Serial No. N7639 NAFO SCR Doc. 25/012

SCIENTIFIC COUNCIL MEETING –-JUNE 2025

Environmental indices for NAFO subareas 0 to 4 in support of the Standing Committee on Fisheries Science (STACFIS) – 2024 update

by

David Bélanger[1], Jonathan Coyne[1] and Frédéric Cyr[2]

[1]Northwest Atlantic Fisheries Centre, Fisheries and Oceans Canada, St. John's (NL)
[2]Center for Fisheries and Ecosystem Research, Fisheries and Marine Institute of Memorial University, St. John's (NL)

BELANGER, D., COYNE, J., & CYR, F. 2025. Environmental indices for NAFO subareas 0 to 4 in support of the Standing Committee on Fisheries Science (STACFIS) – 2024 update. *NAFO Scientific Council Research Document*, SCR Doc. 25/012: 1-18.

Abstract

This document present composite physical and biological indices in NAFO subareas 0-4 in support of the Standing Committee on Fisheries Science (STACFIS). The information is organized in 4 sub-regions: Greenland and Davis Strait (NAFO subareas 0 and 1), Flemish Cap (NAFO division 3M), Grand Banks (NAFO Divisions 3LNO) and the northwest Atlantic as a whole (NAFO subareas 2, 3 and 4) for widely distributed stocks. When put in context with their long-term average, all ocean climate indicators were above normal in 2024, especially warm in NAFO Division 3LNO (Grand Banks). The composite climate indices for subareas 2, 3 and 4 altogether was at its 6th warmest value, with five or the six warmest years all occurred in the last five years (including the record warm in 2021). There has been a general trend toward earlier spring bloom timing across the Canadian Northwest Atlantic since the mid-2010s with near- to earlier-than-normal bloom timing across regions in 2024. Zooplankton abundance and biomass have remained primarily above normal since 2015 on the Grand Bank (3LNO) but have been more variable on the Flemish Cap (3M) during the same period. The environmental indices presented in this report are available at: https://doi.org/10.5281/zenodo.15538217 (Bélanger et al., 2025).

Introduction

This report presents environmental indices intended to provide a synthetic overview of physical and biological conditions in the northwest Atlantic (NAFO subareas 0 to 4; see Figure 1) in support of various NAFO fish stock assessments. This information, also summarized in NAFO Science Council Meeting annual report (e.g., NAFO, 2024), has been compiled with additional details in in a Science Council Research (SCR) document since 2021 (see Cyr & Bélanger, 2021, for the first report of this series). Following the structure of the STACFIS report, the information is organized in 4 sub-regions: Greenland and Davis Strait (NAFO Subareas 0 and 1), Flemish Cap (NAFO Division 3M), Grand Banks (NAFO Divisions 3LNO) and the Northwest Atlantic as a whole (NAFO Subareas 2, 3 and 4) for widely distributed stocks. Each of these sub-regions are discussed separately below.

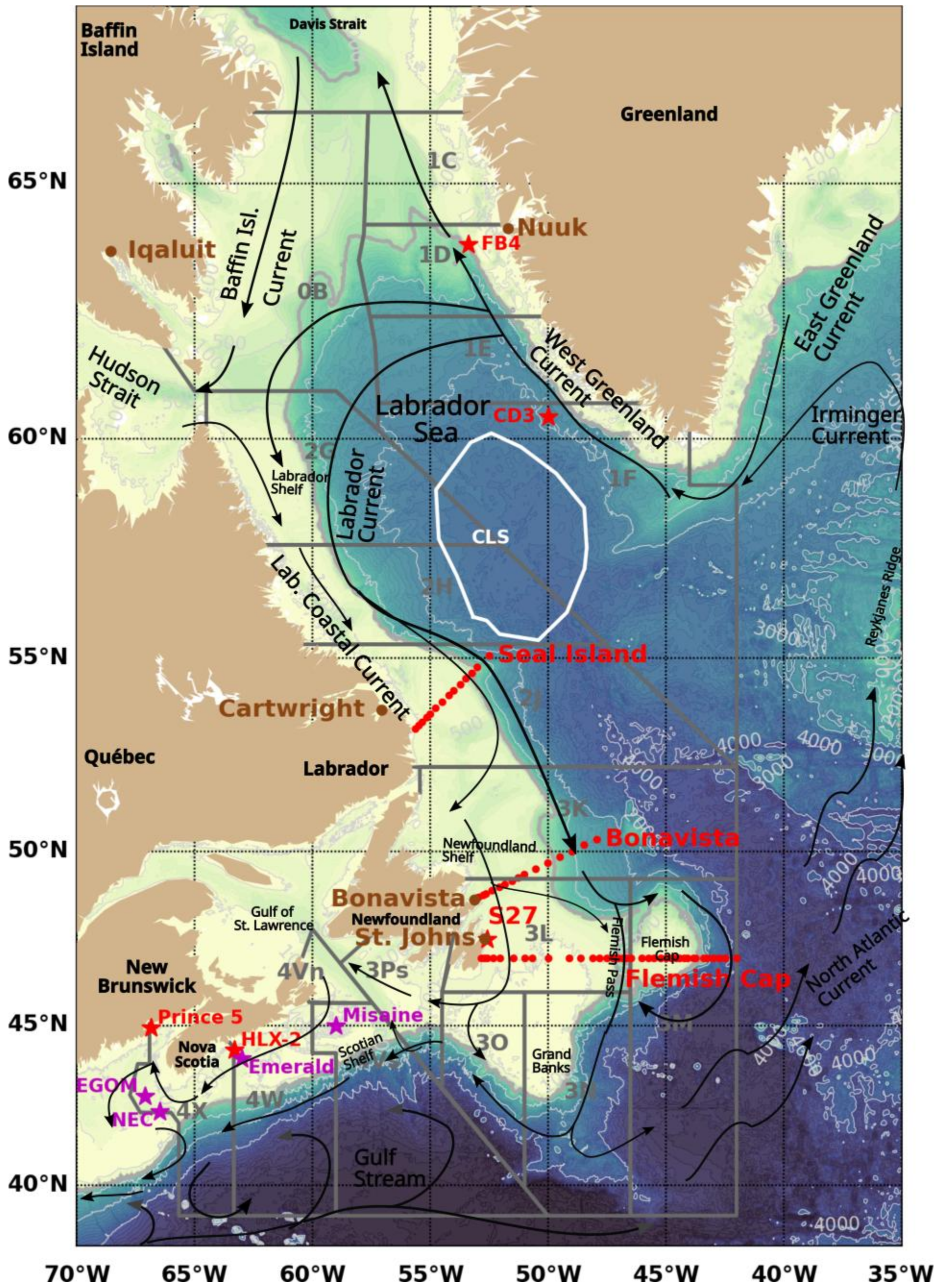

Figure 1. Map highlighting the location of the physical environmental time series used in this report. NAFO Divisions and main bathymetric features of the Northwest Atlantic are highlighted (colormap and gray contours). The thick gray contour is the isobath 1000m that is used here to delimit the continental shelf. The hydrographic sections (Seal Island, Bonavista, and Flemish Cap) reported here are shown with red dots and the high-frequency fixed stations (FB4, CD4, Station 27, Halifax 2, and Prince 5) by red stars. Other stations or areas seasonally sampled for which time series are presented in this report (Misaine Bank, Emerald Basin, Northeast Channel – NEC, and Eastern Gulf of Maine - EGOM) are drawn with purple stars. The stations used for air temperature time series and in brown. The Central Labrador Sea (CLS) polygon used to extract a hydrographic time series used in this report is also shown.

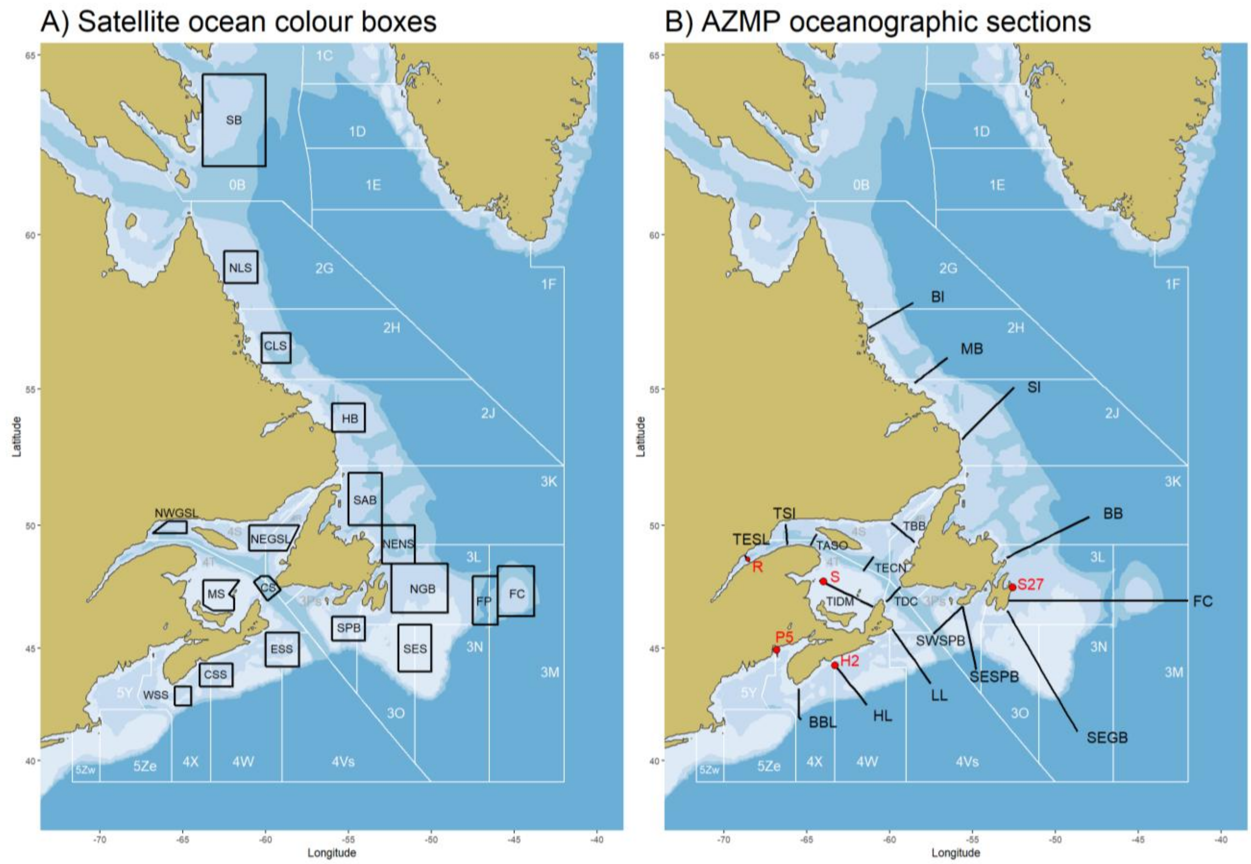

Figure 2. (A) Location of polygons used to calculate spring bloom indices (timing and intensity) from satellite Ocean Color imagery: SB=Southern Baffin, NLS=northern Labrador Shelf, CLS=central Labrador Shelf, HB=Hamilton Bank, SAB=St. Anthony Basin, NENS=northeast Newfoundland Shelf, FP=Flemish Pass, FC=Flemish Cap, NGB=northern Grand Bank, SES=southeast Shoal, SPB=Green-St. Pierre Bank, NEGSL=northeast Gulf of St. Lawrence, NWGSL=northwest Gulf of St. Lawrence, MS=Magdalen Shallows, ESS=eastern Scotian Shelf, CSS=central Scotian Shelf, WSS=western Scotian Shelf, GB=Georges Bank. (B) Location of Atlantic Zone Monitoring Program (AZMP) oceanographic sections (black lines: BI=Beachy Island, MB=Makkovik Bank, SI=Seal Island, BB=Bonavista Bay, FC=Flemish Cap, SEGB=Southeast Grand Bank, TBB=Bonne Bay Transect, TCEN=Central GSL Transect, TDC=Cabot Strait Transect; TESL=St. Lawrence Estuary Transect, TSI=Sept-Îles Transect, TASO=Southwest Anticosti Transect; TIDM=Magdalen Islands Transect, LL=Louisbourg Line, HL=Halifax Line, BBL=Brown Bank Line), and coastal high-frequency monitoring sites (red circles: S27=Station 27; R=Rimouski; S=Shediac Valley; H2=Halifax 2; P5=Prince 5) where biogeochemical data were collected during AZMP seasonal surveys.

Greenland and Davis Strait (NAFO subareas 0 and 1)

Environmental Overview

Hydrographic conditions in this region depend on a balance of ice melt, advection of polar and sub-polar waters and atmospheric forcing including the major winter heat loss to the atmosphere that occurs in the central Labrador Sea. The cold fresh polar waters carried south by the Baffin Island Current are counter-balanced by relatively warmer waters, carried northward by the offshore branch of the West Greenland Current (WGC). The water masses constituting the WGC originate from the western Irminger Basin where the East Greenland Currents (EGC) meets the Irminger Current (IC). While the EGC transports ice and cold fresh Surface Polar Water south along the eastern coast of Greenland, the IC, a branch of the North Atlantic current, transports relatively warm salty Atlantic Waters northwards along the Reykjanes Ridge. After the currents converge, they turn around the southern tip of Greenland, forming the WGC that propagates northward along the western coast of Greenland. The WGC is important for Labrador Sea Water formation, which is an essential element of the Atlantic Meridional Overturning Circulation. At the northern edge of the Labrador Sea, after receiving freshwater input from Greenland and Davis Strait, part of the WGC bifurcates southward along the Canadian shelf edge as the Labrador Current.

Index calculation and data availability

The different composite indices for NAFO Subarea 0 and 1 are presented in Figure 3. Due the remoteness of this region, the number of variables contained in each composite index is limited. The climate index (Figure 3A) is the average of 7 individual time series of standardized ocean temperature anomalies: shallow and deep vertically average ocean temperature in the Central Labrador Sea (50-200 m and 1000-1800 m, respectively), Fyllas Bank Station 4 (FB-4; 0-50 m) and Cape Desolation Station 3 (CD-3; 75-200 m and 2000 m), and air temperatures in Nuuk (Greenland) and Iqaluit (Baffin Island). The location of each time series are shown in Figure 1, with the sea surface temperature (SST) polygon in white (the CLS polygon also represents the hydrographic time series in the Central Labrador Sea), the air temperature stations in brown, and the hydrographic stations with purple stars. CLS, FB-4 and CD-3 hydrographic time series are obtained from the ICES report on ocean climate (IROC; https://ocean.ices.dk/iroc/). The timeseries for CD-3 and FB-4 have however not been updated since 2019 and 2020, respectively.

Spring phytoplankton bloom timing and intensity indices were derived from a single polygon (Southern Baffin Island [SB]; see Figure 2 for location) overlapping NAFO Division 0B Greenland Halibut fishing grounds. Extensive sea ice coverage and high sunlight angle of incidence in the spring at theses latitudes greatly limit satellite data availability over areas associated with other NAFO 0-1 Halibut stocks. No zooplankton time series are available for subareas 0 and 1.

Ocean Climate and Ecosystem Indicators

The ocean climate index in Subarea 0-1 has been predominantly above or near normal since the early 2000s, except for 2015 and 2018 that were below normal (Figure 3A). After 2021 (the second highest value since 2010), the index remained near normal in 2022 and 2023. 2024 was slightly above normal. Before the warm period of the last decade, cold conditions persisted between the mid-1980s and the mid-1990s.

The timing of maximum spring phytoplankton concentration in has been generally near or earlier than normal since 1998 except for 2009 and from 2012 to 2015 where it was later than average. Earlier timing is generally associated with a higher bloom intensity. The 2024 bloom was the second earliest and the most intense of the time series.

2024 Highlights in Ocean Climate and Lower Trophic Levels for SA 0-1

- The ocean climate index in Subarea 0-1 was slightly above normal in 2024.
- Second earliest timing and record-high intensity of the spring bloom for the NAFO 0B Greenland Halibut fishing grounds.

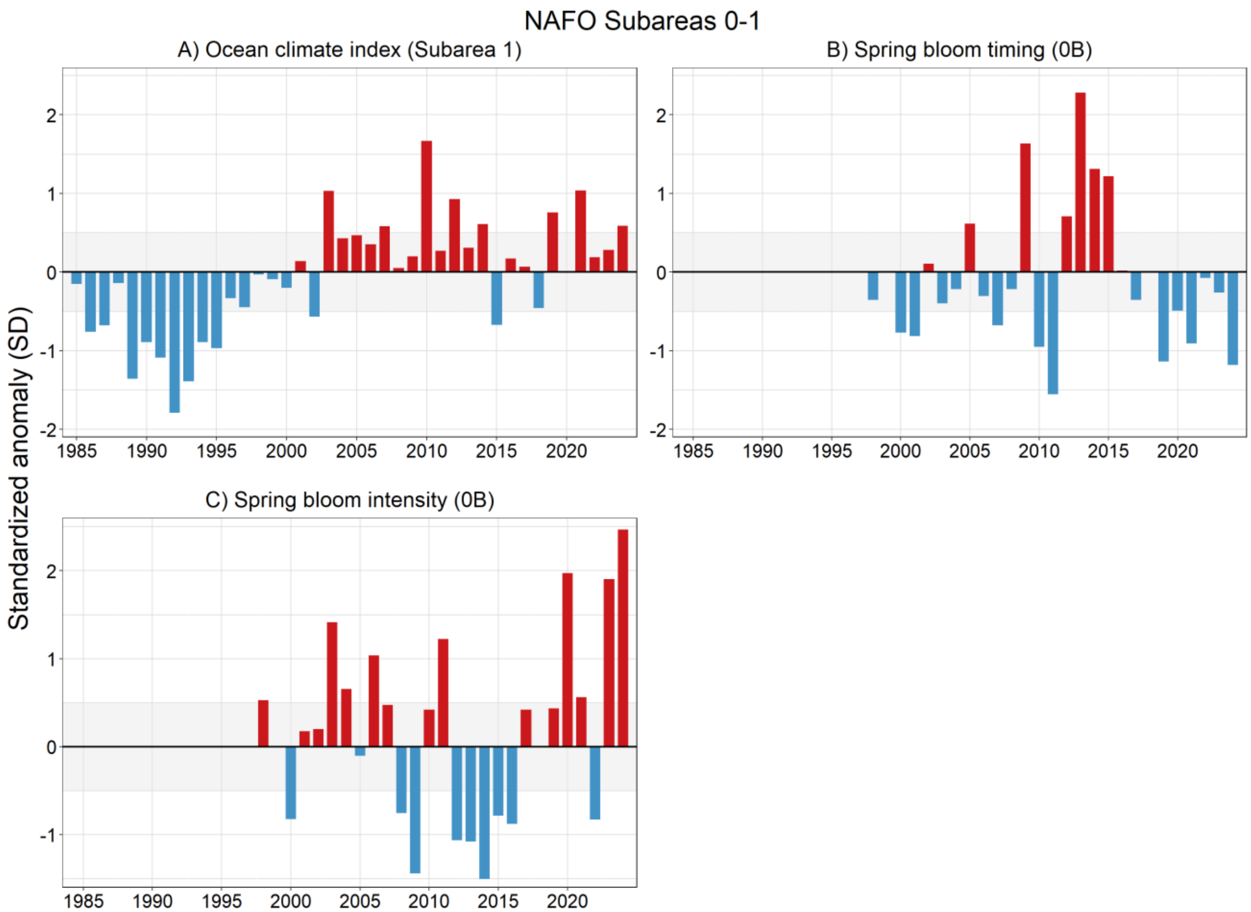

Figure 3. Annual anomalies of environmental indices for NAFO Subareas 0 and 1. The ocean climate index (A) is the average of seven standardized time series: five seawater temperature time series at three hydrographic stations and two air temperatures time series (see text for details). Spring bloom anomalies (B, C) are derived from a single polygon (SB – see Fig. 2A for polygon location). Positive (negative) anomalies indicate late (early) bloom timing or high (low) spring bloom intensity. Anomalies were calculated using reference periods of 1991-2020 for the ocean climate index, and 1999-2020 for the spring bloom indices. Anomalies within ± 0.5 SD (shaded area) are considered representative of normal conditions.

Flemish Cap (NAFO Division 3M)

Environmental Overview

The waters around Flemish Cap are a mixture of Labrador Current Slope Water and North Atlantic Current water. With temperatures ranging from 3-4°C and salinities between 34 and 34.75, these waters are generally warmer and saltier than the polar waters of the Newfoundland Shelf. The general circulation in the vicinity of the Flemish Cap consists of the offshore branch of the Labrador Current, which flows through the Flemish Pass, and a jet that flows eastward north of the Cap and then southward east of the Cap. To the south, the Gulf Stream flows to the northeast to form the North Atlantic Current and influences waters around the southern areas of the Cap (Figure 1). In the absence of strong wind forcing the circulation over the central Flemish Cap is dominated by a topographically induced anti-cyclonic (clockwise) gyre. Variability in the abiotic environment affects the distribution and biological productivity of Newfoundland and Labrador Shelf and Slope waters where arctic, boreal, and temperate species coexist. The elevated temperatures on the Flemish Cap result in relatively ice-free conditions potentially allowing for longer phytoplankton growth seasons compared to the cooler Grand Banks. Additionally, the entrainment of nutrient-rich North Atlantic Current water around the Flemish Cap generally supports higher primary and secondary production compared to adjacent shelf waters. The stability of the circulation pattern may also promote retention of ichthyoplankton over the Grand Bank which could influence year-class strength of various fish and invertebrate species.

Index calculation and data availability

The different composite indices for NAFO division 3M (Flemish Cap) are presented in Figure 4. This is the smallest region considered in this report, and as a result, the number of available time series is relatively low. The ocean climate index (Figure 4A) is the average of 3 time series of standardized ocean temperature anomalies: SSTs in NAFO Division 3M, mean temperature over the offshore portion of Flemish Cap hydrographic section (stations FC-15 to FC-35), and summer mean bottom temperature over the cap. SSTs and observations along Flemish Cap hydrographic section are presented in Coyne et al. (2025). Bottom temperatures for 3M were retrieved from the CABOTS dataset (Coyne & Cyr, 2025). Data used for this calculation is mostly from (although not limited to) the European Union summer survey.

Spring bloom indices are derived from satellite ocean color observations within two polygons: Flemish Pass (FP) and Flemish Cap (FC) (see Fig. 2A for locations). Spring bloom timing is defined as the date when chl-*a* concentration reaches its maximum, while bloom intensity refers to mean chl-a concentration during the bloom period. Zooplankton abundance and biomass indices are based on data from 10 oceanographic stations along the Flemish Cap (FC) section, located in NAFO Division 3M (see Fig. 2B for section locations). The FC section is typically sampled three times per year during AZMP spring (Apr-May), summer (Jul-Aug) and fall (Nov-Dec) surveys. However, NAFO Division 3M was not sampled in spring 2024 due to limited research vessel availability.

Ocean Climate and Ecosystem Indicators

The ocean climate index in Division 3M (Figure 4A) has remained mostly positive between the late 1990s and 2013, and negative between 2014 and 2019, including in 2015 where it reached its lowest value since 1992. Since 2020, a warming phase is emerging, with years 2023 and 2022 ranking respectively as the warmest and second warmest years since the time series started in 1985. 2024 continued this warming phase, although lower than the previous 3 years.

The timing of the spring bloom has shifted from earlier to later than normal every 2-5 years throughout the time series, while bloom intensity has generally remained near to below normal – except for a few years during the 2000s and a period of above-normal intensity from 2018 to 2020 (Figure 4B & C). In 2024, spring bloom timing returned to normal after two consecutive years of later-than-normal blooms (Fig 4B). Spring bloom intensity has shown a decreasing trend since the late 2010s, reaching a below-normal level in 2024 for the first time since 2015 (Fig 4C).

Total copepod abundance increased relatively steadily between 1999 and 2010, with levels shifting from below to above normal levels in 2005. Since then, copepod abundance has been variable, fluctuating between below- and above-normal levels every 1 to 3 years (Figure 4D). The abundance of non-copepod zooplankton – typically dominated by appendicularians and pteropods – was generally normal or below normal from 1999 to 2015, and primarily near or above normal since 2016 (Figure 4E). Total zooplankton biomass, an indicator of energy availability at lower trophic levels, was generally below normal during the late 1990s and early 2000s, and has remained near or above normal since 2006 (Figure 4F). In 2024, copepod abundance returned to a normal level after two years of being below normal, while non-copepod abundance and zooplankton biomass remained within the normal range for the second and third consecutive year, respectively (Figure 4D-F).

Recent Highlights in Ocean Climate and Lower Trophic Levels for 3M

- The 3M warming climate phase starting in 2020 continued in 2024. 2023 and 2022 ranked as the warmest and second warmest years on record respectively.
- The timing of the spring bloom was near normal in 2024, following two years of delayed blooms. Bloom intensity continued its decreasing trend, reaching a lower-than-normal level for the first time since 2015.
- The abundance of copepods was normal in 2024 after two years of below-normal levels, while the abundance of non-copepods remained normal for a second consecutive year. Total zooplankton biomass has remained near normal since 2016, including in 2024.

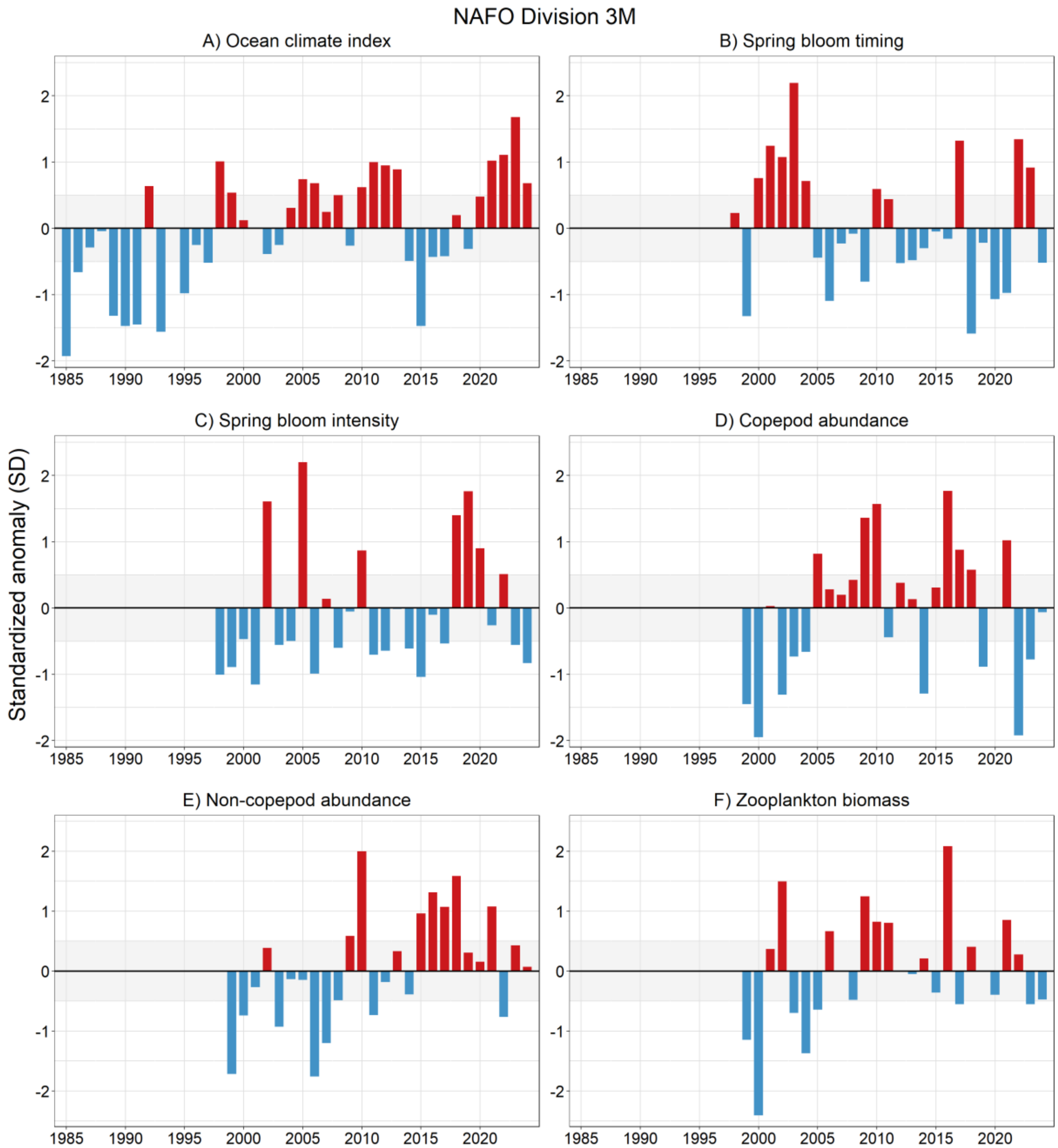

Figure 4. Annual anomalies of environmental indices for the Flemish Cap (NAFO Division 3M). The ocean climate index (A) is the average of three standardized time series of ocean temperature: sea surface temperatures (SSTs), hydrographic section observations, and summer mean bottom temperature over the cap (see text for details). Spring bloom anomalies (B, C) were averaged over two polygons (FP, FC – see Fig. 2A for polygon locations). Zooplankton anomalies (D-F) were calculated using data from the portion of the FC section located within NAFO Division 3M (see Fig. 2B for section locations). Positive (negative) anomalies indicate late (early) bloom timing or conditions above (below) the mean for the reference period. Anomalies were calculated using the following reference periods: ocean climate index: 1991-2020, spring bloom and zooplankton indices: 1999-2020. Anomalies within ± 0.5 SD (shaded area) are indicative of normal conditions.

Grand Bank (NAFO Divisions 3LNO)

Environmental Overview

The characteristics of the Grand Banks water mass are typical of sub-polar waters, with a cold intermediate layer (CIL) formed during winter, which lasts throughout the year until the late fall. The CIL (defined as water <0°C) extends to the ocean bottom in the northern areas of 3LNO, covering the bottom with sub-zero temperatures. The CIL properties are reliable indices of ocean climate conditions in this area. Bottom temperatures are higher in southern regions of 3NO reaching 1 - 4°C, mainly due to atmospheric forcing and along the slopes of the banks below 200 m depth due to the presence of Labrador Slope Water. On the southern slopes of the Grand Bank in NAFO Division 3O bottom temperatures may reach 4 - 8°C due to the influence of warm slope water from the Gulf Stream. The general circulation in this region consists of the relatively strong offshore Labrador Current at the shelf break and a considerably weaker branch near the coast in the Avalon Channel. Currents over the banks are very weak and the variability often exceeds the mean flow.

Index calculation and data availability

The different composite indices for NAFO division 3LNO (Grand banks) are presented in Figure 5. Many time series are available in this well sampled region. The ocean climate index (Figure 5A) is the average of 12 individual time series of standardized ocean temperature anomalies: SSTs for Divis. 3L, 3N and 3O, vertically average ocean temperature (0-176 m) at Station 27, CIL volumes on hydrographic sections Seal Island, Bonavista and inshore Flemish Cap (FC-01 to FC-20), and mean bottom temperature in 3LNO for spring and fall. All these variables are presented in Coyne et al (2025). See Figure 1 for the location of the different NAFO Divisions, location of Station 27 (purple star) and hydrographic sections (red transects).

Spring bloom indices are derived from satellite ocean color observation (OC-CCI) within two polygons: Northern Grand Bank (NGB) and Southeast Shoal (SES) (see Fig. 2A for polygon locations). Zooplankton abundance and biomass indices are derived from data collected at fixed stations located along oceanographic sections Flemish Cap (FC, 3L only) and Southeastern Grand Bank (SEGB), and from the high-frequency monitoring site Station 27 (S27) (see Fig. 2B for the location sections and high-frequency monitoring sites). The FC section is typically sampled in spring (Apr-May), Summer (Jul-Aug) and fall (Nov-Dec), while SEGB is sampled in spring and fall only. In 2024, however, FC and SEGB were occupied in the spring, while S27 was occupied 19 times between January 15th and December 19th.

Ocean Climate and Ecosystem Indicators

The ocean climate index in Divisions 3LNO (Fig. 3A) was well below normal (indicative of cold conditions) between the mid-1980s and the mid-1990s. Following this cold period, the index was mostly normal to above normal between the late 1990s and 2013 (except for 2009 that was below normal), reaching a peak in 2011. The index returned to below normal conditions between 2014 and 2017 (except for 2016 that was normal). Years 2020 to 2024 were well above normal (except for 2023 that was normal), including 2021 and 2020, respectively the warmest and second warmest years on record for this time series started in 1985.

Average spring bloom timing shifted from being primarily earlier than normal between 2005 and 2013 to later than normal from 2014 to 2019. Since 2020, bloom timing has remained within the normal range (Figure 5B). Spring bloom intensity has been variable across the time series, fluctuating between below- and above-normal levels every 2-4 years (Figure 5C). Both timing and intensity indices were normal in 2024.

The abundance of both copepods and non-copepods has exhibited a relatively steady increase over the time series and has remained above normal since 2016 (Figure 5D, E). Although still above normal in 2024, non-copepod abundance has been gradually declining since 2020 (Figure 5E). Total zooplankton biomass was variable during the 2000s, followed by a decline to below-normal levels during the early 2010s. Since 2017, biomass has remained at or above normal, with normal levels observed over the past three years (Figure 5F).

Recent Highlights in Ocean Climate and Lower Trophic Levels for 3LNO

- The ocean climate was slightly warmer than normal in 2024 after being much warmer than normal from 2020 to 2022 and near normal in 2023.
- Spring bloom timing has remained normal since 2020, and the bloom intensity was normal for a second consecutive year in 2024.
- The abundance of both copepods and non-copepods were above normal in 2024, continuing a trend that started in the mid-2010s. Total zooplankton biomass remained normal for a third consecutive year.

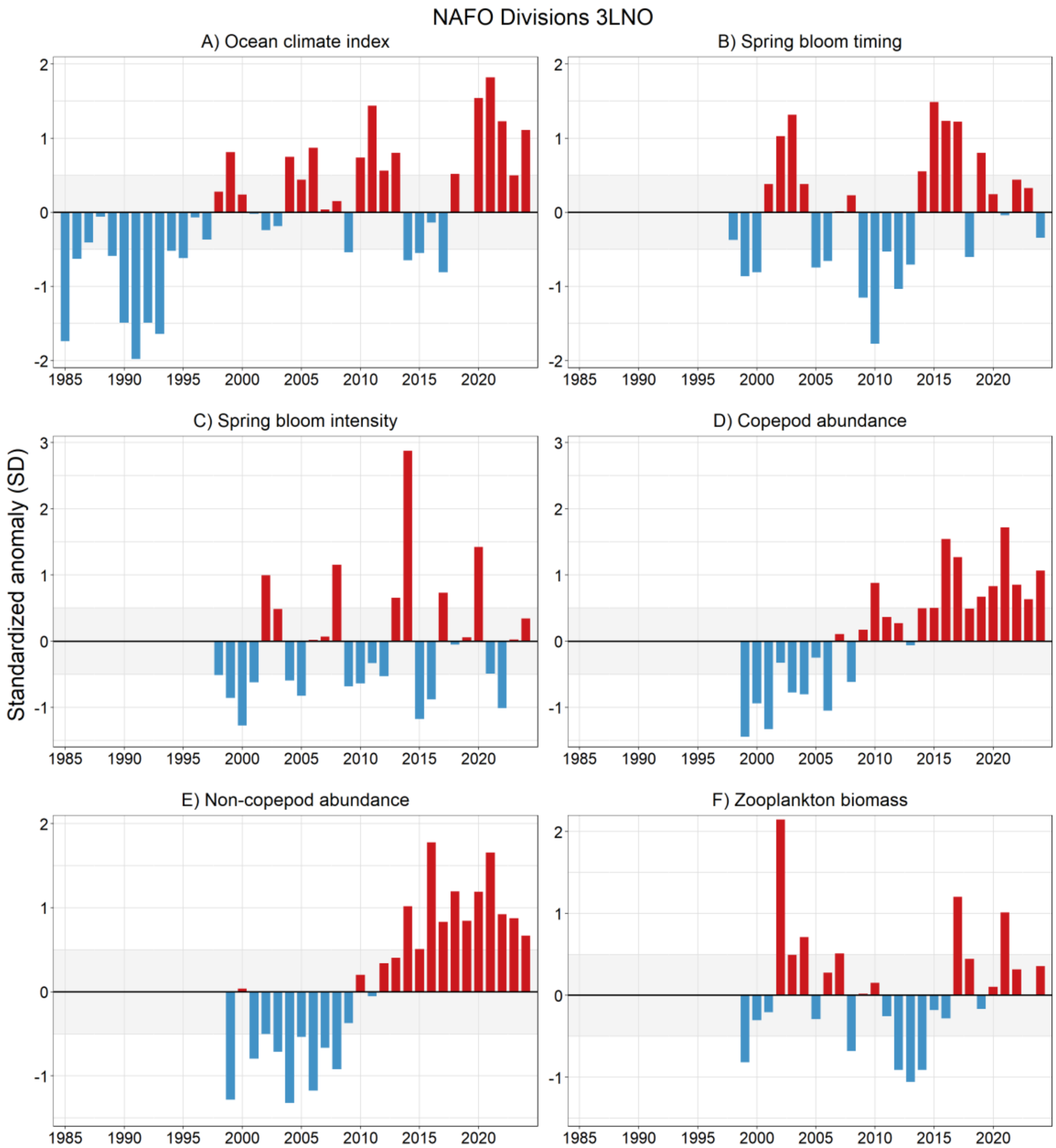

Figure 5. Annual anomalies of environmental indices for NAFO Divisions 3LNO. The ocean climate index (A) is the average of twelve individual time series of standardized ocean temperature anomalies: SSTs for Divisions 3LNO, vertically average ocean temperature (0-176 m) at Station 27, mean temperature and CIL volumes over standard hydrographic sections Seal Island, Bonavista and inshore Flemish Cap (FC-01 to FC-20), and mean bottom temperature in 3LNO for spring and fall (see text for details). Spring bloom anomalies (B, C) were averaged over two polygons (NGB, SE – see Fig. 2A for polygon locations). Zooplankton anomalies (D-F) are derived from two oceanographic sections (3LN portion of FC, SEGB– see Fig 2B for sections location) and one coastal high-frequency sampling site (S27). Positive (negative) anomalies indicate late (early) bloom timing or conditions above (below) the mean for the reference period. Anomalies were calculated using the following reference periods: ocean climate index: 1991-2020, phytoplankton and zooplankton indices: 1999-2020. Anomalies within ±0.5 SD (shaded area) are considered normal conditions.

Newfoundland and Labrador shelf, Scotian Shelf and Gulf of Maine (NAFO Subareas 2, 3 and 4)

Environmental Overview

The water mass characteristics of Newfoundland and Labrador Shelf are typical of polar and subpolar waters with a sub-surface temperature range of -1-2°C and salinities of 32-33.5. Labrador Slope Water flows southward along the shelf edge and into the Flemish Pass region. This water mass is generally warmer and saltier than the polar shelf waters with a temperature range of 3-4°C and salinities in the range of 34-34.75. On average bottom temperatures remain < 0°C over most of the northern Grand Banks but increase to 1-4°C in southern regions and along the slopes of the banks below 200 m. North of the Grand Bank, in NAFO Division 3K, bottom temperatures are generally warmer (1-3°C), except for the shallow inshore regions where they are mainly <0°C. In the deeper waters of the Flemish Pass and across the Flemish Cap bottom temperatures generally range from 3-4°C. Throughout most of the year the cold, relatively fresh water overlying the shelf is separated from the warmer higher-density water of the continental slope region by a strong temperature and density front. This winter-formed water mass is generally referred to as the Cold Intermediate Layer (CIL) and is considered a robust index of ocean climate conditions. In general, shelf water masses undergo seasonal property changes due to the seasonal cycles of air-sea heat flux, wind-forced mixing and ice formation and melt, leading to intense vertical and horizontal gradients particularly along the frontal boundaries separating the shelf and slope water masses.

Temperature and salinity conditions in the Scotian Shelf, Bay of Fundy and Gulf of Maine regions are determined by many processes: heat transfer between the ocean and atmosphere, inflow from the Gulf of St. Lawrence supplemented by flow from the Newfoundland Shelf, exchange with offshore slope waters, local mixing, freshwater runoff, direct precipitation, and melting of sea-ice. The Nova Scotia Current is the dominant inflow, originating in the Gulf of St. Lawrence and entering the region through the Cabot Strait. The Current, whose path is strongly affected by topography, has a general southwestward drift over the Scotian Shelf and continues into the Gulf of Maine where it contributes to the counterclockwise mean circulation. The properties of shelf waters are modified by mixing with offshore waters from the continental slope. These offshore waters are generally of two types, Warm Slope Water, with temperatures in the range of 8-13°C and salinities from 34.7-35.6, and Labrador Slope Water, with temperatures from 3.5°C to 8°C and salinities from 34.3 to 35. Shelf water properties have large seasonal cycles, east-west and inshore-offshore gradients, and vary with depth.

Index calculation and data availability

The different composite indices for NAFO subareas 2, 3 and 4 during 1985-2024 are presented in Figure 6 under the form of stacked bar plots where each color correspond to a composite index for the individual subarea. Many time series are thus used to generate this figure. For the ocean climate index (Figure 6A), the standardized anomalies for SA2 is the result of the average of 8 individual time series: Sea surface temperatures (SST) in Divisions 2GHJ, bottom temperatures in 2H and 2J in the fall, mean temperature and CIL volumes over the hydrographic section Seal Island, and the air temperature in Cartwright (Labrador). For SA3, 16 individual time series are used: SSTs in Divisions 3KLMNOP, vertically averaged ocean temperature at Station 27 (0-176 m), mean temperature and CIL volumes over hydrographic sections Bonavista and Flemish Cap, mean bottom temperature in 3LNO (spring and fall) and 3M (summer), and air temperature in St. John's and Bonavista (Newfoundland). For SA4, 12 individual time series are used: SSTs in Divisions 4VnVsWX, vertically averaged ocean temperature at Station Prince-5 (0-90 m), surface (0-50 m) and bottom (150 m) temperature at Station Halifax-2, bottom temperature in 4VWX (summer), near bottom temperature in Emerald Basin (~250 m) and on Misaine Bank (~100 m), deep (150-200m) temperatures in the Northeast Channel (NEC) and near surface (0-30 m) temperatures in the Eastern Gulf of Maine (EGOM). The location of each component is highlighted in Figure 1. Most of these time series are also presented in Coyne et al. (2025), except for bottom temperature in 3M (see above) and temperatures for NEC and EGOM that have been obtained from the ICES report on ocean climate, as well as data for the Emerald Basin and Misaine Bank (IROC; https://ocean.ices.dk/iroc/).

Phytoplankton spring bloom indices (timing and intensity) are averaged over three polygons for NAFO subarea 2 (NLS, CLS, HB), seven polygons for subarea 3 (SAB, NENS, NGB, FP, FC, SES, SPB), and seven polygons for subarea 4 (NGSL, NEGSL, MS, CS, ESS, CSS, WSS) (see Fig. 2A for polygon locations). Zooplankton abundance and biomass indices are averaged over 3 oceanographic sections in subarea 2 (BI, MB, SI), five sections (BB, FC, SEGB, SESPB, SWSPB) and one high-frequency monitoring site (S27) in subarea 3, and nine oceanographic sections (TESL, TSI, TASO, TBB, TECN, TIDM, TDC, LL, HL, BBL) and four high-frequency monitoring sites (R, S, P5, H2) in subarea 4 (see Fig. 2B for the location oceanographic sections and high-frequency monitoring sites). Zooplankton indices are based on data collected during summer in SA2, during spring, summer and fall in SA3, and during spring and fall in SA4.

Ocean Climate and Ecosystem Indicators

A cumulative climate index for NAFO subareas 2, 3 and 4 (from the Labrador Shelf to the Scotian Shelf) is presented in Fig. 4A. This index highlights the different climate phases undergone by the ecosystem since the mid-1980s. After a period from the mid-1980s to the early 1990s, the index has remained relatively high since (all years since 1993 are normal or above normal). Since 2020, a warm phase has been emerging, which includes the three warmest years on record (respectively 2021, 2022 and 2020) and 2023 that ranks as the 5th warmest. The warm phase continued in 2024, although this year was closer to normal than the previous 4 years. This time series started in1950, although only shown here since 1985.

Spring bloom timing shows generally consistent trends across NAFO Subareas 2-3-4 despite notable interannual variability. The earlier-than-normal blooms observed in recent years contrast with the normal timing recorded from 2013 to 2020 (Fig. 6B). Spring bloom intensity has generally increased since 2015 but declined to near normal in 2024, following record-high values in 2020 and 2023 (Fig. 6C).

Total copepod abundance remained normal across Subareas 2-3-4 for a third consecutive year, including record-high values in 2020 and 2021 that were mainly driven by high abundances in Subareas 2 and 3 (Fig. 6D). The increase in the abundance of non-copepod zooplankton observed around 2015 was also driven by high values recorded in Subareas 2 ad 3 (Fig. 6E). Total zooplankton biomass, on the other hand, generally decreased from 2000 to 2015 and has remained primarily near normal since then (Fig. 6F). The primarily positive biomass anomalies observed in Subareas 2 and 3 since 2016 contrast with the negative anomalies recorded in Subarea 4 during the same period.

Recent Highlights in Ocean Climate and Lower Trophic Levels

- In 2024, the climate in subareas 2 and 3 was above normal while subarea 4 was close to normal. This continues the warming phase started in 2020 (years 2020-2022 were the three warmest years on record).
- Some of the earliest and most intense spring blooms in the time series have been observed since 2020, but both timing and intensity were closer to normal conditions in 2024.
- Copepod and non-copepod abundances have remained normal over the past 2-3 years, following a period of near- to above-normal levels during the mid-2010s and early 2020s.
- Zooplankton biomass was normal in 2024 but comparatively higher in Subareas 2-3 than in Subarea 4, a prevailing situation since 2016.

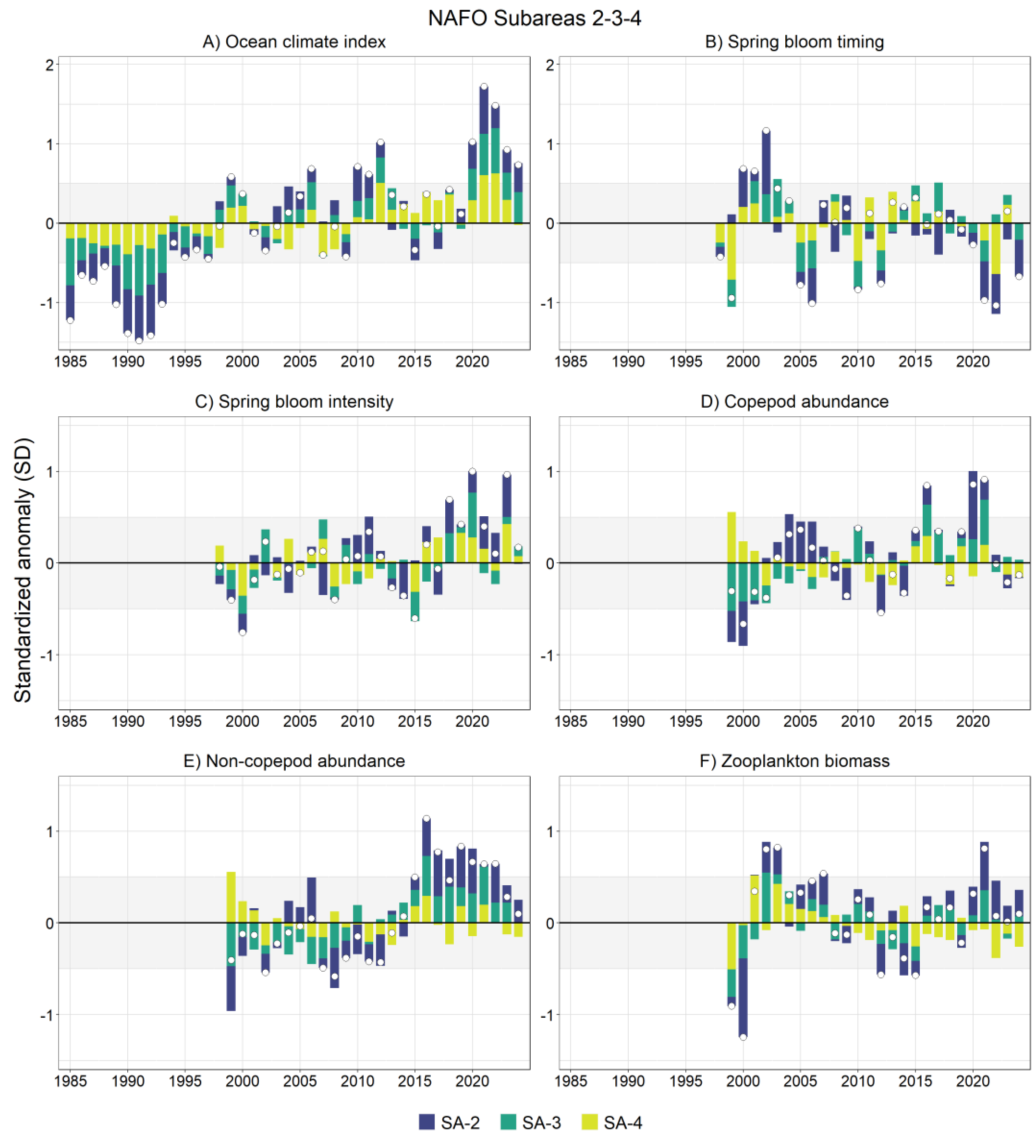

Figure 6. Annual anomalies of environmental indices for NAFO Subareas 2 to 4. The ocean climate index (A) is the average of 8, 16 and 12 individual time series respectively for SA 2, 3 and 4 (see text for details). Spring bloom anomalies (B, C) were averaged over three (NLS, CLS, HB), seven (SAB, NENS, NGB, FP, FC, SES, SPB) and seven (NEGSL, NWGSL, MS, CS, ESS, CSS, WSS) satellite polygons for Subarea 2, 3 and 4, respectively (see Fig. 2A for polygon locations). Zooplankton anomalies were averaged over three sections (BI, MB, SI) for SA-2, three sections (BB, FC, SESG) and one high-frequency sampling site (S27) for SA-3, and 10 sections (TESL, TSI, TBB, TECN, TDC, TIDM, LL, HL, BBL) and four high-frequency sampling sites (R, S, P5, H2) for SA-4 (see Fig. 2B for section locations). Positive (negative) anomalies indicate late (early) bloom timing or conditions above (below) the mean for the reference period. Colored bars length indicates the relative contribution of each NAFO Subarea to the annual mean anomaly (open white circles). Anomalies were calculated using the following reference periods: ocean climate index: 1991-2020, phytoplankton and zooplankton indices: 1999-2020. Mean anomalies within ±0.5 SD (shaded area) is considered normal conditions.

Summary

Highlights of this report can be summarized as follows:

- All ocean climate indicators were above normal in 2024.
- Most of the climate indices have been well above average since 2020 as part of an emerging warming phase that comprises the warmest years on record for SA 2, 3 and 4 (especially 2021 and 2022).
- There has been a general trend toward earlier spring bloom timing across the Canadian Northwest Atlantic since the mid-2010s.
- Zooplankton abundance and biomass have remained primarily above normal since 2015 on the Grand Bank (3LNO) but have been more variable on the Flemish Cap (3M) during the same period.

Data availability

All environmental indices presented in this report are available at:
https://doi.org/10.5281/zenodo.15538217 (Bélanger et al., 2025).

Acknowledgments

The authors would like to thank C. Layton, P. S. Galbraith, P. Fratantoni, J. Mortensen, I. Yashayaev and other contributors to the ICES Report on Ocean Climate (IROC; https://ocean.ices.dk/iroc/) who provided valuable time series used to calculate the different composite indices of this this report. We also thank the crew members of Canadian Coast Guard and RRS Discovery science vessels for their roles in collecting data during seasonal oceanography surveys, as well as DFO seagoing and data analysis teams from the Gulf, Maritimes, and Newfoundland regions who collected, processed and analyzed the data.

References

Bélanger, D., Coyne, J. & Cyr, F. (2025). OceanAccessLab/NAFO_climate_indices: Supporting data for "Environmental indices for NAFO subareas 0 to 4 in support of the Standing Committee on Fisheries Science (STACFIS) – 2024 update" (v2025.1). Zenodo. https://doi.org/10.5281/zenodo.15538217

Coyne, J. & Cyr, F. (2025). Canadian Atlantic Bottom Observations Temperature-Salinity (CABOTS). Federated Research Data Repository. https://doi.org/10.20383/103.0969

Coyne, J., Cyr, F., Snook, S., Bishop, C., Galbraith, P.S., Shaw,J.-L., Chen, N., & Han, G. 2025. Physical Oceanographic Conditions on the Newfoundland and Labrador Shelf during 2024. *Can. Tech. Rep. Hydrogr. Ocean Sci*. XXX, v + 61 p. [In press.]

Cyr, F., & Bélanger, D. (2021). Environmental indices for NAFO subareas 0 to 4 in support of the Standing Committee on Fisheries Science (STACFIS). *NAFO SCR Doc., 21/023*, 18 p.

NAFO. (2024). Report of the Scientific Council Meeting, 31 May - 13 June 2024. *NAFO SCS Doc., 24/16REV*.