0.4	0.4	1.4	-1.4	0.3	0.4	-0.5	-0.3

Nitrate (50-150m)	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Seal Island (2J)	-0.8	-0.3	-0.4	-0.4		0.1	-0.3	0.0	1.1	-2.6	-1.2	-1.8	-1.0	-2.1	-3.5	-2.0
Bonavista (3K)	0.8	0.9	-1.4	-0.1	0.8	0.7	0.2	0.7	0.7	-0.5	-0.6	-2.2	-1.3	-1.3	-2.6	-2.6
Stn 27 (3L)		1.4	0.2	0.2	-0.7	-0.6	0.1	-0.2	0.9	1.4	-0.8	-1.9	-1.0	-1.1	-2.0	-4.7
Flemish Cap (3L, 3M)	0.9	0.5	-0.4	-1.1	0.7	-0.1	0.6	1.5	0.7	-0.3	-1.1	-1.9	-0.2	-2.3	-2.2	-2.7
SE Grand Banks (3LNO)	1.5	-0.4	-0.2	0.9	0.3	1.0	0.2	0.5	0.0	-0.2	-2.3	-1.1	-0.4	-0.4	-1.7	-0.8
NE Gulf of St. Lawrence (4RS)	1.0	1.4	-1.7	-0.1	0.0	-1.5	-0.9	1.4	0.3	0.0	0.1	0.0	-0.4	0.3	0.4	0.8
NW Gulf of St.Lawrence (4ST)	0.6	-1.3	0.3	1.1	0.5	-1.5	-0.9	1.6	0.2	0.4	0.2	-1.3	-0.9	1.7	0.3	0.7
Rimouski (4T)		-0.5	0.9	1.4	-1.3	-0.4	-0.1	0.7	1.3	-1.0	0.3	-1.3	-1.2	0.4	-0.7	1.3
Southern GSL (4T)	-0.87	0.7	-1.35	0.32	0.22	-0.32	-0.9	2.03	-0.47	1.04	0.63	-1.03	-0.87	0.98	1.4	1.68
Shediac (4T)	0.3	1.3	0.2	1.0	0.4	0.5	-0.7	0.7	-1.7	0.5	-0.5	-2.0	-1.6	-0.3	-0.3	0.3
Cabot Strait (3Pn, 4Vn)	0.2	1.5	-0.9			-0.3	-0.4	1.4	-0.9	-0.3	1.1	-1.4	-0.4	1.4	0.6	
Louisbourg (4Vs)	0.6	1.3	-1.3	-1.6	0.5	-0.5	-0.5	1.7	-0.9	0.1	0.2	0.4	-0.9	0.0	-0.9	-0.9
Halifax-2 (4W)	-0.1	1.4	-0.7	0.7	1.3	-0.6	-2.1	0.7	-0.8	0.5	0.3	-0.6	-0.7	1.6	-0.2	0.1
Halifax (4W)	0.9	1.3	0.1	-0.4	-1.4	-0.4	-1.6	1.0	-0.8	0.9	1.0	-0.6	-0.8	0.0	0.1	0.0
Browns Bank (4X)	-0.3	0.5	0.2	-0.6	-1.8	1.8	-0.4	0.5	-1.4	0.1	0.6	0.9	0.5	2.1	0.6	-0.1
Prince-5 (4X)	-1.2	-0.5	-1.0	1.1	1.1	-0.4	-0.4	1.1	-0.4	0.4	1.6	-1.3	-0.6	0.7	-0.6	-0.2

Figure 3. Time series of shallow (0-50m) and deep (50m-bottom) nitrate (combined nitrite and nitrate) inventory anomalies from different oceanographic transects and fixed stations (in bold) from the Atlantic Zone Monitoring Program during 1999-2014. The anomalies for transects were calculated using a general linear model using station, season, and year while the fixed stations only used season and year as inputs and were based on all available seasonal data. Empty white cells indicate missing data; a blue cell indicates lower than normal levels and a red cell indicates higher than normal levels. More intense colours indicate larger anomalies. The numbers in the coloured cells are the differences in the annual average value from the long-term mean (1999-2010) divided by the standard deviation. The NAFO Subareas are sorted roughly by latitude from north (top) to south (bottom) regions.

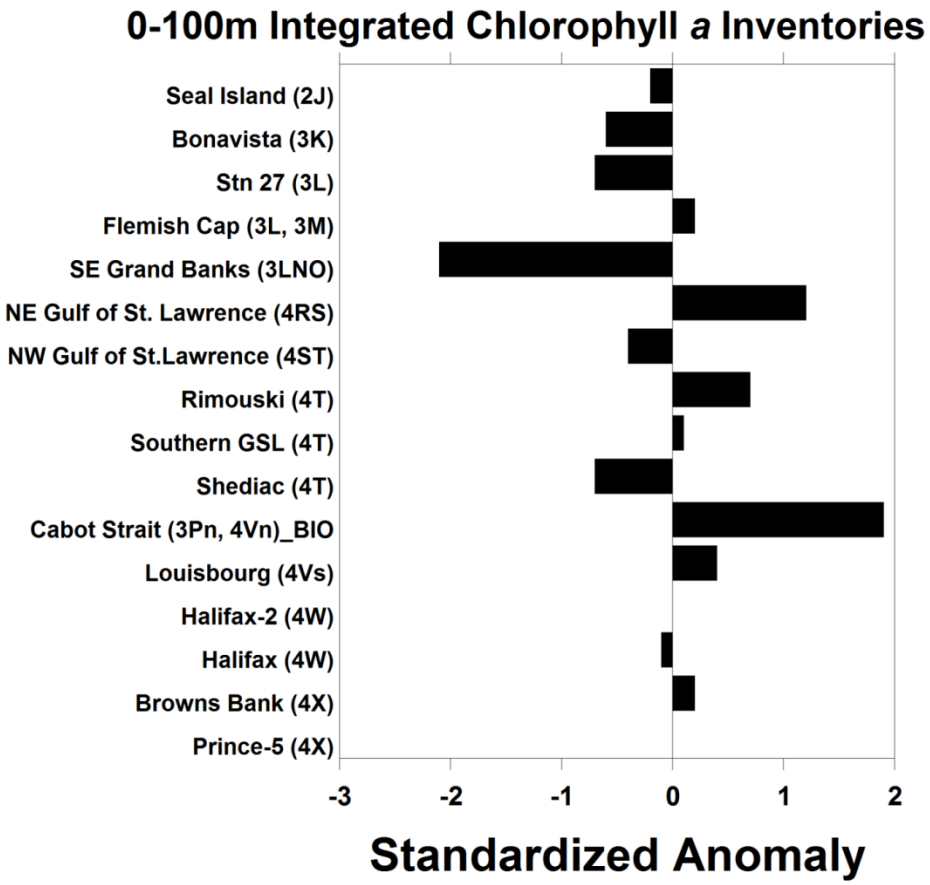

Figure 4. Summary of chlorophyll *a* inventories (0-100m integral) from different oceanographic transects and fixed stations from the Atlantic Zone Monitoring Program during 2014. The standardized anomalies are the differences between the annual average for a given year and the long-term mean (1999-2010) divided by the standard deviation. The chlorophyll *a* anomalies for transects were calculated using a general linear model using station, season, and year while the fixed stations only used season and year as inputs and were based on all available seasonal data. The NAFO Subareas are sorted by latitude from north (top) to south (bottom) regions.

Chlorophyll *a* (0-100m) Biomass	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Seal Island (2J)	2.4	-0.2	0.4	-0.2	-1.1	-0.7	-0.4	0.0	-1.0	-0.9	-0.1	-0.7	-1.0	-0.9	-0.9	-0.2
Bonavista (3K)	-1.4	1.2	0.1	-1.2	-1.5	0.6	0.6	0.6	0.4	-0.9	1.4	0.1	-1.2	-1.7	-0.8	-0.6
Stn 27 (3L)	3.1	-0.1	0.0	-0.1	-0.4	-0.2	-0.6	-0.2	-0.3	-0.7	-0.1	-0.3	-0.7	-0.4	-1.0	-0.7
Flemish Cap (3L, 3M)	2.2	-0.2	-0.2	-0.9	-1.7	0.1	0.2	-0.7	0.9	-0.5	1.0	-0.1	-1.9	-1.5	-0.1	0.2
SE Grand Banks (3LNO)	1.9	-1.4	0.2	-0.3	-1.1	-0.3	0.5	-0.6	0.9	-1.0	1.2	-0.1	-1.8	-0.8	0.9	-2.1
Northeast Gulf of St. Lawrence (4RS)	0.1	-0.6	-1.3	2.5	0.1	-0.1	-1.3	-0.8	0.1	0.5	0.5	0.1	-0.6	-0.1	1.0	1.2
Northwest Gulf of St.Lawrence (4ST)	0.3	-1.9	-0.1	2.4	0.7	0.0	-0.5	-0.4	-0.4	0.6	-0.5	-0.3	-1.2	0.4	-1.8	-0.4
Rimouski (4T)	2.9	-0.4	0.1	-0.2	0.4	-0.9	-0.7	-0.5	0.4	-0.9	-0.1	-0.2	-0.2	0.1	-0.3	0.7
Southern GSL (4T)	0.4	-1.4	0.4	2.3	0.4	-0.9	-0.9	-0.5	0.7	-0.7	-0.4	0.6	-0.7	0.1	0.6	0.1
Shediac (4T)	-0.5	-1.0	-0.1	1.7	0.6	-0.8	-1.5	0.5	1.0	1.1	0.1	-1.1	-1.3	-0.4	0.1	-0.7
Cabot Strait (3Pn, 4Vn)_BIO	1.2	1.3	-0.5			0.5	-0.3	-1.3	0.4	-0.6	0.8	-1.6	0.3	0.3	-1.0	1.9
Louisbourg (4Vs)	-0.1	0.5	-0.4	0.5	1.8	0.4	0.3	-0.9	0.5	0.0	-0.1	-2.4	0.9	0.0	0.2	0.4
Halifax-2 (4W)	2.5	0.8	0.4	-0.1	0.5	-0.6	-0.6	-1.1	-0.7	-0.9	0.2	-0.4	1.0	1.2	0.1	
Halifax (4W)	-0.7	0.7	0.0	-0.2	0.8	-0.3	0.8	-2.1	1.5	0.4	0.4	-1.3	0.5	-0.2	0.6	-0.1
Browns Bank (4X)	-0.4	-0.4	0.0	-0.3	0.3	-0.4	-0.1	-2.0	1.8	-0.5	1.6	0.4	-0.6	1.3	-0.2	0.2
Prince-5 (4X)	0.2	1.6	0.5	0.5	0.0	0.9	-2.0	-0.8	-0.2	-0.8	-0.8	1.0	-0.8	1.3		0.0

Figure 5. Time series of chlorophyll *a* (0-100m) inventory anomalies from different oceanographic transects and fixed stations (in bold) from the Atlantic Zone Monitoring Program during 1999-2014. The anomalies for transects were calculated using a general linear model using station, season, and year while the fixed stations only used season and year as inputs and were based on all available seasonal data. Empty white cells indicate missing data; a blue cell indicates lower than normal levels and a red cell indicates higher than normal levels. More intense colours indicate larger anomalies. The numbers in the coloured cells are the differences in the annual average value from the long-term mean (1999-2010) divided by the standard deviation. The NAFO Subareas are sorted roughly by latitude from north (top) to south (bottom) regions.

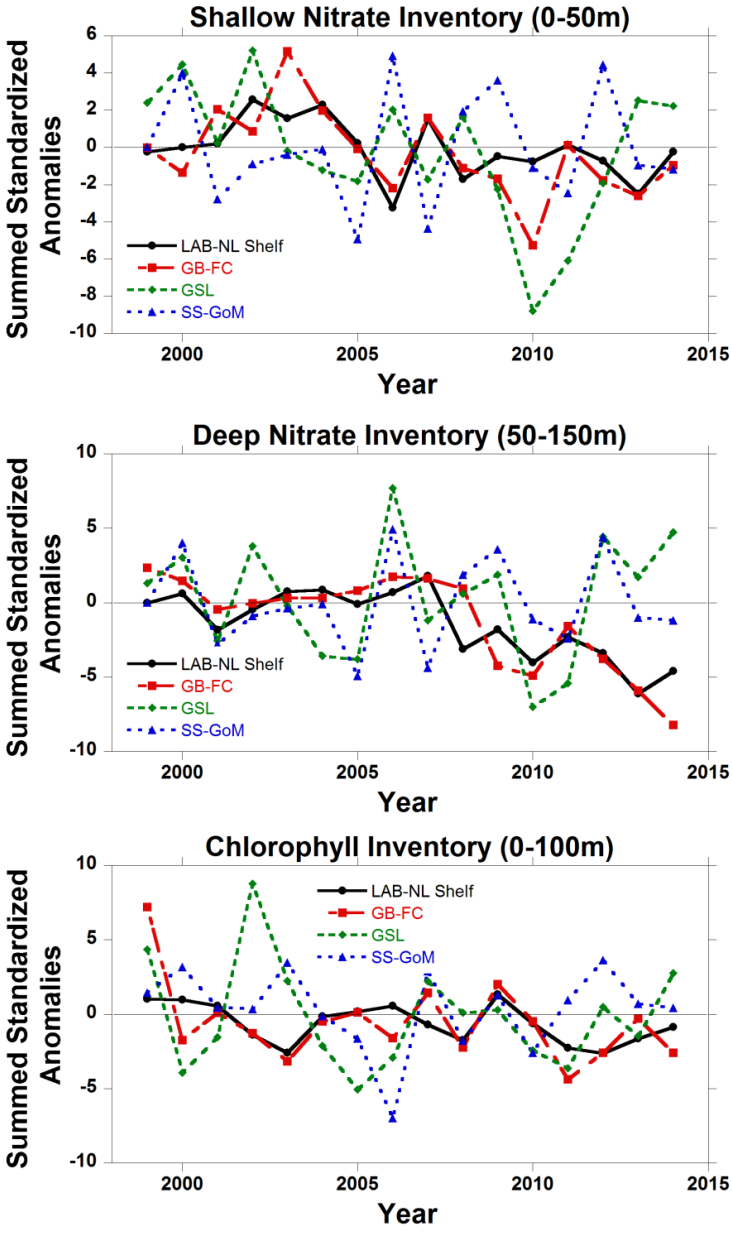

Figure 6. Composite sums of annual anomalies across Labrador and the northeast Newfoundland (LAB-NL) Shelf, Grand Bank and Flemish Cap (GB-FC), Gulf of St. Lawrence (GSL), Scotian Shelf and Bay of Gulf of Maine (SS-GoM) transects and fixed stations for shallow (0-50m) and deep (50m-bottom) nitrate and chlorophyll *a* inventories during 1999-2014.

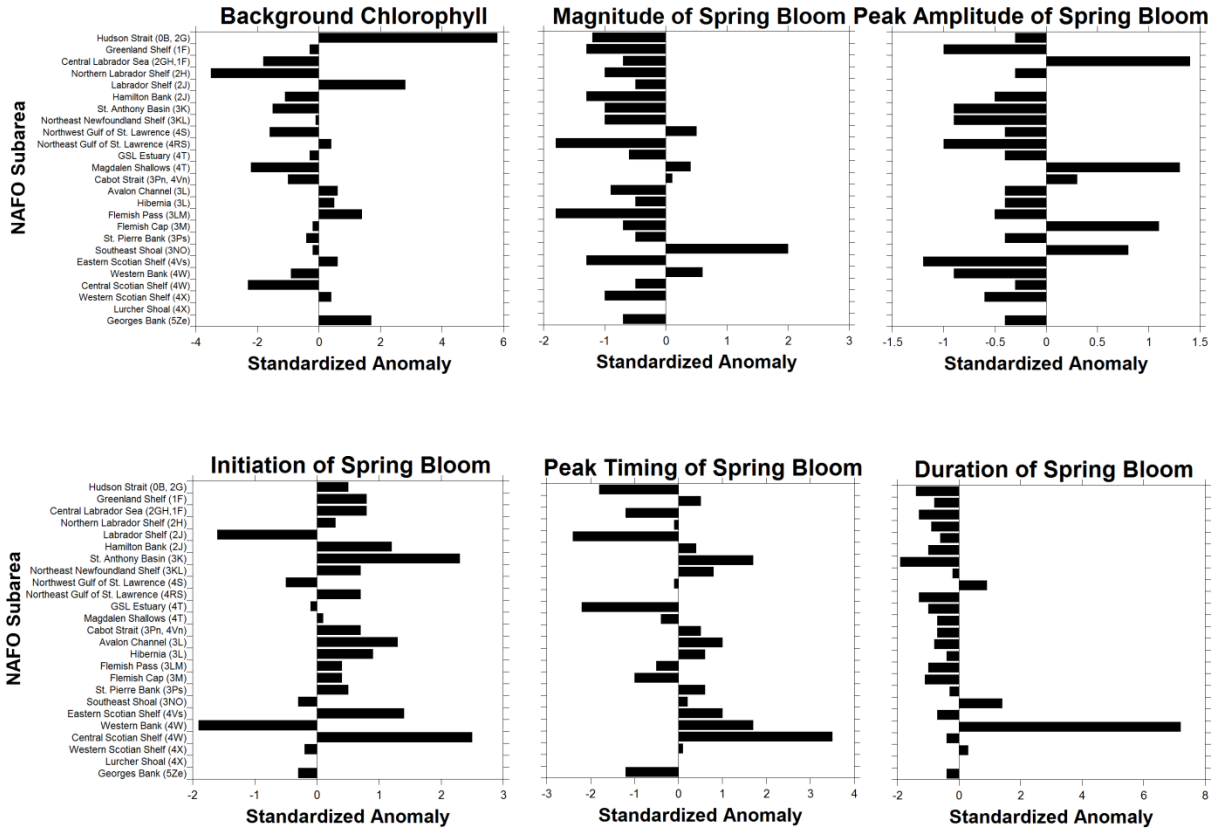

Figure 7. Summary of annual ocean colour anomalies from SeaWiFS and MODIS "Aqua" sensor across the different statistical sub-regions during 2014. The top panels show the extent (background chlorophyll *a* concentration, magnitude, and amplitude) of the spring production cycle while the bottom panels indicate the different timing (peak timing, bloom duration, and initiation) indices. The standardized anomalies are the differences between the annual average for a given year and the long-term mean (1998-2010) divided by the standard deviation. The NAFO Subareas are sorted from northern (top) to southern (bottom) regions. Negative anomalies for the timing indices (initiation, peak timing, and duration) indicate earlier/shorter blooms while positive anomalies indicate the opposite.

Petrie Box	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Hudson Strait (0B, 2G)	-0.8	-0.5	-0.4	-0.6	-0.1	0.5	1.8	-0.2	-1.6	0.2	-0.9	1.7	0.9	0.1	-0.7	1.6	5.8
Greenland Shelf (1F)	-0.6	0.7	-0.4	0.1	0.1	2.2	-1.3	-1.1	-1.0	0.5	-0.6	1.1	0.2	1.6	0.9	-0.3	-0.3
Central Labrador Sea (2GH,1F)	-0.8	-0.3	-0.4	0.0	1.0	-1.1	0.4	-0.7	1.2	-1.1	0.9	1.9	-1.1	1.1	-1.2	1.1	-1.8
Northern Labrador Shelf (2H)	-0.7	-0.4	-0.7	0.4	0.1	-0.8	1.1	-0.7	0.7	0.0	0.0	-1.5	2.4	5.7	-1.3	-2.1	-3.5
Labrador Shelf (2J)	1.1	0.1	0.5	0.9	-1.6	-0.7	1.3	0.6	-1.6	0.0	-1.4	0.2	0.6	4.2	0.9	0.4	2.8
Hamilton Bank (2J)	0.7	-1.4	-0.8	0.5	-0.7	0.0	1.9	-0.4	0.1	-0.8	-0.7	-0.3	1.9	2.5	-0.1	0.4	-1.1
St. Anthony Basin (3K)	-0.3	-0.3	-0.2	-0.1	0.7	0.5	-0.6	-0.3	-0.5	-0.3	-1.3	2.9	-0.3	0.5	-1.3	-0.8	-1.5
Northeast Newfoundland Shelf (3KL)	0.6	-1.0	0.5	-0.2	1.0	-1.1	0.2	-0.3	-0.3	-0.2	-1.4	-0.1	2.4	2.6	0.8	0.7	-0.1
Northwest Gulf of St. Lawrence (4S)	-0.5	-0.1	1.3	0.3	-0.2	-0.8	0.9	-1.0	-1.0	0.0	-1.4	0.4	2.1	3.7	0.4	2.2	-1.6
Northeast Gulf of St. Lawrence (4RS)	0.9	1.7	0.0	1.5	0.9	-0.7	-0.8	-1.4	-0.2	-0.3	-1.4	-0.1	-0.1	4.4	0.1	0.9	0.4
GSL Estuary (4T)	-0.9	0.4	-0.2	-1.2	0.7	-1.1	1.0	0.0	-0.3	0.0	-1.0	0.2	2.4	2.8	0.7	0.5	-0.3
Magdalen Shallows (4T)	0.2	0.7	-0.3	-0.6	0.4	0.0	-1.2		1.6	1.4	-1.4	-1.3	0.5	2.4	-0.1	1.1	-2.2
Cabot Strait (3Pn, 4Vn)	0.9	2.1	-0.9	-0.1	-1.2	-0.7	-0.3	0.0	0.5	-0.5	-0.6	-0.8	1.5	2.9	-0.2	2.2	-1.0
Avalon Channel (3L)	0.0	0.0	-0.3	-1.1	-0.1	-0.7	-0.7	-0.8	0.1	0.5	0.0	-0.1	3.0	4.3	1.1	0.1	0.6
Hibernia (3L)	0.1	-0.3	-0.3	-0.3	0.7	1.0	-0.9	-0.5	0.3	-0.2	-1.2	-0.9	2.6	4.2	-0.1	-0.7	0.5
Flemish Pass (3LM)	-0.1	0.5	0.7	-0.4	1.0	-1.1	-1.0	0.5	-0.6	-0.1	-1.4	-0.2	2.3	0.6	1.2	0.2	1.4
Flemish Cap (3M)						-1.4	-0.3	0.3	-0.3	0.0	-0.2	-0.2	2.2	0.7	1.1	-0.7	-0.2
St. Pierre Bank (3Ps)	0.1	1.9	-0.2	-0.6	1.8	-0.2	-0.7	-0.4	0.7	-0.5	-0.6	-1.7	0.2	6.6	3.0	1.8	-0.4
Southeast Shoal (3NO)	-0.8	-0.7	-0.7	-0.5	0.5	0.7	-0.5	-0.6	-0.6	-0.6	1.5	2.4	0.0	0.4	-0.1	-0.7	-0.2
Eastern Scotian Shelf (4Vs)	-0.3	1.8	0.7	-0.5	-1.0	-0.6	0.1	-0.8	0.3	-2.0	1.0	0.5	0.9	1.1	-2.4	0.7	0.6
Western Bank (4W)	-0.3	1.2	-0.4	-0.3	-0.4	-1.2	0.1	-0.6	-0.3	2.7	-0.8	0.2	0.1	-0.7	0.1	0.4	-0.9
Central Scotian Shelf (4W)	-0.5	0.3	-0.1	-0.6	-0.9	-1.4	-0.1	-1.2	0.1	0.0	0.7	1.6	2.0	1.4	1.9	0.9	-2.3
Western Scotian Shelf (4X)	-0.2	0.6	-0.1	-1.1	-0.5	-0.7	-0.9	-0.2	-0.7	-0.1	-0.1	1.5	2.5	0.6		1.5	0.4
Lurcher Shoal (4X)	-0.2	-0.6	-5.1	0.4	-2.4	0.5	-0.1	1.0	0.6	1.3	-0.8	-0.4	0.6			0.3	
Georges Bank (5Ze)	0.5	1.8	0.2	0.5	-0.4	-1.4	0.1	0.1	-0.2	1.2	-0.7	-2.0	0.2	-0.3	1.4	0.6	1.7

Figure 8. Annual anomalies of background chlorophyll *a* (in mg m^{-3} before and after the spring bloom) derived from SeaWiFS and MODIS "Aqua" sensor imagery across the different NAFO Subareas extending from Georges Bank to the Hudson Strait during 1998-2014. Blue cells indicate lower than normal levels and red cells indicate higher than normal levels. More intense colours indicate larger standardized anomalies. The numbers in the coloured cells are the differences between a given year and the long-term mean (1998-2010) divided by the standard deviation during the reference period. The statistical sub-regions are sorted from northern (top) to southern (bottom) boxes. Blank cells indicate the fitting routine could not be achieved or spring bloom not detected. Data for Flemish Cap are not yet available during 1998-2002 (grey cells).

Petrie Box	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Hudson Strait (0B, 2G)	0.2	-0.7	-0.3	-0.8	-0.5	3.0	-0.4	0.1	0.8	-0.5	-0.4	-0.6	0.1	-0.8	-0.6	-0.5	-1.2
Greenland Shelf (1F)	0.0	0.7	-0.5	1.7	0.9	0.3	-0.9	-1.2	1.0	0.8	-1.5	-1.0	-0.4	0.9	-0.4	-0.7	-1.3
Central Labrador Sea (2GH,1F)	0.0	-0.5	-1.1	-1.2	-0.8	1.0	0.6	1.5	-0.9	1.3	0.5	-1.3	0.9	4.3	-0.6	-0.1	-0.7
Northern Labrador Shelf (2H)	0.0	0.0	-0.7	0.6	-1.0	0.7	-0.7	-0.1	-0.1	-0.5	2.8	0.0	-1.1	-0.8	-0.7	-1.6	-1.0
Labrador Shelf (2J)	-0.2	0.8	-0.6	-0.1	-0.7	-0.1	-1.5	-0.2	0.8	-1.4	2.0	0.1	1.1	-0.4	-0.8	-1.1	-0.5
Hamilton Bank (2J)	-0.4	0.7	-1.1	1.5	-1.0	-0.5	-1.0	-0.2	0.9	-1.5	0.5	1.0	1.1	-0.9	-0.1	-1.6	-1.3
St. Anthony Basin (3K)	-0.3	0.3	-0.9	0.0	0.7	-0.3	-0.5	-0.8	-0.3	-0.6	3.0	0.3	-0.5	0.7	-0.5	-0.7	-1.0
Northeast Newfoundland Shelf (3KL)	0.1	0.2	0.6	-1.4	0.1	-0.5	-0.7	-0.8	1.6	-0.2	-0.7	2.3	-0.4	3.1	-0.9	-1.3	-1.0
Northwest Gulf of St. Lawrence (4S)	1.0	-0.2	-0.2	0.9	-1.4	0.6	1.5	0.0	0.6	-1.0	0.8	-1.7	-1.0	-1.8	3.9	-0.2	0.5
Northeast Gulf of St. Lawrence (4RS)	1.7	-1.0	-1.2	-0.1	-0.7	-0.3	0.4	-0.6	-0.2	0.3	-0.5	-0.1	2.3	-0.2	-0.3	0.9	-1.8
GSL Estuary (4T)	-0.6	-0.1	-0.7	0.1	0.2	0.0	-0.1	-0.2	-0.1	-0.4	3.2	-0.7	-0.5	-0.7	-0.4	1.1	-0.6
Magdalen Shallows (4T)	-0.3	-1.4	0.6	-0.2	0.9	0.5	-0.7		-1.5	1.4	-1.0	0.8	1.0	0.6	3.0	-0.3	0.4
Cabot Strait (3Pn, 4Vn)	1.1	0.3	0.0	-0.8	0.2	0.3	-0.6	-1.2	2.1	1.0	-1.3	-0.1	-1.0	0.1	1.6	-0.3	0.1
Avalon Channel (3L)	-1.5	-0.7	-0.7	-0.2	0.4	-0.3	-0.4	-0.8	0.2	0.4	-0.2	1.3	2.4	0.8	-0.9	-0.6	-0.9
Hibernia (3L)	-0.6	1.7	1.7	-0.9	-0.2	-1.3	0.6	-1.1	-0.3	-0.3	1.0	0.3	-0.5	-0.1	-1.0	-0.6	-0.5
Flemish Pass (3LM)	-1.5	-0.4	0.0	-1.2	1.8	-0.3	0.3	0.6	-0.3	-0.2	-1.1	1.5	0.9	-1.5	-0.8	-0.1	-1.8
Flemish Cap (3M)						0.6	0.1	0.8	1.2	-1.6	-0.7	-1.0	0.6	-1.0	-0.2	-0.1	-0.7
St. Pierre Bank (3Ps)	-0.8	-0.4	-1.1	1.7	-0.2	-0.7	0.0	-0.5	0.1	-0.2	-1.0	1.8	1.3	0.5	1.4	-1.2	-0.5
Southeast Shoal (3NO)	-0.4	0.5	-1.6	0.0	1.3	-0.5	-0.8	-1.0	0.2	-0.8	1.9	1.0	0.2	0.5	-0.9	0.8	2.0
Eastern Scotian Shelf (4Vs)	0.9	-1.0	0.1	-1.2	0.4	-0.3	-0.5	-1.1	0.5	2.2	1.0	-0.7	-0.3	1.0	2.0	0.8	-1.3
Western Bank (4W)	-0.4	-0.4	-0.7	0.0	-0.1	1.2	0.4	-1.1	-0.5	1.7	-1.4	1.8	-0.4	6.1	-0.6	-1.0	0.6
Central Scotian Shelf (4W)	-1.3	-0.1	0.7	-0.1	0.2	1.5	-0.6	-1.6	0.2	1.7	-0.2	0.7	-1.1	-0.6	0.3	-0.8	-0.5
Western Scotian Shelf (4X)	-0.9	-0.6	-1.3	-0.6	0.1	1.7	-1.4	1.3	1.3	0.2	0.2	0.4	-0.5	-0.7		-0.1	-1.0
Lurcher Shoal (4X)	-0.9	-1.0	-1.1	0.6	0.5	0.1	-0.7	-0.9	0.1	-0.3	-0.6	0.6	2.5			-0.8	
Georges Bank (5Ze)	-1.1	-0.5	-0.5	-0.3	0.8	0.7	0.4	-0.6	-0.5	-0.7	-0.6	2.7	0.1	1.2	-0.7	-0.9	-0.7

Figure 9. Annual anomalies of the magnitude (integral of chlorophyll *a* concentration during the bloom in mg m^{-2} d^{-1}) of the spring bloom derived from SeaWiFS and MODIS "Aqua" sensor imagery across the different NAFO Subareas extending from Georges Bank to the Hudson Strait during 1998-2014. Blue cells indicate lower than normal levels and red cells indicate higher than normal levels. More intense colours indicate larger standardized anomalies. The numbers in the coloured cells are the differences between a given year and the long-term mean (1998-2010) divided by the standard deviation during the reference period. The statistical sub-regions are sorted from northern (top) to southern (bottom) boxes. Blank cells indicate the fitting routine could not be achieved or spring bloom not detected. Data for Flemish Cap are not yet available during 1998-2002 (grey cells).

Petrie Box	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Hudson Strait (0B, 2G)	-0.7	0.4	-0.4	0.8	-0.9	1.0	-1.3	-0.1	-0.2	-1.3	1.4	1.7	-0.7	-2.0	-1.7	-1.0	-0.3
Greenland Shelf (1F)	0.0	1.1	-0.6	2.1	0.1	0.9	-0.7	-0.6	0.9	0.2	-1.2	-1.1	-1.0	3.8	-0.5	-0.7	-1.0
Central Labrador Sea (2GH,1F)	-0.4	-0.9	-0.6	1.0	0.4	-0.2	-0.5	-0.3	0.0	-0.2	2.9	-0.8	-0.4	-0.1	0.3	-0.9	1.4
Northern Labrador Shelf (2H)	-0.4	0.1	-0.2	-0.5	-0.8	0.0	-0.5	1.0	-0.2	-0.7	0.1	2.9	-0.7	-0.1	-0.6	-1.5	-0.3
Labrador Shelf (2J)	1.4	1.5	-0.7	-0.7	-1.3	0.5	-0.5	-0.8	-0.7	-1.1	0.9	0.5	1.2	-0.3	-0.6	-0.9	0.0
Hamilton Bank (2J)	-0.7	1.3	-1.0	-0.5	-0.9	0.3	-0.9	-0.6	0.5	-0.7	2.1	0.1	1.0	-0.3	0.1	-0.7	-0.5
St. Anthony Basin (3K)	-0.5	0.5	-1.1	0.8	1.8	-0.4	-0.8	-1.2	-0.2	-0.4	1.6	0.6	-0.8	2.2	-0.8	-0.5	-0.9
Northeast Newfoundland Shelf (3KL)	-0.5	-0.7	0.0	-1.2	0.4	-0.5	-0.7	-0.4	1.9	2.1	-0.8	0.0	0.3	4.0	-0.7	-0.6	-0.9
Northwest Gulf of St. Lawrence (4S)	1.1	-0.1	-1.2	1.3	1.7	-0.2	0.3	0.9	-0.2	-0.7	-0.3	-1.6	-1.0	-1.5	0.2	-0.4	-0.4
Northeast Gulf of St. Lawrence (4RS)	2.4	-0.3	-0.6	0.6	-0.8	-0.7	0.3	-1.2	-0.1	0.1	-0.9	-0.2	1.4	2.7	-0.8	1.3	-1.0
GSL Estuary (4T)	0.1	1.1	-0.6	0.0	0.0	-0.4	-0.2	-0.5	-0.5	-0.5	2.9	-0.6	-0.9	-0.6	-0.7	1.5	-0.4
Magdalen Shallows (4T)	0.3	-1.4	-1.1	-0.2	0.4	-0.7	1.1		-0.3	0.5	-1.0	2.2	0.2	6.6	2.9	-1.3	1.3
Cabot Strait (3Pn, 4Vn)	1.1	1.0	0.3	-0.7	-0.4	0.6	-0.4	-1.3	1.7	0.8	-1.3	-0.3	-1.1	0.1	-0.2	-0.5	0.3
Avalon Channel (3L)	-1.0	-0.6	-0.5	-0.7	-0.6	-0.1	-0.6	-0.9	0.6	0.9	0.0	1.0	2.5	1.1	0.4	-0.1	-0.4
Hibernia (3L)	-0.7	1.4	1.4	-1.0	-0.8	-1.3	-0.1	-1.0	0.1	0.0	1.8	0.2	0.0	0.7	-0.8	-0.9	-0.4
Flemish Pass (3LM)	-0.9	-0.1	-0.4	-1.4	2.0	-0.3	-1.0	0.9	0.0	1.2	0.3	0.7	-1.0	0.0	1.6	-0.1	-0.5
Flemish Cap (3M)						0.4	-0.6	-0.4	2.1	-1.0	0.6	-0.3	-0.8	0.1	2.1	0.1	1.1
St. Pierre Bank (3Ps)	-0.4	0.4	-1.0	2.1	-0.7	-0.3	-0.3	1.0	1.5	-0.2	-1.4	-0.1	-0.6	-0.1	4.7	-1.1	-0.4
Southeast Shoal (3NO)	-0.9	0.1	-1.5	0.3	1.2	0.1	-0.9	-1.3	0.5	-0.3	1.9	-0.1	0.9	-1.1	-0.4	0.8	0.8
Eastern Scotian Shelf (4Vs)	1.5	-0.6	-0.1	-1.1	0.9	0.3	-0.6	-1.3	1.6	0.7	-0.2	-1.5	0.3	1.7	2.1	2.7	-1.2
Western Bank (4W)	-0.5	-0.5	-0.9	-0.4	-0.1	0.3	0.4	-0.6	-0.2	2.9	-1.1	0.4	0.2	2.2	-0.2	-1.0	-0.9
Central Scotian Shelf (4W)	-1.2	-0.7	0.8	-1.2	0.5	1.3	-0.1	-0.9	-0.5	1.8	0.3	0.8	-1.0	-0.3	6.6	-0.5	-0.3
Western Scotian Shelf (4X)	-0.6	-0.4	-0.7	-0.4	0.1	3.0	-0.7	0.6	0.7	-0.5	-0.5	0.0	-0.3	-0.6		-0.6	-0.6
Lurcher Shoal (4X)	-0.6	-0.9	-1.2	2.6	-0.7	0.9	-0.3	-0.8	0.8	-0.2	-0.3	-0.4	-0.1			-0.9	
Georges Bank (5Ze)	-0.6	-0.6	-0.1	3.2	-0.6	0.2	0.0	-0.5	-0.2	-0.6	-0.4	0.1	0.1	0.3	-0.5	-0.5	-0.4

Figure 10. Annual anomalies of the amplitude (peak intensity in mg m^{-3}) of the spring bloom derived from SeaWiFS and MODIS "Aqua" sensor imagery across the different NAFO Subareas extending from Georges Bank to the Hudson Strait during 1998-2014. Blue cells indicate lower than normal levels and red cells indicate higher than normal levels. More intense colours indicate larger standardized anomalies. The numbers in the coloured cells are the differences between a given year and the long-term mean (1998-2010) divided by the standard deviation during the reference period. The statistical sub-regions are sorted from northern (top) to southern (bottom) boxes. Blank cells indicate the fitting routine could not be achieved or spring bloom not detected. Data for Flemish Cap are not yet available during 1998-2002 (grey cells).

Petrie Box	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Hudson Strait (0B, 2G)	0.4	-0.3	0.6	-0.7	-0.1	2.4	-0.7	-1.2	-0.7	0.9	-1.2	0.1	0.5	-0.1	-0.5	-0.2	-1.8
Greenland Shelf (1F)	0.8	1.7	0.1	0.5	-0.4	0.4	-0.9	-2.0	-0.4	0.0	0.0	1.2	-1.0	-0.3	0.2	-0.5	0.5
Central Labrador Sea (2GH,1F)	-0.9	0.1	1.1	-0.9	0.6	-0.6	1.2	1.5	-1.3	-0.9	-1.1	0.2	1.0	-1.5	-0.9	0.1	-1.2
Northern Labrador Shelf (2H)	-0.4	-0.1	0.1	-0.4	0.8	-0.7	-0.3	-0.4	-0.4	2.8	-1.4	0.3	0.1	-0.4	-0.2	-0.1	-0.1
Labrador Shelf (2J)	-0.2	-0.4	1.0	1.4	1.5	-0.1	-0.1	-0.5	-1.5	1.0	-1.1	0.5	-1.4	-0.3	-0.8	-0.7	-2.4
Hamilton Bank (2J)	-0.5	-0.2	1.1	0.8	1.6	0.2	-0.1	-0.5	-1.8	0.8	-1.2	0.7	-1.0	-0.3	-0.9	-0.1	0.4
St. Anthony Basin (3K)	-0.2	-0.7	-1.0	0.1	0.2	1.8	0.8	0.1	-0.1	0.4	-1.1	-1.7	1.4	1.1	1.5	2.0	1.7
Northeast Newfoundland Shelf (3KL)	-0.3	-1.2	0.2	1.4	1.3	1.2	0.7	-0.9	-1.0	0.0	0.6	-0.3	-1.6	0.0	-0.7	0.2	0.8
Northwest Gulf of St. Lawrence (4S)	-0.6	1.0	1.6	0.1	0.5	0.8	0.7	-1.5	-0.4	0.0	0.1	-0.4	-2.0	-1.1	-0.9	-0.3	-0.1
Northeast Gulf of St. Lawrence (4RS)	-0.6	0.1	1.2	0.1	0.8	2.4	-0.7	0.0	-0.9	0.0	-0.1	-0.8	-1.5	-0.4	-0.7	-1.2	0.0
GSL Estuary (4T)	-0.8	-0.4	-0.9	0.7	0.3	0.2	0.5	0.3	-0.3	-0.6	2.7	-0.8	-1.0	-1.7	-1.3	0.3	-2.2
Magdalen Shallows (4T)	0.5	-1.2	1.0	1.3	0.1	-0.1	0.1		0.2	0.0	0.2	0.4	-2.5	-1.2	-2.6	-1.8	-0.4
Cabot Strait (3Pn, 4Vn)	-0.7	-1.5	-0.4	1.2	0.1	0.7	0.6	0.4	-0.6	0.4	1.5	0.3	-2.0	0.8	-0.7	0.3	0.5
Avalon Channel (3L)	0.0	-1.2	-0.5	1.1	0.4	2.1	-0.2	-0.9	0.3	0.0	1.0	-0.9	-1.3	0.1	-0.7	0.3	1.0
Hibernia (3L)	0.7	-0.9	-0.9	0.9	1.7	0.4	-0.3	0.2	0.1	0.1	0.9	-0.8	-2.1	0.3	-0.5	-0.6	0.6
Flemish Pass (3LM)	-0.3	-1.7	0.2	1.1	1.1	1.8	0.2	-0.8	-1.4	-0.2	-0.2	-0.3	0.6	-0.1	-0.6	-0.9	-0.5
Flemish Cap (3M)						2.0	0.8	-0.9	-0.8	-0.5	-0.3	-0.8	0.5	1.2	-0.8	-1.1	-1.0
St. Pierre Bank (3Ps)	-0.1	0.9	-0.3	0.4	0.2	1.3	0.3	-0.7	0.2	-0.2	0.6	0.2	-2.8	-0.5	-1.2	0.0	0.6
Southeast Shoal (3NO)	0.2	-0.4	-0.8	0.5	0.7	1.6	0.7	0.0	-0.1	0.7	0.6	-2.1	-1.5	-0.7	-0.3	0.0	0.2
Eastern Scotian Shelf (4Vs)	-0.1	-1.7	0.5	1.5	0.2	0.9	0.8	-1.0	-0.5	-0.2	0.2	1.1	-1.7	0.0	-2.1	1.1	1.0
Western Bank (4W)	0.1	-2.7	1.5	-0.1	0.4	0.4	0.5	-0.2	-0.9	1.0	0.3	0.0	-0.3	-2.0	0.0	2.4	1.7
Central Scotian Shelf (4W)	-0.6	-2.1	1.9	0.9	0.0	0.8	0.2	-0.4	-0.6	0.2	0.1	0.6	-1.0	0.9	-1.7	1.3	3.5
Western Scotian Shelf (4X)	-0.5	-2.1	1.3	1.6	-0.7	0.7	-0.4	-0.7	-0.4	0.7	0.7	0.3	-0.5	1.0		-4.2	0.1
Lurcher Shoal (4X)	-0.3	-0.8	-6.8	0.8	-2.2	0.4	0.8	0.5	-0.2	0.1	1.6	0.4	-1.0			0.1	
Georges Bank (5Ze)	0.0	-1.9	-1.8	1.2	1.4	0.3	0.0	0.6	-0.8	0.0	0.0	0.1	0.9	0.0	-0.3	1.9	-1.2

Figure 11. Annual anomalies of the peak timing (day of year) of the spring bloom derived from SeaWiFS and MODIS "Aqua" sensor imagery across the different NAFO Subareas extending from Georges Bank to the Hudson Strait during 1998-2014. Blue cells indicate earlier and red cells indicate later than normal blooms. More intense colours indicate larger standardized anomalies. The numbers in the coloured cells are the differences between a given year and the long-term mean (1998-2010) divided by the standard deviation during the reference period. The statistical sub-regions are sorted from northern (top) to southern (bottom) boxes. Blank cells indicate the fitting routine could not be achieved or spring bloom not detected. Data for Flemish Cap are not yet available during 1998-2002 (grey cells).

Petrie Box	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Hudson Strait (0B, 2G)	0.7	-1.0	-0.3	-1.2	-0.2	2.3	0.2	0.1	1.1	0.0	-1.0	-1.2	0.5	0.2	0.2	-0.1	-1.4
Greenland Shelf (1F)	-0.3	-0.6	0.2	-0.6	1.0	-0.8	-0.4	-1.2	-0.2	0.6	-1.1	0.8	2.4	-1.7	0.2	0.1	-0.8
Central Labrador Sea (2GH,1F)	0.1	1.2	-0.7	-1.4	-1.1	0.5	0.9	1.2	-1.0	0.9	-1.2	-0.5	1.0	2.8	-0.9	1.6	-1.3
Northern Labrador Shelf (2H)	0.3	-0.3	-0.7	1.3	-0.6	0.6	-0.4	-0.9	-0.1	0.2	2.4	-1.3	-0.8	-0.9	-0.3	-0.7	-0.9
Labrador Shelf (2J)	-1.1	-0.6	-0.1	0.7	1.3	-0.7	-1.3	0.7	2.0	-0.8	0.5	-0.5	-0.3	-0.3	-0.4	-0.4	-0.6
Hamilton Bank (2J)	0.6	-1.0	0.4	2.3	0.7	-1.0	0.3	0.6	-0.3	-0.7	-1.4	0.2	-0.7	-0.8	-0.5	-1.0	-1.0
St. Anthony Basin (3K)	0.6	-0.1	-1.0	-1.0	-0.6	-0.1	0.3	0.5	-0.3	-1.2	2.6	-0.3	0.7	-0.9	0.5	-1.5	-1.9
Northeast Newfoundland Shelf (3KL)	0.8	1.4	0.4	-0.3	-0.6	-0.3	0.0	-0.8	-0.5	-1.6	0.2	2.2	-0.9	-0.7	-0.4	-1.3	-0.2
Northwest Gulf of St. Lawrence (4S)	-0.3	-0.3	1.5	-0.5	-2.3	0.8	0.9	-0.9	0.7	-0.4	1.1	-0.1	-0.1	-0.7	3.3	0.1	0.9
Northeast Gulf of St. Lawrence (4RS)	-1.1	-1.1	-0.8	-1.1	0.4	1.0	-0.2	2.3	-0.3	-0.1	1.1	-0.1	0.0	-2.1	1.1	-0.9	-1.3
GSL Estuary (4T)	-1.1	-0.4	-1.2	0.6	0.6	0.6	0.2	0.0	0.4	-0.5	2.5	-1.1	-0.5	-1.2	-0.2	1.0	-1.0
Magdalen Shallows (4T)	-0.5	-0.4	2.1	-0.2	0.3	1.1	-1.3		-1.3	0.6	-0.2	-0.8	0.6	-1.7	0.1	1.3	-0.7
Cabot Strait (3Pn, 4Vn)	-0.1	-1.5	-1.0	-0.6	2.3	-0.8	-0.8	1.0	0.5	0.4	-0.3	0.5	0.5	-0.3	6.0	0.6	-0.7
Avalon Channel (3L)	-0.1	0.1	-0.3	1.4	1.6	-0.6	0.8	1.5	-0.9	-1.1	-0.7	-0.7	-1.1	-1.0	-1.6	-0.8	-0.8
Hibernia (3L)	0.4	-0.1	-0.1	0.3	2.1	1.2	1.1	-0.5	-1.0	-0.8	-1.1	-0.1	-1.3	-1.5	-0.8	2.0	-0.4
Flemish Pass (3LM)	-0.3	-0.5	0.0	1.2	-0.7	-0.2	1.5	-0.6	-0.4	-1.0	-1.0	-0.2	2.2	-1.1	-1.3	-0.3	-1.0
Flemish Cap (3M)						-0.1	0.7	0.9	-0.7	-0.8	-1.0	-0.7	1.7	-1.0	-1.1	-0.3	-1.1
St. Pierre Bank (3Ps)	-0.6	-0.8	-0.4	-0.4	0.4	-0.6	0.1	-1.1	-1.0	-0.2	0.8	1.6	2.1	0.5	-1.2	-0.3	-0.3
Southeast Shoal (3NO)	1.7	0.6	-0.6	-0.7	0.0	-1.1	0.1	1.0	-0.5	-1.3	-0.2	1.7	-1.0	5.7	-1.2	-0.2	1.4
Eastern Scotian Shelf (4Vs)	-0.5	-0.9	0.1	-0.7	-0.5	-0.8	-0.2	0.1	-0.8	1.4	1.6	1.9	-0.8	-0.5	0.0	-1.1	-0.7
Western Bank (4W)	0.2	0.1	1.5	0.9	-0.3	0.9	-0.3	-1.2	-0.7	-1.3	-0.1	1.6	-1.2	2.0	-0.9	1.5	7.2
Central Scotian Shelf (4W)	0.4	0.6	-0.4	2.9	-0.5	-0.4	-0.6	-0.8	0.5	-0.6	-0.6	-0.5	0.0	-0.4	-1.6	-0.4	-0.4
Western Scotian Shelf (4X)	0.6	-0.2	0.5	-0.4	-0.6	-1.2	-0.7	-0.5	-0.6	2.0	2.0	-0.3	-0.5	0.4		2.2	0.3
Lurcher Shoal (4X)	-0.7	-0.5	-1.0	-0.6	1.8	-0.5	-0.6	-0.6	-0.5	-0.3	-0.5	0.9	2.0			0.0	
Georges Bank (5Ze)	-0.7	0.7	-0.7	-1.1	2.8	-0.2	-0.1	-0.2	-0.5	-0.1	-0.4	1.0	-0.4	0.0	-0.4	-0.7	-0.4

Figure 12. Annual anomalies of the duration (in days) of the spring bloom derived from SeaWiFS and MODIS "Aqua" sensor imagery across the different NAFO Subareas extending from Georges Bank to the Hudson Strait during 1998-2014. Blue cells indicate lower duration and red cells indicate higher than normal duration of blooms. More intense colours indicate larger standardized anomalies. The numbers in the coloured cells are the differences between a given year and the long-term mean (1998-2010) divided by the standard deviation during the reference period. The statistical sub-regions are sorted from northern (top) to southern (bottom) boxes. Blank cells indicate the fitting routine could not be achieved or spring bloom not detected. Data for Flemish Cap are not yet available during 1998-2002 (grey cells).

Petrie Box	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Hudson Strait (0B, 2G)	-0.5	1.0	0.8	1.0	0.1	-1.0	-0.8	-1.0	-1.9	0.6	0.3	1.5	-0.2	-0.3	-0.6	0.1	0.5
Greenland Shelf (1F)	0.8	1.7	0.0	0.7	-0.8	0.7	-0.6	-1.0	-0.2	-0.3	0.5	0.6	-2.1	0.6	0.0	-0.4	0.8
Central Labrador Sea (2GH,1F)	-0.6	-1.3	1.4	1.0	1.6	-0.9	-0.3	-0.5	0.3	-1.5	0.6	0.7	-0.5	-4.0	0.5	-1.7	0.8
Northern Labrador Shelf (2H)	-0.5	0.0	0.3	-0.8	0.8	-0.7	-0.1	0.0	-0.3	2.3	-2.0	0.6	0.3	0.0	-0.1	0.1	0.3
Labrador Shelf (2J)	0.4	0.0	0.9	0.8	0.5	0.2	0.6	-0.7	-2.2	1.2	-1.2	0.6	-1.0	-0.1	-0.4	-0.4	-1.6
Hamilton Bank (2J)	-1.0	0.6	0.9	-0.8	1.2	1.0	-0.3	-1.0	-1.7	1.4	-0.2	0.6	-0.6	0.3	-0.5	0.5	1.2
St. Anthony Basin (3K)	-0.4	-0.5	-0.4	0.5	0.5	1.6	0.6	-0.1	0.0	0.8	-2.1	-1.4	0.9	1.3	1.1	2.4	2.3
Northeast Newfoundland Shelf (3KL)	-0.7	-1.7	-0.1	1.2	1.3	1.0	0.5	-0.1	-0.4	1.0	0.3	-1.6	-0.6	0.5	-0.2	0.9	0.7
Northwest Gulf of St. Lawrence (4S)	-0.5	1.2	1.0	0.3	1.6	0.5	0.4	-1.1	-0.7	0.2	-0.3	-0.4	-2.0	-0.9	-2.4	-0.4	-0.5
Northeast Gulf of St. Lawrence (4RS)	0.0	0.6	1.6	0.6	0.5	1.8	-0.6	-1.1	-0.7	0.0	-0.7	-0.7	-1.4	0.7	-1.2	-0.8	0.7
GSL Estuary (4T)	1.2	0.4	1.4	-0.4	-0.8	-0.9	0.2	0.2	-0.9	0.4	-2.0	1.3	0.0	0.5	-0.9	-1.5	-0.1
Magdalen Shallows (4T)	0.7	-0.7	-0.6	1.1	-0.1	-0.8	0.9		1.0	-0.4	0.3	0.8	-2.3	0.2	-2.1	-2.2	0.1
Cabot Strait (3Pn, 4Vn)	-0.7	-1.0	-0.2	1.3	-0.5	0.9	0.8	0.2	-0.7	0.3	1.5	0.2	-2.0	0.8	-2.2	0.1	0.7
Avalon Channel (3L)	0.1	-1.0	-0.3	0.0	-0.6	2.1	-0.6	-1.7	0.8	0.7	1.2	-0.3	-0.4	0.7	0.4	0.7	1.3
Hibernia (3L)	0.5	-0.9	-0.9	0.7	0.6	-0.3	-1.1	0.6	0.8	0.7	1.8	-0.8	-1.6	1.3	0.0	-2.0	0.9
Flemish Pass (3LM)	0.0	-1.2	0.2	0.0	1.6	1.8	-1.1	-0.2	-0.9	0.7	0.7	-0.2	-1.4	0.8	0.5	-0.6	0.4
Flemish Cap (3M)						1.5	-0.2	-1.5	0.1	0.5	0.8	0.1	-1.3	1.7	0.6	-0.4	0.4
St. Pierre Bank (3Ps)	0.3	1.0	0.1	0.4	-0.1	1.1	0.1	0.2	0.7	0.0	-0.1	-0.8	-2.9	-0.6	-0.1	0.1	0.5
Southeast Shoal (3NO)	-0.4	-0.6	-0.5	0.6	0.6	1.7	0.6	-0.3	0.1	1.0	0.5	-2.3	-0.9	-2.5	0.1	0.1	-0.3
Eastern Scotian Shelf (4Vs)	0.2	-1.0	0.4	1.9	0.5	1.4	0.8	-1.0	0.1	-1.1	-0.9	-0.3	-1.0	0.4	-2.0	1.8	1.4
Western Bank (4W)	0.0	-2.6	0.7	-0.6	0.5	0.0	0.6	0.4	-0.5	1.6	0.3	-0.8	0.3	-2.9	0.4	1.6	-1.9
Central Scotian Shelf (4W)	-0.7	-1.8	1.5	-1.6	0.4	0.8	0.6	0.4	-0.8	0.6	0.5	0.7	-0.6	0.9	0.2	1.1	2.5
Western Scotian Shelf (4X)	-0.9	-1.5	0.6	1.7	-0.1	1.6	0.3	-0.1	0.2	-1.2	-1.2	0.5	0.0	0.5		-5.3	-0.2
Lurcher Shoal (4X)	0.4	0.0	-2.1	0.7	-2.1	0.5	0.7	0.6	0.2	0.3	1.0	-0.5	-1.8			0.0	
Georges Bank (5Ze)	0.7	-1.8	-0.5	1.7	-1.7	0.4	0.1	0.6	0.0	0.0	0.4	-0.9	1.0	0.0	0.2	1.8	-0.3

Figure 13. Annual anomalies of the initiation (20 % of the bloom amplitude in day of year) of the spring bloom derived from SeaWiFS and MODIS "Aqua" sensor imagery across the different NAFO Subareas extending from Georges Bank to the Hudson Strait during 1998-2014. Blue cells indicate earlier and red cells indicate later than normal blooms. More intense colours indicate larger standardized anomalies. The numbers in the coloured cells are the differences between a given year and the long-term mean (1998-2010) divided by the standard deviation during the reference period. The statistical sub-regions are sorted from northern (top) to southern (bottom) boxes. Blank cells indicate the fitting routine could not be achieved or spring bloom not detected. Data for Flemish Cap are not yet available during 1998-2002 (grey cells).

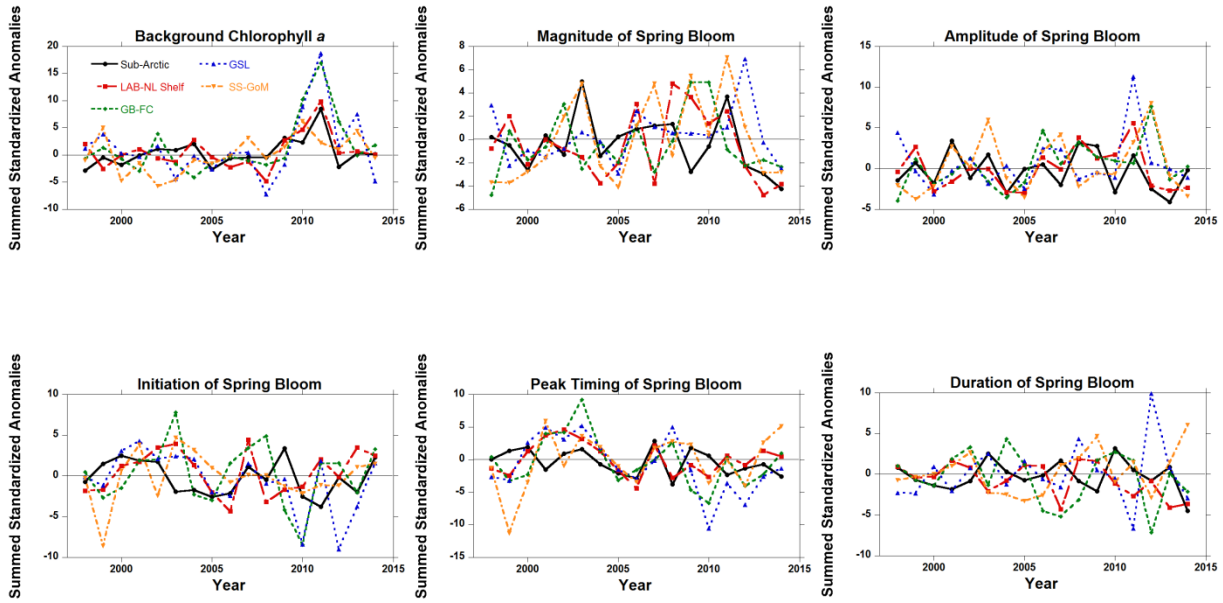

Figure 14. Composite (sum of anomalies) annual anomalies across the Sub-Arctic (Greenland Shelf, Hudson Strait, Central Labrador Sea); Labrador (LAB) and Newfoundland (NL) Shelf (Northern Labrador Shelf, Labrador Shelf, Hamilton Bank, St. Anthony Basin, northeast Newfoundland Shelf); Gulf of St. Lawrence (NE and NW Gulf of St. Lawrence, Estuary, and Magdalen Shallows, Cabot Strait); Grand Bank (GB) and Flemish Cap (FC) (Avalon Channel, Hibernia, Flemish Pass/Cap, St. Pierre Bank and SE Shoal) and Scotian Shelf (SS) and Gulf of Maine (GoM) (Eastern-Central-Western Scotian Shelf, Western Bank, Lurcher Shoal, Georges Bank) for the different ocean colour metrics during 1998-2014.

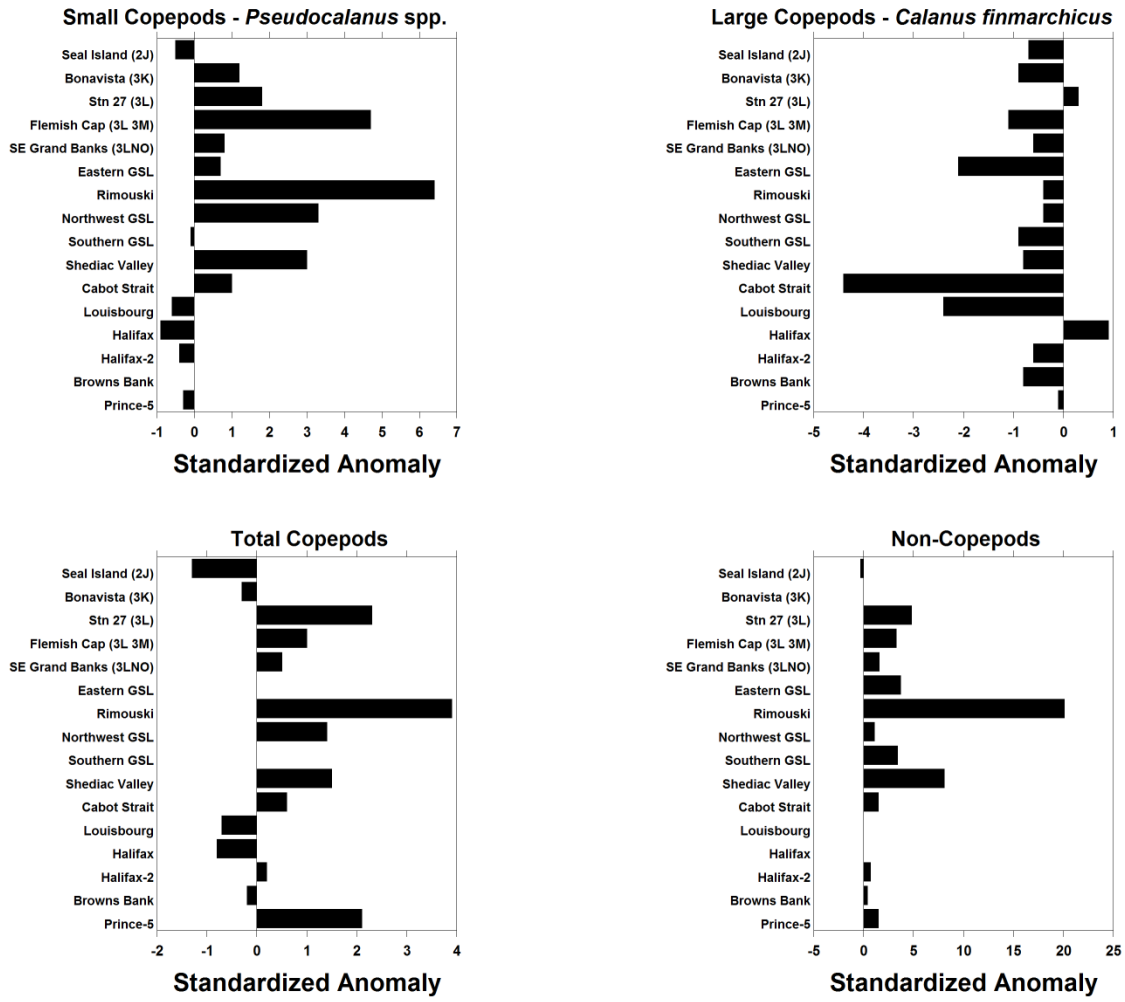

Figure 15. Summary of zooplankton abundance anomalies from different oceanographic transects and fixed stations from the Atlantic Zone Monitoring Program during 2014. The zooplankton abundance anomalies for transects were calculated using a general linear model using station, season, and year while the fixed stations only used season and year as inputs and were based on all available seasonal data. The NAFO Subareas are sorted by latitude from the southern Labrador Shelf - 2J (top) to southern Scotian Shelf - 4X (bottom).

Pseudocalanus spp.	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Seal Island (2J)	0.1	-0.6	0.2	-0.6	0.2	-0.3	-0.7	0.7	1.6	1.5	-2.1	-0.1	0.9	1.8	-0.8	-0.5
Bonavista (3K)	-1.2	-1.8	1.1	0.0	0.5	0.0	-1.0	0.6	-0.5	-0.1	0.9	1.5	-0.5	-0.2	2.8	1.2
Stn 27 (3L)	-0.6	0.8	0.3	0.5	0.3	-1.7	-0.2	-0.7	0.5	-1.5	1.7	0.8	0.2	0.2	0.7	1.8
Flemish Cap (3L 3M)	-0.1	1.4	-0.3	1.5	-0.5	-0.8	-1.4	0.0	-0.8	-0.6	-0.1	1.6	-1.6	-0.3	3.4	4.7
SE Grand Banks (3LNO)	-2.5	1.2	0.6	0.8	-0.7	-0.1	0.7	-0.6	0.5	-0.6	0.0	0.7	1.4	-0.6	1.5	0.8
Eastern GSL		2.5	-1.1	-0.8	-0.4	0.7	-0.4	-0.3	-0.9	0.2	-0.1	0.5	0.7	-0.7	-0.3	0.7
Rimouski							-1.2	-0.4	0.7	-0.7	0.1	1.6	1.6	-1.1	-0.4	6.4
Northwest GSL		0.4	-1.6	-0.6	-1.0	-0.1	-0.9	0.7	1.0	-0.3	0.7	1.8	0.5	-1.4	1.1	3.3
Southern GSL		0.8	-0.9	-0.9	-0.2	0.2	-1.2	0.8	-1.1	-0.3	0.6	2.1	0.3	-0.4	0.9	-0.1
Shediac Valley	1.4	-0.9	2.0	-0.2	0.0	-0.6	0.4	-1.6	-0.9	-0.3	0.1	0.5	1.0	-0.2	-0.4	3.0
Cabot Strait	0.1	-0.8	-0.8		1.8	0.6	0.5	0.4	-1.9	-0.3	-0.3	0.8	-0.5	-1.1	-0.8	1.0
Louisbourg	1.7	-1.5	0.9	1.3	0.2	0.4	-0.2	-0.6	-1.3	-0.1	-1.0	0.1	0.0	-5.4	-1.4	-0.6
Halifax	0.4	0.8	0.4	1.2	0.2	-0.4	-0.4	-2.4	0.3	0.6	0.6	-1.2	-1.1	-1.4	1.0	-0.9
Halifax-2	0.7	0.8	0.0	-0.5	1.1	0.9	-1.7	-1.4	0.1	1.0	0.3	-1.3	-0.8	-1.8	0.4	-0.4
Browns Bank	0.4	0.9	1.3	-0.1	0.6	-0.9	-0.1	-1.1	0.3	1.0	-0.2	-2.1	-1.6	-2.9	0.2	0.0
Prince-5	-1.5	0.3	1.8	-1.4	0.2	0.1	-1.0	-0.4	0.3	1.2	-0.5	0.8	0.4	0.0	0.6	-0.3

Calanus finmarchicus	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Seal Island (2J)	0.1	-2.0	-0.7	0.1	0.2	1.4	1.2	0.4	0.5	0.0	-1.6	0.4	1.0	0.2	0.2	-0.7
Bonavista (3K)	-1.9	-1.9	-0.2	0.1	0.2	1.0	0.1	1.4	0.7	0.0	0.1	0.4	0.0	0.3	1.1	-0.9
Stn 27 (3L)	1.0	0.4	0.1	0.5	0.0	-0.7	-0.1	-0.2	-0.2	-2.7	0.3	1.3	0.5	-0.4	-1.9	0.3
Flemish Cap (3L 3M)	-1.0	-2.5	0.6	0.7	0.0	-0.2	0.5	1.1	-0.3	0.1	-0.2	1.1	1.1	1.3	0.0	-1.1
SE Grand Banks (3LNO)	-2.4	-1.5	0.2	0.7	0.6	0.0	0.9	0.0	0.2	0.0	0.6	0.8	1.1	0.3	0.4	-0.6
Eastern GSL		0.9	-1.1	-0.2	0.4	1.2	-0.4	-0.5	1.3	0.9	-1.1	-1.5	-0.4	-0.1	-1.0	-2.1
Rimouski							-0.9	0.0	1.8	0.3	-0.2	-0.9	-0.8	-0.6	-1.0	-0.4
Northwest GSL		-0.2	-0.9	-0.4	0.5	-0.2	-0.6	2.2	1.5	-0.4	-0.8	-0.9	-0.8	-0.6	-0.6	-0.4
Southern GSL		-1.4	0.0	1.0	0.1	0.4	-1.0	1.0	0.1	1.8	-1.0	-1.0	-1.4	0.4	-0.7	-0.9
Shediac Valley	-0.6	-0.3	-0.3	-0.3	2.6	1.3	-0.5	0.1	-0.4	0.2	-0.9	-0.9	-1.1	-0.3	-1.0	-0.8
Cabot Strait	1.1	-1.2	-1.3		1.2	0.0	0.6	0.2	0.5	0.2	-1.8	0.5	-4.3	-2.5	-3.8	-4.4
Louisbourg	1.0	-1.4	-0.8	2.1	-1.1	-0.1	-0.1	0.3	-0.6	0.3	-0.6	0.9	-1.8	-3.9	-2.3	-2.4
Halifax	-1.3	-0.8	-1.1	1.1	1.1	-0.5	-0.2	-0.6	-0.8	0.9	1.6	0.6	0.0	-1.8	1.1	0.9
Halifax-2	1.1	1.2	1.0	-1.7	0.3	-0.2	-1.4	-0.7	-0.5	1.1	-0.7	0.4	-2.5	-4.1	-1.2	-0.6
Browns Bank	-2.2	-0.3	0.8	0.7	1.2	-1.0	-0.2	0.8	-0.4	0.6	0.9	-0.9	-0.8	-1.7	0.3	-0.8
Prince-5	-2.2	-1.3	0.1	-0.8	0.5	0.9	0.7	1.5	0.2	0.5	-0.1	0.0	0.0	-0.6	-0.1	-0.1

Figure 16. Time series of dominant copepods *Pseudocalanus spp*. (top panel), and *Calanus finmarchicus* (lower panel) abundance anomalies from different oceanographic transects and fixed stations from the Atlantic Zone Monitoring Program during 1999-2014. The copepod abundance anomalies for transects were calculated using a general linear model using station, season, and year while the fixed stations only used season and year as inputs and were based on all available seasonal data. A empty grey cell indicates missing data; a blue cell indicates lower than normal levels and a red cell indicates higher than normal levels. More intense colours indicate larger anomalies. Large standardized anomalies values > ± 5 shown in yellow. The numbers in the coloured cells are the differences from the long-term mean (1999-2010) divided by the standard deviation. The NAFO Subareas are sorted by latitude from north (top) to south (bottom) Subareas.

Total Copepods	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Seal Island (2J)	-0.9	-1.9	-0.9	0.0	0.4	1.5	1.2	1.3	0.2	-0.4	-0.6	0.0	0.1	-0.9	0.1	-1.3
Bonavista (3K)	-1.8	-1.7	-0.4	-0.7	0.5	0.3	-0.3	1.2	0.5	0.4	0.8	1.1	0.0	-1.2	1.5	-0.3
Stn 27 (3L)	-0.5	0.3	-0.5	0.5	0.1	-1.2	0.0	-1.2	0.4	-1.2	2.1	1.1	1.1	-0.3	0.0	2.3
Flemish Cap (3L 3M)	-1.5	-1.3	0.0	-0.4	-0.9	-0.5	0.4	1.1	0.2	0.4	0.5	2.0	0.2	0.8	0.7	1.0
SE Grand Banks (3LNO)	-2.5	0.4	-1.1	-0.1	-0.1	0.1	1.0	-0.4	0.7	0.1	0.8	1.0	1.6	1.1	-0.2	0.5
Eastern GSL		2.1	-2.0	0.1	-0.1	0.7	-0.8	-0.5	0.0	0.4	-0.1	0.3	0.5	-0.7	-1.0	0.0
Rimouski							-1.5	-0.7	1.0	-0.2	1.2	0.2	1.4	-0.4	-0.4	3.9
Northwest GSL		0.1	-1.7	-1.0	-1.2	-0.5	-0.2	1.4	0.4	0.9	0.4	1.3	-0.3	-1.4	-1.2	1.4
Southern GSL		-0.7	-0.3	0.5	-0.8	-0.8	-1.8	1.0	-0.2	1.6	1.1	0.3	0.0	0.2	-1.8	0.0
Shediac Valley	0.7	-0.8	0.0	-0.6	0.8	-0.5	-0.2	-0.8	0.2	2.6	-0.8	-0.5	-0.3	-0.5	-1.7	1.5
Cabot Strait	1.4	-1.3	-1.3		0.9	0.2	0.5	-0.9	-0.3	0.0	-0.7	1.5	-2.0	-1.2	-2.2	0.6
Louisbourg	2.4	-0.4	-0.3	-1.5	0.6	-0.4	0.3	-0.1	-0.8	0.6	-1.0	0.4	-0.5	-0.6	-2.1	-0.7
Halifax	2.1	1.1	0.1	-0.6	-0.2	-1.2	0.8	-1.2	-0.3	-0.2	0.7	-1.1	-1.0	-0.8	-1.4	-0.8
Halifax-2	1.4	1.3	0.5	-1.9	0.0	0.3	0.7	-0.8	-1.2	0.2	0.3	-0.8	-0.7	-1.7	-0.7	0.2
Browns Bank	1.2	1.1	0.7	0.9	0.8	-1.4	-0.9	0.2	-1.3	0.3	-0.8	-1.0	-1.8	0.5	-0.2	-0.2
Prince-5	0.7	0.3	1.7	-1.7	-0.3	-0.1	-1.4	0.7	-0.5	0.1	-0.8	1.2	-0.4	0.7	0.8	2.1

Non-copepods	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Seal Island (2J)	-1.6	-0.7	-0.2	-0.7	-0.1	1.2	1.0	2.0	0.1	-1.0	-0.1	0.2	0.1	-1.0	0.6	-0.3
Bonavista (3K)	-1.5	-1.9	0.2	0.1	0.3	-0.4	-0.2	1.6	0.0	-0.4	1.1	1.1	-0.4	-0.7	1.8	0.0
Stn 27 (3L)	-1.6	1.3	0.0	0.6	0.7	0.1	0.6	-0.9	0.3	-1.8	-0.5	1.1	1.0	1.9	2.0	4.8
Flemish Cap (3L 3M)	-1.9	0.1	0.4	0.7	-0.8	-0.9	0.0	0.4	-0.5	0.2	0.1	2.2	0.6	1.9	2.6	3.3
SE Grand Banks (3LNO)	-2.6	1.5	0.4	0.1	-0.1	-0.4	0.5	0.0	-0.5	-0.1	0.0	1.2	0.5	1.1	0.4	1.6
Eastern GSL		-0.6	-1.4	-0.7	-1.1	0.3	1.7	1.3	1.1	-0.1	0.0	-0.4	4.4	-0.3	1.7	3.7
Rimouski							-1.0	-0.7	1.3	-1.0	0.5	0.9	1.9	-1.1	2.5	20.1
Northwest GSL		-0.6	-0.9	-0.8	-0.3	-0.7	-0.6	1.4	2.2	0.6	-0.1	-0.1	1.2	-0.3	-0.4	1.1
Southern GSL		-0.7	-0.9	-0.3	-0.7	-0.8	0.5	-0.2	0.1	-0.1	0.2	2.7	1.9	1.7	2.4	3.4
Shediac Valley	1.9	-1.2	0.7	-0.1	-1.2	-0.8	0.8	0.4	0.2	1.0	-1.2	-0.6	0.2	4.4	0.3	8.09
Cabot Strait	0.9	-1.0	-0.4		1.0	1.6	-0.6	0.5	-1.7	-0.3	-0.5	0.6	-0.6	-1.5	-1.1	1.5
Louisbourg	1.2	-0.9	1.3	0.2	-0.9	0.1	0.7	0.7	-0.8	0.8	-1.9	-0.5	1.1	-1.7	0.4	0.0
Halifax	1.6	1.4	-1.8	0.1	0.9	0.1	0.4	-0.8	0.0	-0.6	-0.1	-1.1	0.4	0.6	-0.1	0.0
Halifax-2	2.5	0.8	-0.5	-1.1	-0.2	0.7	0.1	-0.8	-0.9	0.5	-0.4	-0.6	0.8	0.2	0.4	0.7
Browns Bank	1.7	1.4	0.3	-0.4	1.1	-0.8	-1.3	-0.6	-0.6	0.4	-1.2	0.1	-1.4	1.2	-0.1	0.4
Prince-5	1.3	1.2	1.4	0.5	-0.5	0.2	-1.1	-1.4	0.2	-0.5	-1.4	0.1	-0.6	0.7	0.9	1.5

Figure 17. Time series of total copepod (top panel) and non-copepod (lower panel) abundance anomalies from different oceanographic transects and fixed stations from the Atlantic Zone Monitoring Program during 1999-2014. The zooplankton abundance anomalies for transects were calculated using a general linear model using station, season, and year while the fixed stations only used season and year as inputs and were based on all available seasonal data. A grey cell indicates missing data; a blue cell indicates lower than normal levels and a red cell indicates higher than normal levels. More intense colours indicate larger anomalies. Large standardized anomalies values > ± 5 shown in yellow. The numbers in the coloured cells are the differences from the long-term mean (1999-2010) divided by the standard deviation. The NAFO Subareas are sorted by latitude from north (top) to south (bottom) Subareas.

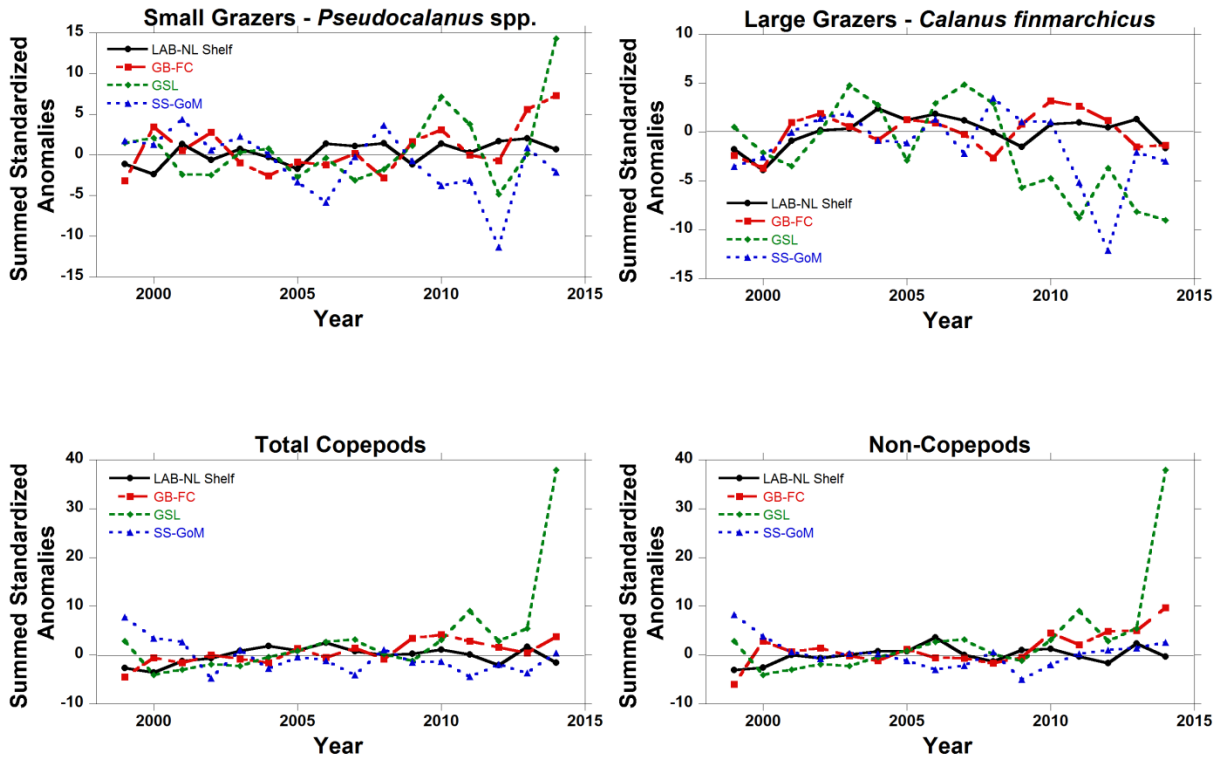

Figure 18. Composite sums of annual anomalies across the Labrador and northeast Newfoundland Shelf (LAB-NL Shelf), Grand Bank-Flemish Cap (GB-FC), Gulf of St. Lawrence (GSL), and Scotian Shelf – Gulf of Maine (SS-GoM) for the different functional zooplankton abundance indices during 1999-2014.

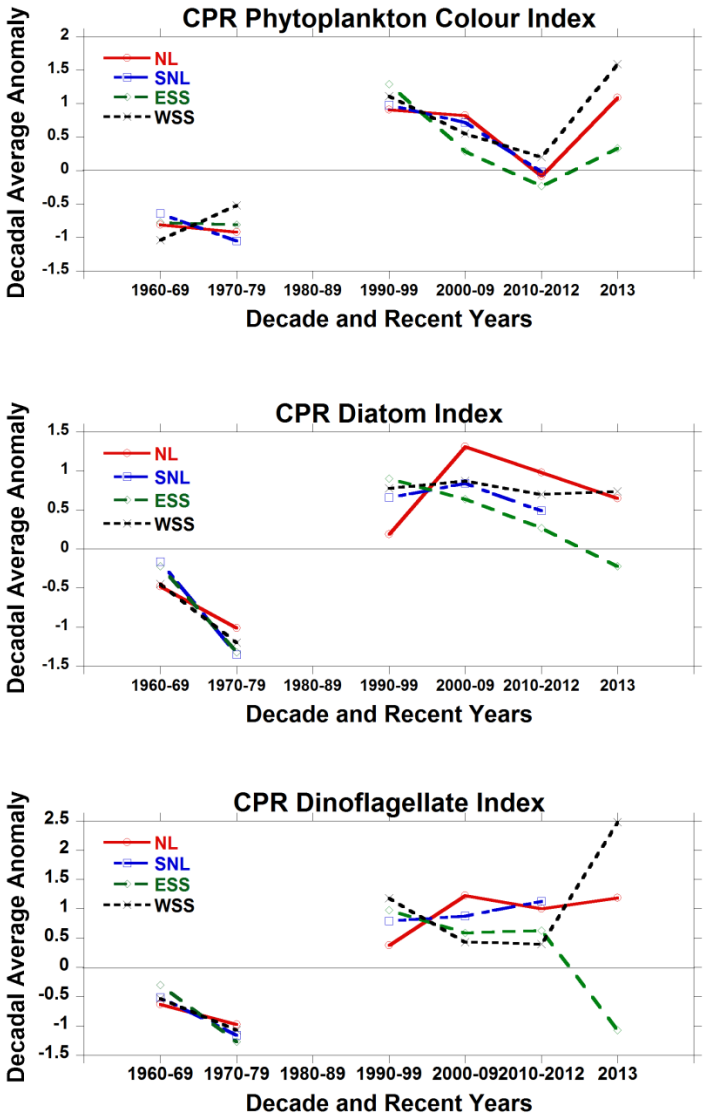

Figure 19. CPR time series for the annual averages for three indices of phytoplankton abundance, calculated from monthly averages over decadal (1960-2009), tri-annual (2010-2012) or annual (2013) periods for four regions in the NW Atlantic. The climatological averages were calculated from the decadal annual averages between 1960 and 2009. The y-axis values are the standardised anomalies. The regions are: Western Scotian Shelf (WSS), Eastern Scotian Shelf (ESS), South Newfoundland Shelf (SNL), Newfoundland Shelf (NL). The annual anomaly from the SNL was not available due to limited availability of data in 2013 and near complete data gap during 1980-1990.

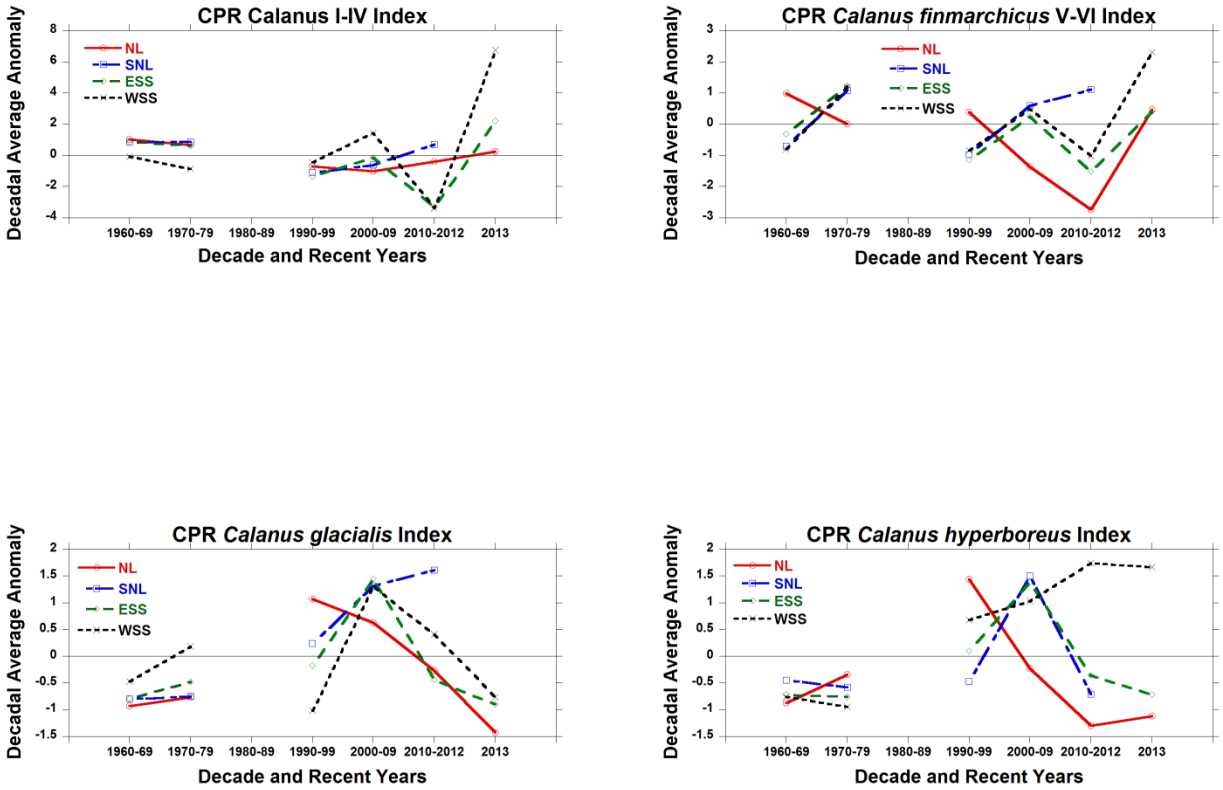

Figure 20. CPR time series for the annual averages for four indices of dominant calanoid copepod early life stages and adults, calculated from monthly averages over decadal (1960-2009), tri-annual (2010-2012) or annual (2013) periods for four regions in the NW Atlantic. The climatological averages were calculated from the decadal annual averages between 1960 and 2009. The y-axis values are the standardised anomalies. The regions are: Western Scotian Shelf (WSS), Eastern Scotian Shelf (ESS), South Newfoundland Shelf (SNL), Newfoundland Shelf (NL). The annual anomaly from the SNL was not available due to limited availability of data in 2013 and near complete data gap during 1980-1990.

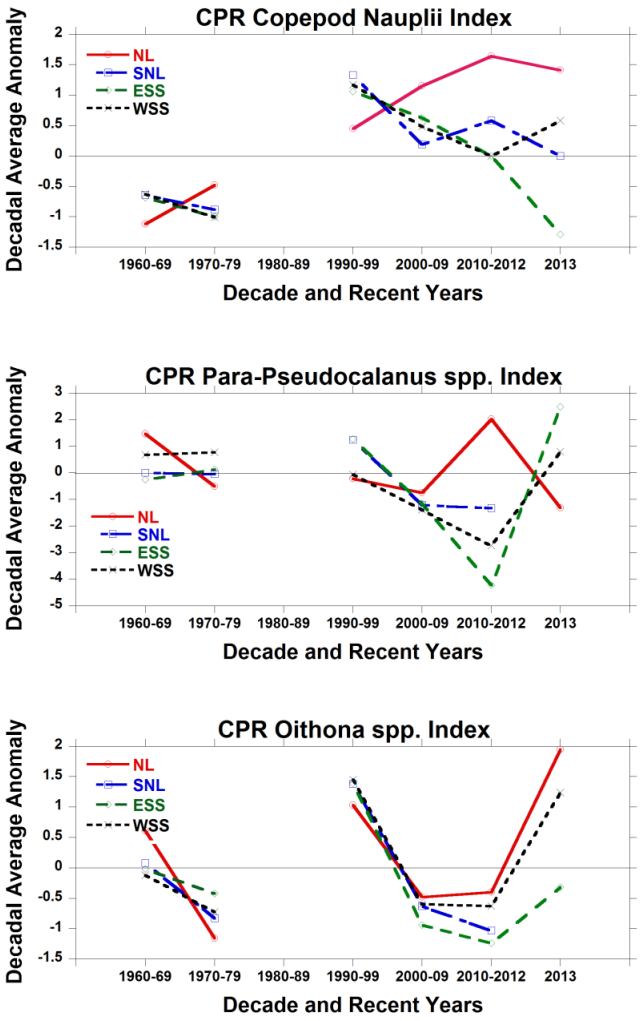

Figure 21. CPR time series for the annual averages for three indices of nauplii stage and small grazing adult copepods, calculated from monthly averages over decadal (1960-2009), tri-annual (2010-2012) or annual (2013) periods for four regions in the NW Atlantic. The climatological averages were calculated from the decadal annual averages between 1960 and 2009. The y-axis values are the standardised anomalies. The regions are: Western Scotian Shelf (WSS), Eastern Scotian Shelf (ESS), South Newfoundland Shelf (SNL), Newfoundland Shelf (NL). The annual anomaly from the SNL was not available due to limited availability of data in 2013 and near complete data gap during 1980-1990.

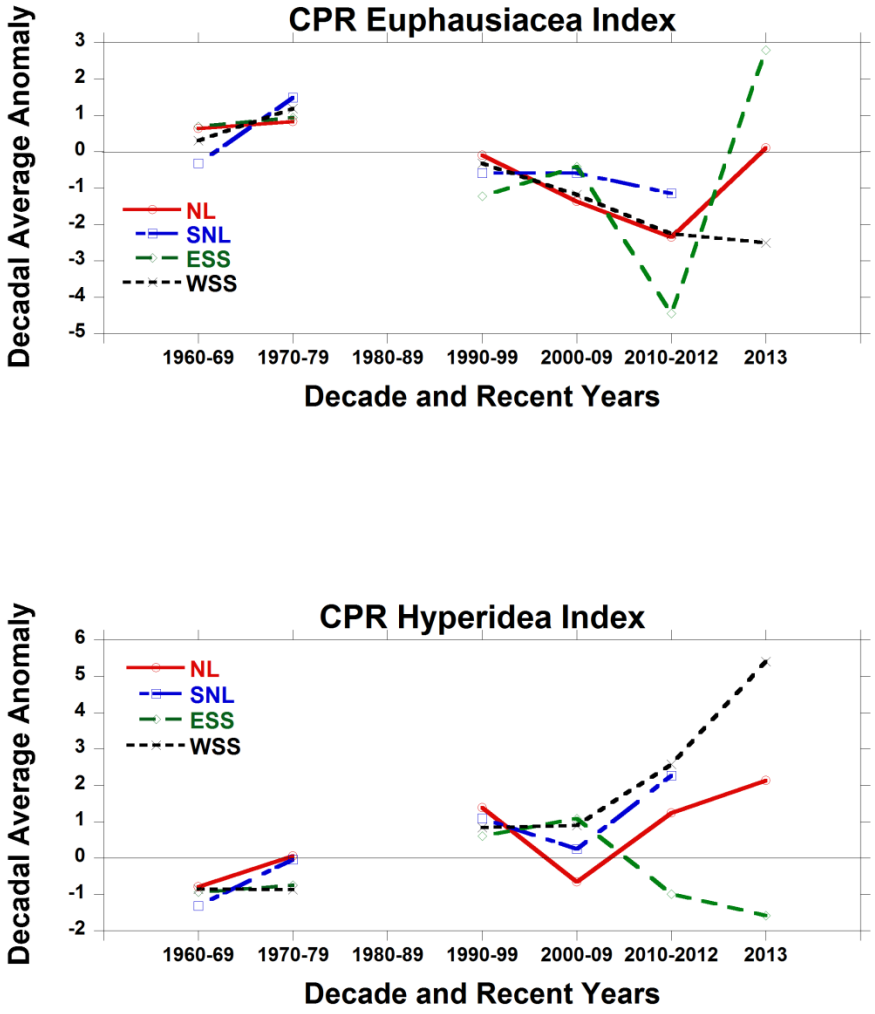

Figure 22. CPR time series for the annual averages for two indices of macrozooplankton taxa, calculated from monthly averages over decadal (1960-2009), tri-annual (2010-2012) or annual (2013) periods for four regions in the NW Atlantic. The climatological averages were calculated from the decadal annual averages between 1960 and 2009. The y-axis values are the standardised anomalies. The regions are: Western Scotian Shelf (WSS), Eastern Scotian Shelf (ESS), South Newfoundland Shelf (SNL), Newfoundland Shelf (NL). The annual anomaly from the SNL was not available due to limited availability of data in 2013 and near complete data gap during 1980-1990.

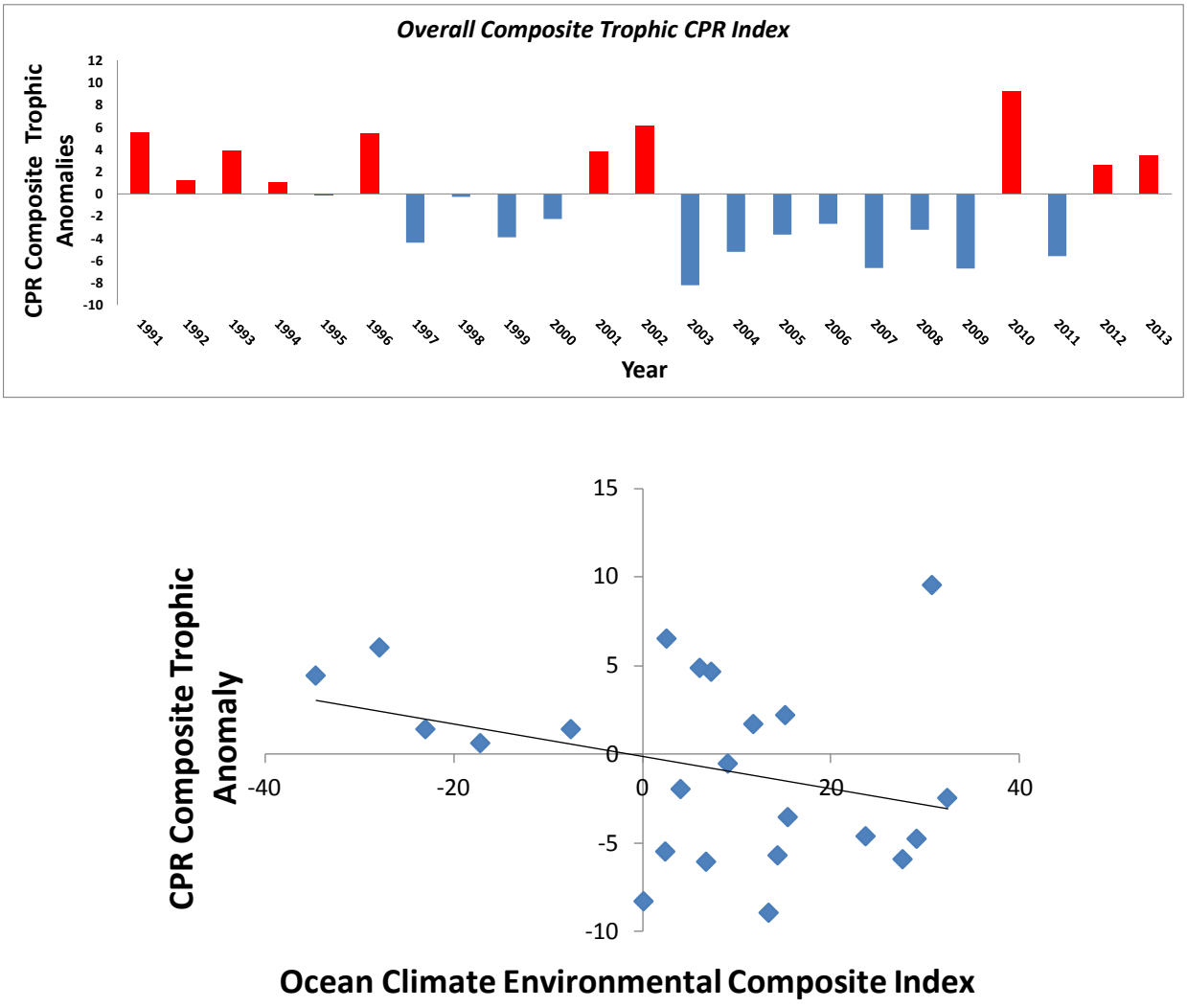

Figure 23. The composite (summed) CPR annual anomalies of all phytoplankton and zooplankton taxa to derive a combined trophic index during 1991 to 2013 (top panel), and relationship between composite CPR index and ocean climate environmental composite index (bottom panel).