Fisheries and Oceans Canada / Pêches et Océans Canada
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

**Canadian Science Advisory Secretariat (CSAS)**

**Research Document 2023/067**

**Quebec Region**

# DFO Monitoring Indicators for the Banc-des-Américains Marine Protected Area: Review, Choice of Measures and State of Knowledge

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November 2023

Canada

**Foreword**

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.


**Published by:**

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca





ISSN 1919-5044
ISBN 978-0-660-68750-6 Cat. No. Fs70-5/2023-067E-PDF


**Correct citation for this publication:**

Faille, G., Côté, G., Blais, M., Gagné, R., Chamberland, J.-M., Galbraith, P.S., Dazé Querry, N., Lehoux, C., Ricard, D. and Starr, M. 2023. DFO Monitoring Indicators for the Banc-des-Américains Marine Protected Area: Review, Choice of Measures and State of Knowledge. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/067. xi + 147 p.

***Aussi disponible en français :***

*Faille, G., Côté, G., Blais, M., Gagné, R., Chamberland, J.-M., Galbraith, P.S., Dazé Querry, N., Lehoux, C., Ricard, D. et Starr, M. 2023. Indicateurs de suivi du MPO pour l’aire marine protégée du Banc-des-Américains : révision, choix des mesures et état des connaissances. Secr. can. des avis sci. du MPO. Doc. de rech. 2023/067. xi + 151 p.*

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## ABSTRACT

Following the 2018 peer review of DFO's ecological monitoring indicators for the Banc-des-Américains Marine Protected Area (MPA), a DFO Scientific Monitoring Committee (BDA SMC) was established. The committee's work has included finalizing the choice of indicators and associated measures, calculating the results, and identifying methods for assessing status and trends in the MPA. To provide information on the various indicators, each measure used was described and the rationale for its use was explained. The spatial and temporal scales and the databases utilized in the calculations were specified. The results for the available time series were presented and the historical trends (pre-MPA) were described. The status of all indicators and measures for which data of sufficient quantity and quality are available was assessed. Two methods are proposed for assessing the status of the indicators and their associated measurements: anomalies (deviation from the mean of a reference period) and fixed thresholds. The status of the indicators is described using three categories: (1) Good/Low/Small change; (2) Medium/Moderate change; and (3) Poor/High/Important change. The limitations associated with the indicators, surveys and associated databases were reviewed. Lastly, a list of priority indicators, which will be reported on more frequently and consistently, was proposed.

# 1. INTRODUCTION

In March 2019, the Canada-Quebec joint project agreement regarding the Banc-des-Américains marine protected area (MPA) was signed. As a result, this MPA benefits from dual protection status, namely as a Marine Protected Area under Canada's *Oceans Act* (Regulation SOR/2019-50) and a proposed aquatic reserve under Quebec's *Natural Heritage Conservation Act*. This marine area was selected for long-term protection because it contains a wide diversity of habitats, making it an important biological crossroads for many pelagic, demersal and benthic species (Savenkoff et al. 2007, 2017; Gauthier et al. 2013). In the long term, the purpose of establishing this MPA is to promote the biological productivity and diversity of fishery resources, as well as the recovery of species at risk.

Three conservation objectives (COs) have been defined (Gauthier et al. 2013) for the MPA:

1. conserve and protect benthic habitats;
2. conserve and protect pelagic habitats and forage species; and
3. promote the recovery of at-risk whales and wolffish(Gauthier et al. 2013)(Gauthier et al. 2013)(Gauthier et al. 2013)(Gauthier et al. 2013).

To date, the MPA's ecosystem has been described and its conservation priorities identified in a number of projects and reports (AECOM Tecsult Inc. 2010; Gauthier et al. 2013; Savenkoff et al. 2015, 2017; Côté et al. 2021). In addition, the pressures on the ecosystem were assessed and presented in the form of a pathway of effects (Gendreau et al. 2018), which supported the development of regulatory measures for the MPA (SOR/2019-50).

An effective monitoring plan for the MPA must be designed in accordance with the protected area's objectives. Specific conservation priorities, pressures, indicators and measures must be identified and linked directly to the COs (Figure 1). Ecological monitoring, which will be implemented by DFO, will enhance the management plan using the results obtained for the indicators (Figure 1). If necessary, this information can be used to adjust the management measures and COs, allowing for adaptive management of the MPA (Figure 1).

Following the designation of an MPA under the *Oceans Act*, an essential step is the implementation of a monitoring program to assess the status of the ecosystem, the achievement of the conservation goal and COs, and the overall effectiveness of management measures. To achieve this, several aspects or types of monitoring can be considered in a monitoring program (MPA Monitoring Enterprise 2011; California Department of Fish and Wildlife and California Ocean Protection Council 2018; Noble James et al. 2018). Based on these different processes, the DFO monitoring program for the Banc-des-Américains MPA will be divided into two components (Table 1):

1. assessment of the MPA's status and trends
2. assessment of the MPA's performance.

A review of the indicators for DFO's ecological monitoring of the MPA was submitted for peer review in May 2018. During this process, the significant ecosystem components (now called *Conservation Priorities*), pressures and indicators that should be monitored were revised (Faille et al. 2019; DFO 2019a). Three types of indicators were identified: direct, indirect and pressure indicators. Indirect indicators will allow for the assessment of the status and general trends of the MPA ecosystem, as will the direct indicators, which may also make it possible to assess the MPA's performance. The review of the existing surveys also enabled us to identify programs already in place that provide relevant data and to target the gaps to be filled by the new surveys to be developed.

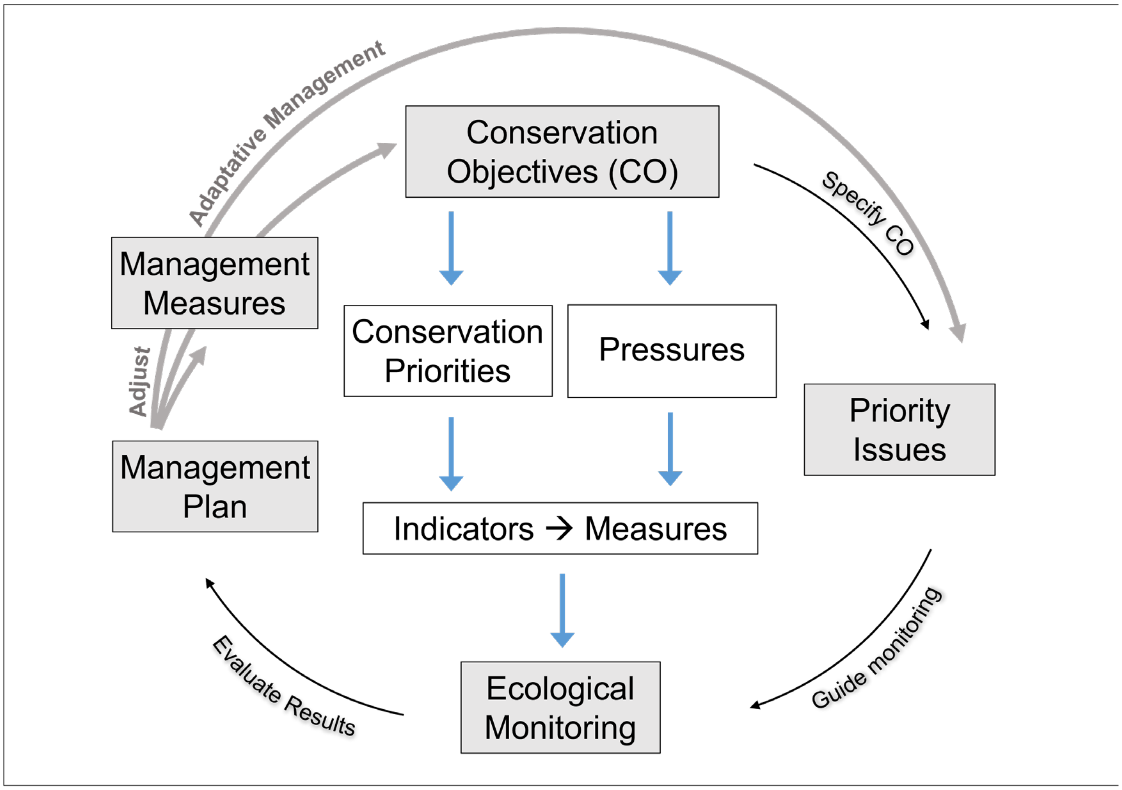
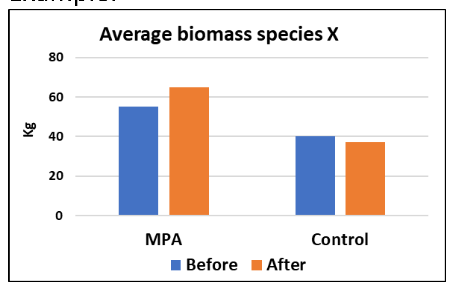



*Figure 1. Hierarchy of the various elements used in the DFO ecological monitoring plan for the Banc-des-Américains MPA (blue arrows and white boxes) and key steps in the monitoring process (black arrows and grey boxes) to enable adaptive management of the MPA (grey arrows).*

To help implement DFO's ecological monitoring of the MPA, a DFO Banc-des-Américains MPA Scientific Monitoring Committee (BDA SMC) was created in January 2019 (see Appendix B for committee membership). The committee's main mandates are to finalize DFO's ecological monitoring plan, oversee the implementation of monitoring, fill knowledge gaps (develop new surveys) and produce monitoring reports. The committee's first task was to finalize DFO's ecological monitoring plan and in particular to look at the first aspect of monitoring, which involved assessing the status of the MPA and its trends. To do this, the committee needed to determine how each indicator would be calculated (i.e. spatial and temporal scales) and which databases or datasets would be used. How the status of the indicators would be assessed also needed to be ascertained. These tasks relied on previous efforts involving the identification of priority issues in the MPA and the associated COs, which required a review of the indicators, resulting in some being eliminated and other new ones being added.

The purpose of this document is to explain and justify the measures selected for each indicator, to describe in detail the data processing methods used, and present the results and historical trends available. In addition, proposed methods for assessing the status of each indicator are presented, to provide a framework for producing the monitoring reports and to ensure that the results presented provide adequate information for the Marine Planning and Conservation Division (MPCD). Lastly, a list of key/priority indicators, which will be reported on frequently and consistently, is proposed.

*Table 1. Key elements of DFO's Banc-des-Américains MPA ecological monitoring program.*

<table>
<tr><td></td><td colspan="2">Main monitoring elements</td></tr>
<tr><td></td><td>1) Assessing MPA status and trends</td><td>2) Assessing the ecological performance of the MPA</td></tr>
<tr><td>Why?</td><td>The objective is to measure the magnitude and direction of long-term changes</td><td>The objective is to investigate the effectiveness of management measures</td></tr>
<tr><td>Which indicators?</td><td>Indirect, direct and pressure indicators</td><td>Some direct indicators</td></tr>
<tr><td>How?</td><td>Use time series to assess status and trends based on methods that allow a classification.<br><br>Example dissolved $O_2$:<br>
<table>
<tr><th>State</th><th>Fixed threshold</th></tr>
<tr><td>Low</td><td>>70</td></tr>
<tr><td>Medium</td><td>30- 70 %</td></tr>
<tr><td>High</td><td>< 30 %</td></tr>
<tr><td>Not assessed</td><td></td></tr>
</table></td><td>Make before-and-after and/or MPA-control site (BACI) comparisons using multivariate statistics<br><br>Example:<br>

</td></tr>
<tr><td>What questions will be answered?</td><td>Did the biomass of species X change over time?<br>Has bottom oxygen decreased over the time series?<br>What is the change in vessel traffic since the establishment of the MPA?</td><td>Is the biomass, size, abundance of indicator species x different in the MPA than outside? Can this difference be attributed to the establishment of the MPA?</td></tr>
</table>

## 2. PRIORITY ISSUES RELATED TO CONSERVATION OBJECTIVES

For the Banc-des-Américains MPA, three conservation objectives (COs) were established to promote the productivity and diversity of fisheries resources associated with the American Bank and its adjacent plains, as well as the recovery of species at risk (Gauthier et al. 2013; Regulation SOR/2019-50). Because these three objectives are so broad, **priority issues** were developed to more specifically guide indicator assessment and MPA monitoring.

Priority issues for CO1 (Conserve and protect benthic habitats*)* are:

- ensure that the diversity and status of the various benthic habitat communities is maintained within the limits of natural variability or improved.
- minimize the negative impacts of human activities on the benthic habitat, associated communities and commercial resources.

Priority issue for CO2 (Conserve and protect pelagic habitats and forage species) is:

- minimize the negative impacts of human activities on pelagic habitats and forage species.

Priority issue for CO3 (Promote the recovery of at-risk whales and wolffish) is:

- minimize the negative impacts of human activities to maintain suitable habitat for at-risk whale and wolffish populations.

The priority issues clarify each of the three COs and specify the intended direction of change to assess the status of the indicators and measures (Figure 1). Thus, the priority issues help guide the monitoring and interpretation of results. The priority issues can be reassessed and adapted periodically during the revision of the MPA management plan using an adaptive management approach.

# 3. UPDATE OF CONSERVATION PRIORITIES, INDICATORS AND PRESSURES

During the 2018 peer review, 15 ecosystem components (now called conservation priorities), six anthropogenic pressures and 33 associated indicators were identified (Appendix C; Faille et al. 2019; DFO 2019a). Following discussion by the DFO scientific monitoring committee (DFO-SMC), the conservation priorities and indicators were reorganized to be presented in a more logical order and hierarchically under each of the COs. In addition, some indicators were renamed or slightly modified to better suit the available data and associated measures. Note that the “Commercial fisheries” pressure was divided into two separate pressures, “Physical disturbance of the bottom” and “Biomass removal”. The list of previous indicators and how they relate to the new ones is presented in Appendix C, allowing the reader to easily associate the 2018 results and the updated list. Following this revision, three pressures and five associated indicators were added to the list.

The added pressures are:

- **Competitors/predators:** this pressure includes the “Lobster on the ridge” indicator (identified in 2018) and the new “Grey seal” indicator.
- **New pressure:** this addition will make it possible to track and identify any new activity in the MPA that has the potential to impede the CO (e.g., native fishing, tourism, etc.).
- **Ghost gear:** this pressure is added because the presence of fixed gear (traps and longline) fisheries in the MPA pose a risk of gear loss (past and future). Gendreau et al. (2018) had identified ghost gear as a pressure, but it had not been included in the pathway of effects because of a lack of available data. The indicators for this pressure have not yet been defined.

The indicators added are the following:

- **Grey seal:** this indicator was added because the species was identified as an element that can affect demersal communities and forage species such as herring by exerting predation pressure (DFO 2011a).
- **Footprint and biomass harvested by scientific activities**: two indicators associated with the scientific activities that take place in the MPA were added to the “Physical disturbance of the bottom” and “Biomass harvesting” pressures, respectively. These activities presently occur at a low frequency and are managed by an activity plan, but from a transparency perspective, it is important to report on these activities.
- **Fishing activity violation**: this indicator has been added to adequately monitor the number of violations related to fishing activities which could negatively impact the MPA. For example, physical disturbance of the bottom in Area 1 (identified as more sensitive) could impede on the achievement of CO1.

- **Several new pressures:** see explanation above.

Selection criteria for indicators were proposed during the 2018 peer review based on different guidelines (Pomeroy et al. 2004; DFO 2013a), but the indicators were not assessed individually (Faille et al. 2019; DFO 2019a). This step was partially completed by the BDA SMC by assessing the indicators using six criteria. The initial *Public awareness* criterion was not assessed, as all indicators are considered to have the potential to meet this criterion, depending on how the results are presented. Furthermore, the initial *Easy to manage* criterion was not assessed for each indicator, as it refers instead to all indicators, the number of which must remain reasonable and avoid redundancy. This criterion will be assessed in the first full monitoring report. The *Measurable* criterion included many elements and was split in two in order to assess the *Cost–benefit ratio* separately. Lastly, the *Researcher support* criterion was replaced with *Sustainability*. Therefore, the following six criteria were used to assess each indicator (tables 2 and 3):

- **Theoretical basis/ecological significance:** the indicators must be solidly based on scientific knowledge.
- **Sensitivity:** the indicators must be sensitive and responsive to management actions.
- **Measurable:** the indicators must be able to be measured using simple, proven methods and equipment (specifically, non-invasive, non-destructive methods). The indicators should have the ability to be measured or estimated on a regular basis, and time series data should ideally be available.
- **Cost–benefit ratio:** the indicators should have a reasonable cost–benefit ratio, and data collection and processing must be feasible using existing financial resources and within reasonable timelines.
- **Interpretable:** the indicators should show specific responses to known causes and allow for the signal to be interpreted to distinguish natural variability from that caused by anthropogenic and environmental pressures.
- **Sustainability:** the indicators should be measured as part of long-term monitoring programs, as much as possible.

Following this assessment, five indicators were eliminated and are shown in Appendix D. It should be noted that the *Interpretable* criterion was considered in its broadest sense and not based on the ability of existing databases to provide a clear statistical signal. In the future, power analyses and the like could help to clarify whether a measure or indicator is truly interpretable using the databases available. Based on the pathway of effects (Gendreau et al. 2018), an updated version of the links between conservation priorities and pressures is presented here according to the new list (Table 4).

*Table 2. List of conservation priorities and indicators and their assessment according to six selection criteria, as well as the main survey(s) associated with each indicator (full survey names are provided in Appendix E).*

**CO1 Conserve and protect benthic habitats (benthic and demersal [BD])**

| **Conservation Priorities** | **Indicators version 2021** | **Main Survey(s)** | **Criteria** | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Theoretical basis** | **Sensitivity** | **Measurable** | **Cost-benefit ratio** | **Interpretable** | **Sustainability** |
| Indicator species of benthic and demersal communities | BD1) Cold water indicator species | R10-Multi sGSL | • | | • | • | • | • |
| | BD2) Warm water indicator species | R10-Multi sGSL | • | | • | • | • | • |
| | BD3) Dominant/key species | R10-Multi sGSL | • | • | • | • | • | • |
| | BD4) Biomass of invertebrates* | R10-Multi sGSL | • | • | • | • | • | • |
| Epibenthic communities | BD5) Epibenthic community A: Rocky ridge | RD1-Imagery | • | • | • | • | • | |
| | BD6) Epibenthic community B: Mixed ridge | RD1-Imagery | • | • | • | • | • | |
| | BD7) Epibenthic community C: Mixed plain | RD1-Imagery | • | • | • | • | • | |
| | BD8) Epibenthic community D: Soft plain | RD1-Imagery | • | • | • | • | • | |
| Demersal communities | BD9) Demersal fish community on the plain | R10-Multi sGSL | • | • | • | • | • | • |
| | BD10) Demersal fish on the ridge | RD6-Bait. Imagery | • | • | • | • | • | |
| Benthic and demersal commercial species | BD11) Snow crab | R13-Snow Crab sGSL | • | • | • | • | • | • |
| | BD12) Harvested groundfish | R10-Multi sGSL | • | • | • | • | • | • |
| Substrate characteristics | BD13) Sediments | RD1-Imagery | • | | • | • | | |
| Endobenthic communities | *pending* | RD2-Grab | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* |
| Suprabenthic communities | *pending* | *Nd* | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* |

**CO2 Conserve and protect pelagic habitats and forage species (Pelagic (P))**

| Conservation Priorities | Indicators version 2021 | Main Survey(s) | Criteria | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Theoretical basis | Sensitivity | Measurable | Cost-benefit ratio | Interpretable | Sustainability |
| Nutrients | P1) Nutrients | R1-AZMP, R6-Helicoptered, R10-R11-Multi n/sGSL | • | | • | • | • | • |
| Phytoplankton | P2) Chlorophyll a | R1-AZMP; R10-R11-Multi n/sGSL | • | | • | • | • | • |
| Zooplankton | P3) Zooplankton | R1-AZMP | • | | • | • | • | • |
| Krill | P4) Krill biomass | R7-Krill; R10-R11-Multi n/sGSL | • | | • | • | • | • |
| Herring | P5) Herring stock biomass sGSL | R8-Herring sGSL | • | | • | • | • | • |
| Capelin | *nd* | *Nd* | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* |

**CO3 Promote the recovery of at-risk whales and wolffish (EP)**

| Conservation Priorities | Indicators version 2021 | Main Survey(s) | Criteria | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Theoretical basis | Sensitivity | Measurable | Cost-benefit ratio | Interpretable | Sustainability |
| Atlantic Wolffish | EP1) Atlantic wolffish | RD4-Scuba diving; RD5-eDNA | • | • | *nd* | *nd* | *nd* | |
| | EP2) Atlantic wolffish bycatch | R10-Multi sGSL; R13-Snow crab sGSL; R15-Observers | • | • | | • | | • |
| Whales | EP3) Fin whale | R21-PAM | • | | • | • | • | • |
| | EP4) Blue whale | R21-PAM | • | | • | • | • | • |
| | EP5) North Atlantic right whale | R21-PAM | • | | • | • | • | • |
| | EP6) Cetacean mortality/accidents | R17-QMMERN | • | • | | • | | • |

*Indicators not retained during peer review (2021)

*Table 3. Updated list of pressures and indicators and their assessment according to six selection criteria, as well as the main survey(s) associated with each indicator (full survey names are provided in Appendix E).*

| **Pressures (Pr)** | **Indicators version 2021** | **Main Survey(s)** | **Criteria** | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Theoretical basis** | **Sensitivity** | **Measurable** | **Cost-benefit ratio** | **Interpretable** | **Sustainability** |
| Climate changes | Pr1) Physical conditions of the pelagic habitat | R3-Ice, R4-SST, R10-R11-Multi n/sGSL | • | | • | • | • | • |
| | Pr2) Physical conditions of the benthic habitat (>100 m) | R1-AZMP, R10-R11-Multi n/sGSL | • | | • | • | • | • |
| | Pr19) Acidification | R1-AZMP, R10-R11-Multi n/sGSL | • | | • | • | • | • |
| | Pr20) Dissolved oxygen | R1-AZMP, R10-R11-Multi n/sGSL | • | | • | • | • | • |
| Invasive Species (AIS) | Pr3) Presence of AIS | RD5-eDNA | • | | *nd* | *nd* | | |
| Competitors/predators* | Pr4) Grey seal* | RD7-Haulouts | • | | • | • | | |
| | Pr5) Lobster on the ridge | RD4-Scuba diving, RD6-Bait. Imagery | • | | • | • | • | |
| Noise | Pr6) Anthropogenic noise | R21-PAM | • | • | • | | • | • |
| | Pr7) Traffic intensity | R18-AIS | • | • | • | • | • | • |
| **Disturbance** | Pr8) Intensity of observation and recreational activities | R22-Act. Report, R18-AIS | • | • | • | • | • | • |
| Collisions | Pr21) Number of collisions | *nd* | • | • | | • | | • |
| | Pr9) Vessel speed | R18-AIS | • | • | • | • | • | • |
| Entanglements | Pr10) Number of entanglements | R17-QMMERN | • | • | • | • | | • |
| Physical disturbance of the bottom | Pr11) Relative footprint of the snow crab fishery | R14-ZIFF | • | • | • | • | • | • |
| | Pr12) Relative footprint of the groundfish fishery | R14-ZIFF | • | • | • | • | • | • |
| | Pr13) Empreinte des activités scientifiques* | R10-Multi sGSL, R13-Snow crab sGSL, RD1-Imagery | • | • | • | • | • | • |
| | Pr14) Fishing activities - violations* | *nd* | • | • | • | • | • | • |
| Biomass removal | Pr15) Snow crab fishery | R14-ZIFF | • | • | • | • | • | • |
| | Pr16) Groundfish fishery | R14-ZIFF | • | • | • | • | • | • |
| | Pr17) Fishing done by scientific activities* | R10-Multi sGSL, R13-Snow crab sGSL | • | • | • | • | • | • |
| New pressure* | Pr18) Number of new pressures* | - | | • | • | • | • | • |
| Ghost gear* | *pending* | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* |
| Pollution | *pending* | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* |

*New pressures and indicators added to the list in 2021.

*Table 4. Linkage between conservation priorities and the pressures affecting them (adapted from Gendreau et al. 2018).*

**CO1 Conserve and protect benthic habitats (benthic and demersal [BD])**

| Conservation Priorities | Climate changes | Invasive Species | Competitors/ predators | Noise | Disturbance | Collisions | Entanglements | Physical disturbance of the bottom | Biomass removal | Ghost gear | Pollution |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Indicator species of benthic and demersal communities | • | • | | | | | | • | • | • | • |
| Epibenthic communities | • | • | | | | | | • | • | • | • |
| Demersal communities | • | | • | | | | | | • | • | • |
| Benthic and demersal commercial species | • | | • | | | | | • | • | • | • |
| Substrate characteristics | | | | | | | | • | | | • |
| Endobenthic communities | • | | | | | | | • | | | • |
| Suprabenthic communities | • | | | | | | | | | | • |

**CO2 Conserve and protect pelagic habitats and forage species (Pelagic (P))**

| Conservation Priorities | Climate changes | Invasive Species | Competitors/ predators | Noise | Disturbance | Collisions | Entanglements | Physical disturbance of the bottom | Biomass removal | Ghost gear | Pollution |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nutrients | • | | | | | | | | | | |
| Phytoplankton | • | | | | | | | | | | |
| Zooplankton | • | | | | | | | | | | |
| Krill | • | | | | | | | | | | |
| Herring | • | | • | | | | | | • | | |
| Capelin | • | | | | | | | | • | | |

**CO3 Promote the recovery of at-risk whales and wolffish (EP)**

| Conservation Priorities | Climate changes | Invasive Species | Competitors/ predators | Noise | Disturbance | Collisions | Entanglements | Physical disturbance of the bottom | Biomass removal | Ghost gear | Pollution |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Atlantic Wolffish | • | | • | | | | | • | • | • | • |
| Whales | • | | | • | • | • | • | | | • | |

# 4. GENERAL METHODOLOGY

## 4.1. SPATIAL SCALE

Not all indicators and associated measures are assessed at the same spatial scale (Appendix F, see "Spatial scales" column). The Banc-des-Américains MPA is subdivided into two main areas. Zone 1, corresponding mostly to the ridge, is subject to stricter conservation measures than Zone 2 (a and b), which includes the northeast and southwest plains (Faille et al. 2019; *Regulations* SOR/2019-50) (Figure 2a). Some indicators are monitored at specific sites in Area 1 and/or Area 2, while several others are monitored throughout the MPA, and a few indicators are monitored in a larger area (which includes the MPA).

### 4.1.1. Oceanographic area

Measures associated with some of the pelagic habitat indicators (P1, P2, P3, P4, and Pr1) are calculated within an oceanographic area larger than the MPA (Figure 2c), because (1) ocean processes occur on a large scale and (2) the number of observations within the MPA is limited. The delineation of this oceanographic area is based on the representativeness of the MPA and considers both inputs (Gaspé Current) and outputs (Magdalen Shallows) while ensuring better accuracy and precision of the estimates of each measure for the area through the use of a larger number of observations. The estimates of the measures therefore reflect a larger area than the MPA but still provide information on the changing status of the oceanographic parameters within which the Banc-des-Américains MPA ecosystem is operating.

### 4.1.2. Benthic area

An area larger than the MPA was also delineated to calculate oceanographic indicators related to benthic habitat (Pr2, Pr19 and Pr20), because (1) ocean processes occur on a large scale and (2) the number of observations within the MPA is limited (Figure 2b). The delineation of the benthic area is based on the representativeness of the MPA seabed and is intended to cover a larger portion of the range of benthic organisms occurring in the Banc-des-Américains MPA. A 90 km × 90 km square covering the MPA was used, but it was truncated to retain only depths similar to those found in the MPA, i.e., a minimum depth of 13 m and a maximum of 174 m (99% of the MPA's depth values fall within this range).

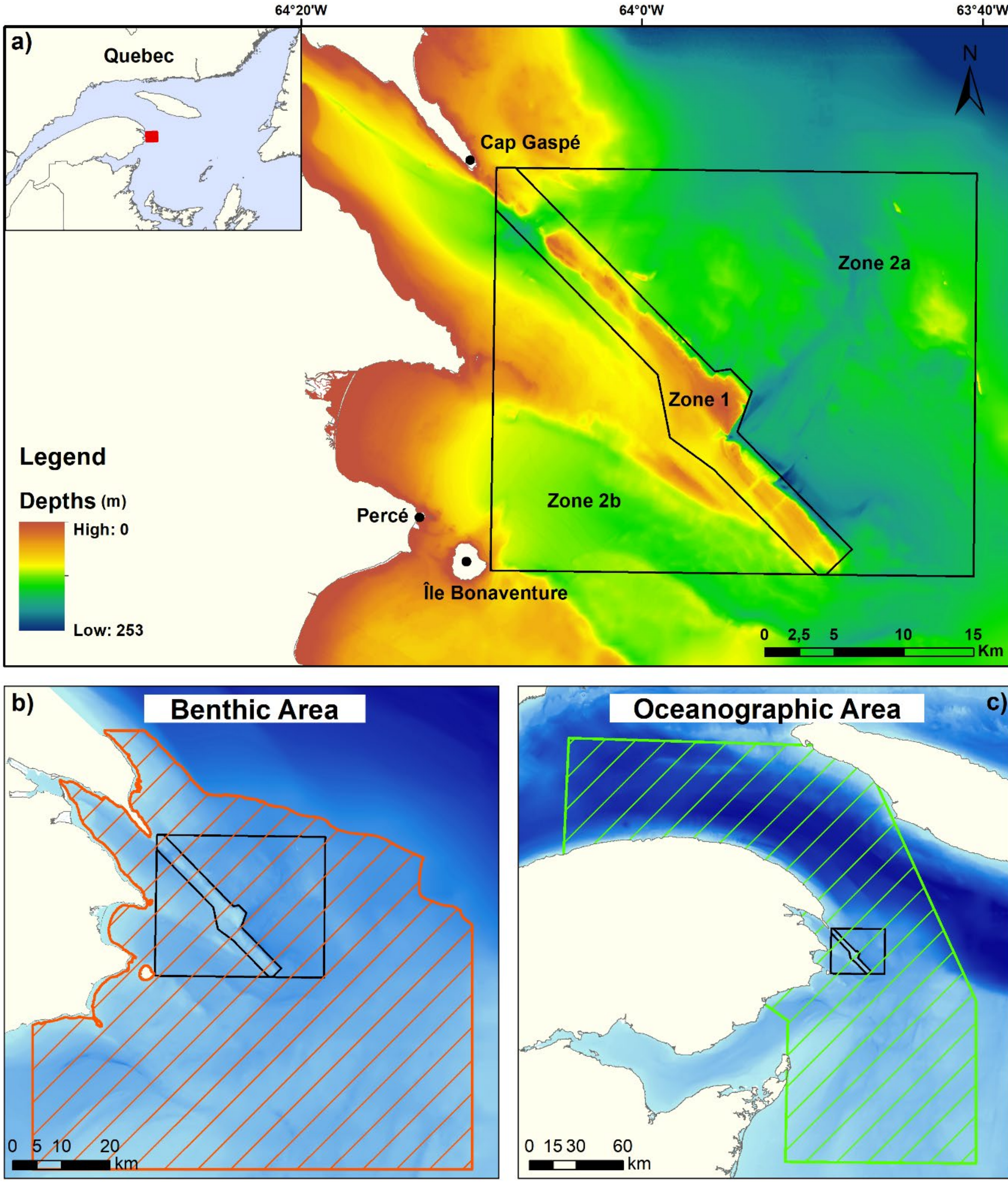



*Figure 2. (a) Boundaries of the Banc-des-Américains MPA and the two regulatory areas present, Zone 1 and Zone 2 (a and b); (b) boundary of the benthic area used to calculate indicators Pr2; (c) boundary of the oceanographic area used to calculate oceanographic indicators P1, P2, P3 and Pr1.*

## 4.2. METHODS FOR ASSESSING THE STATUS OF INDICATORS

One of the objectives of this document is to propose methods for assessing **the status of the indicators**. These methods must be objective and reproducible in order to effectively inform the MPCD about the status and evolution of the MPA. In addition, methods must be developed to ensure that the analysis of the data and presentation of the results are understandable, interpretable and informative (Park Canada Agency 2007, MPA Monitoring Enterprise 2011). Since indicators usually aggregate several measures, it is proposed that the results of the various measures be combined to summarize the status of the indicator. However, in some cases, the indicator has only one measure and therefore the status of the measure is transferred directly to the indicator. Indicators that combine different measures have the advantage of being able to synthesize a large amount of data and information, in order to better inform the MPCD and the public. It is important to note that the aggregation of measures can attenuate or mask signals from important individual measures, which can lead to simplistic conclusions or inappropriate management actions. Therefore, it is important that the limitations of this method are considered when interpreting the results (Parks Canada Agency 2007). To overcome this limitation, it is suggested that the status of each measure be presented in conjunction with the status of the indicators (combination of measures). Different ways have been used to present the results for the indicators (PNM Iroise 2010; MPA Monitoring Enterprise 2011; Sander 2018). In addition, given the diversity of the indicators and measures, it is not possible to have a single method to assess their condition. The use of two methods, anomaly and threshold, is proposed, and the method used for each indicator is listed in Appendix F and G.

### 4.2.1. Anomaly method

The anomaly method is used to highlight variation in the estimation of a measure from a reference period. An annual anomaly value indicates the difference between the value of the measure for the year in question and the average of that measure over the reference period. This difference is then standardized by dividing it by the standard deviation (SD) for the reference period. A negative (or positive) anomaly value means that the value of the measure for the year in question is lower (or greater) than the average for the reference period. Reports from the Atlantic Zone Monitoring Program (AZMP) (Blais et al. 2021; Galbraith et al. 2022) and the Northern GSL Multidisciplinary Groundfish Survey (Bourdages et al. 2021) use the standardized anomaly, among other things, to present the temporal variability of the various variables they report. Some of the monitoring sheets on the state of the St. Lawrence presented under the St. Lawrence Action Plan use the classification of these standardized anomalies for some of their indicators to describe the state of the St. Lawrence (Oceanographic Processes in the Estuary and Gulf, 3rd Ed., 2014). This latter approach is proposed here.

$$\text{Anomaly} = \frac{\text{Average of the year} - \text{reference period average}}{\text{standard deviation for reference period}}$$

Anomalies can be divided into two types:

- **Directional**: Directional anomaly is used when the direction of change (positive or negative) can be interpreted *a priori* as good or bad. In this case, the status is assessed using three categories: Good/Low, Medium, and Poor/High. For example, for marine traffic intensity, the more positive the anomaly is, the more the status of this pressure is “High”. If traffic intensity falls below the average for the reference period, the status would be “Low”, since the pressure induced on the environment would be attenuated (Table 5).
- **Bidirectional**: Sometimes the direction of the change (positive or negative) cannot be interpreted as good or bad. For example, with the measures associated with ice cover, it is difficult to determine whether an increase or decrease in ice cover has a negative or positive effect on the ecosystem as a whole. Instead, the purpose of these measures is to provide information on whether major changes have taken place in the MPA over time. In this case, status is assessed based on the magnitude of change relative to historical data, assuming

that it is desirable to preserve the ecosystem as it was at the time the MPA was established. In this case, status is assessed according to the level of change: Small change, Moderate change, and Important change (Table 6).

#### 4.2.1.1. Threshold method

In some cases, the use of anomalies is not appropriate, such as when threshold values have known biological effects according to the scientific literature. For example, dissolved oxygen and acidification have known physiological/ecological thresholds below which the growth, reproduction and even survival of one or more species are compromised (Table 5). Also, for Atlantic herring stocks, the precautionary approach developed for stock assessments specifies limit reference points (LRP) and upper stock reference (USR) points that can be used as thresholds delineating critical, cautious and healthy statuses. However, for the purposes of monitoring the MPA, the same three status designations will be used as for directional anomalies (Table 5).

*Table 5. Methods for assessing the status of measures and indicators of conservation priorities and pressures: 1) directional anomaly calculated as the mean and standard deviation (SD) of the reference period or 2) known fixed threshold.*

| Status - Directional (conservation priority/pressure) | Anomaly (Conservation priority) | Anomaly (Pressure) | Fixed threshold Dissolved $O_2$ | Fixed threshold Acidification saturation rate | Fixed threshold Herring |
|---|---|---|---|---|---|
| **Good / Low (3)** | Average of the reference period ±1 SD or higher | Average of the reference period ±1 SD or lower | > 70% | > 2 | > USR |
| **Medium / Medium (2)** | -1 SD to -2 SD | +1 to +2 SD | 30–70% | 1–2 | > LRP and < USR |
| **Poor / High (1)** | < -2 SD | > 2 SD | < 30% | < 1 | < LRP |
| **Not assessed** | Insufficient data | | | | |

*Table 6. Method for assessing the status of measures and indicators of conservation priorities and pressures using a two-way anomaly based on the mean and standard deviation (SD) of the reference period.*

| Status – Bidirectional | Anomaly |
|---|---|
| **Small change (3)** | Average of the reference period ±1 SD |
| **Moderate change (2)** | ± 1 to 2 SD |
| **Important change (1)** | > or < 2 SD |
| **Not assessed** | Insufficient data |

### 4.2.2. Addition

When more than one measure is available for an indicator, the annual value of the indicator is obtained by summing the anomalies of each associated measure. In the case of bidirectional anomalies, the absolute values of the anomalies are added together. In the case of thresholds, the scores of each measure are summed to obtain the final status of the indicator (Table 7).

*Table 7. Calculation of the status of the indicator based on the scores of each measure for the method with thresholds.*

| Status of the indicator | Score 1 measure | Score 2 measures | Score 3 measures |
|---|---|---|---|
| **Good / Low** | 3 | 6 | 8-9 |
| **Medium / Medium** | 2 | 4-5 | 5-6-7 |
| **Poor / High** | 1 | 2-3 | 3-4 |
| **Not assessed** | Insufficient data | | |

In this document, these methods are applied to provide an initial portrait of the existing data and to analyze historical trends. For all indicators for which data are available, the status of the measures and indicators is calculated and presented annually. In future monitoring reports, these methods will be used to produce an **overall rating** for each indicator and to analyze observed trends (stable, increasing, decreasing). The overall rating will then be weighted according to the level of confidence (low or good) in the data incorporated in the calculation of each indicator measure. As part of this review, a summary assessment of the confidence level was made qualitatively for each measure, but this assessment could be reviewed in greater depth by the DFO's scientific monitoring committee. The quantity of the data (e.g., frequency, time series, seasonal and spatial coverage, etc.) and their quality (e.g., gear selectivity, taxonomic accuracy, etc.) were considered for this assessment (Appendix F and G). The overall rating will be presented when at least 3 years have elapsed since the MPA was established.

DFO currently has no national framework for assessing indicator status and reporting on results. The methods proposed here may be reviewed and adjusted in light of new knowledge or new DFO guidelines for standardizing the monitoring reports for its MPAs.

# 5. SELECTION OF MEASURES FOR, AND STATE OF KNOWLEDGE ON, CO1[1]

## 5.1. INDICATOR SPECIES OF BENTHIC AND DEMERSAL COMMUNITIES

### 5.1.1. Surveys

The data used for the four indicators were obtained from the multi-species bottom trawl survey in the southern Gulf of St. Lawrence (sGSL), which is conducted by DFO in September (Figure 3). The survey was carried out from on board the *Lady Hammond* from 1985 to 1991, the *CCGS Alfred Needler* from 1992 to 2002 and the *CCGS Wilfred Templeman* in 2003 (Swain et al. 2019). In 2004 and 2005, a comparative fishing experiment was conducted using the *CCGS Alfred Needler* and *CCGS Teleost*. Since 2006, the *CCGS Teleost* has been used for the survey. Although the data obtained in the survey go back to 1971, the time series considered for fish is 1986 to the present and for benthic invertebrates, from 2004 to the present, due to changes in the protocol and variations in taxonomic resolution over time.

The stratified random sampling plan for the survey includes the stations to be surveyed. The Banc-des-Américains MPA lies almost exclusively in stratum 416 of the survey (Figure 3) but part of the MPA, mainly the ridge, is not covered. Because the positions of the stations are random, they vary annually, and the number of stations covered in the MPA has also varied over time. The number of stations visited each year has ranged from zero to four since 1986, for

[1] All measures for each indicator are listed in Appendix F.

an average of 1.5 stations per year. To increase the number of samples and improve the robustness of the survey, the survey area was extended to the entire 416 stratum, where the number of stations visited annually has ranged between 3 and 13, for an average of 7.8 stations per year (Table 8). Therefore, the indicators (BD1, BD2, BD3, BD4, BD9 and BD12) are based on all trawl tows completed in stratum 416, including the MPA (Figure 3).

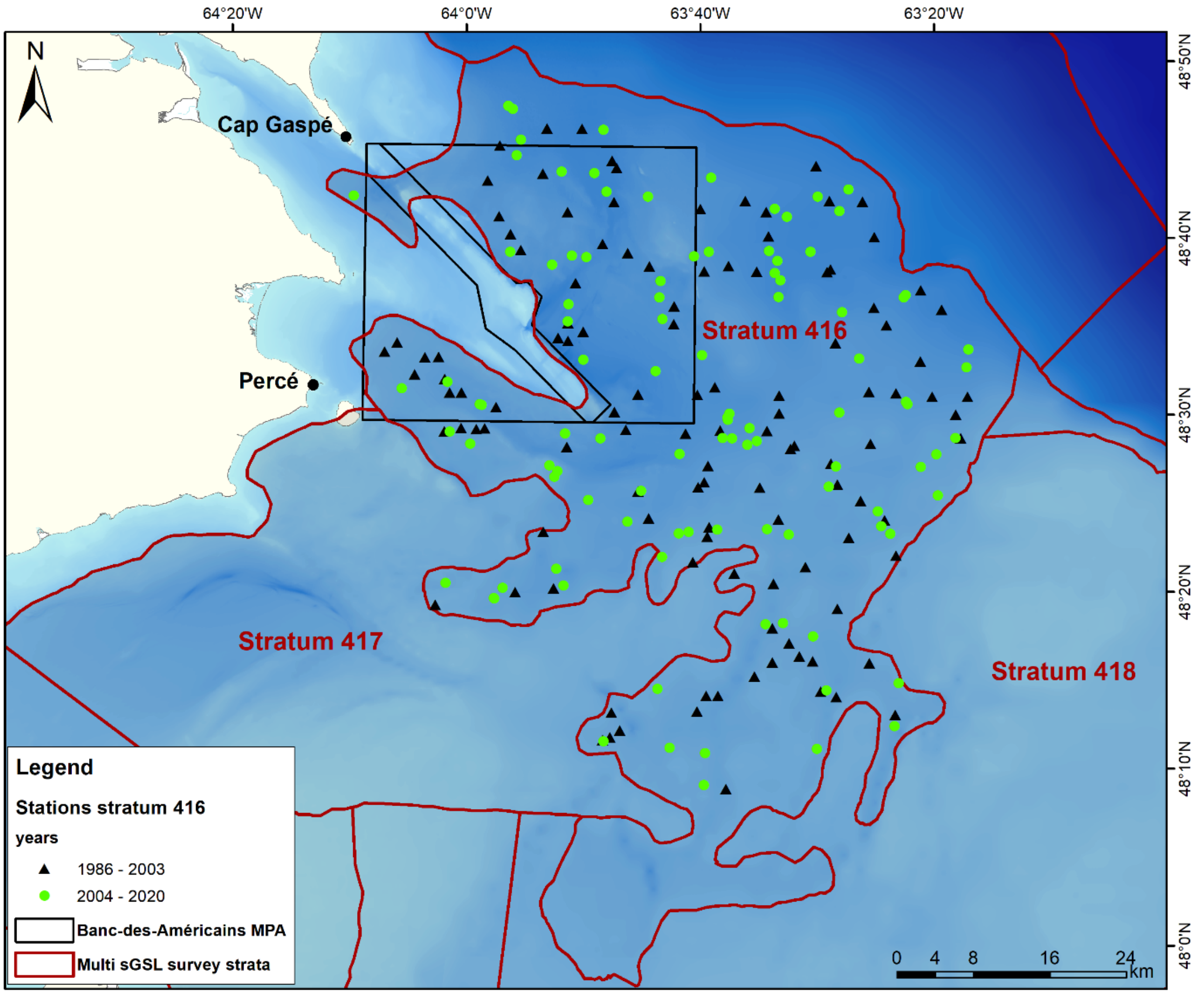



*Figure 3. Location of tows in the Banc-des-Américains MPA during the sGSL multi-species bottom trawl survey between 1986 and 2020, as well as the strata used for random sampling.*

*Table 8. Number of stations covered annually in stratum 416 and in the Banc-des-Américains MPA (BDA MPA) by the sGSL multi-species bottom trawl survey between 1986 and 2020.*

| Year | Stations Stratum 416 | Stations BDA MPA |
|---|---|---|
| 1986 | 9 | 3 |
| 1987 | 9 | 3 |
| 1988 | 13 | 2 |
| 1989 | 7 | 1 |
| 1990 | 8 | 2 |
| 1991 | 9 | 0 |
| 1992 | 10 | 3 |
| 1993 | 9 | 4 |
| 1994 | 8 | 2 |
| 1995 | 8 | 2 |
| 1996 | 9 | 2 |
| 1997 | 8 | 2 |
| 1998 | 8 | 3 |
| 1999 | 8 | 2 |
| 2000 | 8 | 3 |
| 2001 | 7 | 2 |
| 2002 | 9 | 3 |
| 2003 | 3 | 2 |
| 2004 | 12 | 2 |
| 2005 | 8 | 3 |
| 2006 | 8 | 0 |
| 2007 | 8 | 0 |
| 2008 | 8 | 1 |
| 2009 | 8 | 3 |
| 2010 | 8 | 2 |
| 2011 | 6 | 1 |
| 2012 | 5 | 1 |
| 2013 | 6 | 1 |
| 2014 | 8 | 1 |
| 2015 | 8 | 1 |
| 2016 | 8 | 2 |
| 2017 | 6 | 2 |
| 2018 | 8 | 2 |
| 2019 | 5 | 0 |
| 2020 | 4 | 1 |

### 5.1.2. Data processing

The biomass data correspond to the weight in kg per standardized tow (i.e. a daytime tow of 1.75 nautical miles [30 minutes at 3.5 knots] from the *CCGS Teleost* using a Western IIA trawl) (Hurlbut and Clay 1990). The average is calculated based on the stations surveyed in stratum 416 each year.

The reference period used is 2004–2018 for all the indicators and measures presented, and an annual mean is calculated. The reference period does not incorporate the entire time series available for demersal fish, since fish communities changed significantly during the 1990s. Using the entire time series would result in a standard deviation that is much too great and, instead, the objective is to compare how the status of the communities in the MPA has changed since the MPA was established. Therefore, the same reference period is used for demersal fish and invertebrates. However, historical data from 2004 are presented for the measures involving invertebrates and from 1986, for those involving fish.

The status of the measures associated with the BD1 (Cold water indicator species) and BD2 (Warm water indicator species) indicators is determined based on the absolute value of the anomalies. In the case of these bidirectional anomalies, the magnitude of the change is what must be assessed, while the direction of the change is irrelevant. This is because, in the case of these two indicators, it cannot be determined whether an increase or decrease in biomass is good or bad for the MPA. In contrast, the data for the indicators BD3 (Dominant/key species) and BD4 (Invertebrate biomass) are presented as directional anomalies, as they involve sensitive, key or dominant species. A reduction in the biomass of these species is not considered desirable, because the objective is to maintain or improve the initial state of the benthic habitat at the time the MPA was established.

### 5.1.3. BD1) Cold water indicator species

#### 5.1.3.1. Measures retained and state of knowledge

*Measures 1 and 2: Biomass of the 3 most abundant cold water stenotherm species – fish and invertebrates*

To provide general information on the changes in benthic and demersal communities, two lists of fish and invertebrate species that are tolerant of cold water were developed by a taxonomist and specialist in the ecology of marine fauna in the northwest Atlantic (Tables 9 and 10; Appendix H). The aim is to target more sensitive species that could exhibit a rapid response to climatic variations and community evolution. Cold water stenotherms are good indicators of temperature-related changes.

The total biomass of cold water stenothermic fish and invertebrates in each tow is calculated by adding the biomass of the three most abundant taxa (highlighted in bold in Tables 9 and 10). Biomass data are then logarithmically transformed due to their distribution. The mean log value for total tow biomass is then calculated for each year.

*Measures 3 and 4: Estimated biomass of cold water stenotherm species – fish and invertebrates*

For these measures, the 13 fish species and two invertebrate species not considered in measures 1 and 2 were chosen (Tables 9 and 10), to prevent very abundant species from masking the presence of rarer species. The occurrence of these indicator species is assessed in each tow in stratum 416, then the proportion of tows each year with their presence is calculated. Since binomial variables are involved, the data are processed using a Hurdle-type predictive model, in which the estimated biomass of the indicator species is obtained in a two-step process. In the first step, a binomial model is used, the inverse of which (1/logit) is employed to predict the proportion of tows containing the indicator species, while the second step involves gamma prediction, which takes into account the weight of catches greater than zero. Lastly, the Hurdle model combines these two models' predictions in a single prediction.

*Results*

The log total biomass of the three most abundant fish species (Greenland halibut, American plaice and witch flounder) declined steadily between 1986 and 2003, from 4.0 to 1.9 kg/tow (Figure 4) respectively. This difference corresponds to a decrease of 51 kg/tow in the raw data. Despite some fluctuations, log biomass then rose from 2004 to 2010, only to decline again until 2017. Since then, log total biomass of all three species has increased. The estimated biomass of cold water stenothermic fish species has fluctuated frequently during the time series, but these variations have remained low in magnitude, except in 2005 and 2014, when the estimated biomass of these species was much greater. Log total biomass of the three invertebrates species (*Pandalus borealis, Pandalus montagui* and snow crab) gradually declined over the time series, from 2.6 to 0.7 kg/tow between 2004 and 2020. Since 2014, log biomass has been below the average of 2 kg/tow, corresponding to a decrease of 12.6 kg/tow in the raw data. For invertebrates, the estimated biomass of cold water stenothermic species has remained very close to 0 throughout the time series, except in 2014 (Figure 4).

*Status and trend*

In general, the BD1 indicator has had the status of “Small change” throughout the time series (Figure 5). In 2005, 2014 and 2020, the magnitude of change was greater, and the indicator’s status shifted to “Moderate change.” The declining biomass of *Pandalus* shrimp and snow crab contributed to the change in status observed in 2020.

*Table 9. List of cold water stenothermic species (fish)*

| Aphia code* | Latin name | Latin name confirmed | Common name | Thermal thresholds | References |
|---|---|---|---|---|---|
| **127144** | ***Reinhardtius hippoglossoides*** | - | **Greenland halibut** | **0–2°C** | **From Mecklenburg et al. 2018** |
| **127137** | ***Hippoglossoides platessoides*** | - | **American plaice** | **0.5–5.8°C** | **From Mecklenburg et al. 2018** |
| **127136** | ***Glyptocephalus cynoglossus*** | - | **Witch flounder** | **2–6°C** | **Mecklenburg et al. 2018** |
| 126758 | *Anarhichas lupus* | - | Atlantic wolffish | –1.0 to 13°C | Coad et al. 1995 |
| 126759 | *Anarhichas minor* | - | Spotted wolffish | –1.4 to 9°C (usually < 5°C) | Mecklenburg et al. 2018; Dutil et al. 2014 |
| 126757 | *Anarhichas denticulatus* | - | Northern wolffish | –0.2 to 11.9°C | Mecklenburg et al. 2018; Dutil et al. 2014 |
| 126433 | *Boreogadus saida* | - | Arctic cod | –1.8 to 7.9°C | Mecklenburg et al. 2018 |
| 254538 | *Gadus macrocephalus*** | - | Greenland cod | ~1.23°C | Chouinard and Dutil 2004 |
| 127198 | *Gymnocanthus tricuspis* | - | Arctic staghorn sculpin | –1.8 to 12.5°C | Mecklenburg et al. 2018 |
| 127195, 127193, 126147 | *Artediellus uncinatus* | *Artediellus* spp.*** | Arctic hookear sculpin | 0.2 to 2.0°C | Mecklenburg et al. 2018 |
| 127235 | *Cottunculus microps* | - | Polar sculpin | 0.7–13.1°C | Mecklenburg et al. 2016 |
| 309268 | *Uleina olrikii* | *Aspidophoroides olrikii* | Arctic alligatorfish | 0°C (rarely > 2–3°C) | Whitehead et al. 1984 |
| 293624 | *Liparis* | *Liparis bathyarcticus* | Nebulous snailfish | –1.6 to 3.7°C | Mecklenburg et al. 2016 |
| 127215, 127217 | *Eumicrotremus derjugini, Eumicrotremus spinosus* | *Eumicrotremus terraenovae* | Newfoundland spiny lumpsucker | –2 to 5.4°C | Mecklenburg et al. 2018 |
| 229 | *Gymnelus viridis* | - | Fish doctor | 0°C | Marine species identification portal |
| 159817 | *Eumesogrammus praecisus* | - | Fourline snakeblenny | –1.3 to 4°C | Mecklenburg et al. 2018 |

* From the World Register of Marine Species (WoRMS)
*******Gadus macrocephalus*, formerly *Gadus ogac*, change effective 2017-08-17 13:35:34Z by Bailly, Nicolas
***Includes the two species of the genus *Artediellus* from the R10-Multi sGSL survey (*Artediellus atlanticus*, *Artediellus uncinatus* and *Artediellus* sp.)

*Table 10. List of cold water stenothermic species (invertebrates)*

| Aphia code* | Latin name | Latin name confirmed | Common name | Benthic position | Thermal thresholds | References |
|---|---|---|---|---|---|---|
| **107649** | ***Pandalus borealis*** | - | **Northern shrimp** | **Supra** | **0 to 5°C** | **Bergström 2000** |
| **107651** | ***Pandalus montagui*** | - | **Striped shrimp** | **Supra** | **–1 to 21°C** | **Bergström 2000** |
| **107315** | ***Chionoecetes opilio*** | - | **Snow crab** | **Epi** | **–1.8 to 6°C** | **Shackell et al. 2013; Siikavuopio et al. 2017** |
| 140596 | *Bathypolypus arcticus* | *Bathypolypus bairdii* | Baird's spoonarm octopus | Epi | 2 to 8°C | Gardiner and Dick 2010 |
| 125154 | *Leptasterias polaris* | - | Polar sea star | Epi | - | - |

* From the World Register of Marine Species (WoRMS)

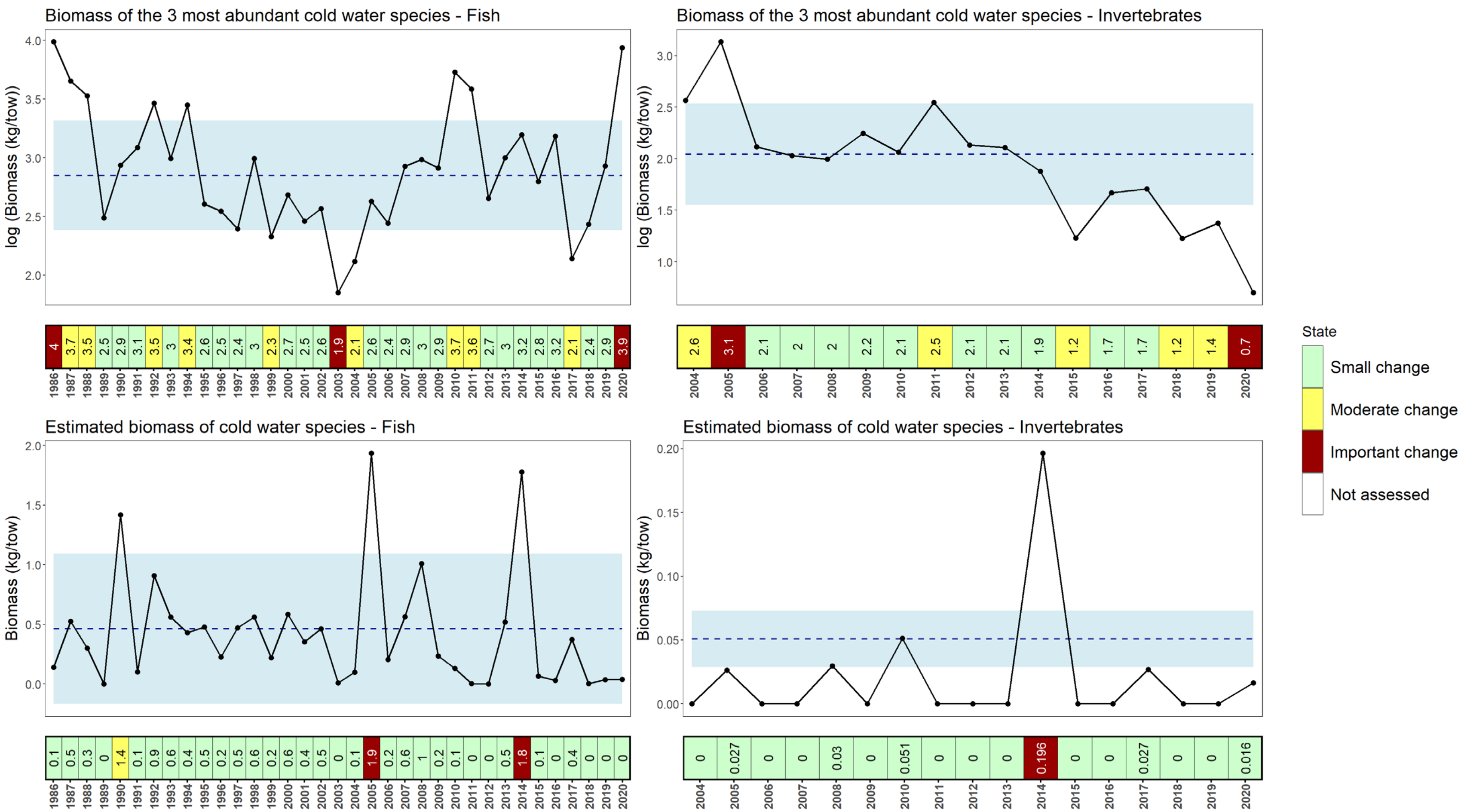



*Figure 4. Time series of the values of the measures associated with the BD1 indicator (Cold water stenotherm species). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).*

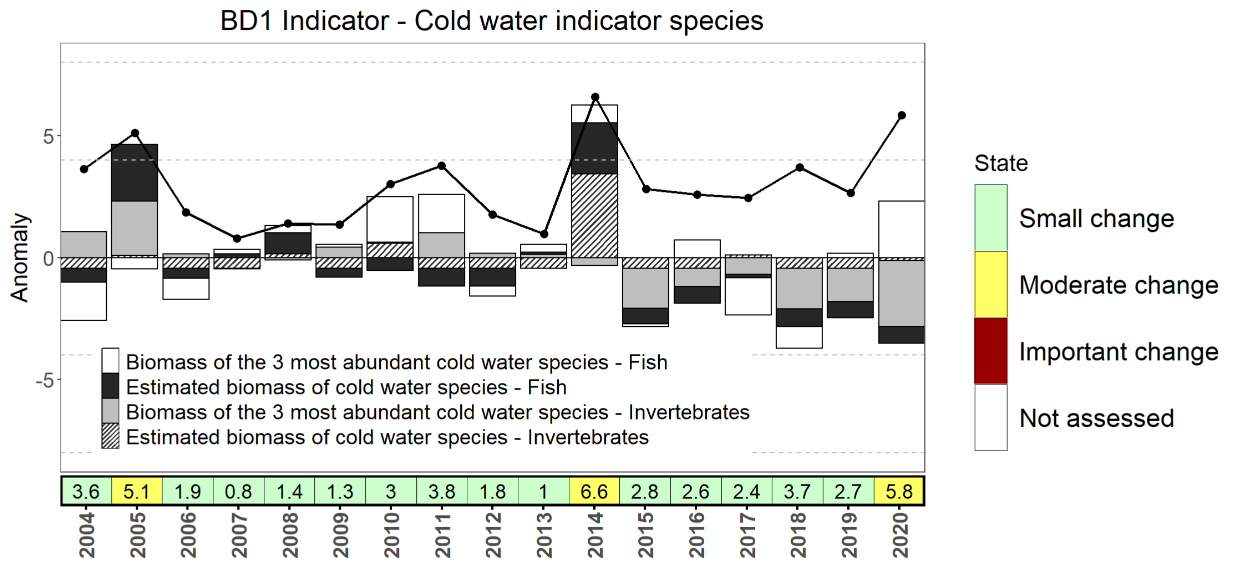



*Figure 5 Time series of anomaly values for the measures associated with the BD1 indicator (Cold water indicator species). The black line corresponds to the sum of the absolute values of the anomalies used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

### 5.1.4. BD2) Warm water indicator species

#### 5.1.4.1. Measures retained and state of knowledge

*Measures 1 and 2: Biomass of the 3 most abundant warm water stenotherm species – fish and invertebrates*

As with the cold water indicator species, a list of indicator species tolerant of warm water was developed to provide information on the evolution of benthic and demersal communities. For this measure, five fish species and three invertebrate species considered to be warm water stenotherms were selected (Tables 11 and 12).

The objective was to choose species that are more sensitive and could exhibit a rapid response to climatic variations and community evolution. Warm water stenotherms are also good indicators of temperature-related changes. Because the species identified are fairly rare or not very abundant, the total biomass of warm water stenothermic fish represents the biomass of all the warm water indicator taxa listed in Table 11, from which the annual mean is calculated. Similarly, the biomass of warm water stenothermic invertebrates includes the three target species (Table 12).

*Measures 3 and 4: Estimated biomass of warm water stenotherm species – fish and invertebrates*

The estimated biomass of warm water indicator species is obtained with the same statistical method that is used for cold water indicator species (section 5.1.1.). Because these are binomial variables, the data are processed using a Hurdle-type predictive model, which integrates the proportion of tows containing the indicator species, and a gamma prediction model, which takes account of the weight of catches greater than zero.

*Results*

Very few warm water stenotherms were present in significant numbers in stratum 416 during the time series (Figure 6 and Appendix I). Observations of warm water fish and invertebrates were scarce, and the mean biomass of these species was very low during the reference period (fish = 0.009 kg/tow and invertebrates = 0.0007 kg/tow). No warm water stenothermic invertebrates have been caught in stratum 416 since 2009.

*Status and trend*

Currently, the real biomass and estimated biomass of warm water stenothermic species (fish and invertebrates) in stratum 416 are very low. The status of indicator BD2 could not be evaluated because of a lack of data, as only a very small number of specimens of warm water indicator species were captured. Nonetheless, this indicator was retained and will be reassessed in future monitoring reports in order to detect the sudden appearance of warmer water species in the study area.

### 5.1.5. BD3) Dominant/key species

#### 5.1.5.1. Retained and non-retained measures and state of knowledge

*Measure 1: Total biomass of fixed and erect taxa (not retained)*

Fixed, erect invertebrate organisms were identified as key elements to be conserved in the MPA (DFO 2019a). Fixed upright taxa, including sponges, soft corals, algae and anemones, are likely to be more vulnerable to pressures such as bottom-contact fishing gear (Fuller et al. 2008; Sciberras et al. 2018). These organisms also provide key structural benthic habitat, which is particularly important on fine sediment plains where the three-dimensional structures that they form provide spatial heterogeneity in an otherwise very homogeneous environment (Bastari et al. 2018; Chimienti et al. 2018a, 2018b). A list of fixed erect taxa was developed from the list in Faille et al. (2019) and is provided in updated form in Table 13 below. The sponges (around 20 species) were grouped together under the broader taxonomic level Porifera due to the recent significant changes in taxonomic resolution.

*Measure 2: Sea urchin biomass (not retained)*

Sea urchins in the genus *Strongylocentrotus* (all species combined) were chosen for their ecological role. They are important grazers and scavengers, and contribute to the structure of benthic communities (Schultz et al. 2016). Sea urchins are also considered to be opportunistic generalists, feeding on what is available in the environment (Sainte-Marie and Paille 2020). These sensitive species have an important trophic role (Scheibling and Hatcher 2013). Moreover, the biomass of this taxon ranks fourth in the survey after shrimp, crabs and basket stars (Figure 7). Sea urchin biomass will be monitored to quickly detect any changes in numbers.

*Measure 3: Predatory starfish biomass (not retained)*

Starfish (also known as sea stars) were chosen because they are sensitive to environmental changes, which could potentially cause mass mortalities (Schultz et al. 2016; Table 14). In addition, they play an important trophic role, structuring the ecosystem through predation (Menge and Sanford 2013; Rahman et al. 2018).

*Table 11. List of warm water stenothermic species (fish).*

| Aphia Code* | Latin Name | Common name | Position | Thermal thresholds | References |
|---|---|---|---|---|---|
| 14 | *Merluccius bilinearis* | Silver hake | Pelagic | 5 to 12°C | MPO 2020 |
| 16 | *Pollachius virens* | Pollock | Pelagic | 0 to 1°C | MPO 2019b |
| 160 | *Argentina silus* | Atlantic argentine | Pelagic | 7 to 10°C | Whitehead et al. 1984 |
| 220 | *Squalus acanthias* | Spiny dogfish | Pelagic | 7 to 15°C | Rose 2005 |
| 300 | *Myoxocephalus octodecemspinosus* | Longhorn sculpin | Demersal | 1.5 to 18.9°C | Moring 2001 |

* From the World Register of Marine Species (WoRMS)

*Table 12. List of warm water stenothermic species (invertebrates).*

| Aphia Code* | Latin Name | Latin name confirmed | Common name | Position | Thermal thresholds | References |
|---|---|---|---|---|---|---|
| 158356 | *Dichelopandalus leptocerus* | - | Bristled shrimp | Supra | 5 to 20°C | Wigley 1960 |
| 135220 | *Cyanea capillata* | *Scyphozoa*** | Jellyfishes | Pelagic | - | - |
| 123776 | *Asterias rubens* | - | Common sea star | Epi | - | - |

* Form the World Register of Marine Species (WoRMS)
** Includes all scyphozoan jellyfish in the R10-Multi sGSL survey

*Table 13. List of fixed, erect taxa collected in the Banc-des-Américains MPA in the sGSL multi-species bottom trawl survey.*

| Latin Name | Latin name confirmed | Common name | Common name (French) | Position |
|---|---|---|---|---|
| *Gorgonocephalus* sp. | *Gorgonocephalus arcticus* | Basket star | Gorgoncéphale | Epibenthic |
| *Boltenia* sp. | *Boltenia ovifera* | Sea potato unspecified | Patate de mer non spécifiée | Epibenthic |
| *Anthozoa* | Actiniaria | Anthozoans | Anémones de mer | Epibenthic |
| *Anthozoa* | Actiniaria | Sea anemone unspecified | Anémone de mer non spécifiée | Epibenthic |
| *Bolocera* sp. | Actiniaria | Deeplet sea anemone | Anémone aplatie | Epibenthic |
| Pennatulacea | - | Sea pen | Plume de mer | Epibenthic |
| *Gersemia rubiformis* | - | Sea strawberry/soft coral | Framboise de mer | Epibenthic |
| *Drifa glomerata* | - | Sea cauliflower | Chou-fleur de mer | Epibenthic |
| Porifera | - | Sponge | Éponges | Epibenthic |

*Table 14. List of predatory starfish selected for indicator BD3*

| Latin Name | Latin name confirmed | Common name | Common name (French) | Position |
|---|---|---|---|---|
| *Asterias* sp. | - | Starfish unspecified | Étoile de mer non spécifiée | Epibenthic |
| *Asterias vulgaris* | *Asterias rubens* | Common sea star | Étoile de mer commune | Epibenthic |
| *Leptasterias polaris* | - | Polar sea star | Étoile de mer polaire | Epibenthic |
| *Hippasteria phrygiana* | - | Horse star | Étoile coussin | Epibenthic |
| *Solaster endeca* | - | Purple sunstar | Soleil de mer pourpre | Epibenthic |
| *Crossaster papposus* | - | Spiny sun star | Soleil de mer épineux | Epibenthic |
| *Pteraster militaris* | - | Winged star | Étoile-coussin boréal | Epibenthic |
| *Diplopteraster multipes* | - | Pincushion star | - | Epibenthic |

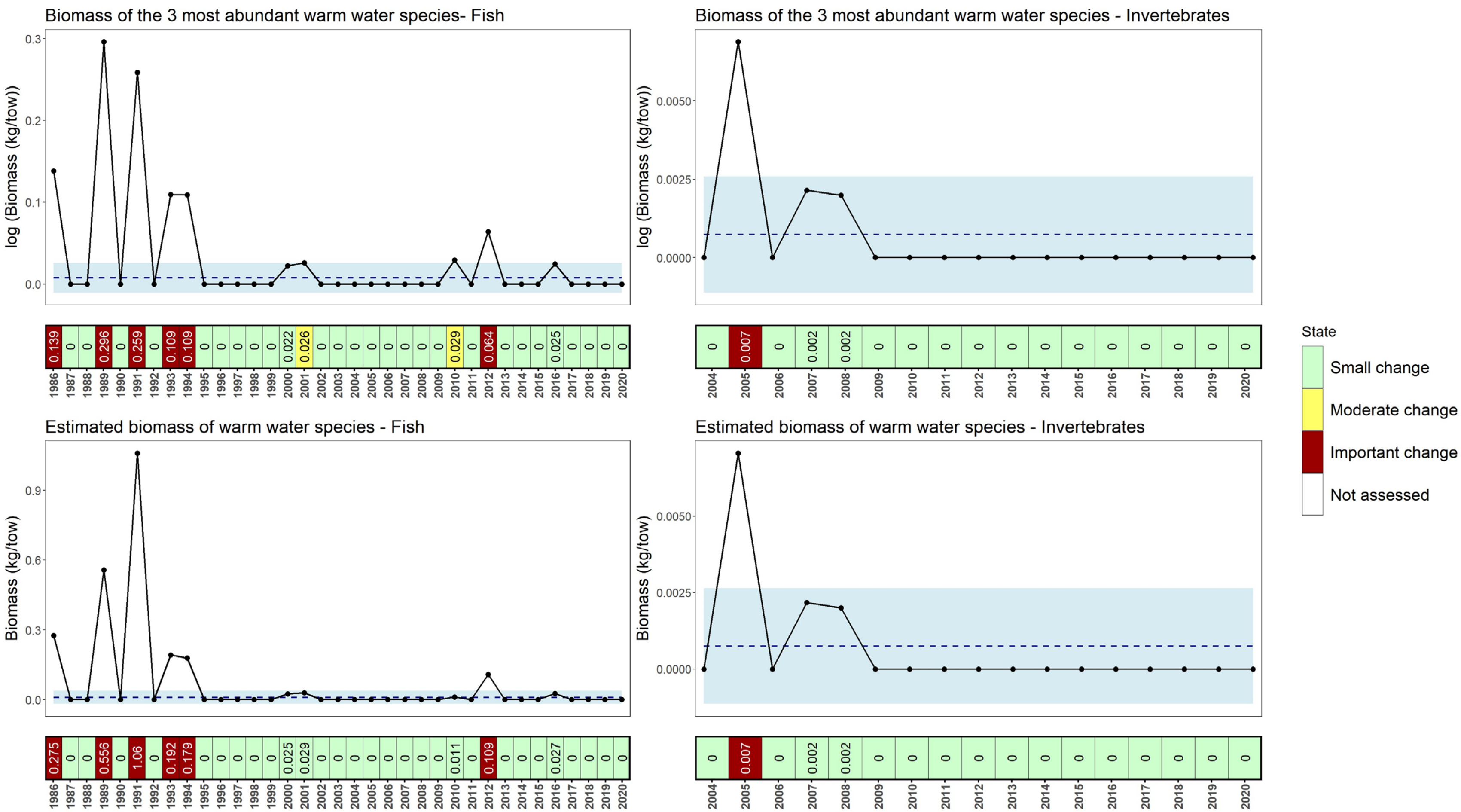



*Figure 6 Time series of the values of the measures associated with the BD2 indicator (Warm water stenotherm species). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).*

Sea stars are important predators, targeting prey such as bivalves, sponges and sea cucumbers (Himmelman and Dutil 1991; Gale et al. 2013). They were retained as key species, and their biomass recorded in order to quickly detect any changes in numbers. Eight predatory starfish species identified in the MPA were chosen to be taken into account in this measure (Table 14).

*Measures 4-5-6: Biomass of* Pandalus*, American plaice and Greenland halibut*

To target the dominant taxa, fish and invertebrate species were selected based on the weight of their catches in the sGSL multi-species survey (R10-Multi sGSL) (Figure 7). Frequency of occurrence was also taken into account in order to exclude rarer taxa. According to the survey data, among invertebrates, shrimp of the genus *Pandalus* (including *P. montagui* and *P. borealis*) and snow crab (*Chionoecetes opilio*) represented the largest catches (kg). Because snow crab is already tracked under the BD1 indicator (stenothermic species) and under the BD11 indicator in association with the conservation priority targeting commercial species, it is not included here. In terms of fish, Atlantic cod, American plaice, Greenland halibut and Atlantic halibut had the highest average biomasses. Cod and Atlantic halibut are already tracked under the BD12 indicator associated with the conservation priority targeting commercial species, so they were not included in indicator BD3. American plaice biomass and Greenland halibut biomass were retained as measures. The biomass data are first logarithmically transformed due to their distribution and the mean total tow biomass is then calculated for each year.

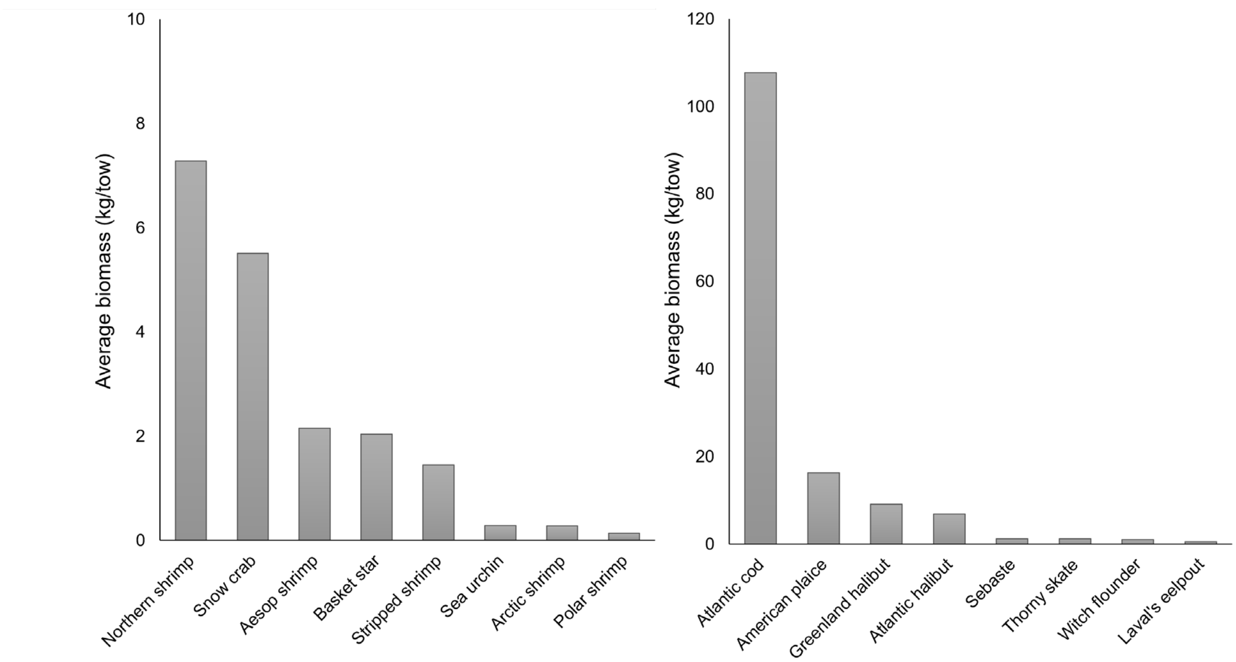



*Figure 7. Average biomass (kg/tow) of the eight most abundant invertebrate and fish taxa observed in the MPA in 2004–2018 (invertebrates) and 1986–2018 (fish). The data are from the sGSL multi-species survey.*

*Results*

Catches of the three key species were highly variable over the time series. A marked increase in fixed, erect taxa was observed in 2006, attributable mainly to a single large catch of *Pennatulacea* (sea pens) (46 kg). Sea urchin biomass appears to have declined between 2004 and 2012 but recovered thereafter. Lastly, catches of predatory starfish were small during the time series, with several oscillations on either side of the reference period mean. In the end, measures 1, 2 and 3 for the BD3 indicator were eliminated during the peer review, due to the fact that the spatial scale of the study was expanded to stratum 416 in the sGSL multi-species survey (R10-Multi sGSL), in order to increase the number of stations visited annually (Figure 8). The information collected in stratum 416 is less relevant to, and less representative of, the MPA in the case of the key species (fixed and erect taxa, sea urchins and predatory starfish). Furthermore, when the study area was expanded, these measures become indirect. These taxa will be monitored in the imagery survey (RD1-Imagery) under the BD5 to BD8 indicators. Because of the removal of these three measures, the name of indicator BD3 was changed to "Dominant species."

Regarding the biomass-based measures, the biomass of *Pandalus* shrimp declined gradually over the time series (Figure 9). The maximum value for log biomass (2.6 kg/tow) was obtained in 2005. From 2011 onwards, catches declined to below the reference period mean (1.0 kg/tow). American plaice catches fluctuated widely throughout the time series, on either side of the reference period mean of 2.5 kg/tow. Despite this variability, a general downward trend was observed from the start of the time series until 2003. Thereafter, log biomass increased until 2011, then decreased again. Since 2017, American plaice catches have been increasing. For Greenland halibut, log biomass values increased from the start of the time series until 2000. Since then, significant fluctuations have been observed, with no overall upward or downward trend discernable. The mean log biomass for the reference period is 1.0 kg/tow.

*Status and trend*

The BD3 indicator, which now includes only the three dominant species, was assigned "Good" status throughout the time series (Figure 10). Negative anomaly values were observed between 2011 and 2019, with the lowest value in 2019. The decline in the biomass of *Pandalus* shrimp and Greenland halibut in 2019 is reflected in a decrease in anomalies but did not influence the status of the indicator for that interval. Overall, the status of the BD3 indicator remained fairly stable.

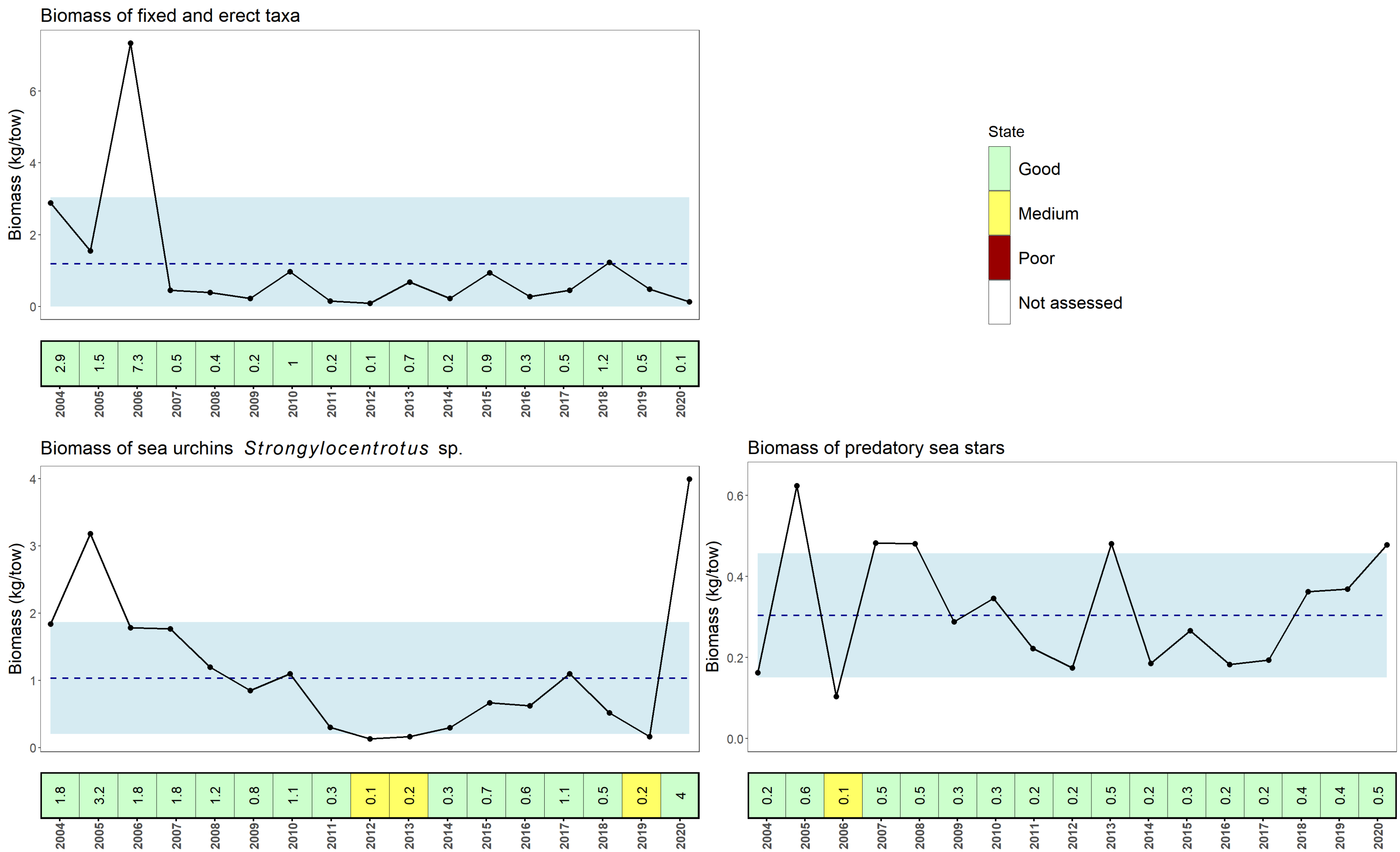



*Figure 8. Time series of measures (key species) associated with the BD3 indicator (Dominant/key species). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).*

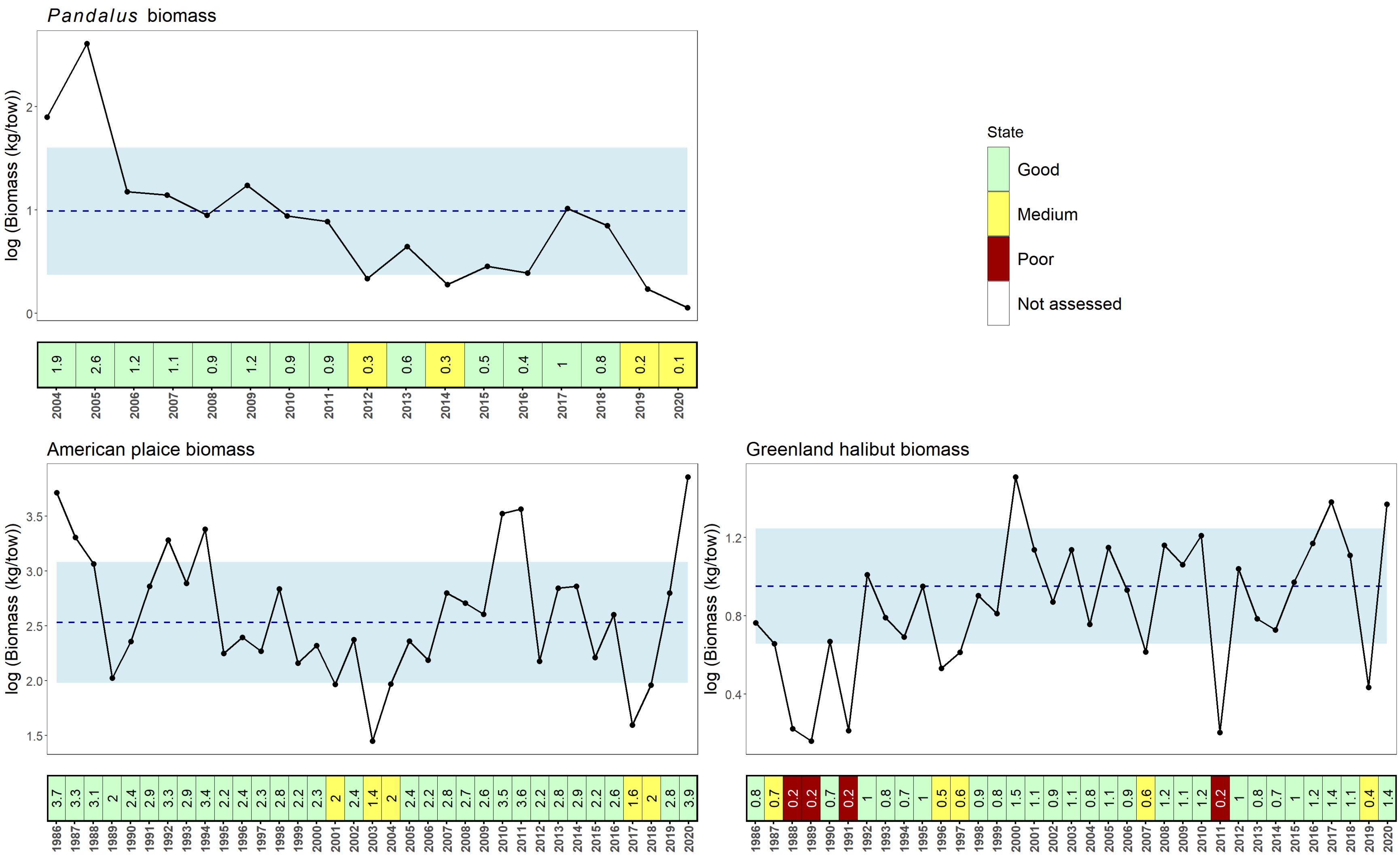



*Figure 9. Time series of measures (abundant species) associated with the BD3 indicator (Dominant/key species). The blue dashed line represents the mean conditions during the reference period (2004–2018) and, the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the average value obtained for each year, colour-coded according to the magnitude and direction of the change observed in relation to the reference period (directional anomaly).*

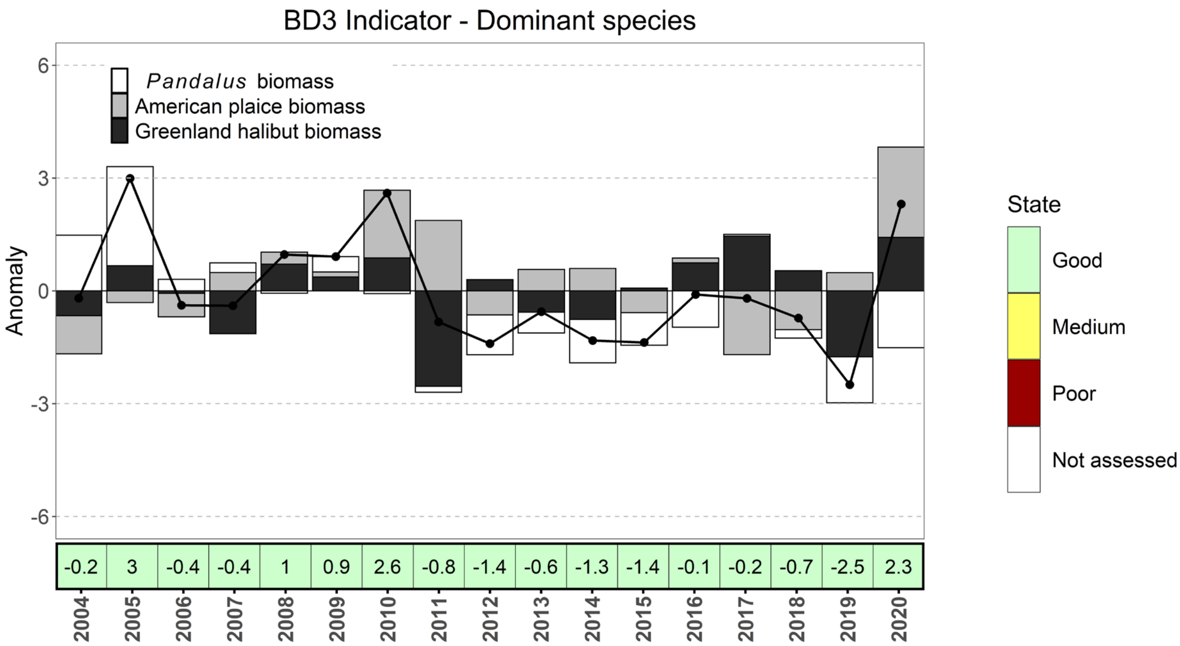



*Figure 10. Time series of anomaly values for each of the measures associated with the BD3 indicator (Dominant species). The black line corresponds to the sum of the actual anomaly values used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

## 5.1.6. BD4) Biomass of invertebrates (not retained)

### 5.1.6.1. Measure not retained and state of knowledge

This indicator was not retained during the peer review because, as was the case for measures 1, 2 and 3 associated with the BD3 indicator, the evaluation of the total biomass of the invertebrates harvested with the trawl in stratum 416 was found to be less relevant and to be unrepresentative of the MPA. Invertebrate biomass will be assessed using the imagery survey. Since it is difficult to obtain biomass data from underwater imagery, the measure associated with indicator BD4 will instead be assessed by the total abundance of epibenthic invertebrates.

*Measure 1: Total invertebrate biomass (not retained)*

This measure was originally chosen to provide general information on the state of the ecosystem and, more specifically, on the state of the benthic communities targeted by CO1. The bottom trawl survey (R10-Multi sGSL) is designed to sample benthic and demersal species, but the gear used is not ideal for sampling fixed benthic invertebrates. Pelagic species can also be caught, but nevertheless have a low catch rate with this gear. Pelagic taxa were excluded from the calculation of total invertebrate biomass. Using biomass rather than abundance makes it possible to take account of colonial epibenthic organisms and a number of taxa such as sponges that are often weighed but not counted in the sGSL multi-species survey.

*Results*

Overall, total invertebrate biomass declined gradually over the time series (Figure 11). The mean reference period biomass was 27.7 kg/tow. The lowest biomass values (just over 9 kg/tow) were recorded in 2015 (n=8) and 2020 (n=4) (Figure 11).

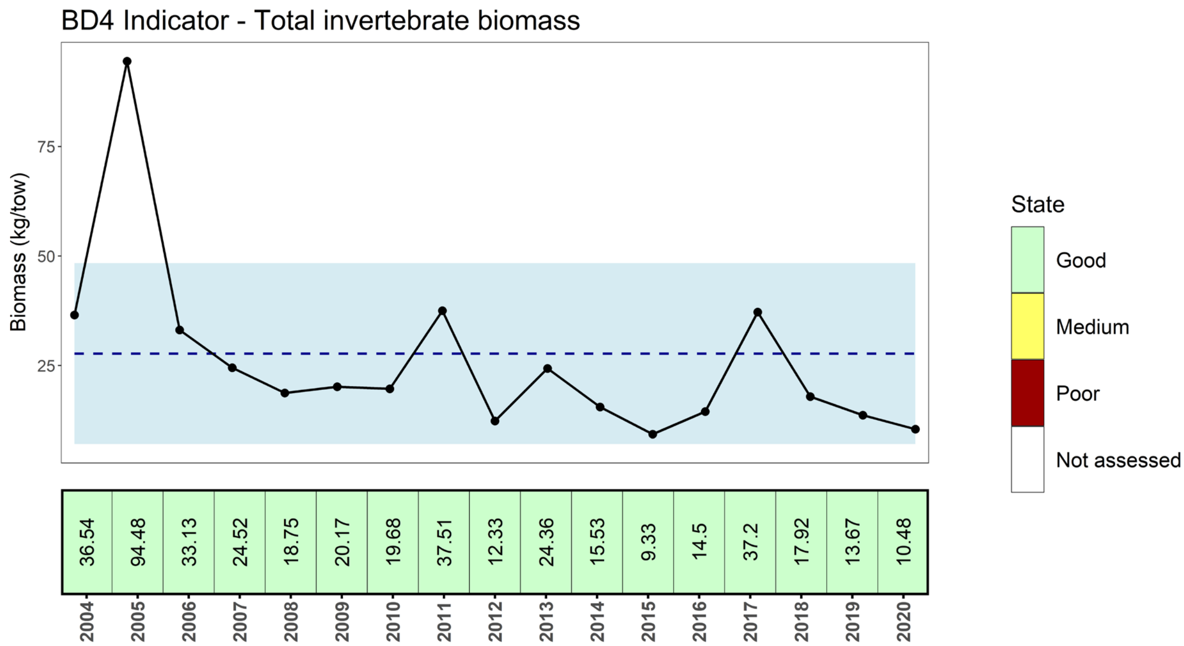



*Figure 11. Time series of the values of the measure associated with the BD4 indicator (Invertebrate biomass). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).*

### 5.1.7. Limitations

The data used for these four indicators, which were obtained from the sGSL multi-species bottom trawl survey (R10-Multi sGSL), are limited. Part of the MPA, mainly the ridge, but also a section of the southwestern plain, is not covered in this survey (Figure 3). In addition, since the establishment of the MPA, scientific trawl surveys are no longer permitted in Zone 1 of the MPA, which corresponds to the ridge and part of the adjacent plains. Although the ecosystem of the northeastern and southwestern plains appears similar, it is difficult to assume that one trawl tow in any given year is representative of the fish and invertebrate communities present, especially since the plains have slightly different depths, the northeastern one has an average depth of 140 m (min. = 55, max. = 206) and the southwestern one, of 94 m (min. = 27, max. = 154). In addition, the sampling intensity in the MPA is low, with an average of 1.5 tows per year. This is why the study area had to be expanded to stratum 416 and the annual mean was used, but it is questionable whether this method can be used to identify clear long-term trends that are sufficiently representative of the processes taking place within the boundaries of the MPA.

The sGSL snow crab bottom trawl survey could be used as an alternative, as it involves more tows per year in the MPA, and the same stations are sampled year after year (see section 5.4.1.1.). For all species other than crab, abundance has been tracked in all tows since 1989, and abundance and biomass, since 2013. However, validation and standardization are required before these data can be used. In future, all the data for the stations in the MPA could be obtained, but historical comparisons would be difficult because additional effort has been expended in taxonomic resolution since 2018.

Owing to the significant lack of data on the BD2 indicator (Warm water indicator species), its status could not be assessed. This indicator will be evaluated in future monitoring reports to detect the appearance of warm water species. The list could be reviewed to ensure that all potential warm water taxa are included. The appearance of warm water fish or invertebrates in the future would in itself be an indication of change, since they are almost completely absent from the MPA.

It should be noted that the various measures proposed for these four indicators will be adjusted and improved based on the results obtained in the regional Ecosystem Approach process. This approach aims to integrate various types of data (physical oceanography, benthic and demersal species, and indices of stock status/productivity, ecological pressures, and communities), create groupings that take into account species' functional traits, and develop indicators. It could inform the selection of key measures adapted to the GSL region.

## 5.2. EPIBENTHIC COMMUNITIES

Four communities were defined through a multivariate analysis of the existing imagery data (2012–2016) based on the occurrence of taxa. Four indicators (BD5, BD6, BD7 and BD8), one for each community, were then proposed. The monitoring measures retained will be based on the abundance and ecological role of certain key taxa in each of these communities, and on diversity indices. These measures will be assessed in the MPA and in control sites outside the MPA using an imaging survey that is being developed using a drop camera system and a benthic sled (RD1-Imagery; Appendix E). A detailed sampling protocol is also being developed and will be presented in a separate technical report, along with the measures retained and the method for assessing indicator status.

## 5.3. DEMERSAL COMMUNITIES

### 5.3.1. BD9) Demersal fish community on the plain

#### 5.3.1.1. Surveys

The data used for this indicator were obtained from the sGSL multi-species bottom trawl survey (R10-Multi sGSL; Appendix E). For further details, see section 5.1.1.

#### 5.3.1.2. Data processing

The total biomass of demersal fish is obtained by combining the biomass (kg) of all species per standardized tow. Total abundance is measured by the sum of the abundance values for all demersal species per standardized tow. Since the number of stations sampled annually in the MPA is very small, the data are averaged across all tows in stratum 416 each year.

The reference period used is 2004–2018. The entire time series available for fish (1986 to the present) is presented. Data for the BD9 indicator are represented using directional anomalies, since one of the general aims of the MPA is to promote biological productivity and the diversity of fishery resources. Therefore, a significant loss of demersal fish community diversity or a decrease in abundance is not considered desirable.

#### 5.3.1.3. Measures retained and state of knowledge

*Measures 1 and 2: Total biomass and total abundance of demersal fish*

Biomass and abundance can be used to detect spatial and temporal variations in communities (Grall and Coïc 2005), and monitoring these two measures helps to provide a general picture of the changes in the demersal fish community on the plains. The total biomass and abundance of demersal fish are obtained in each tow by summing the biomass (or abundance) of all demersal fish species. The biomass and abundance data are then log-transformed to obtain a normal distribution. The annual mean values of log total biomass and log total abundance in all tows are then calculated.

*Measures 3-4-5: Richness, Shannon's diversity index, and Pielou's evenness index*

Variations in diversity indices over time provide an overall characterization of changes in the structure of the demersal fish community in a given period. Measures of species richness and diversity are frequently used in the literature and are simple to measure (Clarke and Warwick 2001). They take account of not only the number of species, but also the distribution of individuals of these species (Grall and Coïc 2005). Species richness corresponds to the total number of taxa recorded in each trawl tow. The value of diversity coefficients (Shannon and Pielou) varies between 0 and 1 (or log S for Shannon diversity). The closer the index value is to zero, the more the community appears to be dominated by one species. However, these indices (Shannon's diversity and Pielou's evenness) are not very sensitive and values are generally not very variable, except for widely divergent communities (or habitats) or heavily disturbed habitats, which is not currently the case in the Banc-des-Américains MPA. They are also highly dependent on sample size and the type of habitat sampled (Clarke and Warwick 2001; Grall and Coïc 2005). Their relevance will be reassessed based on the results they generate in future monitoring reports.

*Other measures to come*

It should be noted that additional measures are being developed and will likely be included in future monitoring reports. One such measure is the stomach fullness index, i.e. the weight of the stomachs of fish caught in the multi-species survey (R10-Multi sGSL). Stomach contents provide information on individuals' diet and condition, as well as on the availability of prey in the environment. More precise measures targeting certain trophic guilds are also envisaged when the classification of taxa by functional traits is completed under the Ecosystem Approach.

*Results*

The logarithm of the total biomass of demersal fish on the plains declined at the beginning of the time series, but catches have increased steadily since 2004. In 2009, 2012 and 2017, observed values were slightly below the reference period mean of 3.8 kg/tow but, since 2018, have been above this baseline value. These results are consistent with the collapse of groundfish stocks observed in the 1990s on a larger scale throughout the Gulf (DFO 2011b). However, the increase in biomass in stratum 416 in recent years appears to be of greater magnitude than in the Gulf as a whole. A similar but less pronounced pattern can be observed using log-transformed total abundance data. The highest abundance was observed in 2020 (Figure 12). Large catches in stratum 416 in 2020 were mainly made up of small Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*) individuals.

The species richness index has fluctuated quite a bit during the time series, but the fluctuations have been of low magnitude, and a trend in either direction is not readily discernable. Species richness in the survey generally ranged from 8 to 12 groundfish species (Figure 13). The values for the Shannon's diversity and Pielou's evenness indices also showed frequent fluctuations, but of low magnitude. However, a certain trend was apparent in these two indexes, the values of which exceeded the average from 1995 to 2009 but were mostly below the average before and after this period. These declines in diversity may indicate higher catches of one (or a few) species in these years.

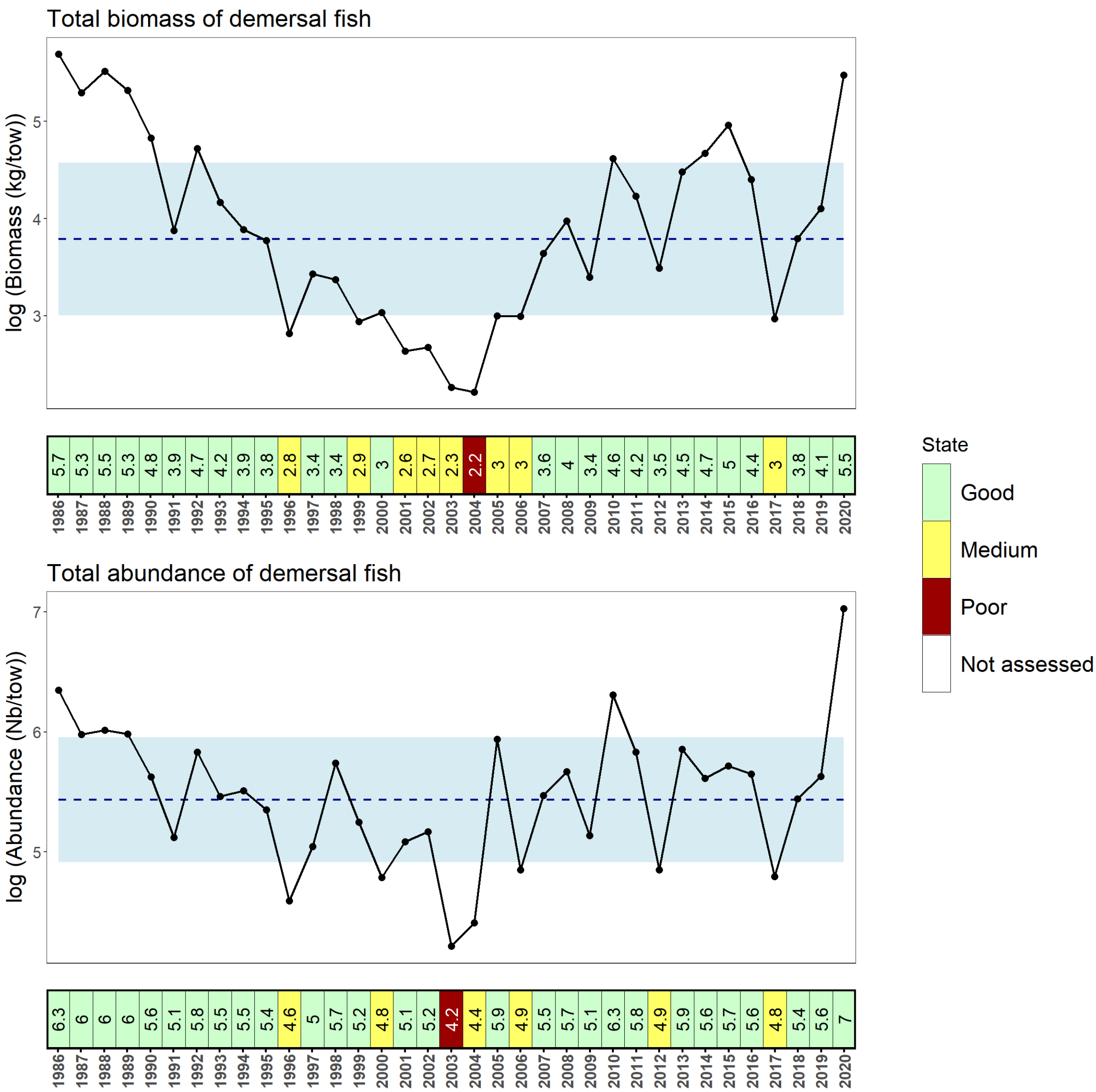



*Figure 12. Time series of the values of measures 1 (Total biomass) and 2 (Total abundance) associated with the BD9 indicator (Demersal fish community on the plain). The blue dashed line represents the mean conditions during the reference period (2004–2018) and, the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (directional anomaly).*

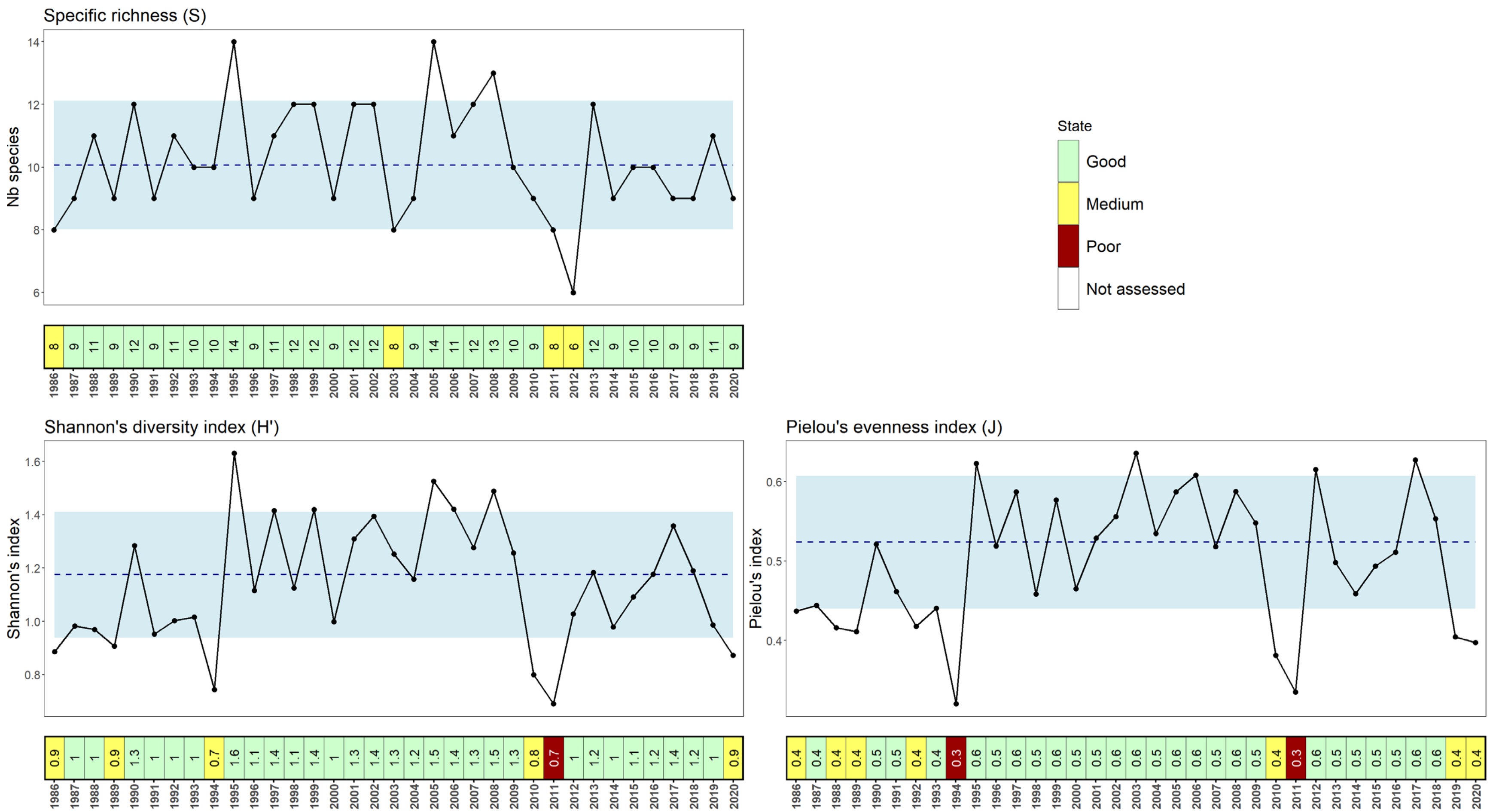



*Figure 13. Time series of the values of measures 3 (species richness), 4 (Shannon's diversity index) and 5 (Pielou's evenness index), associated with the BD9 indicator (Demersal fish community on the plain). The blue dashed line represents the mean conditions during the reference period (2004–2018) and, the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude and direction of the change observed in relation to the reference period (directional anomaly).*

*Status and trend*

The BD9 indicator for demersal fish communities on the plains, a sum of five measures, as assigned the status of “Good” throughout the time series, despite several variations of low magnitude (Figure 14). The anomaly values for the indicator were lowest in 1994 and 2011, just below the threshold for “Medium” status. In both cases, a significant drop in the value of the Shannon’s diversity and Pielou’s evenness indices was observed. It is important to note that the opposite trend was observed for the two measures related to abundance and biomass. Before 1994, the anomalies for abundance and biomass were predominantly positive, while those for the three diversity measures were negative. After 1994, the opposite trends were found, persisting until 2009. This observation helps to explain why, despite significant changes in demersal fish communities over the past 40 years, the indicator appears stable, calling into question the relevance of combining these five measures in a single indicator. This issue must be reviewed by the BDA SMC.

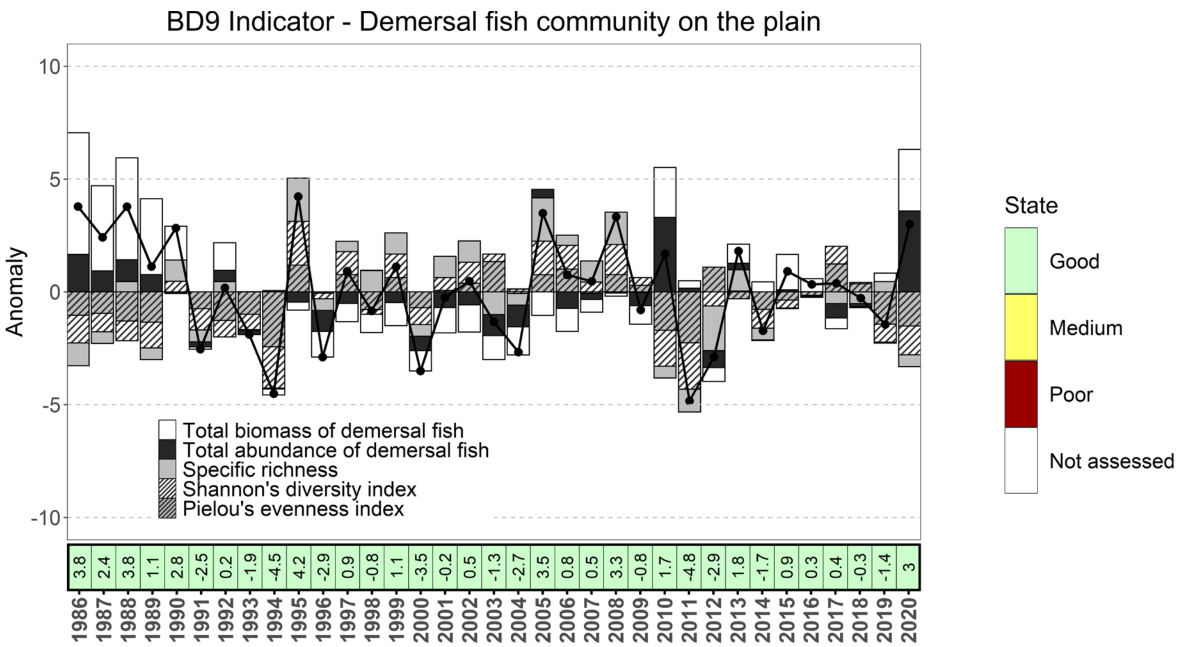



*Figure 14. Time series of anomaly values for each of the measures associated with the BD9 indicator (Demersal fish community on the plain). The black line corresponds to the sum of the actual anomaly values used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

### 5.3.2. BD10) Demersal fish on the ridge

No data are currently available for this indicator. An imagery survey using baited equipment is being developed, and a baseline characterization will be performed over the next few years. Following this characterization, the measures associated with the BD10 indicator (Demersal fish on the ridge) will be refined.

### 5.3.3. Limitations

The same concerns over low sampling intensity in the sGSL multi-species trawl survey apply to the BD9 indicator as the BD4 indicator (see section 5.1.7.). It is also important to note that the value of the diversity indexes is directly related to the taxonomic level at which identifications are made. Variations in the taxonomic levels used during the time series must be verified and, if necessary, species will need to be classified at a higher taxonomic level (e.g. genus or family) to standardize observations.

## 5.4. BENTHIC AND DEMERSAL COMMERCIAL SPECIES

Between 2004 and 2018, commercial fishing in the Banc-des-Américains MPA was largely dominated by the snow crab fishery, which is a trap fishery (Figure 15). The longline fishery is the second largest in the MPA, targeting Atlantic halibut (94% of longline landings) and Atlantic cod to a lesser extent (6%) (Figure 15). Consequently, the three species retained for this conservation priority are snow crab, Atlantic cod and Atlantic halibut.

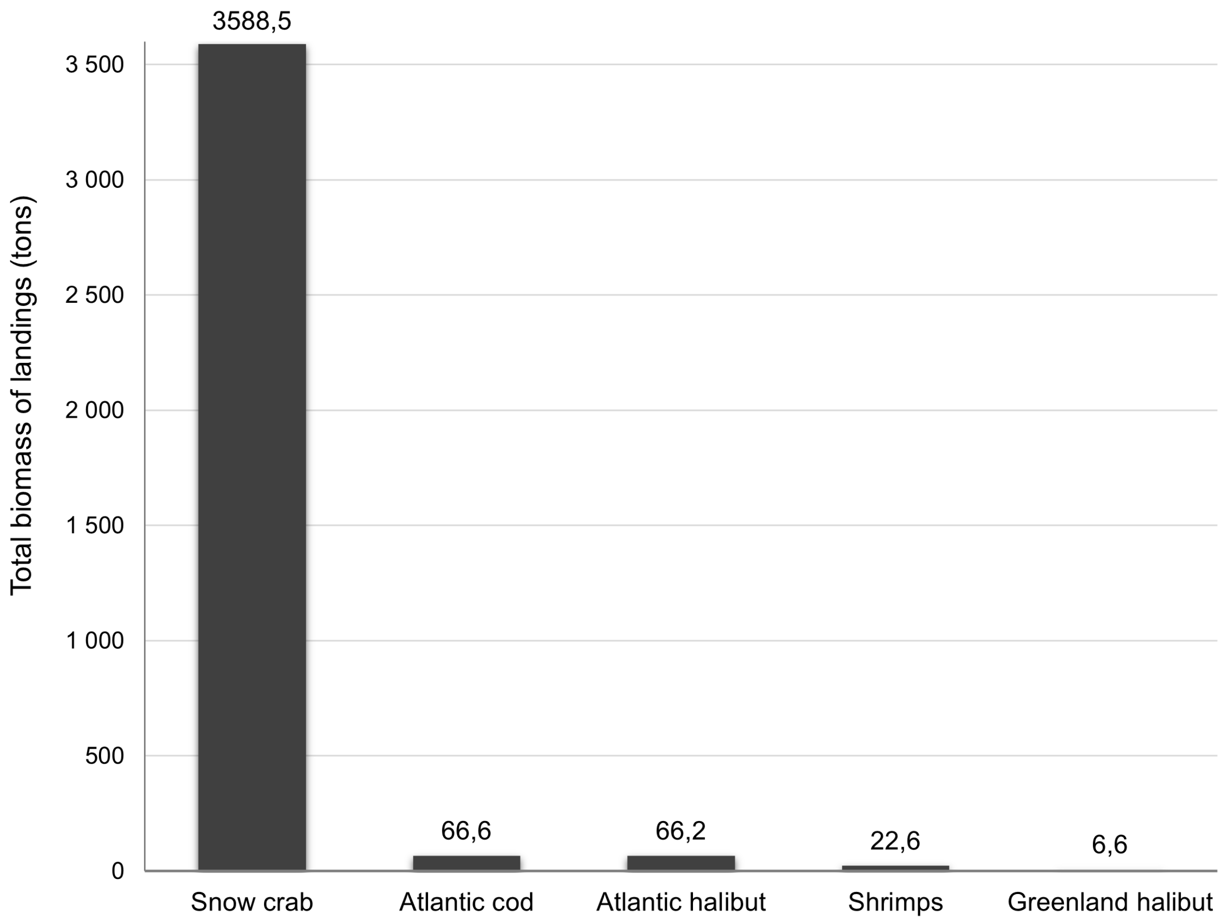



*Figure 15. Total biomass of landings in the Banc-des-Américains MPA by species, between 2004 and 2018, using fishing data from Zonal Interchange File Format (ZIFF) files.*

### 5.4.1. BD11) Snow crab

#### 5.4.1.1. Surveys

The sGSL snow crab bottom trawl survey has covered the Banc-des-Américains MPA annually since 1988 (R13-Crab sGSL, Appendix E). A nephrops trawl is towed for 4 to 6 minutes (Wade et al. 2018) and each crab caught is described according to various biological criteria, such as size (carapace width), sex, maturity and mature females' reproductive status. In addition, since 1989, the fish and invertebrate species caught in each tow have been identified to species or another taxonomic group (e.g. anemones, brittle stars) and counted. Since 2013, the biomass of this bycatch has also been recorded (Hébert et al. 2018). Starting in 2009, length frequencies for fish have been obtained at 100 stations, previously selected at random from the entire survey.

A fixed station sampling plan was used, with the stations selected initially at random from a regular grid, although some of the stations have changed location several times (Figure 16). Since 1989, four to seven stations (six per year on average) have been sampled in Zone 2 of the MPA (Figure 16). This survey provides data from before the MPA's establishment and from outside its boundaries. The time series presented covers the period from 1989 to 2000.

Fishery data are stored in a database containing Zonal Interchange File Format (ZIFF) files. ZIFF files integrate information from logbooks completed by commercial fishers (fishing locations and landings); some landings values are then adjusted with data from the Dockside Monitoring Program (DMP).

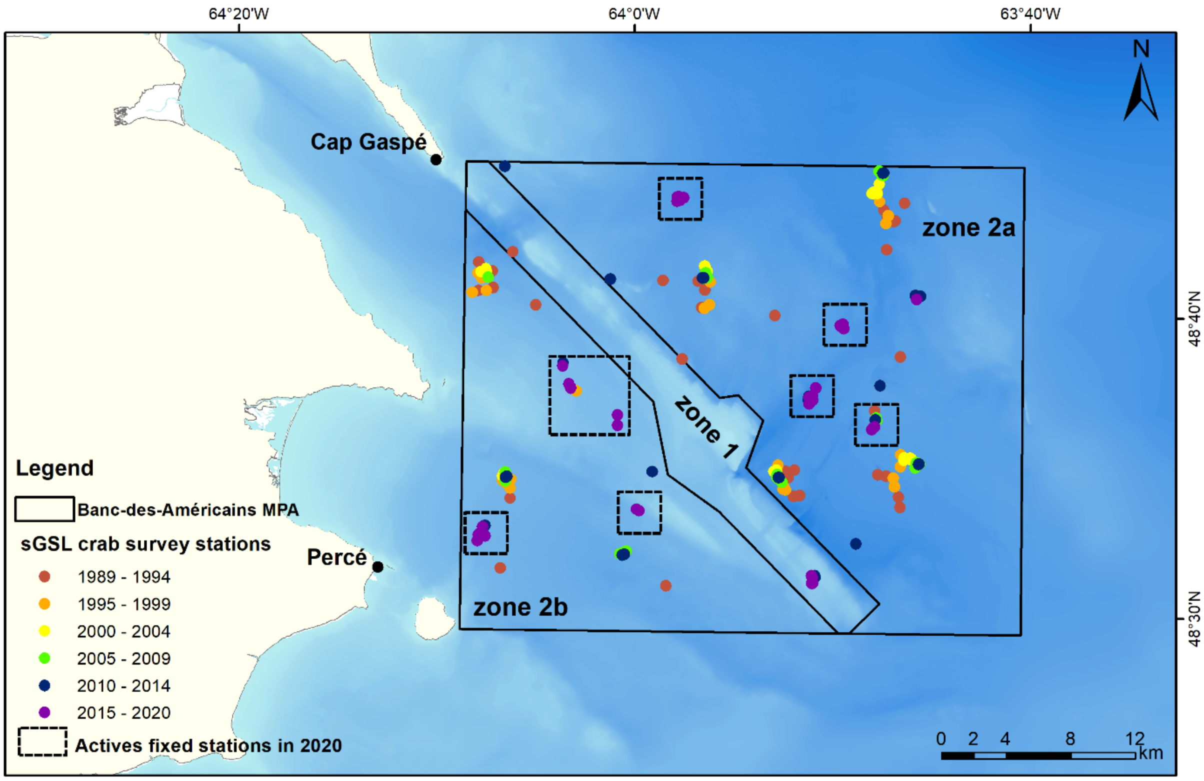



*Figure 16. Location of tows in the Banc-des-Américains MPA in the sGSL snow crab bottom trawl survey from 1989 to 2020, as well as at fixed stations still active in 2020.*

#### 5.4.1.2. Data processing

Snow crab abundance is calculated by averaging the species' abundance at all the stations in the MPA for each year. The time series covers the period from 1989 to 2020.

The catch per unit effort (CPUE) is calculated directly from logbook fishing data (ZIFF files) and corresponds to the ratio between total landings (kg) by the fishery and total effort (number of traps hauled). Data are available for the period from 2004 to 2018.

Annual anomalies for all these measures are calculated as the deviation between the annual mean and the reference period mean (2004–2018), standardized by the standard deviation for the reference period. The anomaly value is used to assign an annual status to the measure (directional anomaly).

#### 5.4.1.3. Measures retained and state of knowledge

*Measures 1 and 2: Abundance of male snow crabs of commercial size and mature female snow crabs*

The snow crab fishery is the main commercial fishery in the MPA. It exclusively targets mature male crabs with a carapace width of ≥ 95 mm (DFO 2021). Consequently, monitoring the abundance of commercial-sized male snow crabs is critical. Mature females are the second most important life stage to monitor, given their importance to the population's reproductive potential. Snow crabs undergo natural cyclical fluctuations in abundance. As a result, viewing observations in the MPA in the context of sGSL stock dynamics is very important in interpreting the measures and the indicator.

*Measure 3: Snow crab CPUE*

The CPUE is used to assess the performance of the fishery and represents the biomass (kg) per trap haul. It is calculated directly from fishing data in ZIFF files (logbooks). The CPUE corresponds to the ratio between total landings (kg) by the fishery and total effort (trap hauls). Because there is a natural abundance cycle for snow crab, a decrease in the CPUE is not cause for concern unless the CPUE is very low, especially if pre-recruitment looks like it will be poor. Similarly, a high CPUE is a positive sign that the crab population is healthy and that crabs are readily available.

*Results*

Throughout the time series, the abundance of commercial-sized male snow crabs (≥ 95 mm) fluctuated around the reference period mean of 2,811 ind./km$^2$ (Figure 17). From 2008 onward, abundance gradually declined and, since 2014, has been below the reference period mean. According to the sGSL snow crab stock assessment, between 2008 and 2019, geographic concentrations of commercial-sized male crabs appear to have moved further south of the Banc-des-Américains MPA (DFO 2020a). The abundance of commercial-sized male crabs in the sGSL stock has trended upward since 2009 according to the 2019 stock assessment (DFO 2020a).

Regarding the abundance of mature females, a recruitment event was observed at the beginning of the time series, followed by a sharp decline and then a second recruitment event between 1998 and 2004 (Figure 17). Since 2013, the abundance of mature females has remained below the reference period mean of 10,246 ind./km$^2$. This contrasts with the broader-scale stock dynamics in the southern Gulf, where the abundance of mature females has risen since 2006.

From 2004 to 2007, the CPUE gradually increased, then fluctuated around the reference period mean of 59 kg/trap haul (Figure 17). After a rising trend until 2013, the annual CPUE declined and, since 2016, has been below the reference period mean. From 2011 to 2015, CPUE values observed in the Banc-des-Américains MPA were slightly higher than those recorded in Area 12 overall, but since 2016, they have been lower (MPO 2020a).

*Status and trend*

The status of the BD11 indicator has predominantly been "Good" during the time series (Figure 18). However, from 2013 onward, the sum of anomaly values declined gradually and, in 2018, the status of the indicator was rated "Medium." This change in status is attributable to the parallel decrease in the values of the three measures associated with the indicator. In general, in recent years, the abundance of commercial-sized male crabs and mature females and the value of the CPUE have declined in the Banc-des-Américains MPA. On a broader scale, the results of the sGSL snow crab stock assessment indicate that the biomass of commercial-sized male crabs is within the healthy range according to the precautionary approach adopted, and female abundance is high. In addition, positive signs of recruitment were observed.

### 5.4.2. BD12) Harvested groundfish

#### 5.4.2.1. Surveys

The data used for the BD12 indicator come from the sGSL multi-species bottom trawl survey (R10-Multi sGSL, Appendix E) and fisheries data in the ZIFF database. For more details, see sections 5.1.1. and 5.4.1.1.

#### 5.4.2.2. Data processing

The estimated biomass of Atlantic halibut catches and the abundance of Atlantic cod correspond respectively to the weight in kilograms and the number of individuals per standardized tow (i.e. a daytime tow of 1.75 nautical miles [30 minutes at 3.5 knots] from the *CCGS Teleost* using a Western IIA trawl). Because the number of stations visited in the MPA each year is very small, the data were taken from the entire 416 stratum and averaged annually.

Owing to the large number of null values in the distribution of Atlantic halibut abundance data, these data were processed using a Hurdle-type predictive model, in which the estimated biomass of halibut catches is a prediction of the "Hurdle" model obtained in two steps. First, a binomial model (with logit link) is used to predict the proportion of tows with Atlantic halibut catches, then the gamma prediction model takes into account the weight of catches greater than zero. Lastly, the Hurdle model integrates these two predictions in a single biomass prediction presented in kg/tow.

For Atlantic cod, abundance data were favoured over biomass data in order to take account of the number of individuals regardless of size. The abundance data were log-transformed to obtain a normal distribution. The mean annual abundance (log) in the tows was then calculated.

The CPUE, which corresponds to the relationship between total longline landings (kg) and total effort (number of hooks), was calculated directly from ZIFF file fishing data. The longline fishery in the MPA targets Atlantic halibut and cod almost exclusively. Data are available for the 2004–2018 period. The reference period used covers the same period, and the mean of all tows each year is calculated. Data for the BD12 indicator are presented in the form of directional anomalies, in line with the objective of maintaining or improving the state of the benthic habitat when the MPA was established. Therefore, a loss of biomass of commercial demersal fish is not considered desirable.

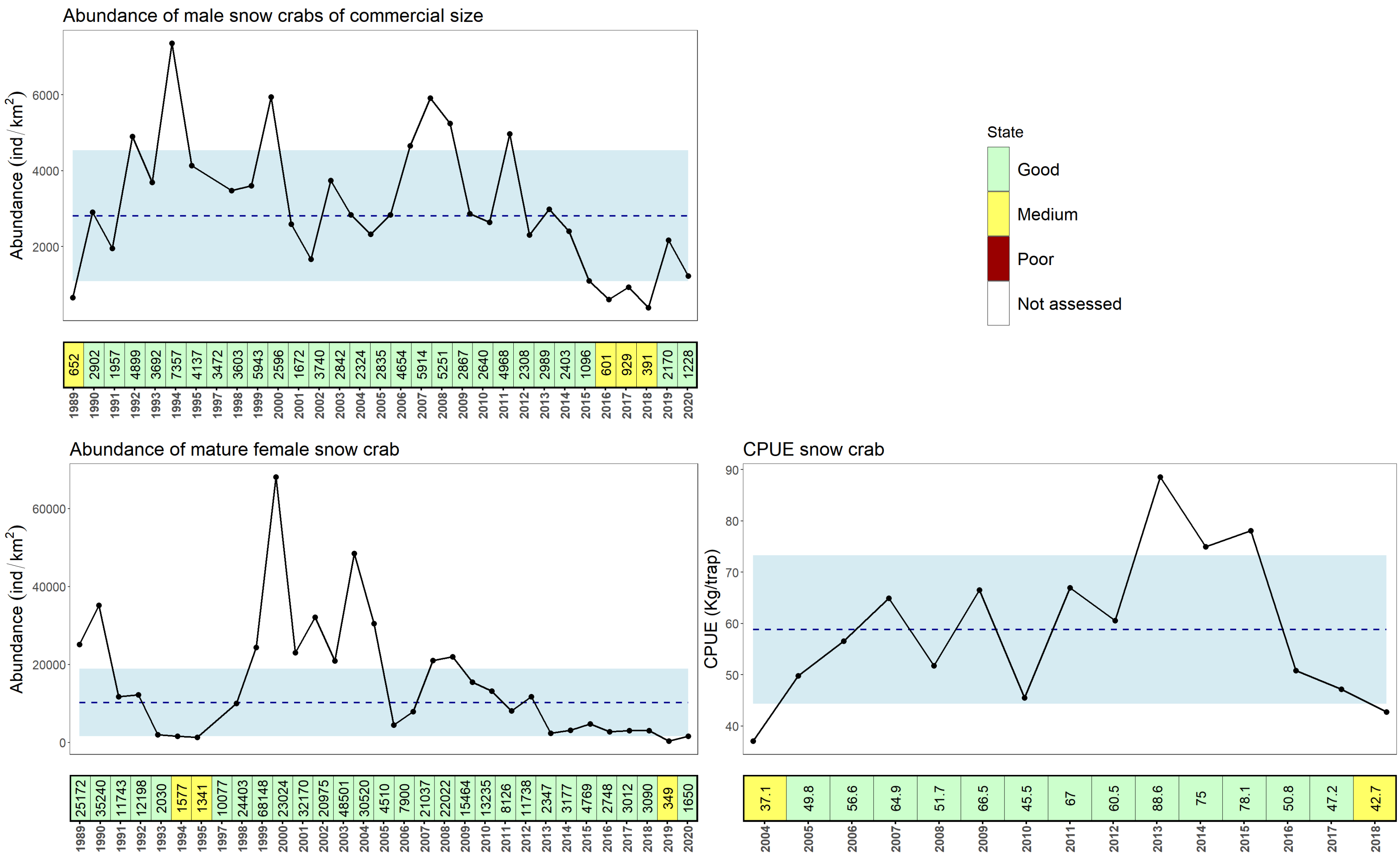



*Figure 17. Time series of the values of the measures associated with the BD11 indicator (Snow crab). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude and direction of the change observed in relation to the reference period (directional anomaly).*

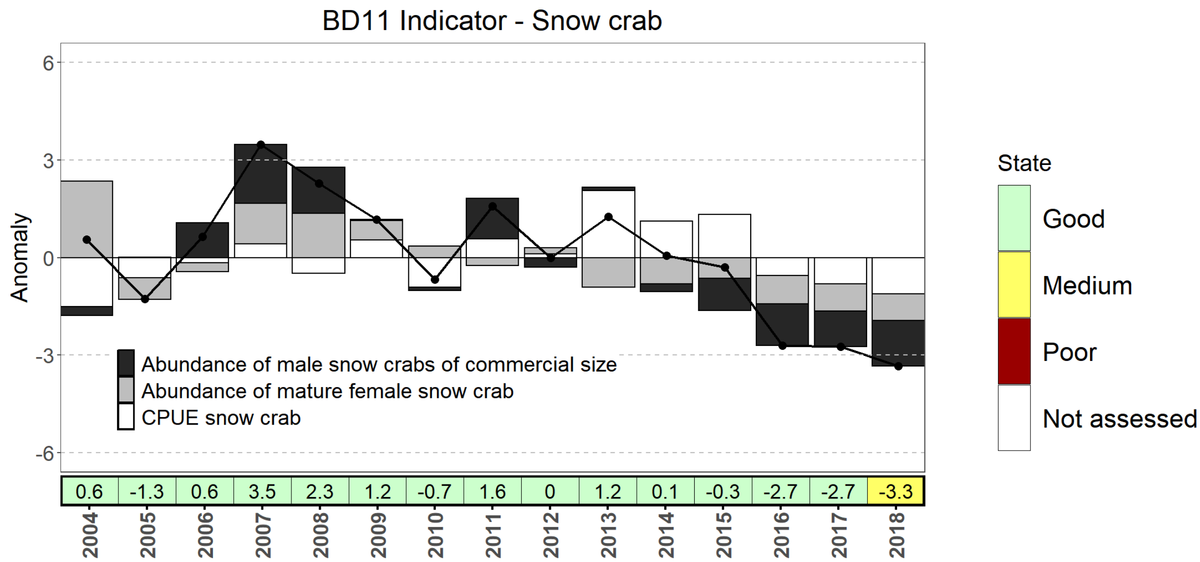



*Figure 18. Time series of anomaly values for each of the measures associated with the BD11 indicator (Snow crab). The black line corresponds to the sum of the actual anomaly values used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

### 5.4.2.3. Measures retained and state of knowledge

*Measure 1: Estimated biomass of Atlantic halibut catch*

The Atlantic halibut population is increasing (DFO 2019c), and longline fishing is still allowed in Zone 2 of the MPA. The Atlantic halibut fishery is the second largest fishery in the MPA, despite its small landings (5.5 tonnes/year on average), so it seems important to monitor trends in this species.

*Measure 2: Abundance of Atlantic cod*

The Atlantic cod fishery in the MPA is marginal, but given the species' historical importance, the decision was made to monitor it in the MPA. Monitoring the species will also make it possible to determine whether the population is recovering differently inside and outside the MPA as a result of the management measures in place in the MPA.

*Measure 3: Groundfish CPUE*

CPUE is used as an indicator of longline fishing success. CPUE corresponds to the total landed biomass (kg) per hook for all groundfish species. As with crab, CPUE provides indirect information on the health of groundfish stocks.

*Results*

The estimated biomass of Atlantic halibut remained near zero until 2007, and then rose slowly. Beginning in 2019, a sharp increase was then observed, from 4.2 kg in 2010 to 36.5 kg in 2011 (Figure 19). After declining in 2012, the estimated biomass of Atlantic halibut fluctuated to some extent but, overall, was stable at above the reference period mean of 10.9 kg per tow (Figure 19). In 2017 and 2018, according to the assessment of the Gulf of St. Lawrence Atlantic halibut stock (DFO 2019d), the abundance of commercial-sized halibut (over 85 cm) based on scientific bottom trawl surveys was higher than in previous years.

The mean abundance of Atlantic cod declined sharply between 1986 and 2011, with the lowest values recorded from 2001 to 2004. These results are consistent with the collapse of groundfish stocks observed in the 1990s on a wider scale throughout the Gulf (DFO 2011b). Abundances subsequently increased from 2004 to 2020, from 0.5 to 6.2 ind./tow (log), equivalent to a difference in non-log-transformed abundance of 517 ind./tow. In 2020, Atlantic cod abundance was higher than at the beginning of the time series (Figure 19). A closer look at the 2020 biomass data shows the presence of a number of smaller individuals, a potential positive sign of recruitment. CPUE values from the longline fishery have also fluctuated over the time series, displaying a gradual upward trend. It should be noted that no longline fishing was done in the MPA in 2004 and 2006 (Figure 19). Since 2015, the values measured, which range from 0.3 kg to 0.4 kg/hook, have been above the reference period mean of 0.2 kg/hook. Similar CPUE values have also been observed in the longline fishery throughout Divisions 4RST (DFO 2019d).

*Status and trend*

The status of the BD12 indicator was measured using the longest time series for which data on all three measures were available: from 2004 to 2018. No longline fishing was recorded in the MPA in 2004 and 2006. As a result, the CPUE-based measure was not calculated, and its status in these three years could not be assessed. The indicator was described as having “Good” status throughout the time series (Figure 20), although a clear improving trend can be seen. The sum of the anomalies was negative at the start of the time series, but this value steadily increased and became positive from 2011 onward. This pattern is attributable to the simultaneous increase in the estimated biomass of Atlantic halibut, in the abundance of Atlantic cod (which is gradually recovering following its collapse from 1986 to 2004) and in the CPUE for the longline groundfish fishery.

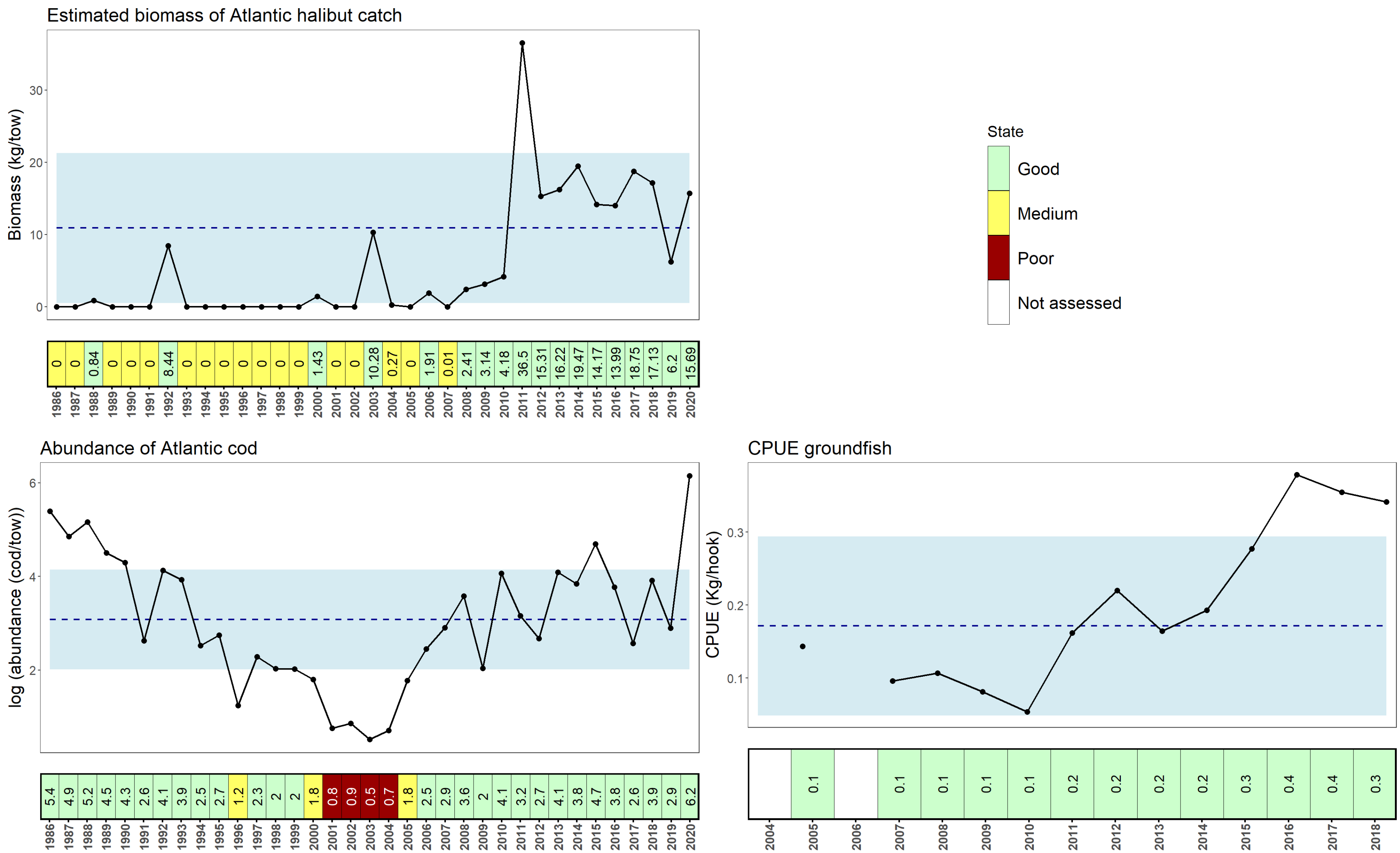



*Figure 19. Time series of the values of the measures associated with the BD12 indicator (Harvested groundfish). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude and direction of the change observed in relation to the reference period (directional anomaly).*

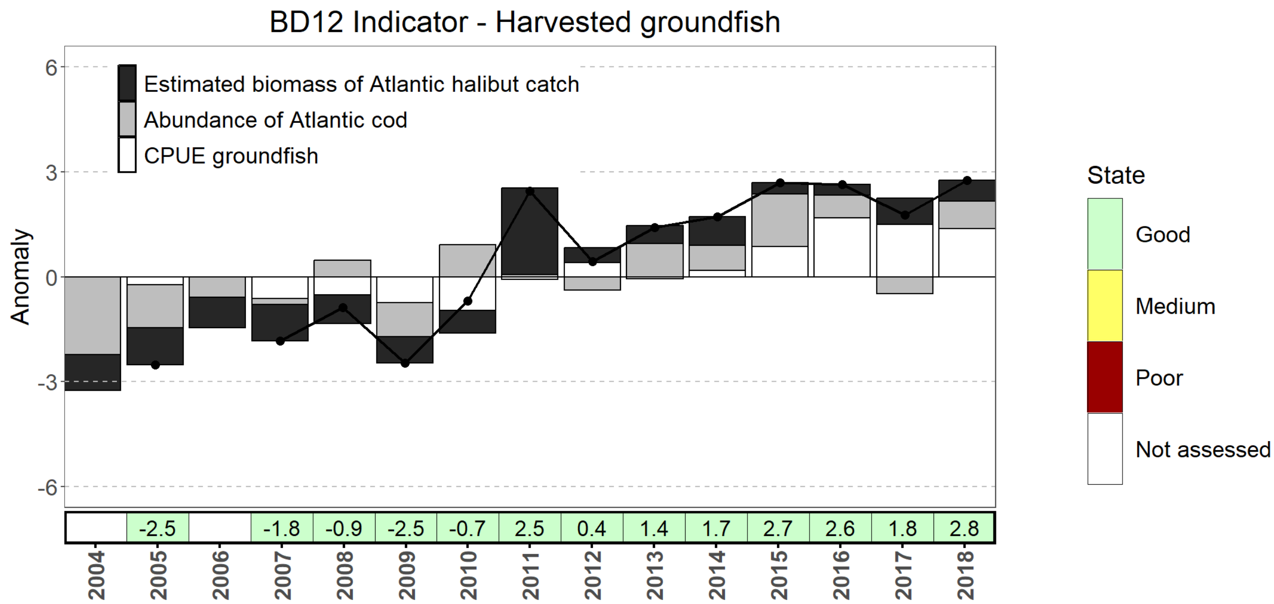



*Figure 20. Time series of anomaly values for each of the measures associated with the BD12 indicator (Harvested groundfish). Only the measures involving Atlantic cod abundance and size are shown, since very little data are available for Atlantic halibut. The black line corresponds to the sum of the actual anomaly values used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

### 5.4.3. Limitations

The measures used to assess the status of the BD11 indicator do not take account of recruitment. Consequently, the possibility of adding the following additional measure should be considered: the abundance of male crabs (pre-recruit categories R4, R3 and R2) potentially recruited to the fishery in the future. These categories cover male crabs with carapace widths between 56 mm and 83 mm and over. Some of these crabs could be recruited to the fishery within two to four years (DFO 2020a).

The catchability of Atlantic halibut in the multi-species bottom trawl survey is poor, especially for larger individuals, but the survey seems do a better job capturing halibut under the 85-cm commercial limit (50–60 cm halibut) (Desgagné, DFO, pers. Comm., April 1, 2021). A scientific longline survey and tagging program for the entire Gulf of St. Lawrence has been in place since 2017, but few, if any, stations are visited annually in the Banc-des-Américains MPA (DFO 2019d). The survey area could be extended to the stratum surrounding the Banc-des-Américains MPA. This measure remains very relative, given the fact that very little data are available to define the status of the measures associated with Atlantic halibut.

The information in the ZIFF files on fishing event locations could be incomplete. The percentage of georeferenced data has increased substantially in recent years, but the positions of a number of fishing events remain unspecified and these events have therefore been excluded from the CPUE calculations.

## 5.5. SUBSTRATE CHARACTERISTICS

### 5.5.1. BD13) Sediments

Substrate types directly influence the associated benthic communities, mainly through the nature of the sediments and their grain size. Accurately characterizing substrates and monitoring changes in them ties into benthic monitoring and the broader CO1 to “conserve and protect benthic habitats.” As with the BD5, BD6, BD7 and BD8 indicators, an imagery survey is being developed using a drop camera system and a benthic sled (RD1 Imagery, Appendix E). A detailed sampling protocol is being formulated and will be presented in a separate technical report, along with the measures retained and the method for assessing the status of the indicator. A grab sampling survey could also be implemented to collect physical samples for particle-size analysis (RD2 Grab, Appendix E).

## 5.6. ENDOBENTHIC AND SUPRABENTHIC COMMUNITIES

No indicators have currently been identified for these two conservation priorities, as no data have yet been analyzed. A basic characterization is needed to validate the relevance of monitoring these priorities and to inform the choice of indicator and measures. Surveys are being developed to collect baseline data, such as stomach contents and the use of a grab to collect sediments and endobenthos samples.

# 6. CHOICE OF MEASURES FOR, AND STATE OF KNOWLEDGE ON, CO2[2]

## 6.1. NUTRIENTS

### 6.1.1. P1) Nutrients

#### 6.1.1.1. Surveys

Nutrient data come from the Convection mission (R6-Helicoptered, March), the June and October–November AZMP missions (R1-AZMP), and the August and September multi-species surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E). For the nutrient indices associated with the middle (intermediate) layer (50–150 m), data from the winter mission are not used since nutrient sampling is only carried out at the surface. The time series began in 1999. The total number of stations in the oceanographic area where nutrient samples are collected ranges annually between 32 (in 2020) and 96 (in 2012), with an average of 66 stations per year.

#### 6.1.1.2. Data processing

Raw nutrient data collected at each depth are vertically integrated (trapezoidal integration) for the water layer of interest (surface layer: 0–50 m; middle [intermediate] layer: 50–150 m). The annual concentration of the nutrient in the oceanographic area is estimated using the following general linear model (GLM):

$$\log_{10}(Concentration + 1) = \alpha + \beta_{YEAR} + \delta_{STATION} + \gamma_{SEASON} + \varepsilon$$

as presented in Pepin et al. (2013) and Johnson et al. (2016), where α is the intercept, ε is the error, and β, δ and γ take into account the effect of year, station and season, respectively. The

[2] All measures for each indicator are listed in Appendix F.

same model is used to estimate average winter nitrate concentrations by removing the variable γ (season).

Annual anomalies are calculated based on the deviation between the annual mean and the reference period mean (1999–2018). This deviation is then standardized by dividing it by the standard deviation of the reference period. The absolute value of the anomaly is used to characterize the annual status of the measure (bidirectional anomaly). The indicator status corresponds to the sum of the absolute anomaly values for each measure.

#### 6.1.1.3. Measures retained and state of knowledge

*Measure 1: Winter average nitrate in the surface layer (0–50 m)*

Nitrate is the limiting nutrient for the growth of phytoplankton in the marine environment. The average nitrate concentration in the 0–50 m layer in winter provides an indication of the amount of nitrates available to phytoplankton during the upcoming growing season in the part of the water column where primary producers are concentrated. Winter nitrate concentrations in the water column are strongly linked to the intensity of winter mixing (Levasseur et al. 1984) and are not influenced by biological consumption. This makes inter-annual trends easier to identify and simplifies their interpretation compared with nutrient inventories in the surface layer during the production season.

*Measure 2: Average annual nitrate in the middle layer (50–150 m)*

Nitrates in the 50–150 m layer represent a type of nutrient reserve for phytoplankton, and may become available following sporadic episodes of strong winds and intense mixing during the growing season, or following winter convective mixing at the start of the following year. Generally speaking, since phytoplankton do not have direct access to this resource, it is not influenced by daily consumption. The average annual nitrate concentration in the middle layer, which takes into account the production season, is therefore a more stable index than the same average in the surface layer, and can serve as an indicator of ecosystem productivity in the following year.

*Measure 3: Average annual N:P ratio in the middle layer (50–150 m)*

The N:P ratio can be used to interpret changes in nitrate concentrations in relation to changes in phosphate concentrations, which also affect the composition of phytoplankton communities (Egge 1998) and therefore influence system productivity. Changes in the N:P ratio in the middle layer, which is minimally influenced by the daily consumption of nutrients by phytoplankton, more directly reflect the changes in water masses, nutrient inputs from rivers, and microbiological processes involved in biogeochemical cycling (Pahlow and Riebesell 2000; Arrigo 2005) than nitrate concentrations alone.

*Results*

In the oceanographic area, the winter nitrate inventory in the surface layer averaged 515 mmol $m^{-2}$ during the reference period. A historical low was observed in 2010–2011, when concentrations reached approximately 350 mmol $m^{-2}$ (Figure 21). Since then, concentrations have remained relatively stable at around the historical average.

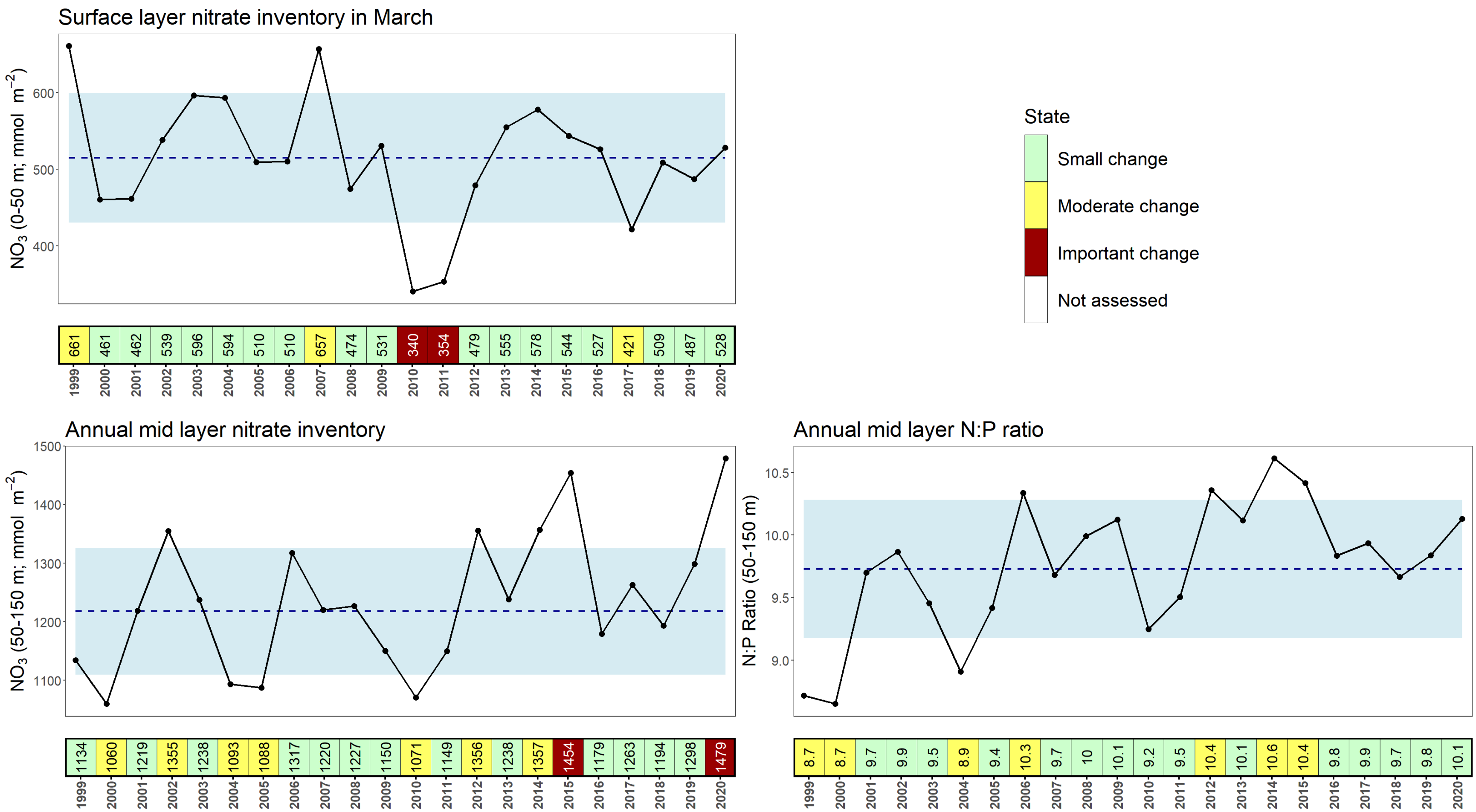



*Figure 21. Time series of the values of the measures associated with the P1 indicator (Nutrients). The blue dashed line represents the mean conditions during the reference period (1999–2018), and the blue shading, the ±1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).*

The average annual nitrate inventory in the middle layer of the oceanographic area is 1,218 mmol m$^{-2}$. Nitrate concentrations appear to be trending upwards slightly, with the highest concentrations recorded in 2012, 2014, 2015 and 2020, and the lowest recorded at the beginning of the time series (2000, 2004, 2005 and 2010). The average annual N:P ratio in the middle layer also appears to be trending upwards, from 8.7 at the beginning of the time series to 10.1 in 2020. Its average value over the reference period is 9.7 (Figure 21).

*Status and trend*

Over the time series, the status of the P1 indicator has ranged from "Small change" to "Moderate change." Since 2016, the indicator has been relatively stable and close to the reference period mean, except in 2020 when it was assigned a "Moderate" level of change due to high nitrate concentrations in the middle layer (Figure 22).

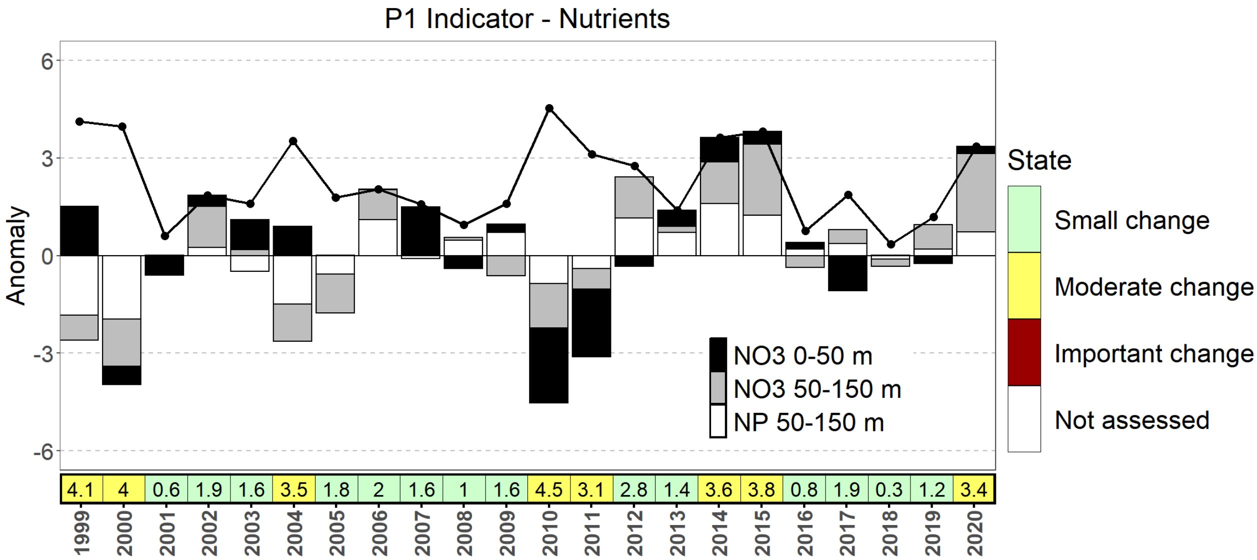



*Figure 22. Time series of anomaly values for each of the measures associated with the P1 indicator (Nutrients). The black line corresponds to the sum of the absolute values of the anomalies that are used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

#### 6.1.1.4. Limitations

The existing surveys seem to provide an accurate characterization of the oceanographic area.

## 6.2. PHYTOPLANKTON

### 6.2.1. P2) Chlorophyll *a*

#### 6.2.1.1. Surveys

Chlorophyll *a* data are obtained in the June and October–November AZMP missions, and the August and September multi-species surveys (R1-AZMP, R10-Multi sGSL and R11-Multi nGSL; Appendix E). The time series began in 1999. The total number of stations in the oceanographic area where chlorophyll *a* samples were collected has ranged from 15 (in 2020) to 42 (in 1999) annually, with an average of 33 samples annually.

#### 6.2.1.2. Data processing

Chlorophyll data collected at each depth are vertically integrated (trapezoidal integration) for the water layer of interest (0–100 m). The annual chlorophyll *a* concentration in the oceanographic area is estimated using the following GLM:

$$\log_{10}(Concentration + 1) = \alpha + \beta_{YEAR} + \delta_{STATION} + \gamma_{SEASON} + \varepsilon$$

as presented in Pepin et al. (2013) and Johnson et al. (2016), where α is the intercept, ε is the error, and β, δ and γ take into account the effect of year, station and season, respectively.

Annual anomalies are calculated based on the deviation between the annual mean and the reference period mean (1999–2018). This deviation is then standardized by dividing it by the standard deviation of the reference period. The absolute value of the anomaly is used to characterize the annual status of the measure (bidirectional anomaly). Since the P2 indicator (chlorophyll *a*) is only based on a single measure, the annual status of this measure also describes the annual status of the indicator.

#### 6.2.1.3. Measures retained and state of knowledge

*Measure 1: Annual average chlorophyll* a *in the 0–100 m layer*

Chlorophyll *a* concentrations are an indicator of phytoplankton biomass and therefore provide information on the amount of energy available in the system at the base of the food chain. Furthermore, chlorophyll *a* appears to be a predictor of North Atlantic Right Whale distribution (Pendleton et al. 2012). Integration of the data for the first 100 m of the water column makes it possible to take into account the abundance of all the phytoplankton in the water column. Although data are not available on the spring bloom, the data gathered still cover most of the production season (June–November) and therefore provide an overall index of the average phytoplankton biomass available during this period.

*Results*

In the oceanographic area, the mean annual value of vertically integrated chlorophyll *a* in the 0–100 m layer is 50.1 mg $m^{-2}$ for the reference period. Between 2002 and 2011, the chlorophyll *a* inventory registered a significant decline of approximately 50%. Since 2011, the average annual chlorophyll *a* inventories have seesawed back and forth between values near the minimum and maximum values of the time series (Figure 23).

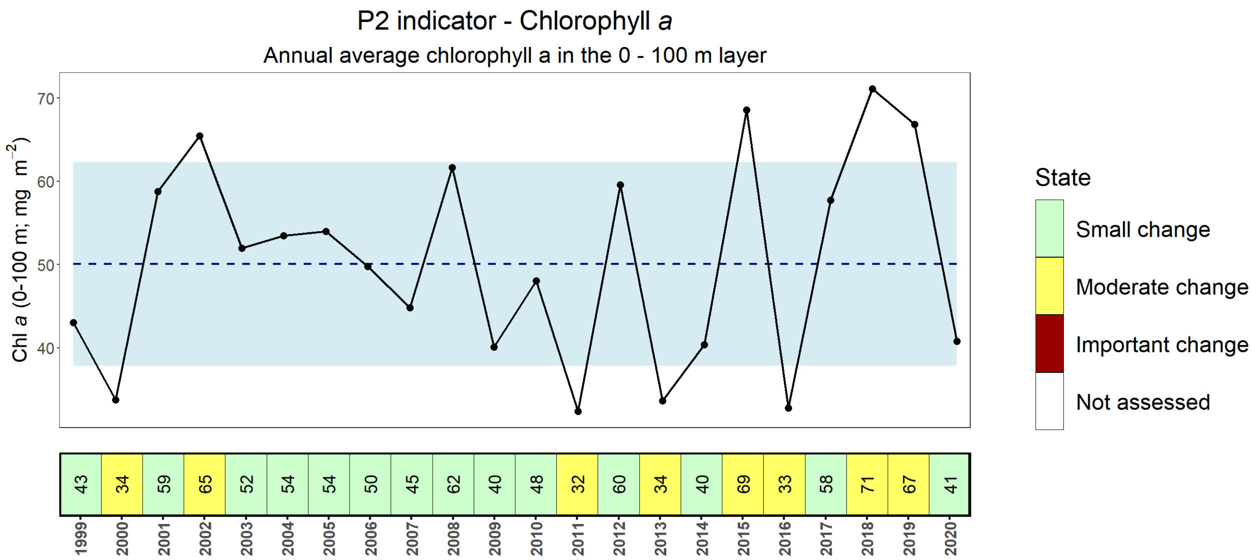



*Figure 23. Time series of the values of the measure associated with the P2 indicator (Chlorophyll* a*). The blue dashed line represents the mean conditions during the reference period (1999–2018), and the blue shading, the ±1 standard deviation around this mean. The strip below the graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).Status and trend*

While the indicator remained relatively stable between 2003 and 2007, from 2011 onwards, the mean annual chlorophyll *a* inventory experienced major fluctuations, primarily corresponding to a “Moderate” level of change (Figure 23).

#### 6.2.1.4. Limitations

The existing surveys seem to provide an accurate characterization of the oceanographic area. Obtaining information on the characteristics of the spring phytoplankton bloom in the Banc-des-Américains MPA from satellite imagery would also be useful. However, ocean colour data in coastal areas are associated with significant biases, making them difficult to use.

## 6.3. ZOOPLANKTON

### 6.3.1. P3) Zooplankton

#### 6.3.1.1. Surveys

Data on meso-zooplankton (< 1 cm) biomass and abundance are obtained from the June and October–November AZMP missions (R1-AZMP; Appendix E). The time series began in 2000 for all measures except dry weight, for which the series began in 2001. During each of these missions, 13 stations were sampled inside the oceanographic area, for a total of 26 zooplankton samples collected annually.

#### 6.3.1.2. Data processing

Mesozooplankton samples are collected using bottom-to-surface vertical ring net (200-µm mesh) tows and therefore they correspond to all meso-zooplankton present throughout the water column. The annual concentration of mesozooplankton in the oceanographic area is estimated using the following GLM:

$$\log_{10}(Concentration + 1) = \alpha + \beta_{YEAR} + \delta_{STATION} + \gamma_{SEASON} + \varepsilon$$

as presented in Pepin et al. (2013) and Johnson et al. (2016), where α is the intercept, ε is the error, and β, δ and γ take into account the effect of year, station and season, respectively.

Annual anomalies are calculated based on the deviation between the annual mean and the reference period mean (2000–2018 or 2001–2018). This deviation is then standardized by dividing it by the standard deviation of the reference period. The absolute value of the anomaly is used to characterize the annual status of the measure (bidirectional anomaly). The indicator status corresponds to the sum of the absolute values of the anomaly for each measure.

#### 6.3.1.1. Measures retained and state of knowledge

*Measure 1: Average annual dry weight of meso-zooplankton*

Meso-zooplankton serve as the link in the food chain between phytoplankton and the higher trophic levels. Measuring its biomass therefore yields information on the amount of energy available to higher trophic levels. More specifically, the data collected cover the beginning (June) and end (November) of the production season, providing a broad overview of the average amount of energy available during this period. Dry weight is a more accurate indicator than wet weight of the amount of energy available, since it does not take into account the large quantities of water that may be found in gelatinous meso-zooplankton.

*Measures 2, 3 and 4: Average annual abundance of small calanoid, large calanoid and non-copepod species*

Most meso-zooplankton biomass is made up of large and small calanoids, and these two groups play distinct ecological roles in aquatic ecosystems, notably in terms of their quality as prey items for a given predator. Large calanoids (*Calanus* spp.) are a particularly important component in the diet of the North Atlantic Right Whale (Pendleton et al. 2012). Monitoring these two groups, as well as non-copepods, may be useful in detecting changes in the structure of zooplankton communities, which could impact higher trophic levels.

*Results*

In the oceanographic area, meso-zooplankton dry weight mainly declined between 2001 and 2011, before reaching a record high in 2012. Since 2015, the value of meso-zooplankton dry weight has predominantly been below the reference period mean (7.2 g $m^{-2}$). In the early 2000s, the abundance of large calanoids was relatively stable at near the reference period mean of about 31,000 individuals $m^{-2}$. Starting in 2006, this measure experienced significant variability, reaching historic lows in 2015 and 2017. Similar trends were seen in the abundance of small calanoids and non-copepods in the oceanographic area, both increasing until they reached respective maximums between 2014 and 2016. Starting in 2017, their abundance stabilized around the reference period mean of 29,000 and 17,500 individuals $m^{-2}$ for small calanoids and non-copepods, respectively (Figure 24).

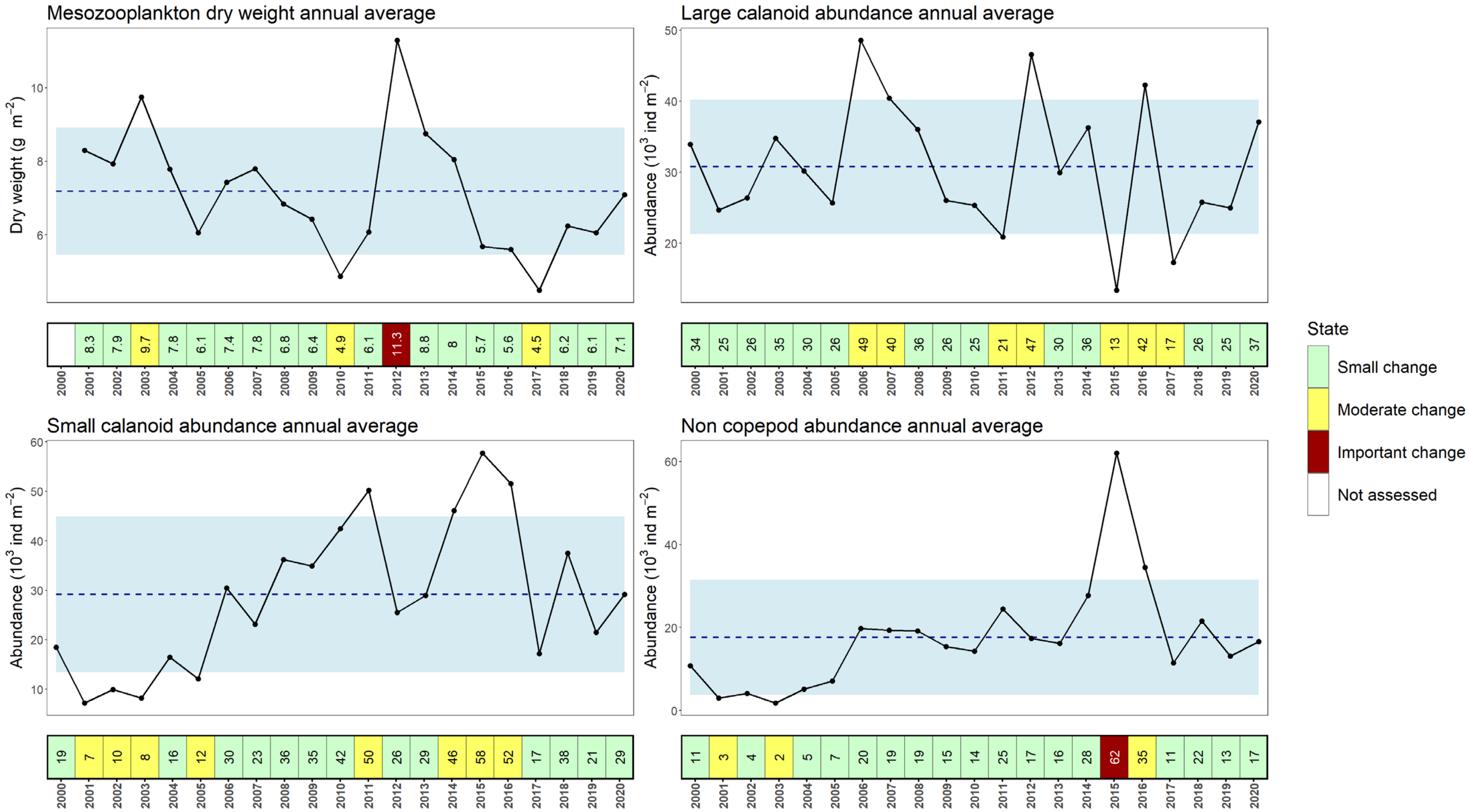



*Figure 24. Time series of the values of the measures associated with the P3 indicator (Zooplankton). The blue dashed line represents the mean conditions during the reference period (2000–2018), and the blue shading, the ±1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).*

*Status and trend*

The P3 indicator was generally characterized as representing a “Small” level of change during the first half of the time series. However, during the second half, more pronounced anomalies were observed in a number of measures, and the indicator tended to be associated more consistently with a “Moderate change” level (Figure 25).

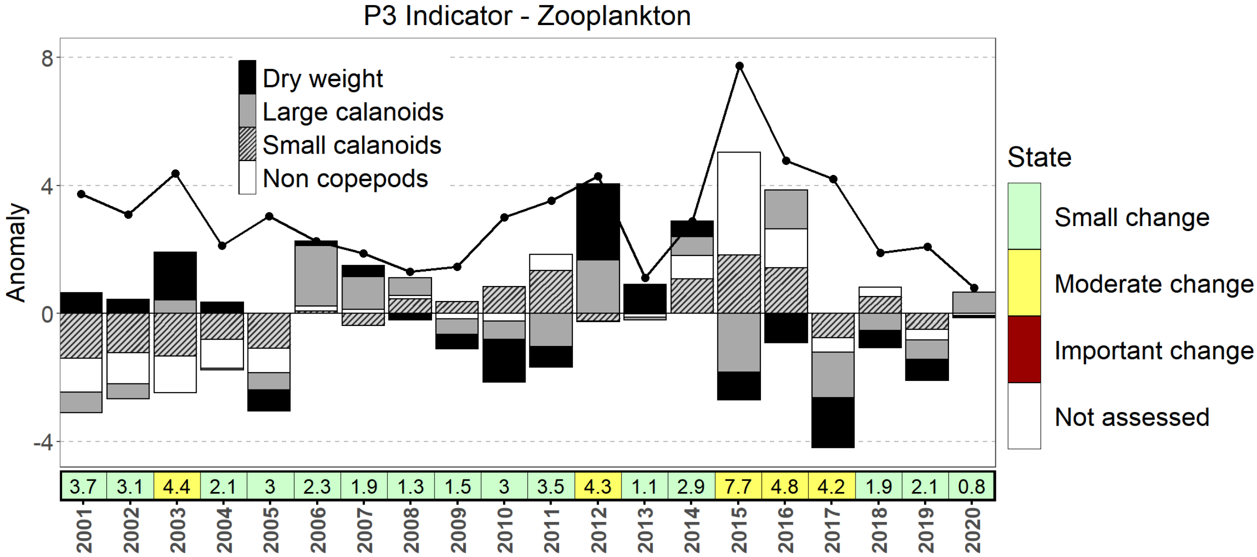



*Figure 25. Time series of anomaly values for each of the measures associated with the P3 indicator (Zooplankton). The black line corresponds to the sum of the absolute values of the anomalies that are used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

#### 6.3.1.2. Limitations

The current surveys seem to allow an accurate characterization of the oceanographic area. Data from the August and September multi-species surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E) are also available. Zooplankton samples collected during these missions are analyzed using a semi-automated procedure involving ZooImage 5.5.2 software (Grosjean et al. 2018). At the current time, these results cannot be combined directly with the data from the AZMP surveys (R1-AZMP). However, in the event that the current measures do not provide sufficient information on the status of the P3 indicator (Zooplankton), additional measures using the August and September data specifically could be envisaged.

## 6.4. KRILL

### 6.4.1. P4) Krill Biomass

#### 6.4.1.1. Surveys

Values for krill biomass are obtained from multi-frequency acoustic data (38, 70, 120 and 200 kHz) recorded during two surveys usually conducted in August in the Estuary and northern Gulf of St. Lawrence. The first survey was carried out from 2008 to 2018 from on board the *FG Creed* (R7-Krill; Appendix E). This stratified random survey is performed along equidistant transects approximately 10–20 km apart, with the position of the first transect determined randomly. Transects are typically perpendicular to the coastline to intercept krill aggregations. In each stratum, a sample is taken from a water layer with a high concentration of krill to validate the acoustic signal and determine the average size of krill in the stratum. Stratum 8a covers the Banc-des-Américains MPA and was sampled from 2009 to 2018 (McQuinn et al. 2013, 2015). The second source of acoustic data is the August multi-species bottom trawl survey in the northern Gulf (R11-Multi nGSL; Appendix E), in which acoustic data have been recorded since 2012. This stratified random survey does not target krill aggregations and does not cover coastal regions with high krill densities. Since the mission begins and ends in Gaspé, acoustic data are collected in the MPA when the vessel is transiting to sampling stations.

#### 6.4.1.2. Data processing

Acoustic data are processed using manual and automated procedures as outlined in McQuinn et al. (2013, 2015). Artifacts are removed and the signal classified according to the scattering of the acoustic signal. The classification algorithms are able to identify three categories of krill: *Meganyctiphanes norvegica*, *Thysanoessa raschii* and a mixed signal when the two species cannot be differentiated. Other krill species do not represent significant biomass in the Estuary and Gulf of St. Lawrence. Data are integrated vertically (0–220 m) and horizontally (500 m). Restricting the integration of data to the upper 220-m depth window limits the contamination of the acoustic signal by mysids and the copepod *Calanus hyperboreus*. Numbers of krill are estimated from the area backscatter and the species target strength function and krill biomass, from a length-weight function (McQuinn et al. 2015).

#### 6.4.1.3. Measures retained and state of knowledge

*Measure 1: Wet weight of krill (August average)*

Krill play an important role in the diet of many species of invertebrates, fish, seabirds and marine mammals (Savenkoff et al. 2013). This index shows the amount of energy directly available to higher trophic levels. The distribution of the Blue Whale, a species that feeds almost exclusively on krill, is strongly associated with krill distribution (McQuinn et al. 2016). The use of a more general indicator of krill availability allows the total biomass to be obtained by adding a mixed category for acoustic signals that do not allow the two species to be differentiated.

*Measures 2 and 3: Wet weight of* Thysanoessa raschii *and* Meganyctiphanes norvegica *(August average)*

The individual biomass of *M. norvegica* is almost an order of magnitude greater than that of *T. raschii* (Benkort et al. 2019). Their different sizes and distinct spatial and vertical distribution patterns mean that these two species are not of equal importance to all their predators (Plourde et al. 2014; McQuinn et al. 2015). For example, *T. raschii* forms denser, shallower aggregations, making it more accessible to marine mammals that need to return repeatedly to the surface to breathe, since they expend less energy consuming it than they do on deeper prey (Doniol-Valcroze et al. 2011; McQuinn et al. 2016).

*Results / Status and trend*

The data are not presented in this report, as their analysis has not been completed.

#### 6.4.1.4. Limitations

The *FG Creed* survey is no longer conducted annually, and the coverage provided by the *Teleost* survey is less suited to krill sampling. Work is under way to develop a conversion factor between the two surveys. Additionally, although acoustic signal contamination by other taxa is limited in deeper areas, large aggregations of *C. hyperboreus* are classified as krill in shallow areas. Since copepods are much smaller, a very high density of them is required to override the signal received from a single krill. Work is also under way to assess the extent of this contamination.

## 6.5. HERRING

### 6.5.1. P5) sGSL herring stock biomass

In the sGSL, Atlantic herring consists of two genetically distinct spawning stocks: spring spawners and fall spawners. The data used to characterize this component of the pelagic ecosystem come directly from the stock assessment for the species (DFO 2020b).

#### 6.5.1.1. Surveys for spring spawners

In the sGSL, two data sources are used as abundance indices for the assessment of spring spawners: catch per unit effort (CPUE) in the commercial fishery and a fishery-independent abundance index. Commercial CPUE is expressed in terms of proportions-at-age (ages 4 to 10) and a total biomass index for these ages, from 1990 to 2019. An annual acoustic survey (scientific survey) has been conducted in September and October since 1994 to obtain estimates of proportions-at-age (ages 4 to 8) and an aggregated biomass index for these ages.

#### 6.5.1.2. Surveys for fall spawners

A commercial CPUE disaggregated by age (ages 4 to 10) and region (north, central and south) for fall spawners has been available since 1986, along with three scientific surveys. The annual acoustic survey conducted since 1994 provides an estimate of proportions-at-age (ages 2 and 3) as well as an aggregated biomass index for these ages. The sGSL bottom trawl survey has been used to produce an age-aggregated abundance index (ages 4 to 6) for fall spawners since 1994. Lastly, an experimental nets survey has been conducted on the species' spawning grounds since 2002 (northern and southern regions) or 2003 (central region), and used to calculate proportions at ages 3 to 9.

#### 6.5.1.3. Data processing

Abundance indices from the commercial fishery and scientific surveys, as well as catch-at-age and weight-at-age data from the commercial fishery, are used as inputs for statistical catch-at-age (SCA) models. The dynamics of the spring spawning stock are modelled for the entire sGSL, while fall spawning stock dynamics are modelled by region. With respect to fall spawners, the spawning stock biomass (SSB) values obtained with the model are summed to obtain the SSB for the entire sGSL. In order to assess spring spawners, the SCA model uses catchability to the fixed gear fishery and time-varying natural mortality. Two types of SCA models were used for the 2020 assessment of fall spawners: an SCA model with time-varying catchability and fixed natural mortality, and a model with time-varying catchability and natural mortality. The results of the second model will be presented in this document, as its predictions were deemed more conservative and realistic. A more suitable model could not be identified in the peer review (DFO 2020b). Abundance indices and model outputs are available annually, but are updated every two years for the stock assessment.

A precautionary approach (PA) was developed for these herring stocks based on SSB values. Limit reference points (LRPs) and upper stock references (USRs) define the healthy, cautious and critical zones under the precautionary approach (DFO 2006). With respect to fall spawners, two USRs were identified for the periods of low (1978–2001) and high (2002–2019) natural mortality. The status of the measures and indicator is assessed according to the thresholds defined under the precautionary approach (Table 5). To obtain the status of the indicator (threshold method), the scores obtained for each measure are added together (Table 7).

### 6.5.1.4. Measures retained and state of knowledge

*Measures 1 and 2: SSB of spring and fall herring from sGSL*

Herring is a key forage species in the Banc-des-Américains MPA. No sources of data representative of herring abundance in the MPA are available. Therefore, the measures used to determine the status of the indicator are based on the assessment of the herring stocks in the entire sGSL. The SSB values estimated by the analytical models for spring spawners and fall spawners incorporate a number of peer-reviewed indicators and represent the best available measures of the status of both herring spawning stocks in the southern Gulf.

*Results*

The SSB of spring spawners ranged from 37 kt to 190 kt from 1978 to 1995. It subsequently declined, and the stock has been in the critical zone since 2002 (Figure 26). The SSB of fall spawners in the entire sGSL was high from the mid-1980s to the early 1990s. It then declined in the 1990s, before increasing again in the late 1990s and peaking in 2011. The SSB has plummeted since 2011 and was in the cautious zone in 2019 (Figure 26).

*Status and trend*

Over the course of the time series, the status of the P5 indicator was “Poor” in the early 1980s, then fluctuated between “Good” and “Medium” from the late 1980s to the early 2000s (Figure 27). The indicator subsequently fell back down to “Poor” in 2002, before improving to “Medium” from 2008 to 2016. This decline is mainly attributable to the condition of spring spawners, which is poorer than that of fall spawners. Since 2017, the sum of the scores of the measures has resulted in “Poor” status. Increased natural mortality caused by predation by grey seals and Atlantic Bluefin Tuna is thought to be mainly responsible for the downward trajectories of both stocks (DFO 2020b).

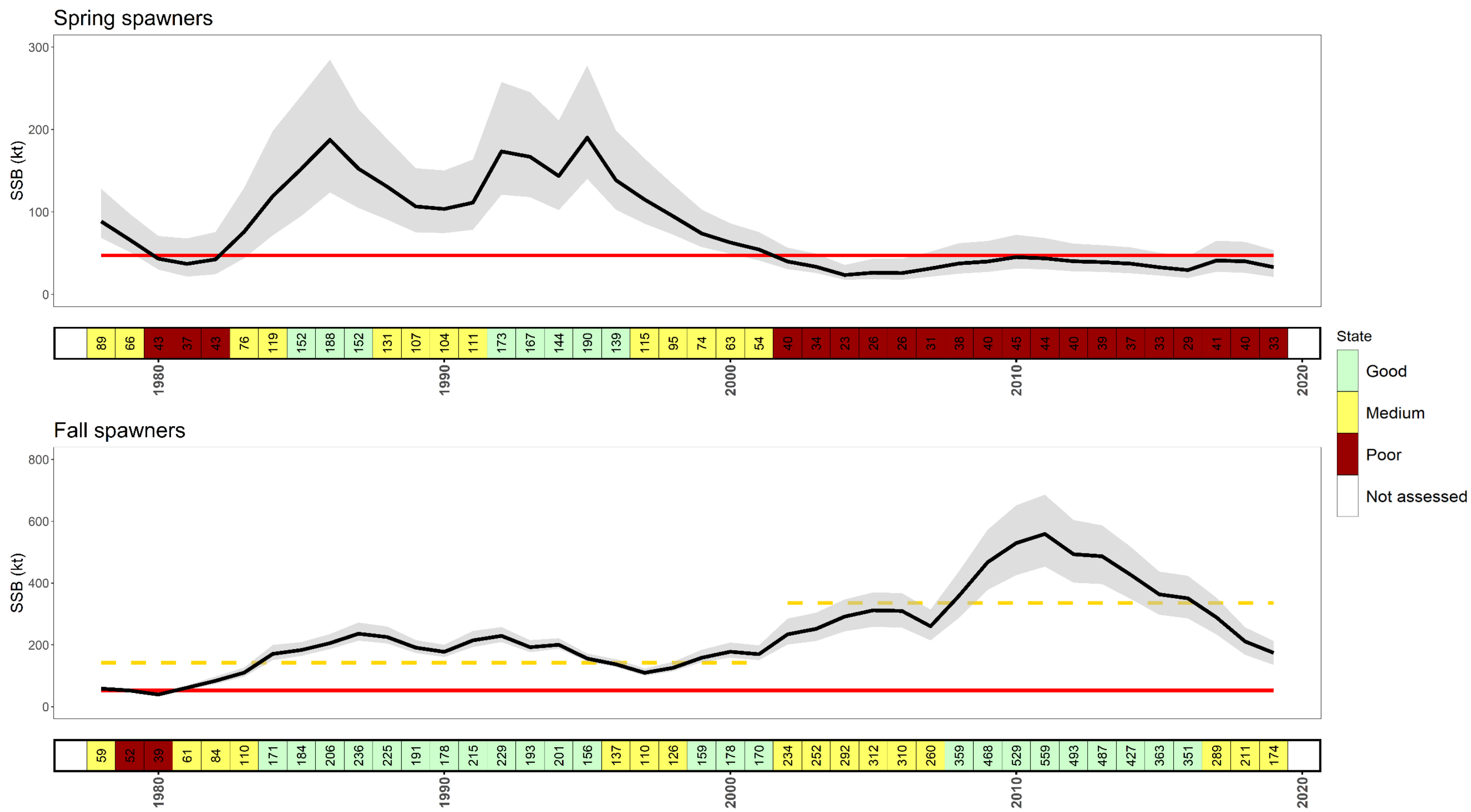



*Figure 26. Spawning stock biomass (SSB) of spring- and fall-spawning herring in the sGSL according to SCA models. The LRP and USR are indicated by the red and yellow horizontal lines, respectively. The strip below each graph shows the value obtained each year, colour-coded according to the threshold established (Table 5).*

| | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SS | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 2 |
| FS | 2 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| Sum | 4 | 3 | 2 | 3 | 3 | 4 | 5 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 5 | 4 | 4 |

| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SS | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| FS | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| Sum | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 |

*Figure 27. The sum of the scores assigned to each of the measures associated with the P5 indicator (sGSL herring stock biomass) for the entire time series. The sum of the scores is used to assign an annual status to this pelagic indicator.*

#### 6.5.1.5. Limitations

The information currently available on herring inside the boundaries of the MPA is insufficient; however, developing a species-specific survey in or around the MPA would have limited value. The area of the MPA is not large enough to monitor highly mobile forage species such as herring. Local data acquisition is therefore not planned in the short term. Given this, it is suggested that the SSB values from the sGSL herring stock assessment be retained, as they represent good indicators of the regional context in which the MPA is found.

## 6.6. CAPELIN

Currently, no indicators have been identified for this conservation priority, as no data are available for the MPA. An abundance index is being developed for stock assessment purposes, to be based on the August and September multi-species surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E).

# 7. CHOICE OF MEASURES FOR, AND STATE OF KNOWLEDGE ON, CO3[3]

## 7.1. ATLANTIC WOLFFISH

### 7.1.1. EP1) Atlantic Wolffish

The presence and abundance of Atlantic Wolffish will be monitored using scuba diving and environmental DNA surveys (RD4-Scuba diving and RD5-eDNA; Appendix E). Both types of surveys are currently under development. Once baseline data are available, the measures to be considered and the method for assessing the status of the indicator will be determined.

### 7.1.2. EP2) Atlantic Wolffish bycatch

Atlantic Wolffish bycatch can occur in the commercial fishery and during scientific surveys. The extent of this bycatch depends mainly on the type of gear used. Currently, the two main commercial fisheries that take place in the MPA are a snow crab trap fishery, and a groundfish longline fishery, targeting mainly Atlantic halibut (and occasionally Atlantic cod). Before the area was designated an MPA, northern shrimp and groundfish trawl fisheries and several gillnet fisheries took place. However, since the establishment of the Banc-des-Américains MPA, both types of commercial fisheries have been prohibited throughout the MPA. For scientific activities, surveys are carried out using trawls.

Bycatch in the snow crab trap fishery, the main commercial fishery in the MPA, is very low to almost non-existent (Côté-Laurin et al. 2014; Zisserson et al. 2019). A report on Canada’s commercial fisheries (Boudreau et al. 2017) states that at-sea observers occasionally record bycatch in the sGSL snow crab fishery, but it is so minimal that these data are not captured electronically. However, Atlantic Wolffish are likely to more frequently occur as bycatch in longline fisheries (Boudreau et al. 2017). With respect to trawling, Atlantic Wolffish catches are recorded, but the quantities harvested and frequency of occurrence remain low (DFO 2013b).

[3] All measures for each indicator are listed in Appendix F.

### 7.1.2.1. Surveys

*At-sea observers*

To assess this indicator, data on bycatch in the commercial groundfish and northern shrimp fisheries are obtained from Fisheries Management from at-sea observer data (1996–2020). At-sea observer coverage is a condition of licence to ensure the effective management and control of the fisheries. The percentage of at-sea observer coverage is specific to each type of fishery and fishing area, ranging from 10% to 20% in the Atlantic halibut fishery and from 5% to 20% in the Atlantic cod fishery.

The database provided includes the following information:

- Year, date and local time of start and end of effort;
- Latitude and longitude at the start and end of effort;
- Type of fishery and name of target species;
- Gear type;
- Name of species caught;
- Biomass retained, discarded and caught (kg).

*Scientific surveys*

Bycatch data are also available from scientific research activities, including catches in the sGSL multi-species bottom trawl survey (R10-Multi sGSL) from 1985 to 2020, and the snow crab bottom trawl survey (R13-Snow crab sGSL) from 2006 to 2020.

### 7.1.2.2. Data processing

For the at-sea observer data, the number of fishing events with Atlantic Wolffish bycatch was recorded. Data were extracted based on the boundaries of the Banc-des-Américains MPA.

For both scientific surveys, data on Atlantic Wolffish biomass were calculated per standardized tow (i.e. a daytime tow of 1.75 nautical miles [30 minutes at 3.5 knots] from the *CCGS Teleost* using a Western IIA trawl) (Hurlbut and Clay 1990). Similar to other measures using data from the sGSL multi-species survey (R10-Multi sGSL), the area corresponds to stratum 416 and the annual mean is presented. Since Atlantic Wolffish catches in the part of stratum 416 surrounding the Banc-des-Américains MPA are very small, the estimated biomass of Atlantic Wolffish is obtained with a Hurdle-type predictive model that incorporates the proportion of tows with catches and a gamma prediction model that takes into account the weight of catches greater than zero. For more details, see section 5.4..2. A method for assessing the status of the indicator is not proposed, since very little at-sea observer and scientific survey data are available. Therefore, the anomaly method cannot be used and no threshold has been defined.

### 7.1.2.3. Measures retained and state of knowledge

*Measure 1: Proportion of commercial fishing events with Atlantic wolffish bycatch*

This proportion is calculated by strictly taking into account fishing events where an at-sea observer was present, rather than all commercial fishing events. This measure provides an index of the fishing pressure on the Atlantic Wolffish, but also of its abundance in the MPA area. An increase in the abundance of Atlantic Wolffish is likely to be accompanied by the same trend in bycatch.

*Measure 2: Estimated biomass of Atlantic wolffish by scientific surveys*

This measure provides an indirect index of Atlantic Wolffish abundance in the MPA area. In this case, an increase in the proportion of tows with Atlantic Wolffish bycatch would be positive and could indicate a larger population.

*Results*

Apart from the bycatch amounts observed in 2000, 2014 and 2019, minimal Atlantic Wolffish bycatch was recorded by at-sea observers in commercial fisheries in the Banc-des-Américains MPA, and no temporal trend could be discerned (Figure 28, Table 15). A total of 50 kg of bycatch was recorded between 1996 and 2020, 94% of which was harvested by fixed longlines used in the Atlantic halibut fishery (Figure 28, Table 15). A total of 150 at-sea observer trips were made in the MPA between 1996 and 2018, including 115 between 1996 and 2002, mainly involving commercial bottom trawl fisheries (Figures 29 and 30). In the MPA, the percentage of at-sea observer coverage averaged 31.7% annually between 2004 and 2018, with a minimum of 11.1% in 2018 and a maximum of 100% in 2004. Coverage could not be estimated before 2004, because of the lack of georeferenced data on commercial fishing activities.

No Atlantic Wolffish bycatch was recorded in the scientific snow crab bottom trawl survey (R13-Snow crab sGSL) between 2006 and 2020. Therefore, only data from the sGSL bottom trawl survey (R10-Multi sGSL) are presented (Figure 31). The estimated biomass of Atlantic Wolffish bycatch was at its highest at the beginning of the time series (Figure 31). Starting in the early 1990s, the biomass fluctuated greatly, and the absence of wolffish bycatch became more frequent in stratum 416. The reference period mean is 0.08 kg per tow (Figure 31).

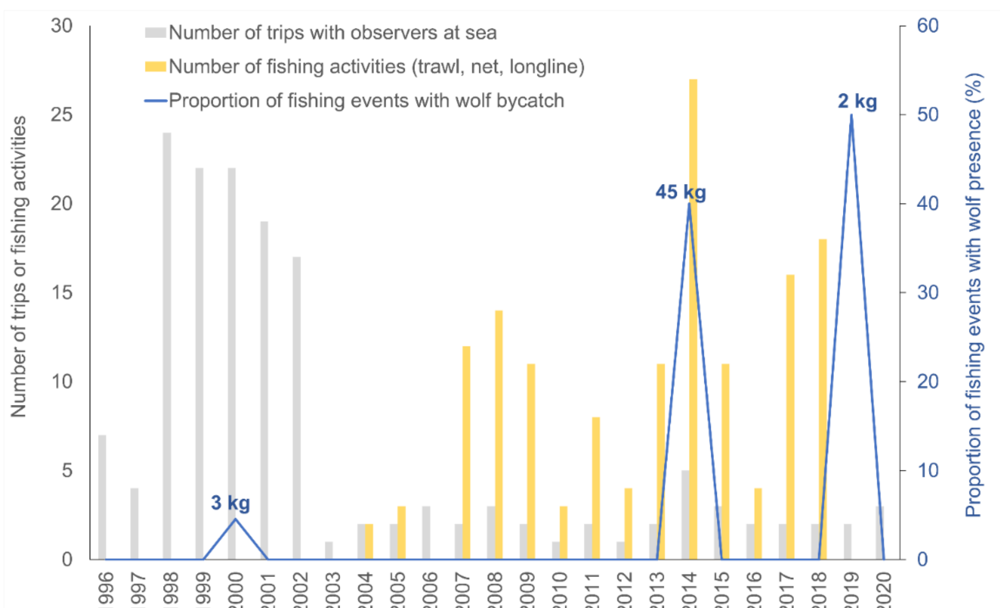



*Figure 28. Total bycatch (kg) of Atlantic Wolffish, number of at-sea observer trips, and proportion of fishing events with wolffish bycatch (blue line) per year in the Banc-des-Américains MPA based on at-sea observer data from 1996 to 2020. The number of fishing activities (longline, trawl and gillnet) that occurred in the MPA is also shown, but only from 2004 onwards.*

*Table 15. Summary of bycatch (kg) of Atlantic Wolffish and at-sea observer trips in the Banc-des-Américains MPA based on at-sea observer data from 1996 to 2020.*

| Data by period | Atlantic wolffish by-catch (kg) | Number of at-sea observer trips |
|---|---|---|
| Total 1996–2018 | 48 (n = 3) | 150 |
| Annual average 1996–2018 | 2.07 | 6.52 |
| Standard deviation 1996–2018 | 9.38 | 7.9 |
| 2019 | 2 (n = 1) | 2 |
| 2020 | 0 | 3 |

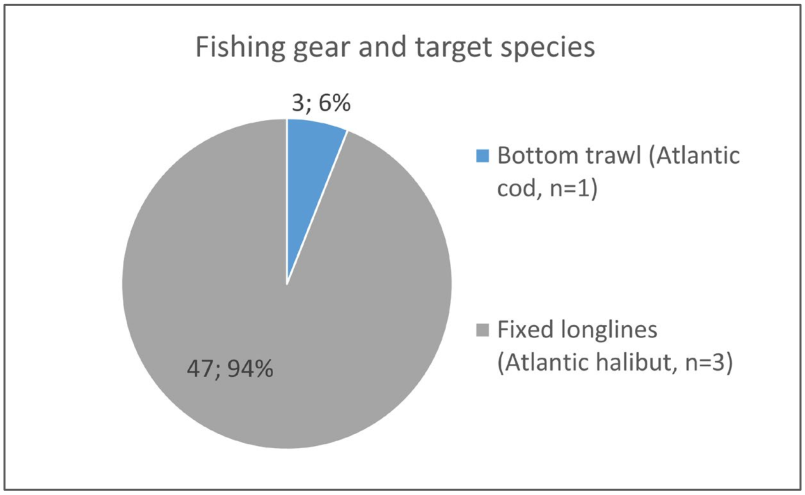



*Figure 29. Fishing gear used and target species for all Atlantic Wolffish bycatch (kg) in the Banc-des-Américains MPA based on at-sea observer data from 1996 to 2020.*

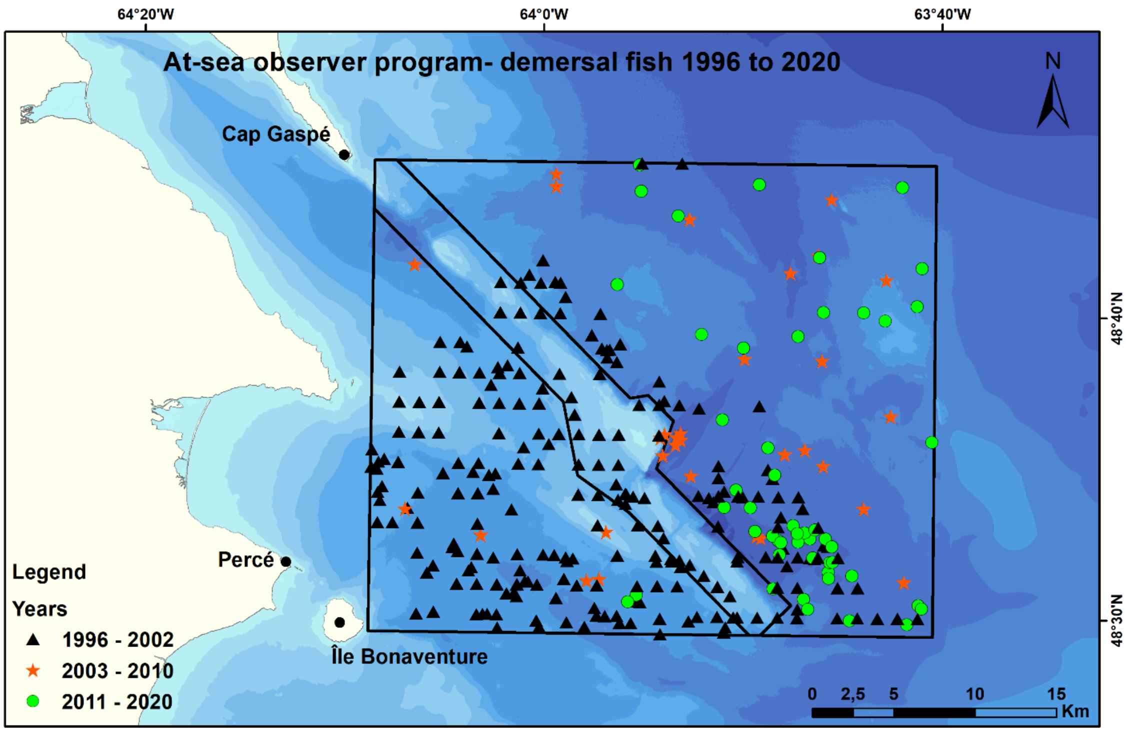



*Figure 30. Location of at-sea observer trips between 1996 and 2020 in the Banc-des-Américains MPA by year.*

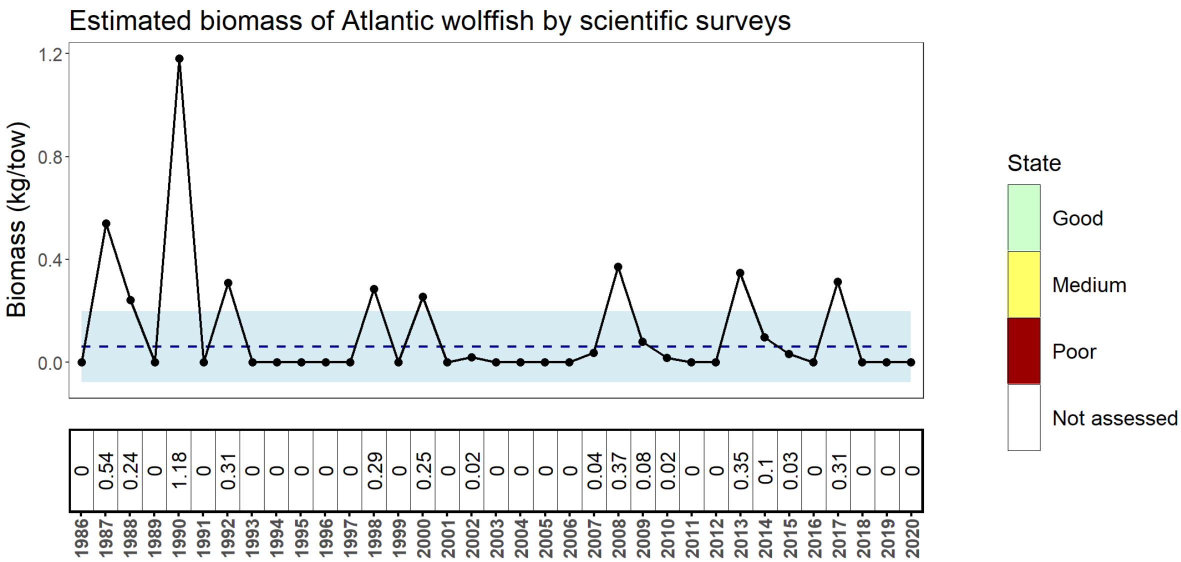



*Figure 31. Time series of the values of measure 2 associated with the EP2 indicator (Atlantic Wolffish bycatch). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ±1 standard deviation around this mean. The strip below the graph shows the value obtained for each year. The status of the indicator could not be assessed.*

*Status and trend*

Insufficient data on bycatch in the MPA is available from commercial fisheries with at-sea observers, and consequently the status of this indicator cannot be assessed. Similarly, the bycatch data in stratum 416 are insufficient. Therefore, the status of the EP2 indicator was not assessed. However, continuing to monitor the progression of this indicator over time is essential in order to observe potential changes in Atlantic Wolffish numbers.

### 7.1.3. Limitations

Assessing the full extent of the Atlantic Wolffish bycatch in commercial fisheries is challenging. There are two sources of data: logbooks and at-sea observer data. Logbook data have not been included. Fishers are required to report bycatch of species at risk, such as Atlantic Wolffish; however, this requirement is not verified by any legal authority, so the consistency of these data is uncertain. Consequently, only at-sea observer data were analyzed. However, the information collected through the at-sea observer program is incomplete, since it only covers a certain percentage of fishing activities.

The use of wolffish bycatch as a pressure indicator may be problematic, since Atlantic Wolffish are supposed to be released in the water when they are caught, and the species' survival rate is still significant (Grant and Hiscock 2014). However, there is a potential for ambiguity in the interpretation of the indicator involving Atlantic Wolffish abundance and biomass. An increase in bycatch could indicate a negative change, as a greater number of fish are harvested. Conversely, the same increase could also indicate the increased abundance of wolffish in the ecosystem, which would be positive.

As a result of the analysis of the available data and the limitations identified, it is impossible to assess the status of this indicator. Nevertheless, it is proposed that the indicator be retained and presented in future monitoring reports to provide additional information, and its relevance will be reassessed over time.

## 7.2. WHALES

### 7.2.1. EP3) Fin Whale; EP4) Blue Whale; EP5) North Atlantic Right Whale

Three indicators were retained involving each of the whale species at risk that are observed in the Banc-des-Américains MPA. To obtain information on these indicators, passive acoustic data obtained in other projects covering the MPA, among other areas, could be used (R21-PAM; Appendix E; Simard et al. 2016, 2019; Roy et al. 2019). Acoustic data were targeted, as they can provide information on the relative occurrence of different species over the course of the season. Currently, these data are compiled annually, enabling interannual comparisons. Note, however, that the data cover an area larger than the MPA, due to the detection radius of the acoustic receivers. DFO aerial surveys could also be used to support acoustic measurements. The abundance data obtained are point data (one day) and variable in frequency (at least once every 10 years), which is considered less suitable for long-term monitoring. The analysis of acoustic data for the purposes of monitoring the Banc-des-Américains MPA and the selection of measures to be retained will be carried out in a subsequent stage.

### 7.2.2. EP6) Cetacean mortality/accidents

#### 7.2.2.1. Surveys

The data used for the indicator involving the number of cetaceans that are sick, injured, live stranded or dead come from cases reported to the Quebec Marine Mammal Emergency Response Network (QMMERN) between 2012 and 2020. A monthly report on these cases is sent to the Marine Conservation and Planning Division, Quebec Region, DFO, and includes the following information:

- Date incident reported;
- Common name of the species;
- Number of animals involved;
- Latitude and longitude;
- Location (municipality);
- Type of incident (dead [beached], dead [floating], live [entangled], harassment, injured or sick, live [stranded], etc.);
- Visual documentation (from 2019 only);
- Confirmation (from 2019 only);
- Degree of certainty regarding identification (certain/uncertain, from 2020 only).

#### 7.2.2.2. Data processing

Since the precise location (latitude and longitude) of mortalities/accidents does not necessarily represent the exact location of the event, the QMMERN data were filtered for the municipalities of Gaspé and Percé (Figure 32). Therefore, the data retained incorporate a larger area than the MPA in order to make it possible to obtain general information on all recorded mortalities and accidents. Data were compiled for all cetacean species and separated into three categories:

1. Whale species at risk (Blue Whale, Fin Whale, North Atlantic Right Whale and Beluga Whale);

2. Other baleen whale species not designated at risk (Humpback and Common Minke whales, whale sp.); and
3. Toothed cetaceans not designated at risk (Short-finned Pilot Whale, Harbour Porpoise, Atlantic White-sided Dolphin, cetacean sp.).

A method for assessing the indicator has not been proposed, as insufficient data are available and the data that are available are associated with a high degree of uncertainty. Therefore, the anomaly method cannot be used and a threshold has not been defined.

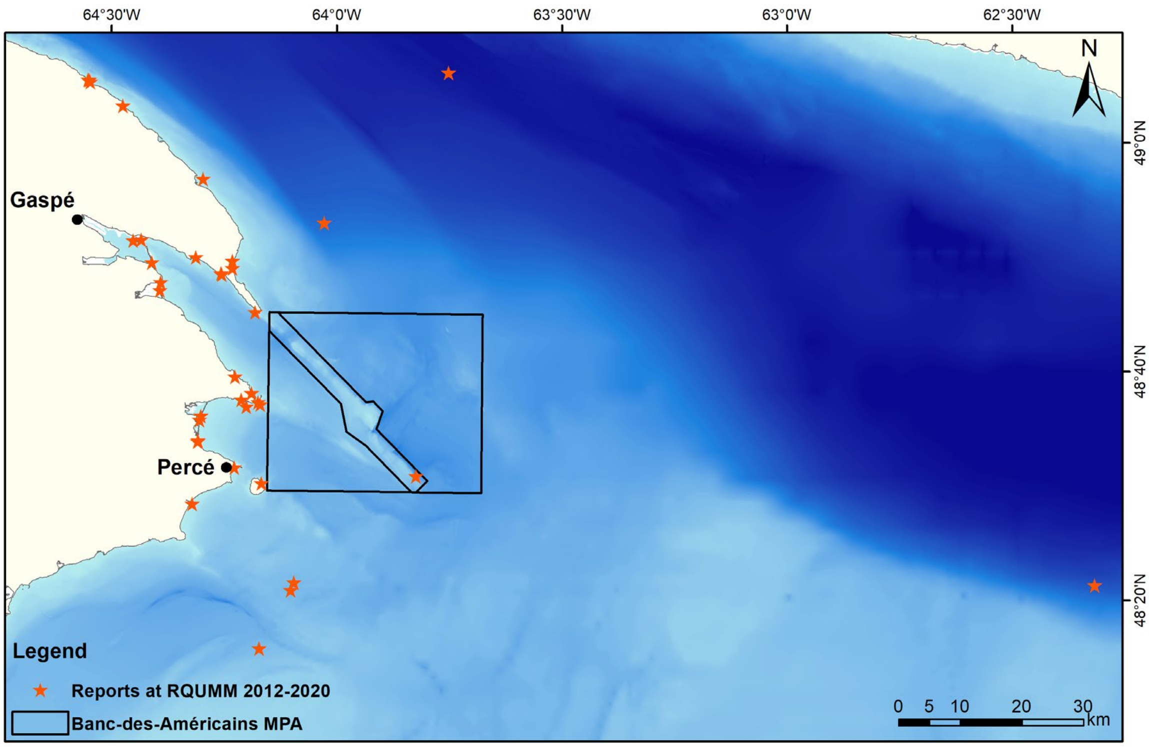



*Figure 32. Locations of QMMERN reports for the 2012–2020 period for the Gaspé and Percé sectors.*

### 7.2.2.3. Measures retained and state of knowledge

*Measures 1 and 2: Total number of reports of sick, injured, stranded individuals and carcasses for Species at Risk and other species (large marine mammals, dolphins, porpoises)*

The number of sick or injured cetaceans is reported to the QMMERN call centre for the municipalities of Gaspé and Percé. Sick or injured cetaceans include any free-swimming individual exhibiting unusual behaviour, signs of illness, serious injury or a low body mass condition. Individuals struck by boats are also included in this category. The total number of live stranded cetaceans reported to QMMERN in the same sectors is added to this figure. The total number of carcasses represents the number of dead cetaceans found on shore or at sea. These measures were selected to provide information on the general health of cetaceans in the Banc-des-Américains MPA area. A separate measure is calculated for cetacean species at risk, i.e. Beluga Whale, North Atlantic Right Whale, Blue Whale and Fin Whale, as well as one for all other cetacean species in the area, including other baleen whales and toothed cetaceans.

*Results*

The total number of reports of sick, injured or stranded individuals consisting of toothed cetaceans not designated at risk, followed by other baleen whale species not designated at risk, appears to be on the rise in recent years, and these reports are more frequent for the former (species not at risk) than for species at risk, for which the number of reports is more stable (Figure 33, Table 16). Nearly half of the incidents reported to QMMERN between 2012 and 2020 in the municipalities of Gaspé and Percé involved the Harbour Porpoise (46%; 36 cases). The Common Minke Whale was involved in 9% of incidents (7 cases), while Beluga and Humpback whales were each involved in 6% of incidents (5 cases each).

Reports of carcasses (at sea or on shore) are the most frequent type of incident (94%; 74 cases, Table 16) and appear to have increased between 2012 and 2020, while the trends for the other incident types (sick or injured individuals and live strandings) seem less apparent, (Table 16).

*Status and trend*

The status of the EP6 indicator could not be assessed, as there are too many uncertainties associated with the QMMERN data (see section 7.2.3. Limitations ) to enable a meaningful assessment. Nevertheless, the raw data are presented to show the progression of incidents in the area over time.

*Table 16. Number of individuals reported to QMMERN for each type of incident involving cetaceans in the municipalities of Gaspé and Percé during the 2012–2020 period. The total and mean number of incidents and standard deviation are presented for the reference period (2012–2018). Others = baleen whales and toothed cetaceans not designated at risk; SAR = species at risk.*

**Reference period**

| Year | Sick/injured individuals | | Live strandings | | Carcasses | | Total accidents | |
|---|---|---|---|---|---|---|---|---|
| | Other | SAR | Other | SAR | Other | SAR | Other | SAR |
| **2012** | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0 |
| **2013** | 0 | 0 | 0 | 0 | 7 | 0 | 7 | 0 |
| **2014** | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0 |
| **2015** | 0 | 0 | 0 | 0 | 3 | 4 | 3 | 4 |
| **2016** | 2 | 0 | 0 | 0 | 8 | 0 | 10 | 0 |
| **2017** | 0 | 0 | 0 | 0 | 11 | 2 | 11 | 2 |
| **2018** | 0 | 0 | 0 | 0 | 6 | 3 | 6 | 3 |
| **Total** | 2 | 0 | 0 | 0 | 41 | 9 | 43 | 9 |
| **Mean** | 0 | 0 | 0 | 0 | 6 | 1 | 6 | 1 |
| **SD** | 0.8 | 0 | 0 | 0 | 3.1 | 1.7 | 3.4 | 1.7 |

**2019–2020**

| Year | Sick/injured individuals | | Live strandings | | Carcasses | | Total accidents | |
|---|---|---|---|---|---|---|---|---|
| | Other | SAR | Other | SAR | Other | SAR | Other | SAR |
| **2019** | 0 | 2 | 0 | 0 | 8 | 1 | 8 | 3 |
| **2020** | 0 | 0 | 1 | 0 | 14 | 1 | 15 | 1 |

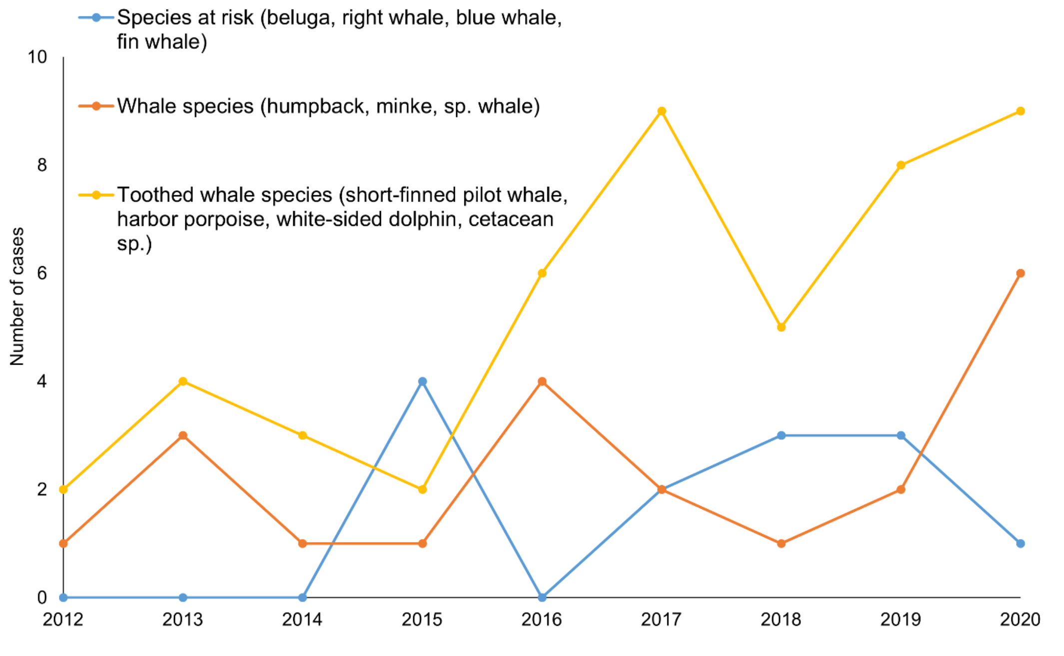



*Figure 33. Number of reported cases of carcasses, live strandings and sick or injured animals for cetacean species at risk, other baleen whale species and toothed cetaceans recorded by QMMERN from 2012 to 2020 in the municipalities of Gaspé and Percé.*

### 7.2.3. Limitations

For the EP6 indicator, data from QMMERN were analyzed for the municipalities of Gaspé and Percé, providing a general overview of cetacean mortalities and accidents in the region, but not specifically in the Banc-des-Américains MPA. Indeed, the MPA represents a small proportion of the area used by marine mammals for migration and feeding. Moreover, injured or sick cetaceans continue to travel and carcasses may drift from the point of origin, which makes it impossible to accurately determine the time and place of the incident (Henry et al. 2012). Carcasses tend to sink rather than drift, so they are not all recorded, particularly Blue Whale carcasses (COSEWIC 2002; DFO 2017). Furthermore, since the Banc-des-Américains MPA is not a coastal MPA, no strandings occur there. These previously mentioned phenomena justify the selection of a larger area (the municipalities of Gaspé and Percé) for the analysis of these indicators.

The data used in this analysis correspond to the cases reported to QMMERN. Therefore, it is important to note that these data underestimate the actual number of incidents that have taken place in the area. These data are essentially based on voluntary observations, not all incidents are systematically reported and the proportion of incidents reported may fluctuate over time (public awareness). Consequently, this indicator should therefore be interpreted with caution.

# 8. CHOICE OF MEASURES FOR, AND STATE OF KNOWLEDGE ON, PRESSURES[4]

## 8.1. CLIMATE CHANGE

### 8.1.1. Pr1) Physical conditions of the pelagic habitat

#### 8.1.1.1. Surveys

Temperature and salinity data come from vertical profiles taken during the August and September multi-species surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E). These surveys, carried out at the same time of the year since 1985, provide good coverage of the oceanographic area of the Banc-des-Américains MPA. The ice data come from weekly ice charts issued by the Canadian Ice Service (ECCC; R3-Ice; Appendix E). Sea surface temperature (SST) data come from a homogenized blend of AVHRR (advanced very high resolution radiometer) data (Pathfinder 5.3, DFO-MLI and DFO-BIO; Galbraith *et al.* 2021; R4-SST; Appendix E).

#### 8.1.1.2. Data processing

For all indicators associated with temperature or salinity in the water column, including the volume and depth of the cold intermediate layer (CIL), horizontal grids are interpolated from all available data for each 1-m depth zone. Average temperature and salinity values are then calculated as the mean of the values at the relevant depths of all grid points in the oceanographic area. The volume and depth of the CIL are calculated from the interpolated horizontal grids. For surface temperatures, the mean value of the daily temperature anomalies (May to November) of all pixels in the oceanographic area is calculated, and this mean anomaly is added to the climatological mean for the area (Galbraith et al. 2021). For ice, grids are created for the first and last day that ice was present at each grid point, and the duration corresponds to the number of weeks ice was present at each grid point. The values of all grid points in the oceanographic area are then averaged.

Annual anomalies for all these measures are calculated based on the deviation between the annual mean and the reference period mean (1989–2018). This deviation is then standardized by dividing it by the standard deviation for the reference period. The absolute value of the anomaly is used to characterize the annual status of the measure (bidirectional anomaly).

Since this indicator encompasses a wide range of measures, some measures have been grouped according to the part of the water column that they are associated with to create sub-indicators. To calculate the final status of the indicator while establishing more accurate findings for each of the three sub-indicators (physical conditions in the surface layer, physical conditions in the intermediate layer, and ice conditions), an annual status was first assigned to each of these sub-indicators based on the sum of the absolute anomaly values (bidirectional anomaly). The totals for each sub-indicator were then added and plotted to characterize the annual status of the indicator.

#### 8.1.1.3. Measures retained and state of knowledge

*Measure 1: Mean surface temperature (May–Nov.) derived from satellite data (SST)*

Temperature can have a direct impact on pelagic species' distribution and metabolism. The distribution of the North Atlantic Right Whale is thought to be influenced by the SST (Pendleton et al. 2012). During the months of May to November, air temperatures equal to or below the

[4] All measures for each indicator are listed in Appendix G.

freezing point do not act as a limiting factor on the surface temperature. Therefore, the mean temperature in the oceanographic area of the Banc-des-Américains MPA during these months is representative of summer heat.

*Measure 2: Average summer temperature (Aug.–Sept.) at the surface (0–30 m)*

The water temperature in the 0–30 m layer reaches the peak of its seasonal cycle in August, almost at the same time as the August and September multi-species surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E), which provide good coverage of the entire oceanographic area of the Banc-des-Américains MPA. The 0–30 m layer includes the surface layer down to the upper limit of the cold intermediate layer (CIL), and is therefore different from the surface temperature as measured by remote sensing.

*Measure 3: Average summer salinity (Aug.–-Sept.) at the surface (0–30 m)*

The salinity of the 0–30 m layer in August and September reflects the summer stratification of the water column and may have an impact on primary productivity. The August and September multi-species surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E) provide good coverage of the entire oceanographic area of the Banc-des-Américains MPA, and have allowed reliable estimates of the average salinity of the 0–30 m layer at the same time of year since 1987.

*Measures 4, 5 and 6: First and last day of ice, and duration of the ice season*

The first and last day of ice occurrence, as well as the duration of the ice season, are indicative of the severity of winter. The break-up of the ice cover is a determining factor in the stratification of the water column and the phenology of the spring phytoplankton bloom. Ice cover is also of great importance to certain species of fish, as well as many marine mammals, in particular serving as a temporary habitat for harp seals (Johnston et al. 2012).

*Measure 7: Average summer temperature (Aug.–Sept.) in the cold intermediate layer (CIL; 40–100 m)*

Water depths between 40 m and 100 m generally represent CIL waters. The CIL is especially important for feeding by Fin Whales and Blue Whales, and is used by forage fish species (herring, capelin) and zooplankton. The August and September multi-species surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E) provide good coverage of the entire oceanographic area of the Banc-des- Américains MPA, and have provided reliable estimates of the average temperature in the CIL at the same time of year since 1985.

*Measure 8: Depth of the upper limit of the cold intermediate layer (CIL; 2°C)*

The depth of the upper limit of the CIL helps in determining its location in the water column. Generally, the greater the volume of the CIL, the shallower the upper limit. The 2°C limit was chosen because the minimum temperature sometimes does not reach 1°C in a large proportion of the oceanographic area of the MPA; a depth that is defined over a large area is preferable. The August and September multi-species surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E) have provided good coverage of the CIL in the oceanographic area of the Banc-des-Américains MPA at the same time of year since 1985.

*Measure 9: Volume of the cold intermediate layer (CIL; 1°C)*

The intensity of the CIL is relatively well defined by its volume, i.e. the volume of water colder than 1°C in the entire oceanographic area of the Banc-des-Américains MPA. The August and September multi-species surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E) have provided good coverage of the CIL in the oceanographic area at the same time of year since 1985.

*Results*

The physical conditions in the surface layer have changed significantly over the time series. The SST appears to have experienced two separate regimes: the first between 1982 and 1992, when temperatures were near 8.7°C, and a second since 1992, with temperatures closer to the reference period mean of 9.5°C. In 1994, the minimum summer temperature in the surface layer (0–30 m) during the time series was measured at 7.3°C, while the maximum of 10.8°C was reached in 2020. In the early 2000s, the surface layer temperature stabilized around the reference period mean of 9.5°C, with a slight upward trend thereafter. The salinity of the surface layer (0–30 m) in summer was very high at the beginning of the time series. It then hovered around the reference period mean (29.7°C) from the late 1990s until recently. However, since 2016, it has been slightly below the reference period mean (Figure 34).

Ice conditions in the oceanographic area varied significantly between the beginning of the time series and 2020. Sea ice appeared later and later until 2010, but, since then, this date has varied significantly, although it has never reverted to the series minimum (earliest date) recorded during the first decade of the time series. The average first day of ice in the reference period is January 18. The ice break-up date was relatively stable at around the reference period mean (March 22) until 2010, when it was extremely early (February 12). The other two earliest instances of ice break-up took place in 2013 and 2018. The duration of ice cover therefore shows a decrease over the time series, from a maximum of 104 days in 1993 to a minimum of 14 days in 2010. Over the past three years, the ice cover duration has remained stable around the reference period mean of 65 days (Figure 35).

The physical conditions in the CIL also varied considerably over the time series. The average water temperature in the 40–100 m layer was very high in 1985 (1.5°C), but plummeted quickly to the series minimum in 1991 (0°C). Subsequently, an overall upward trend was noted in the CIL temperature, which reached 1.2°C in 2020. The average for the reference period is 0.64°C. In contrast to this pattern, the volume of the CIL colder than 1°C during summer increased rapidly at the beginning of the time series, before subsequently experiencing a general downward trend, albeit marked by significant fluctuations. While the maximum volume was obtained in 1991 (2,049 $km^3$), the minimum volume was measured in 2012 (578 $km^3$). The average volume of the CIL for the reference period is 1,403 $km^3$. Unlike the other two measures, the upper limit of the CIL, when defined by the 2°C isotherm, does not show a clear trend. The beginning and end of the time series are characterized by significant variations in depth on either side of the reference period mean (36.3 m). However, between 1994 and 2013, the upper limit of the CIL gradually became deeper, by approximately 7 m (Figure 36).

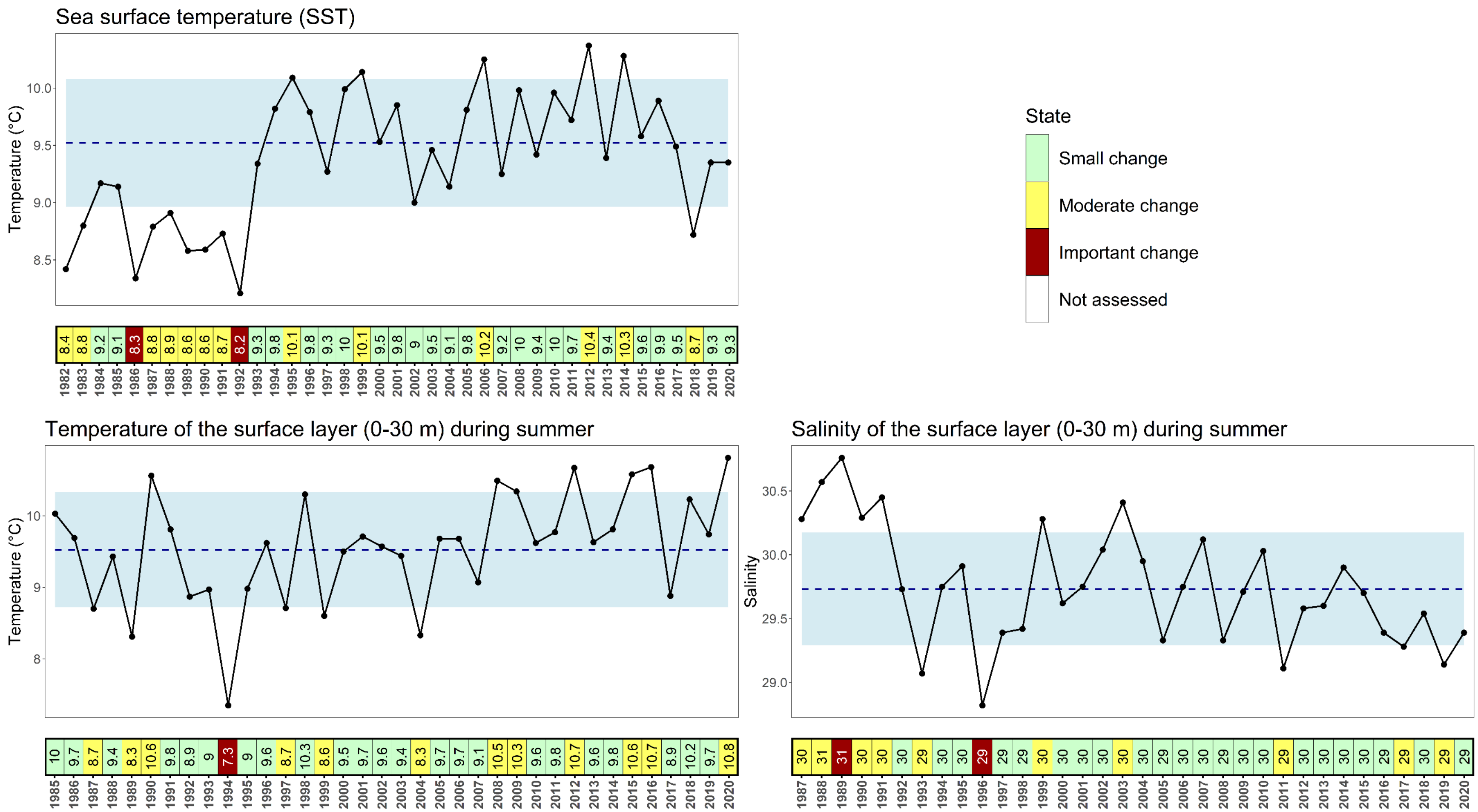



*Figure 34. Time series of the values of the measures associated with the "physical conditions in the surface layer" sub-indicator of the Pr1 pressure indicator. The blue dashed line represents the mean conditions during the reference period (1989–2018), and the blue shading, the ±1 standard deviation around this average. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).*

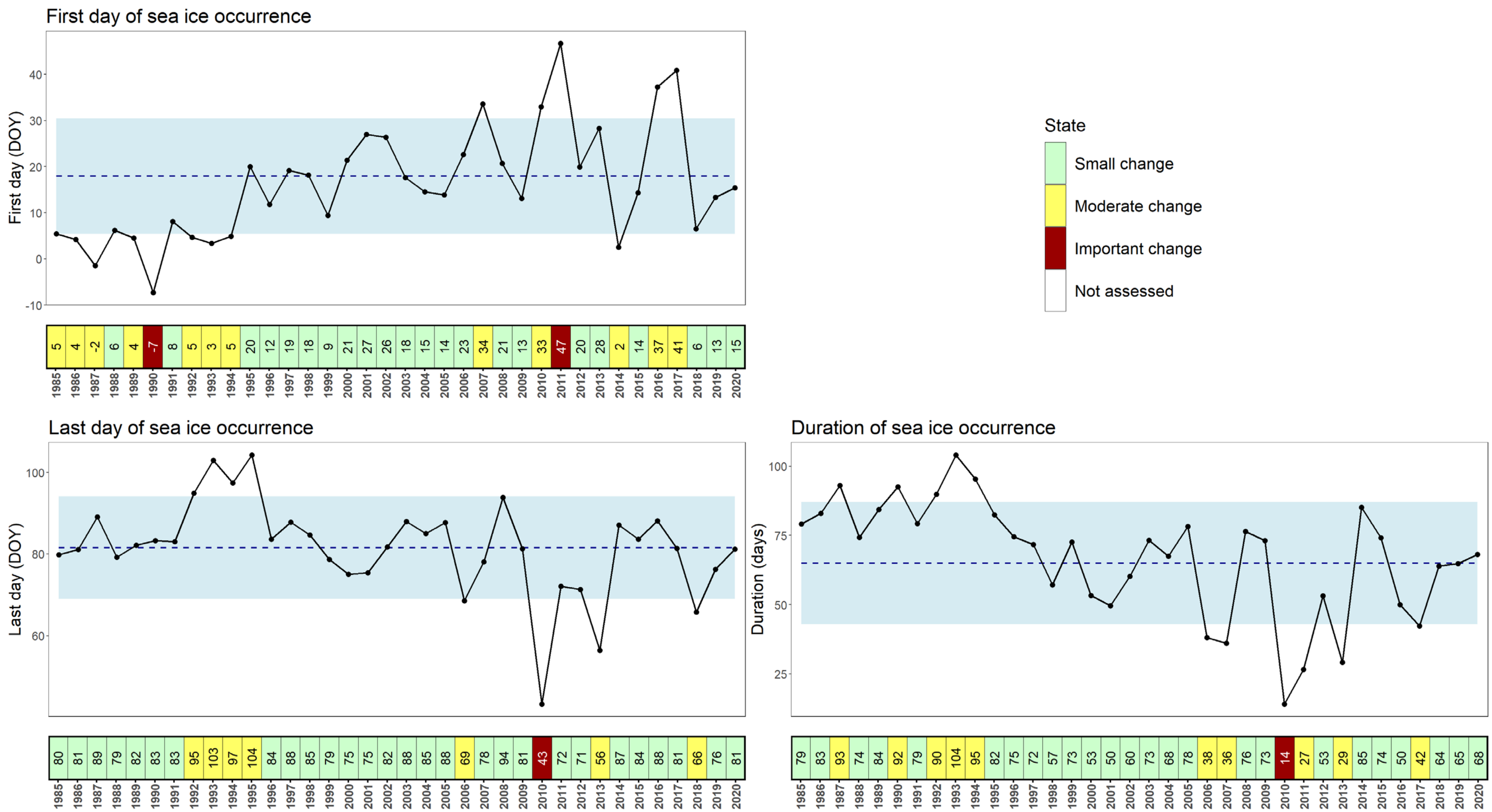



*Figure 35. Time series of the values of the measures associated with the "ice conditions" sub-indicator of the Pr1 pressure indicator. The blue dashed line represents the mean conditions during the reference period (1989–2018), and the blue shading, the ±1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).*

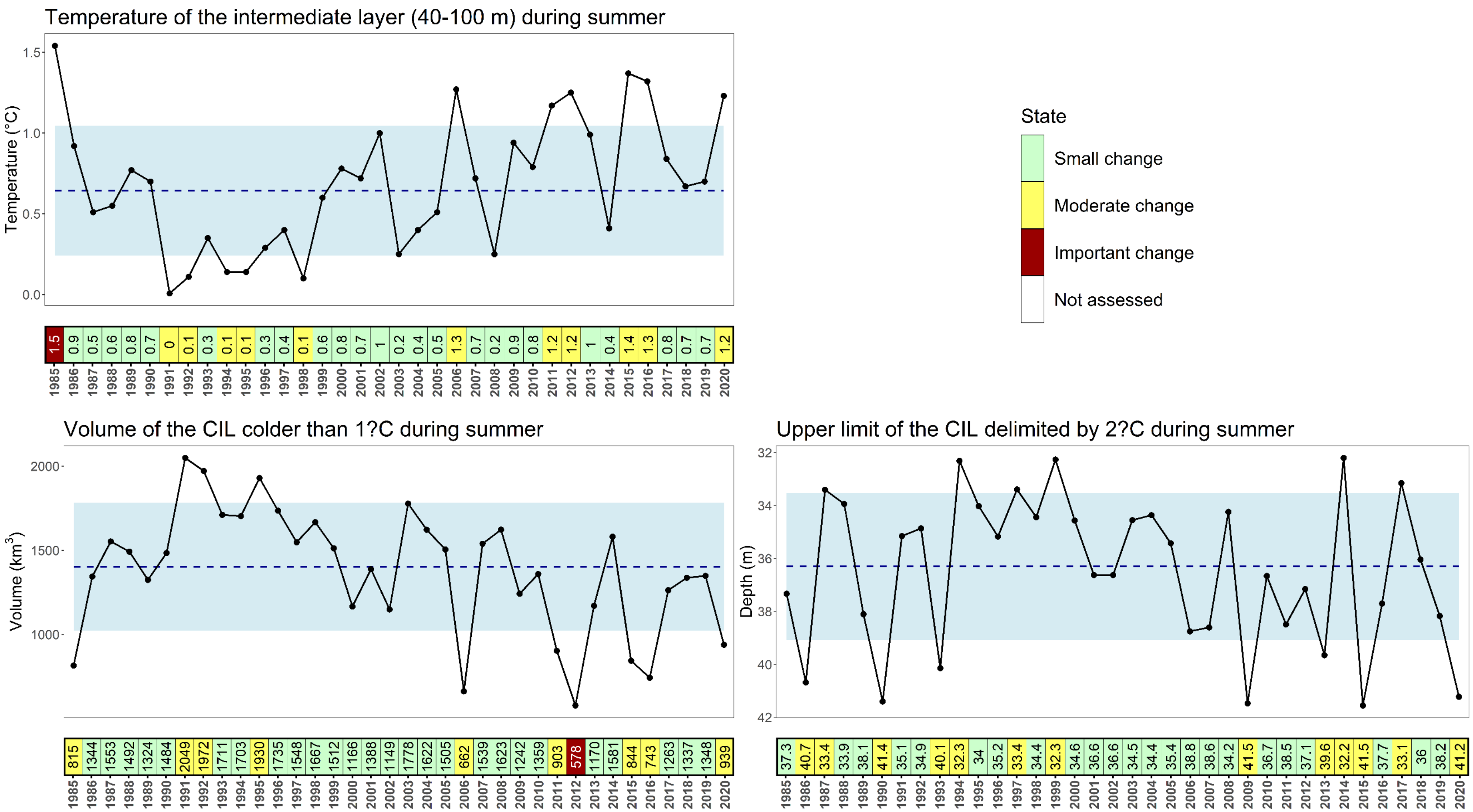



*Figure 36. Time series of the values of the measures associated with the "physical conditions in the intermediate layer" sub-indicator of the Pr1 pressure indicator. The blue dashed line represents the mean conditions during the reference period (1989–2018), and the blue shading, the ±1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).*

*Status and trend*

Despite the gradual warming of surface waters, the status of the “physical conditions in the surface layer” sub-indicator has been relatively stable since 1995, and generally corresponds to a “Small change” (Figure 37). Ice conditions at the beginning of the time series were consistently assigned a “Moderate change” status but a “Small change” status in the rest of the time series. Given the early break-up of the ice cover in 2010, “Important change” status was assigned that year (Figure 38). The “physical conditions in the intermediate layer” sub-indicator has been mostly at “Small change” status over the time series, and no clear trend can be discerned. The greatest total anomalies associated with a “Moderate change” were observed in 2015 and 2020, under similar conditions in both cases: a deep CIL with a high temperature and low volume (Figure 39). Lastly, the status of the Pr1 indicator was almost always “Small change” during the time series. The greatest total anomalies were observed in the early 1990s, when particularly cold conditions were experienced. Starting around 2010, the total anomalies rose slightly again, although this was generally associated with a “Small change” status, this time linked to warmer conditions (Figure 40).

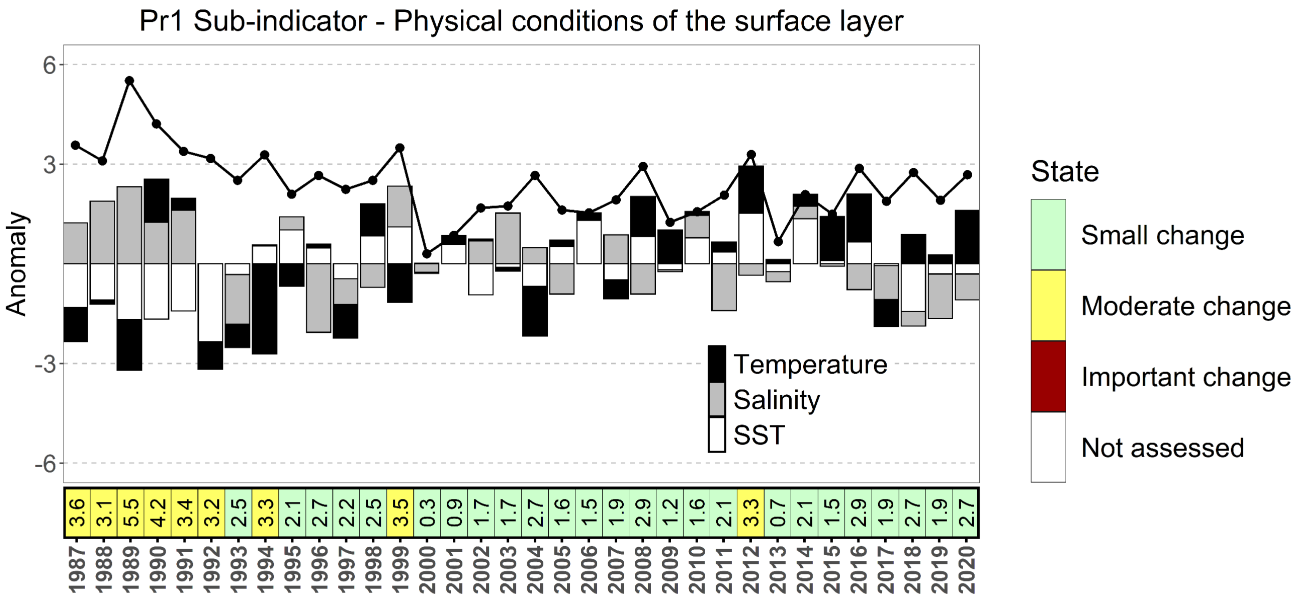



*Figure 37. Time series of anomaly values for each of the measures associated with the “physical conditions in the surface layer” sub-indicator of the Pr1 pressure indicator. The black line corresponds to the sum of the absolute values of the anomalies that are used to assign an annual status to the sub-indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

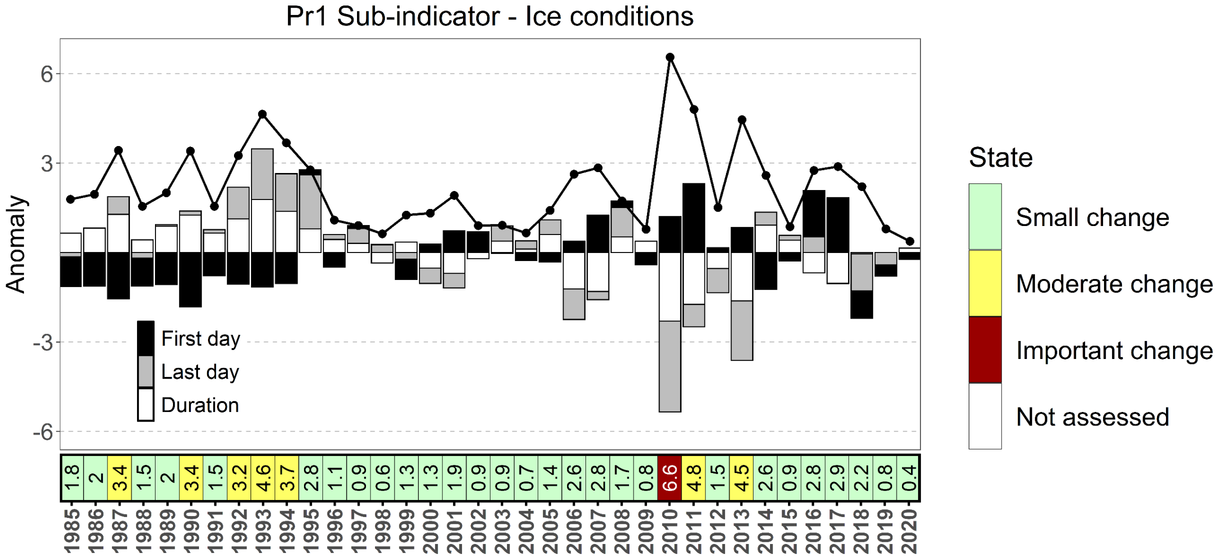



*Figure 38. Time series of anomaly values for each of the measures associated with the "ice conditions" sub-indicator of the Pr1 pressure indicator. The black line corresponds to the sum of the absolute values of the anomalies that are used to assign an annual status to the sub-indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

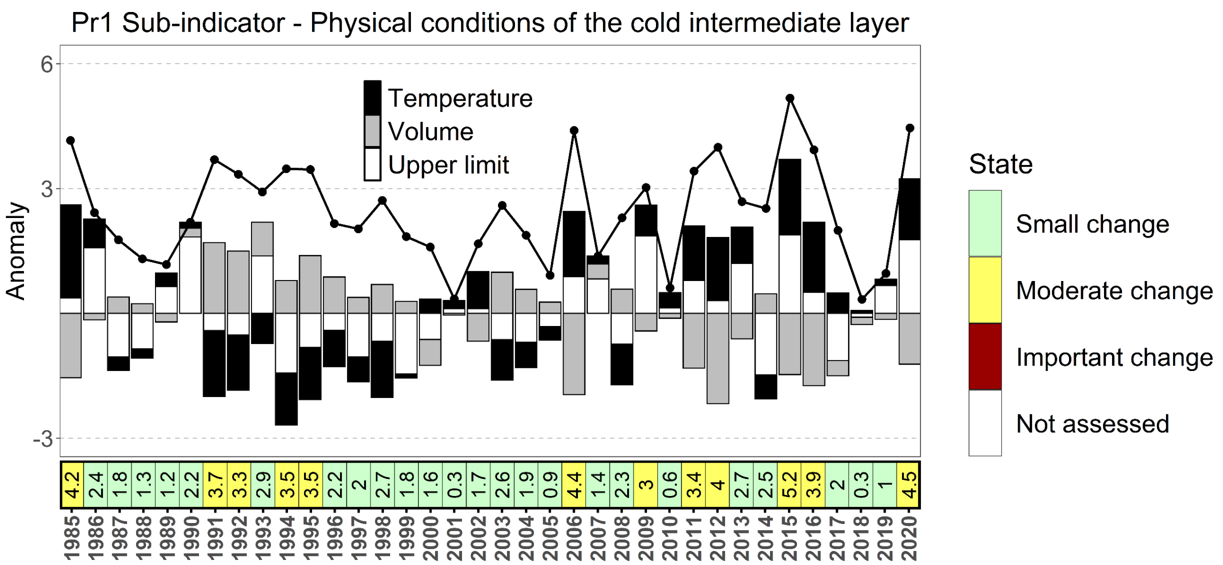



*Figure 39. Time series of anomaly values for each of the measures associated with the "physical conditions in the intermediate layer" sub-indicator of the Pr1 pressure indicator. The black line corresponds to the sum of the absolute values of the anomalies that are used to assign an annual status to the sub-indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

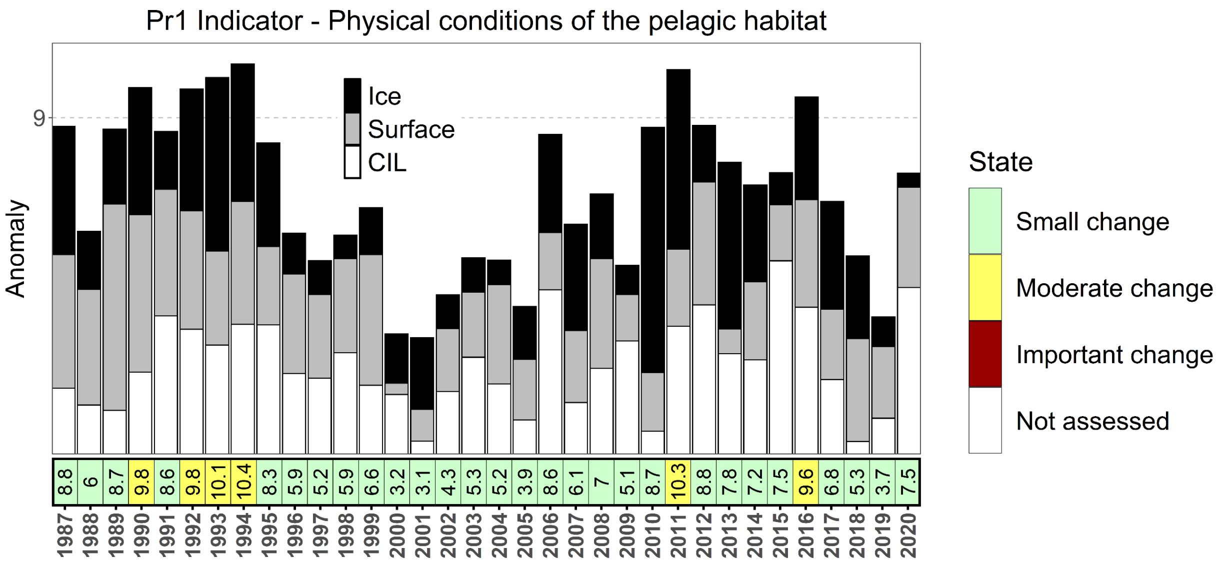



*Figure 40. Time series of the sums of the absolute values of the anomalies for each of the sub-indicators associated with the Pr1 pressure indicator (Physical conditions of the pelagic habitat). The black line corresponds to the sum of the absolute values of the anomalies for each of the measures that are used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

## 8.1.2. Pr2) Physical conditions of the benthic habitat (> 100 m)

### 8.1.2.1. Surveys

The temperature and salinity data were obtained from Conductivity-Temperature-Depth (CTD) profiles taken during the August and September multi-species groundfish surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E). The time series for the temperature and salinity measures in the area of interest date back to 1985 and 1987, respectively. On average, 30 CTD profiles were taken in the benthic area.

### 8.1.2.2. Data processing

For temperature and salinity, horizontal grids are interpolated from all available data for each 1-m depth zone. The bathymetric depth is then used at each grid point to determine the temperature and salinity at the bottom from the interpolated grid at that depth. The mean temperature and salinity in the benthic area is then calculated for the grid points with a depth of > 100 m. Annual anomalies for temperature and salinity are calculated based on the deviation between the annual mean and the reference period mean (1989–2018). This deviation is then standardized by dividing it by the standard deviation of the reference period. The absolute value of the anomaly is used to characterize the annual status of the measure (bidirectional anomaly).

### 8.1.2.3. Measures retained and state of knowledge

*Measures 1 and 2: Average temperature and salinity (Aug.–Sept.) near the bottom (> 100 m)*

The near-bottom temperature and salinity can have a direct influence on the metabolism of certain benthic organisms. In particular, temperature plays a significant role in the distribution of Atlantic Wolffish (Kulka et al. 2004). Near-bottom water temperatures in areas deeper than 100 m are influenced by the CIL (its maximum depth and minimum temperature), as well as by the temperature of the deep waters below the CIL, where accelerated warming has occurred in the last decade (Galbraith et al. 2020).

*Results*

The lowest near-bottom (> 100 m) summer temperatures were recorded in the late 1980s and early 1990s. The temperature then rose from 0.8°C in 1991 to 3.1°C in 2012 and, since then, has been around 2.5°C. The mean near-bottom summer temperature for the reference period is 2.0°C. The near-bottom summer salinity has been relatively stable since the early 2000s, remaining around the reference period mean of 33.2 (Figure 41).

*Status and trend*

Although the near-bottom (> 100 m) temperature of the benthic area has increased, the small change in salinity means that the Pr2 indicator has mainly been assigned a “Small change” status during the past decade (Figure 42).

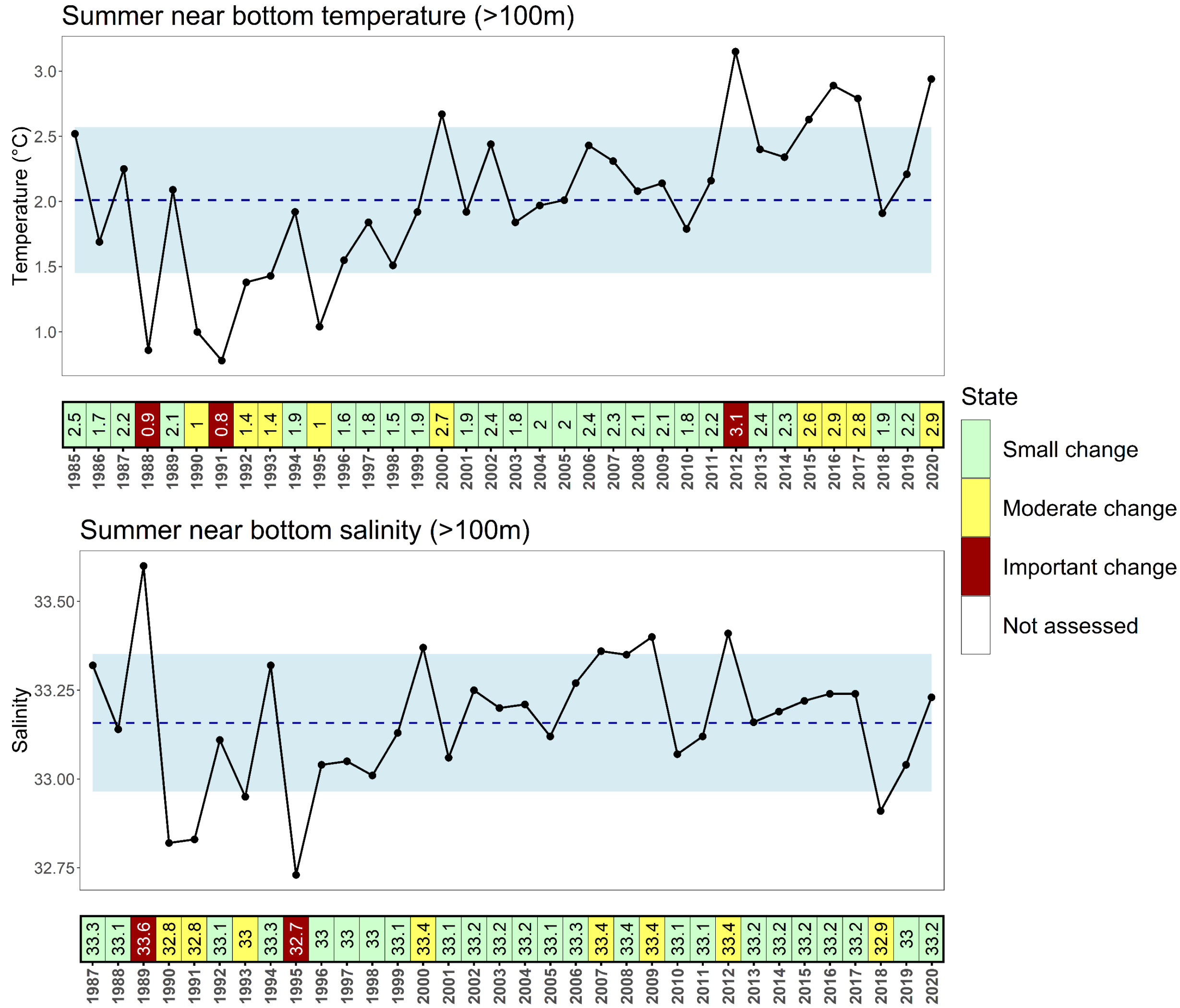



*Figure 41. Time series of the values of the measures associated with the Pr2 pressure indicator (Physical conditions of the benthic habitat [> 100 m]). The blue dashed line represents the mean conditions during the reference period (1989–2018), and the blue shading, the ±1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude of the change observed in relation to the reference period (bidirectional anomaly).*

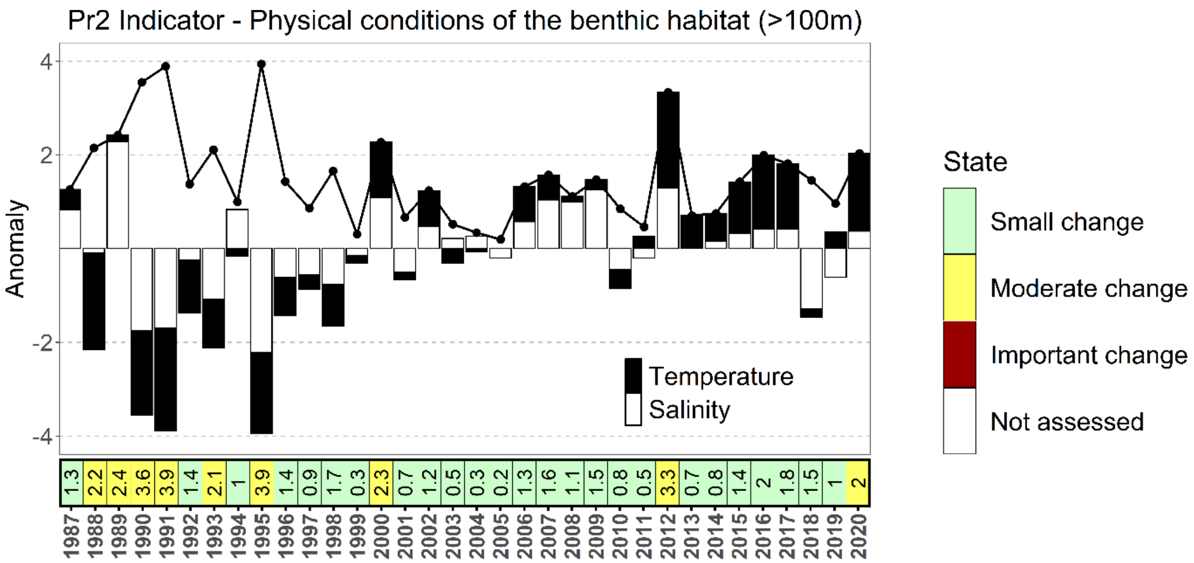



*Figure 42. Time series of anomaly values for each of the measures associated with the Pr2 pressure indicator (Physical conditions of the benthic habitat [> 100 m]). The black line corresponds to the sum of the absolute values of the anomalies that that are used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

### 8.1.3. Pr19) Acidification of the benthic habitat (> 100 m)

#### 8.1.3.1. Surveys

Data for the measures associated with acidification were obtained mainly from the June and October–November AZMP missions (R1-AZMP; Appendix E), and the August and September multi-species surveys (R10-Multi sGSL and R11-Multi nGSL; Appendix E). The time series began in 2011. A limited number of samples have been collected annually in the deep pelagic zone (> 100 m), consisting of one sample in 2011, four samples in 2017, five samples in 2018 and 2019, and three samples in 2020.

#### 8.1.3.2. Data processing

With respect to the acidification-associated measures, the mean of the values obtained each year in the near-bottom benthic area (> 100 m) was used. It is well known that, below a saturation rate of 1, aragonite and calcium carbonate dissolve, resulting in the "High" pressure status associated with this threshold. Moreover, according to some studies, certain organisms already experience effects at a saturation rate of below 2 (Waldbusser et al. 2015), although tolerance of such a rate is highly variable from one species to another. Therefore, the status associated with both measures was assigned using the threshold method, with the ranges presented in Table 5. By totalling the scores associated with the status of each measure, the status of the indicator can be described using the method outlined in Table 7.

#### 8.1.3.3. Measures retained and state of knowledge

*Measures 1 and 2: Average saturation rate of calcite and aragonite near the bottom (> 100 m)*

In the context of ocean acidification, a phenomenon that extends to the St. Lawrence Estuary (Mucci et al. 2011), monitoring variations in pH over time is vital, since acidification operates in conjunction with hypoxia to cause metabolic stress in benthic organisms, thereby modifying their distribution patterns (Pörtner 2008). Like oxygen, surface pH is greatly influenced by seasonal mixing and photosynthesis, and is therefore highly variable over time. Consequently, monitoring the acidification process on the bottom (> 100 m) should enable more stable trends to be observed than on the surface. In particular, near-bottom aragonite and calcite saturation states will be monitored, as they represent the most comprehensive measures of all. These two measures interact with pH, alkalinity (ocean buffering capacity) and environmental conditions (temperature, salinity and nutrients), and allow the impact of acidification on the growth rate and survival of many benthic and pelagic organisms to be directly assessed (Feely et al. 2012).

*Results*

The calcite saturation state ranges between 1.1 and 1.3 over the time series, slightly above the dissolution threshold, unlike the aragonite saturation state, which is below this threshold, with values ranging from 0.7 to 0.8 (Figure 43).

*Status and trend*

The Pr19 indicator was assigned "High" status throughout the time series, mainly as a result of the aragonite saturation state, which is below the threshold of 1 (Figure 44). Insufficient data are available to identify a historical trend.

#### 8.1.3.4. Limitations

Acidification data in the area of interest are limited, partly because the time series is short, but also because few pH and alkalinity samples have been taken in this area. In the future, the current surveys should provide an accurate characterization of the measures related to acidification, if a station in the area of interest is added to each survey when the research vessel is transiting this area.

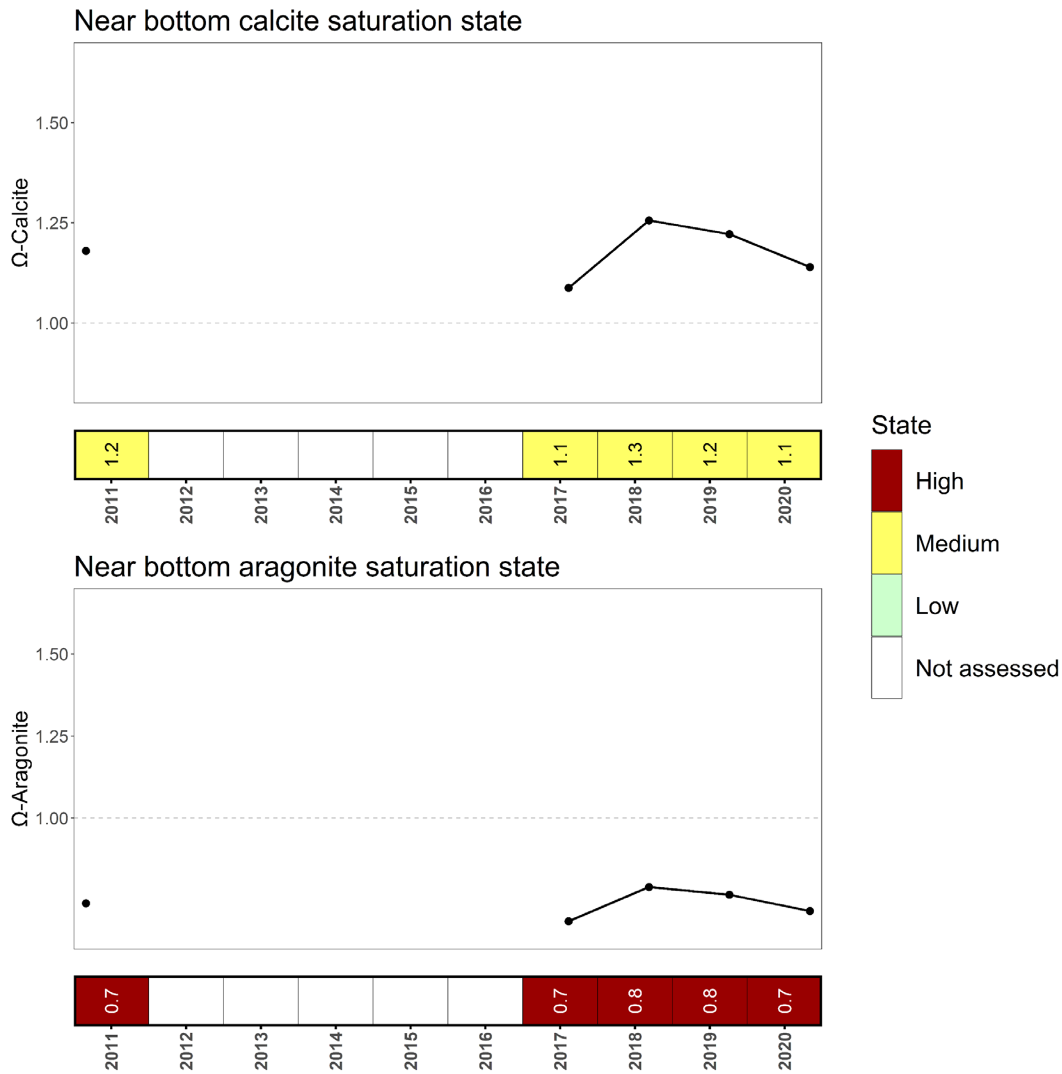



*Figure 43. Time series of the values of the measures associated with the Pr19 pressure indicator (Acidification of the benthic habitat [> 100 m]). The grey dashed line represents one of the thresholds associated with the different statuses (> 2: Low, 1–2: Medium, < 1: High). The strip below each graph shows the value obtained for each year, colour-coded according to the known threshold criterion.*

Pr19 Indicator - Acidification

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Average saturation rate of calcite near the bottom (>100 m) | 2 | | | | | | 2 | 2 | 2 | 2 |
| Average saturation rate of aragonite near the bottom (>100 m) | 1 | | | | | | 1 | 1 | 1 | 1 |
| **Sum of scores** | 3 | | | | | | 3 | 3 | 3 | 3 |

State
High
Medium
Low
Not assessed

*Figure 44. Time series of the values for each of the measures associated with the Pr19 pressure indicator (Acidification of the benthic habitat [> 100 m]). The sum of the scores associated with the saturation rate status is used to assign an annual status to the indicator, which is colour coded as described in the legend to the right of the table.*

### 8.1.4. Pr20) Dissolved oxygen in the benthic habitat (> 125 m)

#### 8.1.4.1. Surveys

Data on dissolved oxygen were obtained mainly from the June and October–November AZMP missions (R1-AZMP; Appendix E), as well as from the multi-species surveys in August and September (R10-Multi sGSL and R11-Multi nGSL; Appendix E). The time series used dates back to 2002 in the targeted area. An average of 30 CTD profiles are taken every year in the benthic area.

#### 8.1.4.2. Data processing

As for indicator Pr2, horizontal grids are interpolated from all the data available for each 1-m depth zone. The bathymetric depth is then used at each grid point to determine dissolved oxygen on the bottom from the horizontal grid interpolated at that depth. The mean value in the benthic area is then calculated for the grid points with a depth > 125 m.

For dissolved oxygen, a fixed threshold is used to characterize the status of the indicator (Table 5). The thresholds for normoxia and hypoxia were set at 70% and 30%, respectively (Plante et al. 1998; Chabot and Dutil 1999; Chabot and Claireaux 2008; Brennan et al. 2016). Beyond these thresholds, certain organisms experience effects on their metabolism depending on their tolerance of hypoxic stress. In addition, only the grid points located in depths greater than 125 m are retained (as opposed to 100 m, which was used for the other indicators), since oxygen depletion problems are likely to occur below this depth. The proportion of waters deeper than 125 m in the MPA is around 50%, and approximately 25% of these waters are near the bottom in the benthic zone.

However, it should be noted that, given the fact that the lethal thresholds for many species are below 30%, any saturation value below that threshold is considered to cause serious stress (and very serious stress below 20%), even if the terminology used (“High” pressure), which was chosen to ensure consistency throughout the document, might suggest a lower level of stress than that actually generated.

#### 8.1.4.3. Measures retained and state of knowledge

*Measure 1: Dissolved oxygen saturation value near the bottom (> 125 m)*

Surface oxygen concentrations are strongly influenced by seasonal mixing and photosynthesis and consequently are highly variable over time and, furthermore, are not limiting for benthic organisms living at depths above 125 m. Therefore, measures of near-bottom oxygen concentrations at depths greater than 125 m appear to be a better way of monitoring the pressure exerted by oxygen levels on benthic and demersal organisms. Oxygen concentrations directly affect the metabolisms of many organisms, including cod, Greenland halibut, northern shrimp and Atlantic Wolffish, in some cases, as soon as oxygen saturation drops below 70% (Chabot and Dutil 1999; Chabot and Claireaux 2008; Brennan et al. 2016). An oxygen saturation level of 30% is generally used to describe hypoxic conditions in the waters of the Gulf of St. Lawrence (Plante et al. 1998). This threshold corresponds to areas avoided by Atlantic cod. Only a few species, including northern shrimp and Greenland halibut, are capable of tolerating hypoxic conditions at oxygen saturation levels below 20% (Dupont-Prinet et al. 2013a, 2013b).

*Results*

The near-bottom (> 125 m) oxygen saturation level increased somewhat between 2002 and 2014, from 49% to 68% but, in more recent years, has rapidly declined, returning to the saturation levels found at the start of the time series (Figure 45). Therefore, the mean saturation level in 2020 was 50%.

*Status and trend*

The status of the Pr20 indicator has been "Medium" throughout the time series (Figure 45), with no significant trend identified.

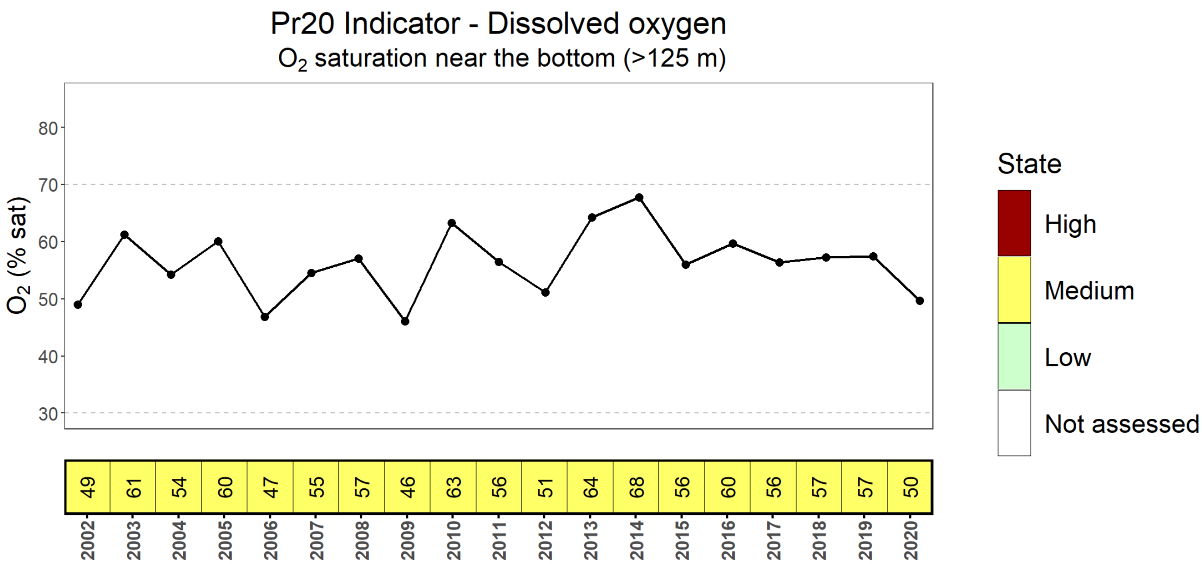



*Figure 45. Time series of the values of the measure associated with the Pr20 pressure indicator (Dissolved oxygen). The grey dashed lines represent the limits of the intervals associated with the different statuses (> 70%: Low; 30-70%: Medium; < 30%: High). The strip below the graph shows the value obtained for each year, colour-coded according to a known threshold criterion.*

## 8.2. PRESENCE OF AQUATIC INVASIVE SPECIES (AIS)

At this time, no aquatic invasive species (AIS) have been confirmed in the Banc-des-Américains MPA, although some encrusting AIS have been observed in the Gaspé region (e.g. *Membranipora membranacea*) (Simard et al. 2013). Potential eDNA monitoring of AIS is envisaged; however, the collection of data for this indicator has not been deemed a priority. As a result, no measures associated with AIS have been included in this report.

## 8.3. COMPETITORS/PREDATORS

### 8.3.1. Pr4) Grey seal

The grey seal has been added as a pressure indicator, since it is a significant predator in demersal communities in the Gulf of St. Lawrence (DFO 2011a; Swain and Benoît 2015). Seal abundance in the MPA area can be considered an indirect indicator for assessing the status of, and changes in, the demersal communities in the MPA. However, it should be noted that, because grey seals undertake daily migrations of up to 30 km, and even over 60 km in some cases (Goulet et al. 2001), monitoring these animals in the MPA cannot provide exact information on their presence there, but only their presence in the larger area.

Systematic aerial surveys are typically performed by DFO every five years (Hammill et al. 2017). In addition, the capacity and expertise required to conduct pinniped surveys will be developed by the Mi'gmaq Wolastoqey Indigenous Fisheries Management Association (MWIFMA) under a contribution agreement, in collaboration with Forillon National Park. Surveys to determine the size of the grey and harbour seal populations, as well as the inventory and mapping of potential haul-out sites, will be conducted.

Since no data have been analyzed yet, the measures to be used and the state of knowledge are not described in this rapport.

### 8.3.2. Pr5) Lobster on the ridge

Lobster is a major benthic predator (DFO 2014) and could have impacts on benthic and demersal communities in the MPA, for example, by competing with other species usually present there. Since lobster populations in the Gaspé are increasing (DFO 2016, 2019e), it was decided that the presence and abundance of lobster on the ridge should be monitored, since the depths in this area correspond to those potentially used by this species.

An imaging survey using baited equipment is being developed. An exploratory mission took place in the summer of 2020, and a sampling protocol will be developed. Since the survey is still under development, data processing, the measures to be used and the state of knowledge are not presented in this report.

## 8.4. NOISE

### 8.4.1. Pr6) Anthropogenic noise

To date, no database has been analyzed to assess noise in the Banc-des-Américains MPA. This indicator will be developed notably through data acquisition and a baseline characterization of the area.

### 8.4.2. Pr7) Traffic intensity

#### 8.4.2.1. Surveys

The data used to characterize the intensity of vessel traffic in the MPA were obtained from an AIS (Automatic Identification System) database provided by the Canadian Coast Guard (R18-AIS; Appendix E). The Innovation Maritime research centre was mandated in January 2020 to extract and analyze traffic data for MPA monitoring purposes. The data currently available for the area cover the period from March 2012 to December 2019. All types of AIS signals (i.e. Class A and Class B) were considered. The two transceiver systems have a number of differences but, for the purposes of these analyses, the most important one is transmission frequency. Position reports for Class A vessels are transmitted at intervals of between 2 and 10 seconds, whereas Class B reports are transmitted every 30 seconds. In addition to positioning information, AIS data include so-called static information about vessels, such as size, name and type. In cases when this information was not transmitted (less than 2% of vessels), other data sources were used to complete this information.

#### 8.4.2.2. Data processing

Innovation Maritime produced annual and monthly statistics for the entire period, based on predefined vessel categories (Table 17). Following a preliminary analysis of the results, it was decided that the Merchants and Passengers categories should be combined in the new category of Commercial. The largest vessels, which are required to use AIS, are found in these two categories (Figure 46) and, therefore, all traffic in these categories is monitored. The Marine Operations category was also taken into account, as it represents a large number of transits in the MPA (nearly 25%, Table 17 and Figure 47). The Fishing and Recreational Boaters categories are not considered, because the related AIS data are too fragmented and thus do not provide a representative picture of these sectors. Moreover, the average vessel size in these categories is much smaller. Lastly, data on the Observation Cruises category has only been obtained since the summer of 2019. These data will be taken into account in another indicator, Pr8 (Intensity of observation and recreational activities), once a time series becomes available.

The two measures are presented in the form of annual means. Since three months of data are missing (January–March) for 2012, that year was not included, and 2013–2018 was used as the reference period. Data for the Pr7 indicator are presented using directional anomalies, since they are directly related to the following priority issue: *Minimize the negative impacts of human activities to maintain suitable habitat for at-risk whale populations*. Therefore, an increase in commercial traffic and marine operations could have an impact on noise disturbance and adversely affect marine mammals in the area.

*Table 17. Categories of vessels in AIS data from 2012 to 2019.*

| Categories | Types of vessels | % of total number of passages |
|---|---|---|
| **Merchants** | Cargo, tanker | 33.6 |
| **Marine Operations** | Tugboat, dredger, pilot boat, research, coast guard, icebreaker, military, patrol boat | 24.4 |
| **Passengers** | Cruise ship, ferry | 18.8 |
| **Fishing** | Fishing vessel | 7.8 |
| **Recreational boaters** | Pleasure boat, yacht, sailboat | 15.3 |
| **Observation cruises** | Whale watching cruise company | *nd (just in 2019)* |
| **Unknown** | Information not available | 0.1 |

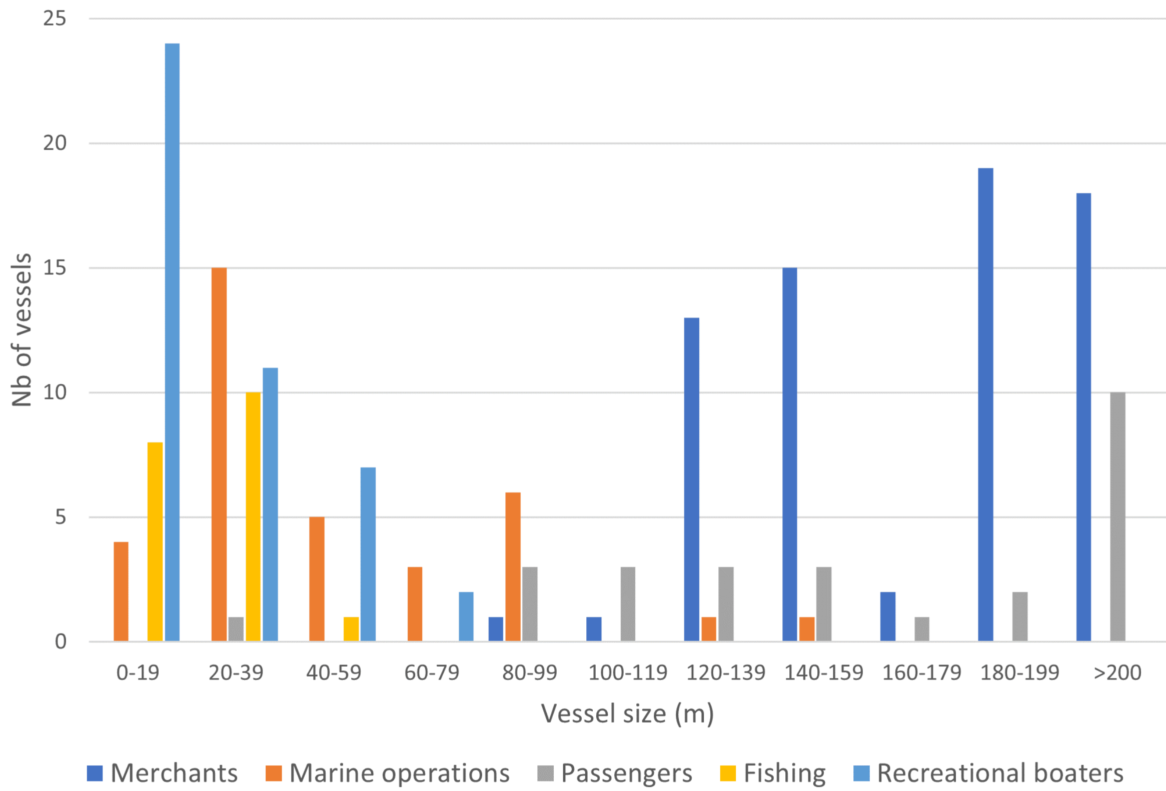



*Figure 46. Total number of vessels of each type by size class.*

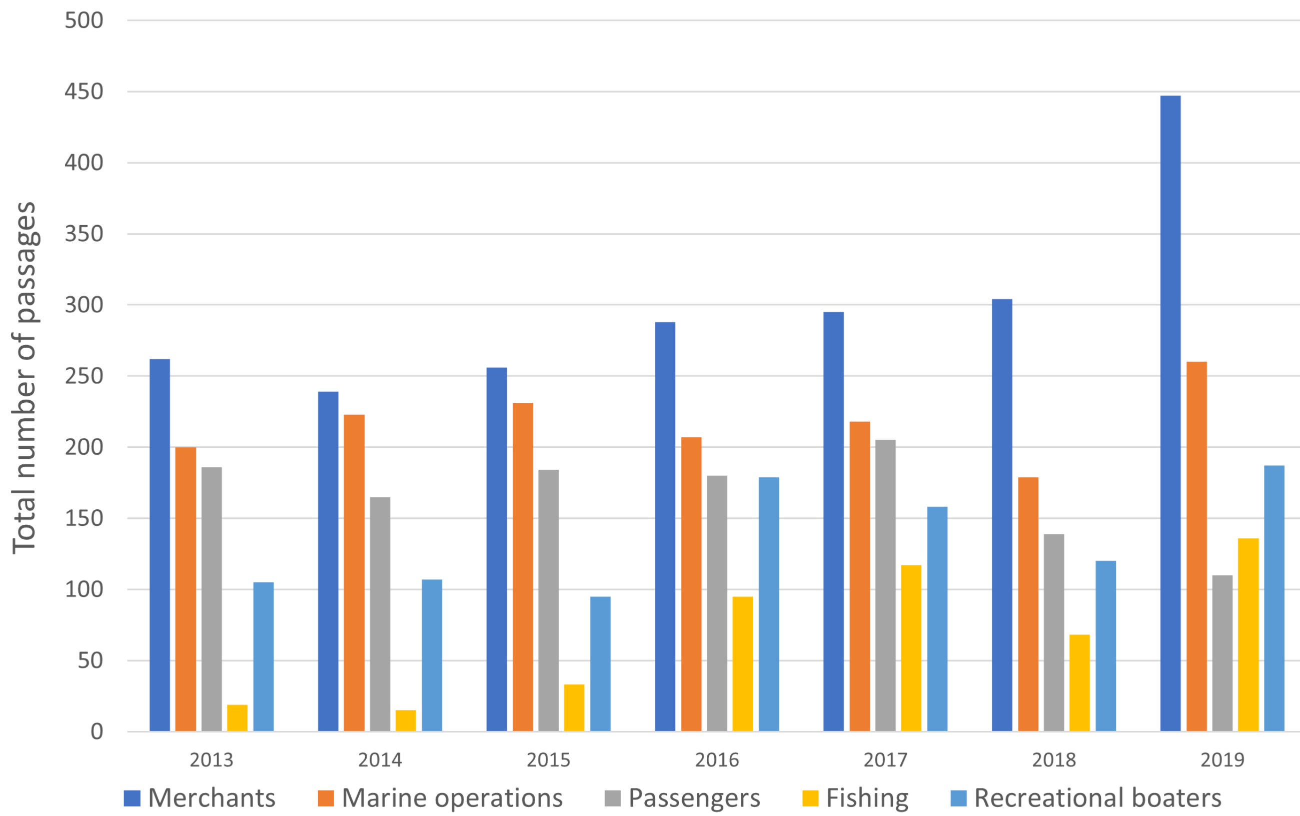



*Figure 47. Number of transits in the MPA per year by vessel type.*

#### 8.4.2.3. Measures retained/not retained and state of knowledge

*Measures 1 and 2: Total number of passages for commercial traffic and marine*

Indicator Pr7 (Traffic intensity) is used as a proxy indicator to provide information on potential disturbance due to noise. The greater the traffic intensity, the greater the potential risk of disturbance to marine mammals from noise. The total number of transits (i.e. passages) represents the sum of all transits within the boundaries of the MPA by all vessels in a given category in a given year. Therefore, a vessel could make several transits per day if it sails through the MPA at different times of the day.

*Measures 3 and 4: Total transit time in the BDA for commercial traffic and marine operations*

Total transit time was retained as a complementary measure to the total number of passages. Since 2017, slowdown measures (speed < 10 knots) have been in place in the area from May to November to protect the North Atlantic Right Whale. A slowdown may possibly result in less noise but, since the transit will be longer, the noise will persist in the habitat longer. The total transit time is represented by the total annual number of hours of vessel presence in the MPA for the vessel categories considered.

*Results*

The total number of transits per year by vessels in the Commercial category trended upward beginning in 2013, in general exceeding the reference period mean of 450 transits (2013–2018). The peak was reached in 2019, with 557 transits of vessels in the Commercial category, which represents an average of 1.5 vessels transiting the MPA each day. A similar trend was observed in the number of transits in the Marine Operations category, which remained near the mean (210 transits per year) from 2013 to 2017, declined significantly in 2018, and then peaked in 2019. Commercial vessels are therefore responsible for roughly twice as many transits annually in the MPA than those in the Marine Operations category (Figure 48). As for the total annual transit time in the MPA, an increase has been observed for Commercial vessels since 2017, the value reaching nearly 1,000 hours in 2019. Total transit time for Commercial vessels remained relatively stable during the reference period, with nearly 400 hours in the MPA, but increased dramatically in 2019 (Figure 49).

*Status and trend*

Only the two measures related to the number of vessel transits were considered in the calculation of this indicator. During the reference period (2013–2018), the Pr7 indicator remained “Low.” The status of the indicator in 2019 was “High,” which can be explained by the increase in traffic in the Commercial and Marine Operations categories (Figure 49).

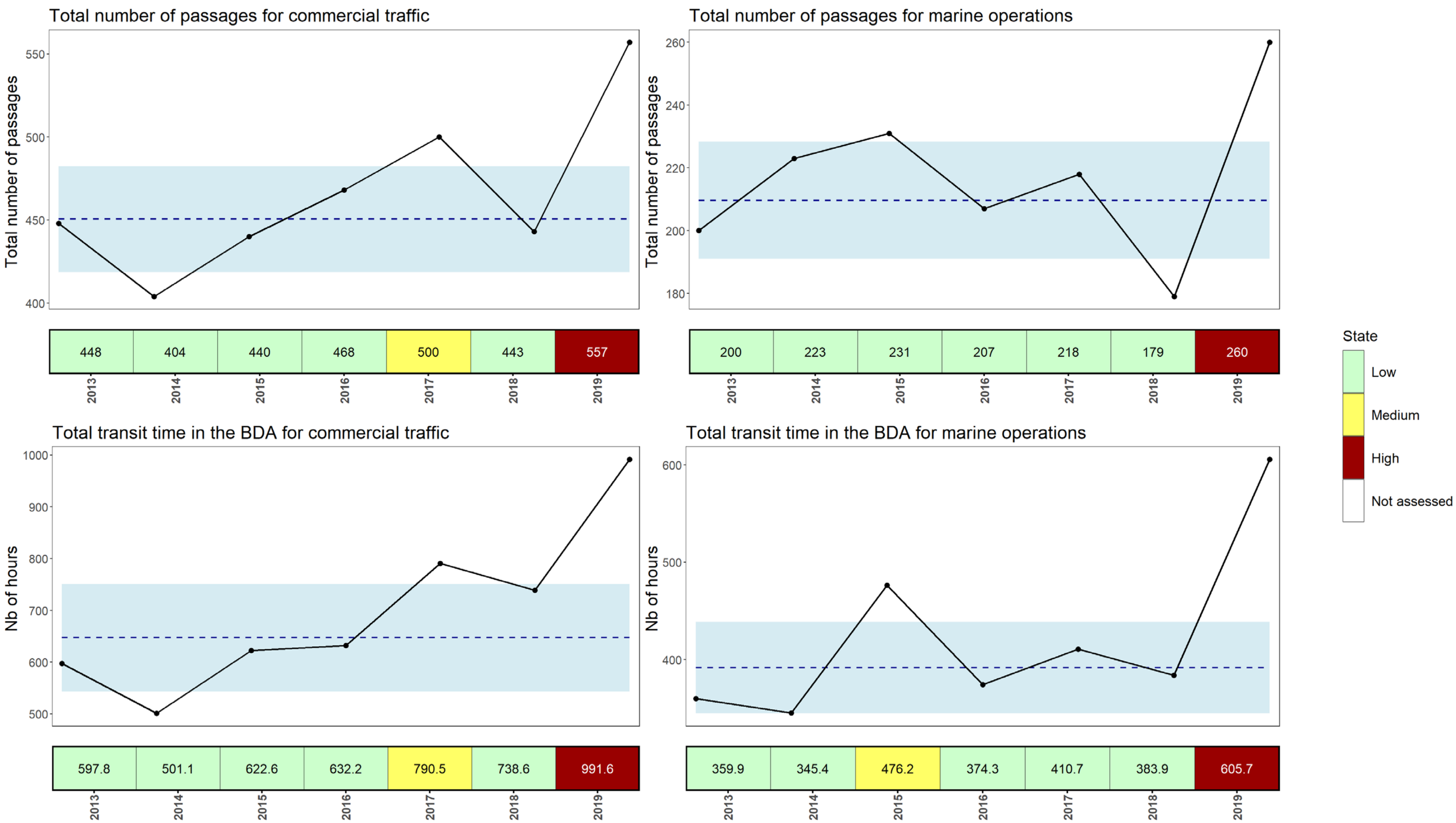



*Figure 48. Time series of the values of the measures associated with the Pr7 pressure indicator (Traffic intensity). The blue dashed line represents the mean conditions during the reference period (2013–2018), and the blue shading, the ±1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude and direction of the change observed in relation to the reference period (directional anomaly).*

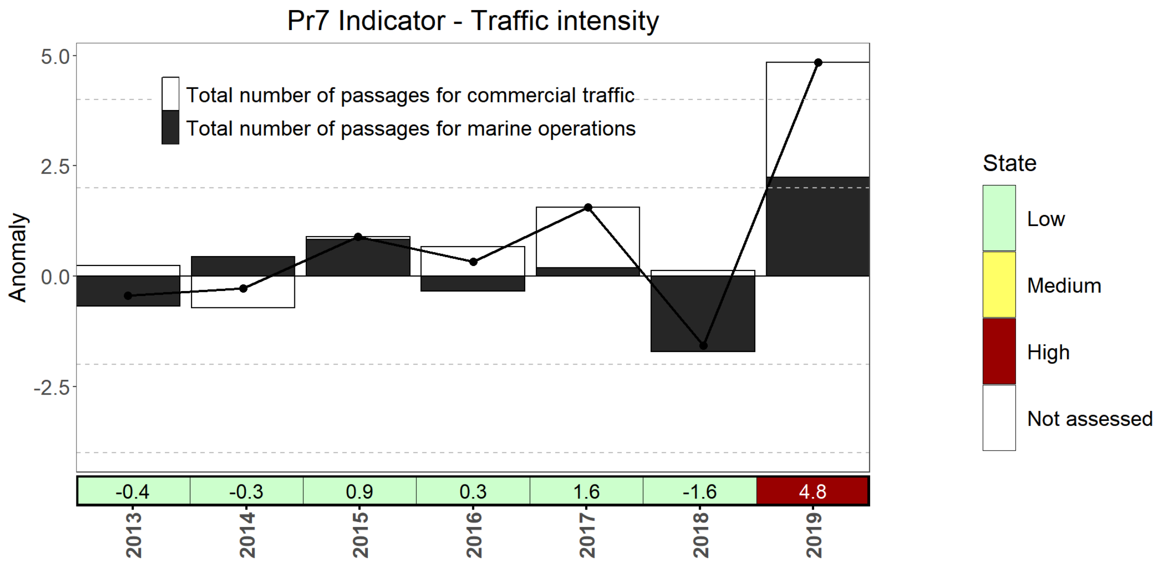



*Figure 49. Time series of anomaly values for each of the measures associated with the Pr7 pressure indicator (Traffic intensity). The black line corresponds to the sum of the actual anomaly values that are used to assign an annual status to the indicator, which is shown in the strip below the graph, colour coded according to its status.*

#### 8.4.2.4. Limitations

To date, the annual values of the measures involving vessel traffic have been used to provide information for the indicator, but monthly data are also available. Whether calculating measures for a specific period is useful will need to be considered. This period could take into account speed restriction (slowdown) measures for the North Atlantic Right Whale (in effect from May 1 to November 15 since 2018) in order to adopt a consistent approach. It would also be important to determine whether there is a more critical period for the marine mammals identified in the CO3 for the MPA.

## 8.5. DISTURBANCE

### 8.5.1. Pr8) Intensity of observation and recreational activities

This indicator is designed to provide information on commercial marine life observation activities, as well as recreational activities such as pleasure boating. At present, only the commercial observation component is addressed because no data are available on recreational activities.

#### 8.5.1.1. Surveys

*Activity reports for commercial marine tourism activities*

Since the Banc-des-Américains area was designated an MPA in 2019, cruise operators using the area for commercial marine tourism purposes must have an activity plan approved by the Department to be able to carry out their activities in the area. As well, under the *Banc-des-Américains Marine Protected Area Regulations*, an activity report containing the data collected, including travel dates and geographic coordinates, must be provided to the Department within 90 days of the last day of the activity. To make this task easier, since 2020, cruise operators with an approved activity plan have been given a data entry form to fill out (Appendix H). This annual report will help provide the information needed to document the intensity of marine life observation activities in the MPA.

Since 2006, the Marine Mammal Observation Network (Réseau d'Observation de Mammifères Marins, or ROMM) has also been characterizing marine life observation activities around the Gaspé Peninsula and, as a result, has amassed a bank of information on the presence of marine mammals and vessels. In 2015, DFO mandated ROMM to develop an initial portrait of marine life observation activities in the Banc-des-Américains area. Consequently, from December 9, 2015 to January 6, 2016, ROMM conducted a survey of the companies concerned. Survey questions focused on the fleet of vessels used, the duration of tours, the targeted species and the preferred locations for observing marine mammals (ROMM 2016, 2019a, 2019b).

#### 8.5.1.2. Data processing

Since no historical data were available for this indicator, the measures will be analyzed and assessed after commercial tourism activities in the Banc-des-Américains MPA have been monitored for several years. Nevertheless, an initial qualitative portrait based on ROMM data and a review of activity report data has been provided here, along with a description of the measures to be used in the future.

#### 8.5.1.3. Measures retained and state of knowledge

*Measure 1: Total number of marine observation trips*

This measure represents the total number of marine observation tours during the season run by commercial tourism companies with a Department-approved activity plan for the Banc-des-Américains MPA.

*Measure 2: Average trip duration*

This measure represents the average duration of marine observation tours during the season run by commercial tourism companies with a Department-approved activity plan for the Banc-des-Américains MPA.

*Measure 3: Number of observation vessels*

This measure represents the total number of vessels to be used during the season by commercial tourism companies with a Department-approved activity plan for the Banc-des-Américains MPA.

*Measure 4: Length of the marine observation season*

This measure corresponds to the earliest start date and the latest end date of the marine observation season across all commercial tourism operators with a Department-approved activity plan for the Banc-des-Américains MPA.

These four measures make it possible to generally assess the intensity of marine life observation activities in the Banc-des-Américains MPA. The main threats associated with these activities are disturbance caused by vessel noise and the risk of disturbance to and collisions with marine mammals.

*Results – Initial portrait*

According to the results of the survey conducted by ROMM in 2015–2016, seven marine observation companies were operating in the Banc-des-Américains area, two in Percé and five in the Gaspé area. The seven companies owned a total of 14 vessels, five large ones (accommodating 80–150 passengers), four medium-sized ones (for 40–50 passengers), four zodiac vessels (accommodating 12–25 passengers) and one sailboat (for six passengers; Table

18). In the main, activities started in early June and ended in mid-October, with the high season running from mid-July to mid-August. The number of tours, lasting an average of two and a half hours each, varied from one to four per day, depending on demand and the weather (ROMM 2019a; Table 18).

*Results – Activity reports*

In 2019, four companies submitted an activity plan and received departmental approval to conduct commercial tourism activities in the Banc-des-Américains MPA, compared to two companies in 2020. This decline is partly due to the impact of COVID-19. In 2019, the four companies owned a total of six vessels. The season started in June and ended in late October with tours lasting an average of two hours and 45 minutes. Owing to the inaccurate data reported in 2019 by firms, it was impossible to accurately determine the total number of marine life observation tours run that year. In 2020, the two companies owned a total of two vessels and gave a total of 99 tours during the season (Figure 50). The season started in July and ended in late September with tours lasting an average of two hours and 45 minutes.

*Status and trend*

Since accurate data are not available for the measures retained, the status of the Pr8 indicator is not assessed in this document.

*Table 18. Summary of data on intensity of marine life observation activities based on the initial portrait by ROMM (2019a) and activity reports.*

| Measures | Initial Portrait (2015–2016) | Activity Reports 2019 | Activity Reports 2020 |
|---|---|---|---|
| Number of companies | 7 | 4 | 2 |
| Total number of observation trips | Between 1 and 4 per day | na | 99 (59 in July, 34 in August and 6 in September) |
| Average trip duration | 2h30 | 2h45 | 2h45 |
| Number of observation boats | 14 | 6 | 2 |
| Length of the observation season | Mid-May to mid-October (about 150 days) | Beginning of June to end of October (about 150 days) | Beginning of July to end of September (about 90 days) |

### 8.5.1.4. Limitations

No annual survey has been established that has collected data in the past on marine life observation activities in this area. However, some data collected in more recent years can be used to document the measures retained. Since these data come from different sources (e.g. ROMM, companies with an approved activity plan for the Banc-des-Américains MPA) and have different purposes, they are not comparable and are described for each source separately. As a result, the status of the indicator could not be assessed. In the future, the information collected from activity reports based on DFO’s detailed data entry form (Appendix H) will allow the collection of standardized data on these activities. In addition, since 2020, most marine observation companies have procured AIS beacons. The use of the resulting AIS traffic data could allow other measures associated with this indicator to be identified for monitoring purposes.

The Pr8 indicator also includes a recreational boating component, which has not been assessed for now, because no data are available. An initial portrait of recreational boating (number of marinas, number of members, etc.) in the area is underway in collaboration with MMAFMA.

## 8.6. COLLISIONS STOP

### 8.6.1. Pr9) Vessel speed

#### 8.6.1.1. Survey

The data used to characterize the speed of vessel traffic in the MPA come from an AIS database provided by the Canadian Coast Guard (R18-AIS; Appendix E). For more information, see section 8.4.1.4.

#### 8.6.1.2. Data processing

For vessel speed, the data were processed in the same way as described in section 8.4.1.4. In addition, daily data on each transit through the MPA were analyzed in order to compile the total number of transits (commercial and marine operations) with a speed greater than 10 knots.

#### 8.6.1.3. Measures retained and state of knowledge

*Measures 1, 2 and 3: Average speed of commercial and marine operations vessels and number of runs that reached a speed > 10 knots*

Vessel speed can provide information on collision risks. Published studies and research results show that the likelihood of a fatal collision between a whale and a large vessel is higher when the vessel is travelling at speeds greater than 10 knots. In addition, reducing vessel speed would reduce the risk of these fatal collisions, to different degrees depending on the species (Vanderlaan and Taggart 2007; Conn and Silber 2013).

*Results*

The average annual speed of commercial vessels transiting the MPA remained stable from 2013 to 2016, at close to 13 knots. It then fell sharply to an average of 10.6 knots in 2019. The average speed of Marine Operations vessels hovered around the reference period mean of 11.9 knots from 2014 to 2018. A higher speed of 13.5 knots was observed in 2013, while the lowest average speed of 8.7 knots was observed in 2019. The annual number of transits through the MPA exceeding 10 knots was stable from 2013 to 2016 at slightly above the average, with values ranging from 400 to 450 transits. A sharp drop was observed from 2016 onwards with about half as many transits through the MPA at a speed over 10 knots (Figure 50).

*Status and trend*

Since 2013, the status of the Pr9 indicator has shown an improving trend, changing from "Medium" to "Low" (Figure 51). Since 2014, this status has remained "Low" and the trend towards decreasing speed has continued, primarily due to the speed limit measures that Transport Canada has implemented since August 2017 to protect the North Atlantic Right Whale. This limit of 10 knots, which is in effect for more than half the year (from late April to mid-November in 2018–2020, from mid-August to mid-January in 2017) directly influences the total number of transits over 10 knots.

#### 8.6.1.4. Limitations

See section 8.4.1.4.

## 8.7. ENTANGLEMENTS

### 8.7.1. Pr10) Number of entanglements

#### 8.7.1.1. Surveys

The data used for the Pr10 indicator come from cases reported to QMMERN from 2012 to 2020. For more information, see section 7.2.3.

#### 8.7.1.2. Data processing

QMMERN data were filtered for the Gaspé and Percé municipalities and for all cetacean species. The total annual number of entanglements is shown. A method for assessing the indicator was not proposed because of the paucity of data and the high degree of uncertainty associated with them. Therefore, the anomaly method cannot be used, and a threshold was not defined.

#### 8.7.1.3. Measure retained and state of knowledge

*Measure 1: Number of cetacean entanglements*

This measure represents the total number of cetaceans entangled in gear and equipment and reported to the QMMERN call centre for the municipalities of Gaspé and Percé.

*Results*

From 2012 to 2020, three entangled Humpback Whales and one Common Minke Whale were reported to QMMERN in the municipalities of Gaspé and Percé (Table 19, Figure 33).

*Status and trend*

The status of the Pr10 indicator was not assessed. Data on this issue are scarce, and no logical threshold has yet been identified for categorizing the indicator. However, reporting the number of entanglements is still useful.

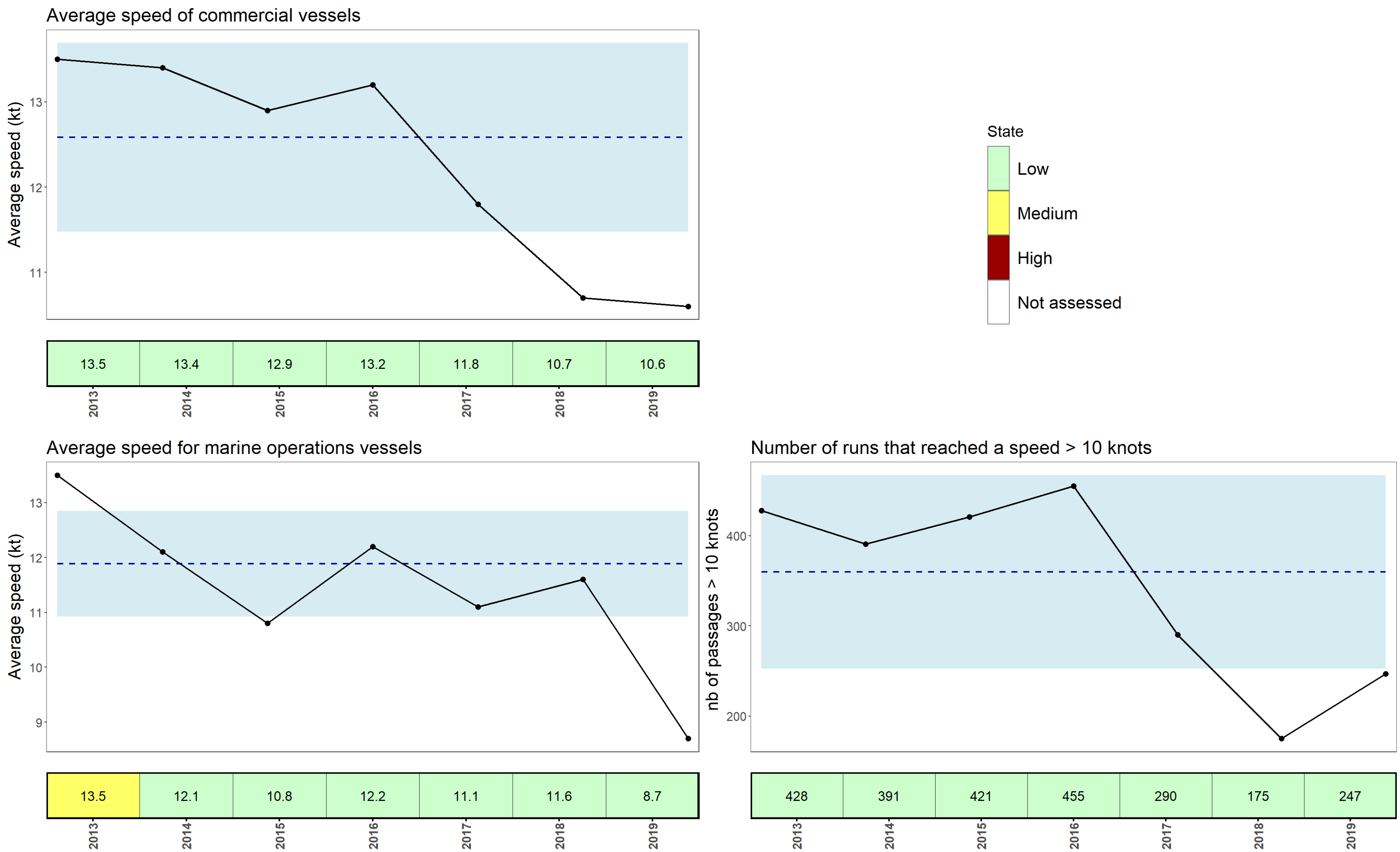



*Figure 50. Time series of the values of the measures associated with the Pr9 pressure indicator (Vessel speed). The blue dashed line represents the mean conditions during the reference period (2013–2018) and the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude and direction of the change observed in relation to the reference period (directional anomaly).*

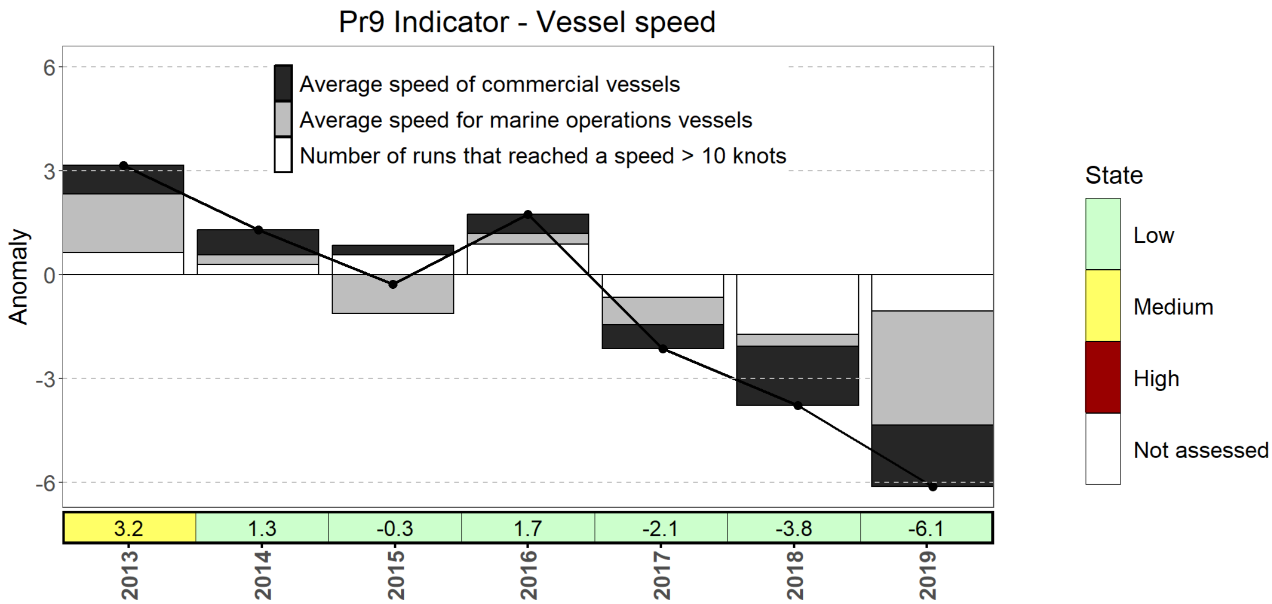



*Figure 51. Time series of anomaly values for each of the measures associated with the Pr9 pressure indicator (Vessel speed). The black line corresponds to the sum of the actual values of the anomalies that are used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

*Table 19. Number of cetacean entanglements from 2012 to 2020 in the municipalities of Gaspé and Percé reported to QMMERN.*

| **Reference period** | |
|---|---|
| Year | Entanglements |
| 2012 | 1 |
| 2013 | 0 |
| 2014 | 1 |
| 2015 | 0 |
| 2016 | 0 |
| 2017 | 0 |
| 2018 | 0 |
| Total | 2 |
| Mean | 0 |
| Standard deviation | 0,5 |

| **2019–2020** | |
|---|---|
| Year | Entanglements |
| 2019 | 2 |
| 2020 | 0 |

### 8.7.1.4. Limitations

Data were analyzed for the municipalities of Gaspé and Percé, providing an assessment of entanglements in the region, but not specifically in the Banc-des-Américains MPA. The MPA represents a relatively small area compared to the vast territory where marine mammals migrate and feed. In addition, entangled cetaceans continue to travel, thus making it difficult to know with any accuracy exactly where they became entangled.

## 8.8. PHYSICAL DISTURBANCE OF THE SEABEDS

### 8.8.1. Pr11) Relative footprint of the snow crab fishery

#### 8.8.1.1. Surveys

The data used to calculate the measures were obtained from ZIFF files (R14-ZIFF; Appendix E).

#### 8.8.1.2 Data processing

The time series of data from the ZIFF files covers the period from 2004 to 2018. Before 2004, the proportion of fishing activities in the logbooks with precise positions (latitude and longitude) was significantly lower. The snow crab fishing effort is determined by calculating the number of traps reported in the MPA each year. To assess the fishery's relative footprint, a grid with 1-$km^2$ cells was used to record fishing activities. Each point representing a fishing event is recorded in a grid cell. Next, the proportion of cells exposed to fishing events relative to all cells in the MPA is calculated.

The annual anomalies for these two measures are calculated based on the deviation between the annual mean and the reference period mean (2004–2018). The value of the anomaly is used to characterize the annual status of the measure (directional anomaly) since increasing the relative footprint of the fishery is contrary to CO1.

#### 8.8.1.2. Measures retained and state of knowledge

*Measure 1: Snow crab fishing effort (number of traps hauled)*

The snow crab fishing effort provides an estimate of fishing intensity and is expressed as the number of trap hauls reported in the MPA during the year.

*Measure 2: Proportion of the MPA affected by the crab fishery (%)*

The relative footprint of the snow crab fishery can be assessed by calculating the proportion of the MPA affected by fishing activities. This proportion can be used to estimate the area of the seabed that could potentially be subjected to physical disturbances, but does not represent the actual area affected by all fishing gear.

*Results*

The fishing effort estimated from the logbook data (ZIFF files) varied widely from 2004 to 2011. The number of trap hauls reported in the MPA almost doubled from 2011 to 2012, and then levelled off until 2016. An increase in the number of trap hauls was observed in 2017, with this number peaking in 2018 at 8,602. Since 2017, the values recorded for this measure have exceeded the reference period mean of 4,530 trap hauls. Much the same pattern can be observed in the proportion of the MPA affected by the snow crab fishery over the time series. Since 2013, this proportion has generally been higher than the reference period mean of 7.8% (Figure 52). In 2009 and 2018, the area affected by the snow crab fishery peaked at 12.2% and 11.3% of the MPA, respectively.

*Status and trend*

The status of the Pr11 indicator was generally “Low” from 2004 to 2018, although the sum of anomalies indicated an upward trend. This increase was reflected in a change of status in 2018 to “Medium,” like the one in 2009 (Figure 53).

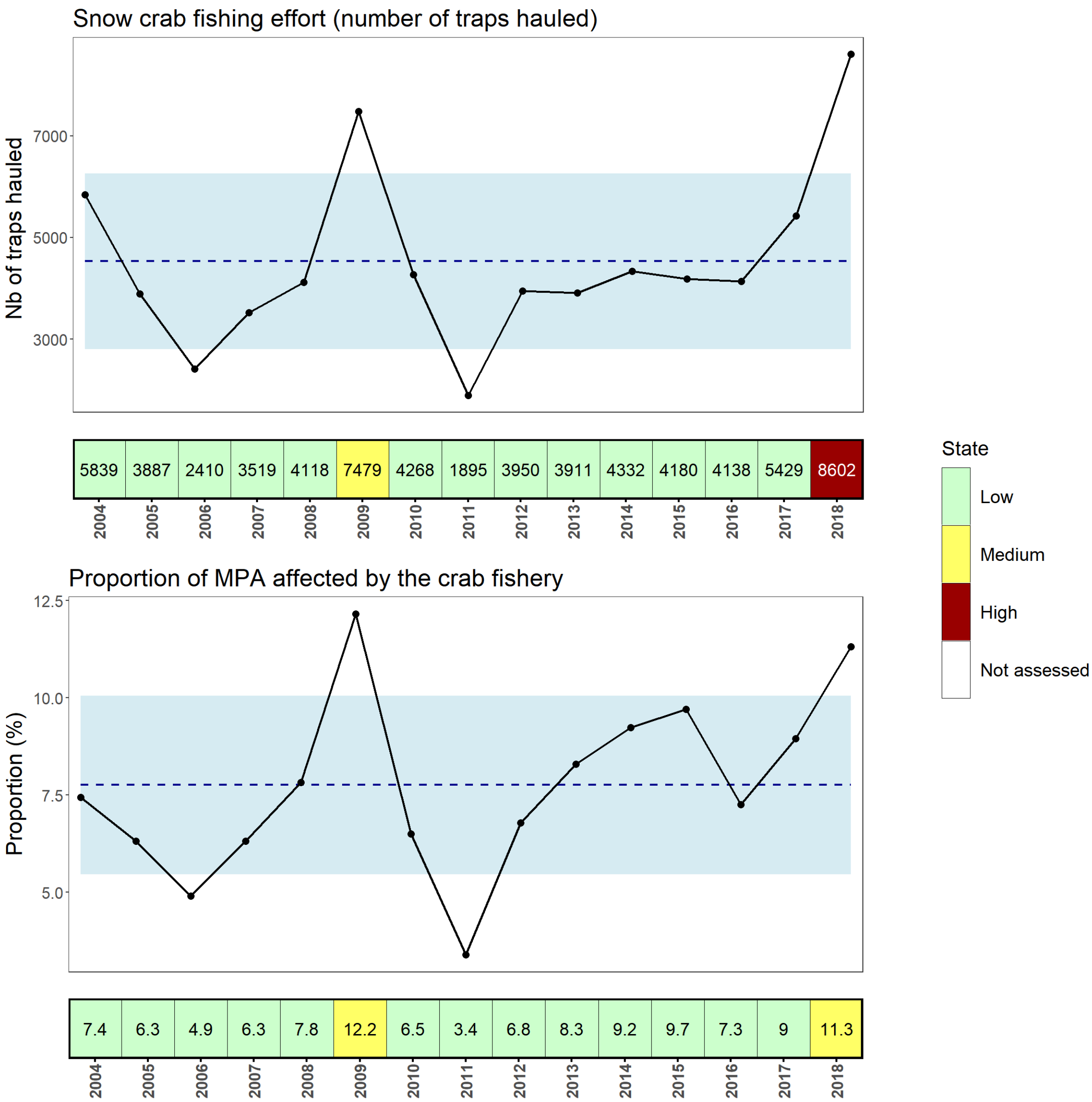



*Figure 52. Times series of the values of the measures associated with the Pr11 pressure indicator (Relative footprint of the snow crab fishery). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude and direction of the change observed in relation to the reference period (directional anomaly).*

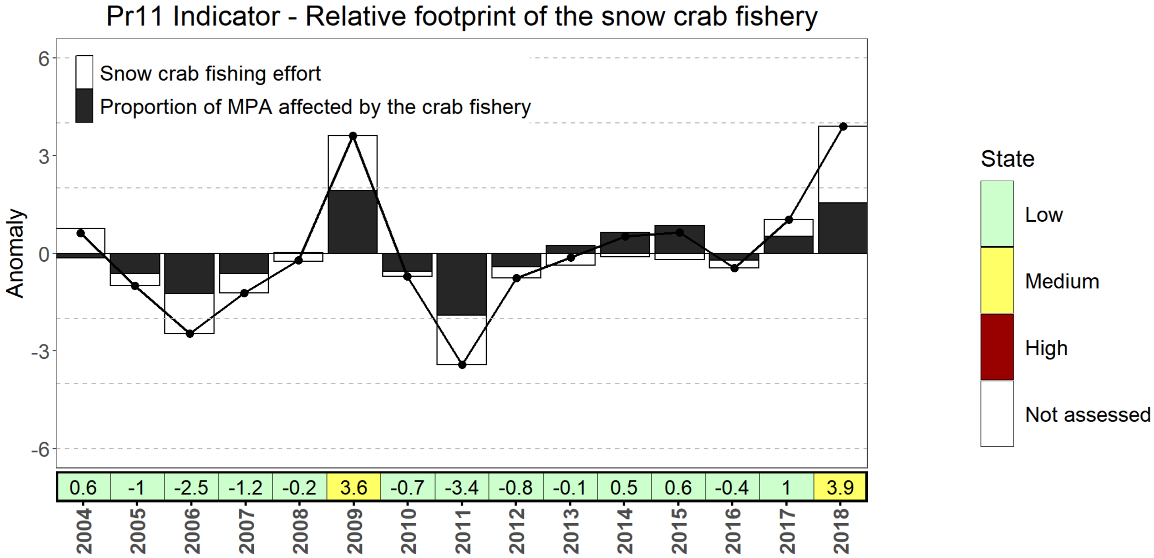



*Figure 53. Time series of anomaly values for each of the measures associated with the Pr11 pressure indicator (Relative footprint of the snow crab fishery). The black line corresponds to the sum of the actual values of the anomalies that are used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

### 8.8.2. Pr12) Relative footprint of the groundfish fishery

#### 8.8.2.1. Surveys

The data used to calculate the measures were obtained from the ZIFF files (R14-ZIFF, Appendix E). These files incorporate information from the logbooks completed by commercial fishers and provide fishing positions and landings (kg) of the various species. Some landings values are then adjusted using the data from the Dockside Monitoring Program (DMP).

#### 8.8.2.2. Data processing

The time series incorporating the data from the ZIFF files covers the period from 2004 to 2018. Before 2004, the proportion of fishing activities in the logbooks with accurate locations (latitude and longitude) was significantly lower. Only the longline groundfish fishery is still allowed to operate in the MPA. The data used for this indicator therefore relate to longline fishing activities. Longline fishing effort is reported in terms of the total number of hooks. To assess the relative footprint of this fishery, a grid with 1-km$^2$ cells was used to report fishing activities. Each point representing a fishing event is recorded in a grid cell. Next, the proportion of cells exposed to a fishing event in relation to all MPA cells is calculated. Note that this calculation is very approximate but is used to compare changes in the fishery over time.

The annual anomalies for these two measures are calculated based on the deviation between the annual mean and the reference period mean (2004–2018). The value of the directional anomaly is used to characterize the annual status of the indicator, since an increase in the fishing footprint can be expected to impact a greater proportion of benthic organisms, which is contrary to CO1.

#### 8.8.2.3. Measures retained and state of knowledge

*Measure 1: Groundfish fishing effort (total number of hooks)*

The longline fishing effort provides an estimate of fishing intensity and represents the total number of hooks used in the MPA during the year.

*Measure 2: Proportion of MPA affected by the groundfish fishery (%)*

The relative footprint of the longline fishery can be assessed by calculating the proportion of the MPA where fishing activities take place. This proportion makes it possible to estimate the area of the seabed potentially subjected to physical disturbance, but this does not represent the actual area affected by all fishing gear.

*Results*

No longline fishing was recorded in the MPA in 2004 and 2006. The total number of hooks deployed in the MPA fluctuated in the years between 2005 and 2013, generally remaining below the reference period mean of 47,765 hooks. A sharp increase was observed in 2014, when a peak of 143,600 hooks was reached. Since 2017, the longline fishing effort has been above the reference period mean (Figure 54). The relative footprint of the longline fishery has followed a similar pattern over the time series, peaking at 2.6% in 2014. Since 2017, the area affected by the groundfish fishery has exceeded the reference period mean of 0.9% (Figure 54); however, the reference period mean is still very low (less than 1% of the MPA).

*Status and trend*

The status of the Pr12 indicator has generally remained “Low” since 2004. It experienced a series of ups and downs beginning in 2004, and anomaly values were generally negative between 2004 and 2016. In 2014, the status of the pressure indicator shifted to “High” as a result of the simultaneous increase in fishing effort and the proportion of the MPA affected by longline fishing. Since 2016, the sum of the anomalies has increased, pointing to an upward trend. This increase is consistent with the higher CPUE value for the longline fishery and the increased abundance of groundfish (cod and halibut) seen in the values of the measures for the BD12 indicator. In 2018, the positive anomalies resulted in a change to “Medium” status. Lastly, the time series used (2004–2018) represents a low level of fishing compared to the 1980s and 1990s. However, owing to the lack of georeferenced data for this period, comparison over a longer reference period is not possible (Figure 55).

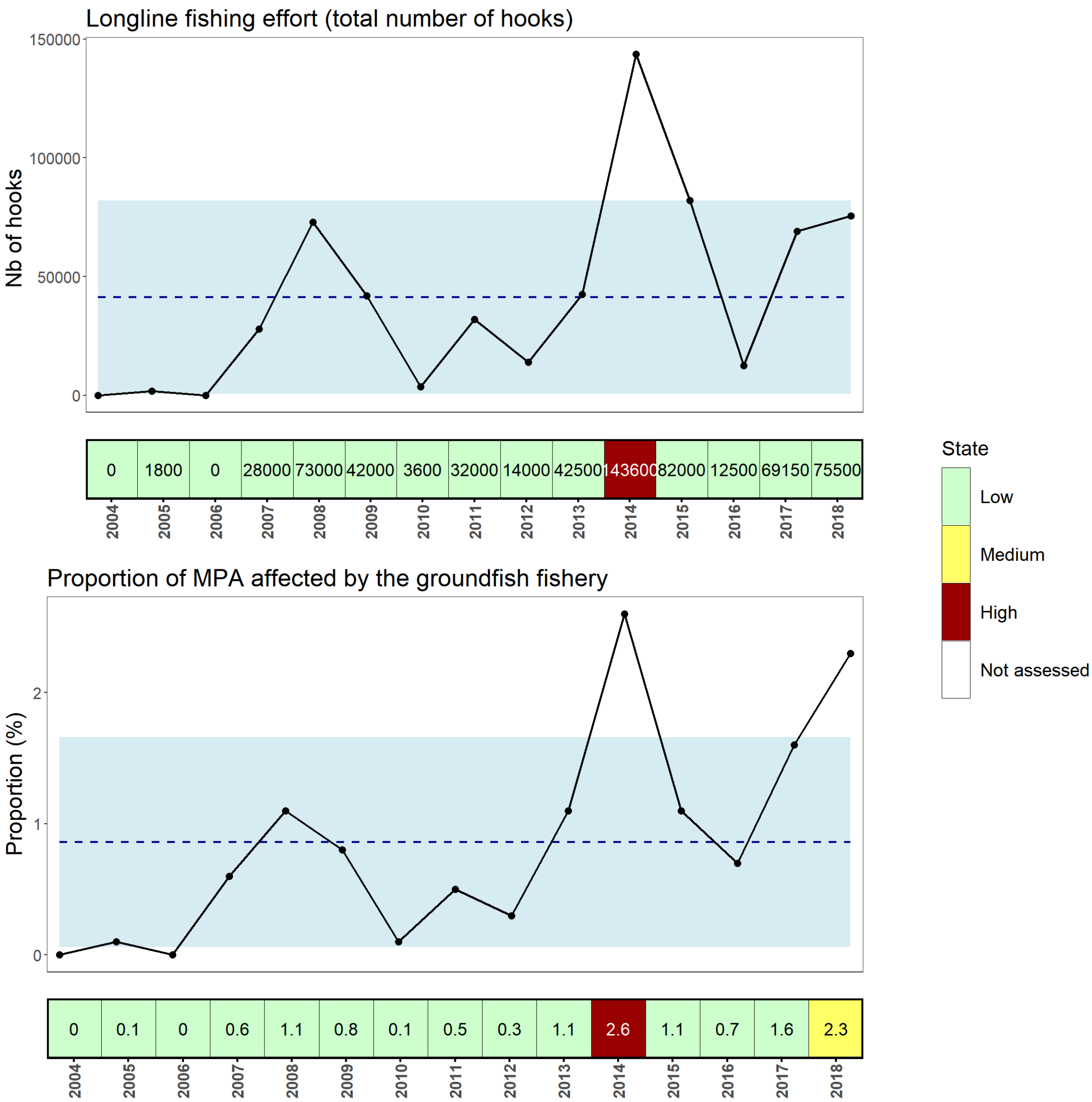



*Figure 54. Time series of the values of the measures associated with the Pr12 pressure indicator (Relative footprint of the groundfish fishery). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude and direction of the change observed in relation to the reference period (directional anomaly).*

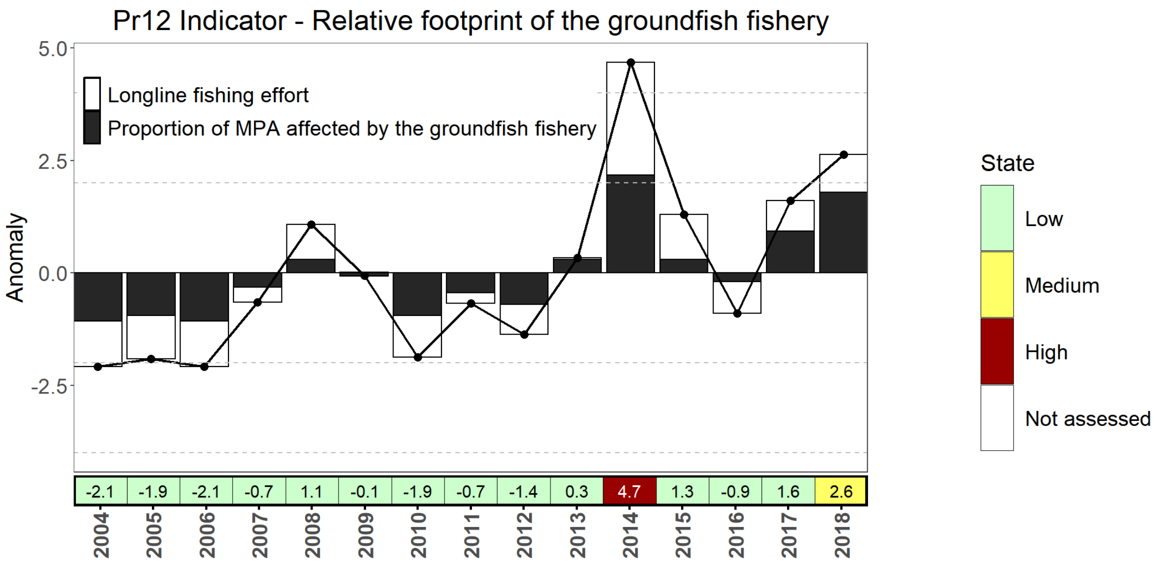



*Figure 55. Time series of anomaly values for each of the measures associated with the Pr12 pressure indicator (Relative footprint of the groundfish fishery). The black line corresponds to the sum of the actual values of the anomalies that are used to assign an annual status to the indicator, which is shown in the strip below the graph, colour coded according to its status.*

## 8.8.3. Pr13) Footprint of scientific activities

### 8.8.3.1. Surveys

The data used for this indicator are obtained from the multi-species bottom-trawl survey (R10-Multi sGSL; Appendix E), the sGSL snow crab bottom trawl survey (R13-Snow crab sGSL; Appendix E) and the imagery survey (RD1-Imagery). For more details, see sections 5.1.1. and 5.4.1.1. The benthic community imaging survey is under development, but a few tows were performed in the MPA between 2012 and 2020 using the benthic sled. Consequently, the area affected by the benthic sled was also taken into account in the estimation of the footprint of scientific activities.

### 8.8.3.2. Data processing

The footprint of scientific activities corresponds to the proportion of the MPA affected by scientific activities on the seabed. The number of tows performed annually in each of the three surveys varies over time. In some years, only one survey was carried out in the MPA (Table 20). The average swept area between the doors of a towed trawl corresponds to approximately 0.1402 km$^2$ in the sGSL multi-species survey (R10-Multi sGSL) and 0.0083 km$^2$ in the snow crab survey (R13-Snow crab sGSL) (Benoît et al. 2020). A benthic sled tow covers an average area of 0.00045 km$^2$. Two camera systems (drop cameras and baited cameras) are used to monitor epibenthic and demersal communities in the MPA. The drop camera system is deployed mainly on the ridge, while the baited camera system can be deployed both on the ridge (Zone 1) and the plains (Zone 2). The impact of these two systems on the seabed is negligible, which is why their footprint was not considered in the assessment of the Pr13 indicator. Table 20 shows the number of tows between 2012 and 2020. No method has yet been chosen to assess the status of this indicator.

*Table 20. Number of tows performed in the Banc-des-Américains MPA in scientific research surveys between 1985 and 2020.*

| Year | Trawl tows R10-Multi sGSL | Trawl tows R13-Snow crab sGSL | Sled lines RD1-Imagery | Deposited cameras RD1-Imagery | Baited cameras RD6-Bait. imagery | Total area ($km^2$) |
|---|---|---|---|---|---|---|
| 1986 | 3 | 0 | 0 | 0 | 0 | 0.4206 |
| 1987 | 3 | 0 | 0 | 0 | 0 | 0.4206 |
| 1988 | 2 | 0 | 0 | 0 | 0 | 0.2804 |
| 1989 | 1 | 7 | 0 | 0 | 0 | 0.1983 |
| 1990 | 2 | 5 | 0 | 0 | 0 | 0.3219 |
| 1991 | 0 | 6 | 0 | 0 | 0 | 0.0498 |
| 1992 | 3 | 6 | 0 | 0 | 0 | 0.4704 |
| 1993 | 4 | 6 | 0 | 0 | 0 | 0.6106 |
| 1994 | 2 | 6 | 0 | 0 | 0 | 0.3302 |
| 1995 | 2 | 7 | 0 | 0 | 0 | 0.3385 |
| 1996 | 2 | 0 | 0 | 0 | 0 | 0.2804 |
| 1997 | 2 | 6 | 0 | 0 | 0 | 0.3302 |
| 1998 | 3 | 6 | 0 | 0 | 0 | 0.4704 |
| 1999 | 2 | 6 | 0 | 0 | 0 | 0.3302 |
| 2000 | 3 | 6 | 0 | 0 | 0 | 0.4704 |
| 2001 | 2 | 6 | 0 | 0 | 0 | 0.3302 |
| 2002 | 3 | 6 | 0 | 0 | 0 | 0.4704 |
| 2003 | 2 | 6 | 0 | 0 | 0 | 0.3302 |
| 2004 | 2 | 6 | 0 | 0 | 0 | 0.3302 |
| 2005 | 3 | 6 | 0 | 0 | 0 | 0.4704 |
| 2006 | 0 | 7 | 0 | 0 | 0 | 0.0581 |
| 2007 | 0 | 7 | 0 | 0 | 0 | 0.0581 |
| 2008 | 1 | 7 | 0 | 0 | 0 | 0.1983 |
| 2009 | 3 | 7 | 0 | 0 | 0 | 0.4787 |
| 2010 | 2 | 7 | 0 | 0 | 0 | 0.3385 |
| 2011 | 1 | 7 | 0 | 0 | 0 | 0.1983 |
| 2012 | 1 | 4 | 14 | 135 | 0 | 0.1752 |
| 2013 | 1 | 4 | 69 | 0 | 0 | 0.1818 |
| 2014 | 1 | 6 | 0 | 76 | 0 | 0.19 |
| 2015 | 1 | 5 | 3 | 58 | 0 | 0.1821 |
| 2016 | 2 | 5 | 27 | 69 | 0 | 0.3252 |
| 2017 | 2 | 5 | 0 | 0 | 0 | 0.3219 |
| 2018 | 2 | 6 | 0 | 20 | 0 | 0.3302 |
| 2019 | 0 | 7 | 27 | 65 | 0 | 0.0614 |
| 2020 | 1 | 7 | 0 | 366 | 22 | 0.1983 |

#### 8.8.3.3. Measures retained and state of knowledge

*Measure 1: Science activities footprint (proportion of MPA affected)*

The science activities footprint is used as a measure of the proportion of the MPA affected (i.e. swept by tows) by the three science surveys. As proposed by Benoît et al. (2020), the annual proportion of the area affected by the three surveys can be calculated using the following formula:

$$\boldsymbol{Proportion\ of\ area\ impacted} = \frac{\text{Area swept by one tow}_s \ * \ \text{Number of tows in the year}_s}{\text{Area of the MPA}}$$

Thus, the proportion of the MPA affected is the area swept by an average standard tow in survey *S* multiplied by the number of tows carried out in survey *S* that year, divided by the area of the Banc-des-Américains MPA (1,000 $km^2$). The total footprint is measured by summing the annual proportion affected by the multi-species bottom trawl survey ($km^2$), the snow crab research survey ($km^2$) and the imagery survey (R10-Multi sGSL, R13-Snow crab sGSL, RD1-Imagery; Appendix E).

*Results*

The proportion of the MPA affected annually by scientific activities varies greatly over the time series. The minimum values observed generally coincide with the years when only the snow crab bottom trawl survey was being conducted in the area. A smaller area is swept by each tow in the snow crab research survey and benthic imagery survey than in the sGSL multi-species survey. The average proportion of the MPA affected by scientific surveys during the reference period is 0.00026 (0.026%). The lowest value was recorded in 1991 (0.005%), when only six tows for the snow crab survey were carried out, and the highest value in 1993, when more tows (10) were performed (0.06%) (Figure 56). Note that, despite this increase in scientific activities, the area affected by these activities remains very low throughout the time series, at less than 0.1%, compared with the area affected by the gear used in the commercial fishery (Figures 52, 54 and 56).

*Status and trend*

Although the value of the Pr13 indicator is variable over the time series, the proportion of the MPA affected annually by scientific surveys represents only a small percentage of the total area of the MPA, less than 0.1% (1 $km^2$) (Figure 56). The indicator was not assigned a status. It should be noted that the resulting pressure on the seabed is considered very low (below 0.1%) throughout the time series.

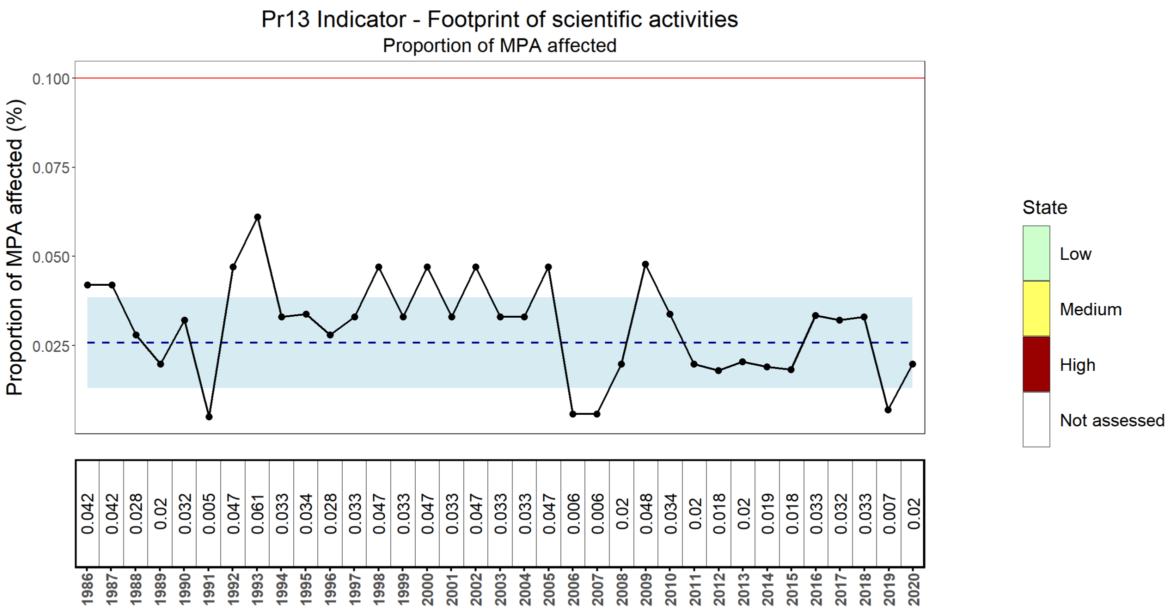



*Figure 56. Time series of the values of the measure associated with the Pr13 pressure indicator (Footprint of scientific activities). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The status could not be assessed. The red line represents 0.1% of the total MPA area (1 km$^2$).*

### 8.8.4. Pr14) Fishing activities – violations

This indicator was added to take account of fishing-related violations in Zones 1 and 2 of the MPA, which would increase the extent of disturbances to the seabed.

### 8.8.5. Limitations

Information in the ZIFF files on the location of individual fishing events may be incomplete. The percentage of georeferenced data has increased substantially in recent years, but a number of events were not covered and therefore were not considered in the calculations of fishing effort and footprint. Moreover, a single position (latitude and longitude) is recorded per landing, which may represent a full day of fishing activities. Consequently, the quantity of fishing gear reported to be operating in the MPA may include equipment that is also deployed outside the MPA. The unknown proportion deployed within the MPA leads to considerable uncertainty in the data. In addition, it is difficult to accurately assess the footprint of a fishing event, since only one position (latitude-longitude) is provided, while each trap's actual position on the bottom is not known. The number of traps reported for one logbook entry may vary greatly (from 1 to 300). The same issue occurs with longlines, since the position of the entire line is not known and the length of the line can vary (from 320 to 6,000 hooks). Therefore, the method used to calculate the spatial footprint of the commercial fisheries using a grid for each event is intended as an approximation, may result in overestimation, and is associated with a high degree of uncertainty. The key is to use the same method over time to ensure valid comparisons.

## 8.9. BIOMASS SAMPLING

### 8.9.1. Pr15) Snow crab fishery

#### 8.9.1.1. Surveys

The data used to calculate the measures for the Pr15 indicator come from the ZIFF files (R14-ZIFF; Appendix E). For more details, see sections 5.4.1.1. and 5.4.3.

The data used to estimate the exploitation rate for snow crab are derived from the ZIFF data and the sGSL snow crab bottom trawl survey (R13-Snow crab sGSL; Appendix E). For more information, see section 5.4.1.1.

#### 8.9.1.2. Data processing

The exploitation rate for snow crab is calculated by dividing the current year's commercial catches by the estimated biomass of commercial-sized males based on the previous year's bottom trawl survey.

The total landings in a given year, in tonnes, in the snow crab fishery is used to calculate the landed biomass in the fishery.

For this indicator, anomalies are calculated based on the deviation between the annual mean and the reference period mean (2004–2018). The value of the anomaly is used to characterize the annual status of the measure (directional anomaly). Since this pressure is exerted on snow crab populations in the MPA, an increase in the exploitation rate and the biomass harvested by the fishery is not considered desirable.

#### 8.9.1.3. Measures retained and state of knowledge

*Measure 1: Snow crab exploitation rate*

This measure enables the proportion of the exploitable population that is harvested annually to be quantified. The snow crab bottom trawl survey is conducted after the end of the commercial fishing season and after the annual recruitment of new commercial-sized crabs. Thus, the exploitation rate for year *y* is calculated as the ratio of the landed biomass in year *y* to the estimated commercial biomass in the previous year (*y-1*) (DFO 2012).

*Measure 2: Biomass of snow crab landings*

This measure is used to quantify the amount (biomass) of the resource that is removed from the MPA. It corresponds to the total landed weight (at dockside) and is expressed in tonnes per year.

*Results*

The snow crab exploitation rate ranged between 13% and 36% between 2004 and 2016. However, beginning in 2017, it climbed to 74%, which is well above the reference period mean of 22%. Indeed, in 2016, 2017 and 2018, the abundance of commercial-sized male crabs was at its lowest in the time series (Figure 17), which should be reflected in the biomass data. Exploitation rates measured in the MPA were lower than in Area 12 between 2004 and 2016, while, in 2017 and 2018, exploitation rates were higher than that of Area 12, with a rate below 44% (Hébert et al. 2018). In addition, the biomass harvested in the MPA over the time series has fluctuated in relation to the reference period mean of 239 tonnes. The highest landings were recorded in 2009, with nearly 433 tonnes harvested, while the lowest landings were recorded in 2011, with only 124 tonnes harvested. From 2013 onwards, landings declined, eventually dropping below the reference period mean (Figure 57).

*Status and trend*

The pressure level represented by the Pr15 indicator, which equals the sum of the anomalies for the two measures, was generally “Low” over the time series. However, its status changed to “Medium” in 2017 and 2018, attributable to the significant increase in the exploitation rate observed in those years. Note that the biomass of landings also increased between 2016 and 2018 (Figure 58).

### 8.9.2. Pr16) Groundfish fishery

#### 8.9.2.1. Surveys

Data extracted from the ZIFF files are used to calculate the measures for the Pr16 indicator (R14-ZIFF, Appendix E). For more details, see sections 5.4.1.1. and 5.4.3.

#### 8.9.2.2. Data processing

The landed biomass in the longline fishery is assessed by totalling all landings in a given year, expressed in tonnes.

Anomalies for this indicator are calculated based on the deviation between the annual mean and the reference period mean (2004–2018). A directional anomaly is used to determine the annual status of the measure. Since this pressure is exerted on the groundfish populations present in the MPA, an increase in the biomass harvested by the fishery is not considered desirable.

#### 8.9.2.3. Measures retained and state of knowledge

*Measure 1: Biomass of groundfish landings*

This measure is used as an indicator of the biomass removed from the MPA. It corresponds to the total weight of landings and is expressed in tonnes per year.

*Results*

The biomass removed by the longline fishery in the MPA between 2004 and 2013 remained fairly stable, and below the reference period mean of nearly 10 tonnes per year. Landed biomass increased significantly in 2014, to 27 tonnes from 7 tonnes in 2013. Since then, landed biomass in the longline fishery has remained above the reference period mean, except in 2016 when a significant decrease in landings was observed (Figure 59). Note that the reference period is from 2004 to 2018, or after the collapse of the groundfish fishery. The mean used is therefore very low compared with landings in the region in the 1980s and 1990s.

*Status and trend*

Between 2004 and 2013, the status of the Pr16 indicator was “Low”. Because of a sharp increase in landed weight in 2014, the status of the indicator moved to “Medium” that year, and remained there until 2018. However, a decline in the biomass harvested by the commercial fishery was seen in 2016, when the status of the indicator returned to “Low” for that year (Figure 60). Landings by the longline fishery appear to be increasing and to be following the same dynamic as the Atlantic halibut stock in Division 4RST (DFO 2019d). Similarly, the abundance of Atlantic halibut and Atlantic cod has been increasing in the MPA in recent years (Figure 19), making more resources available to the fishery.

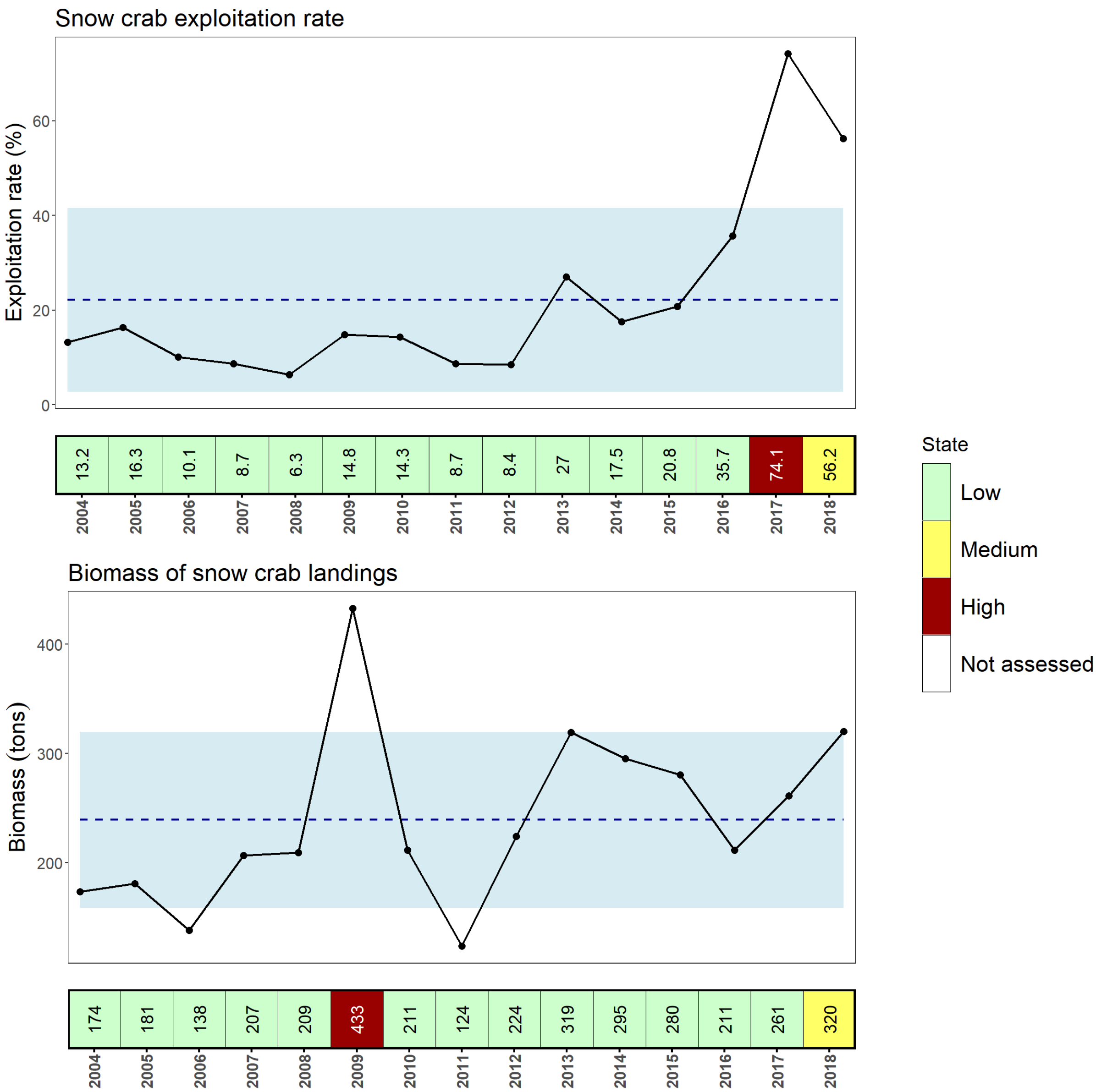



*Figure 57. Time series of the values of the measures associated with the Pr15 pressure indicator (Snow crab fishery). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this average. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude and direction of the change observed in relation to the reference period (directional anomaly).*

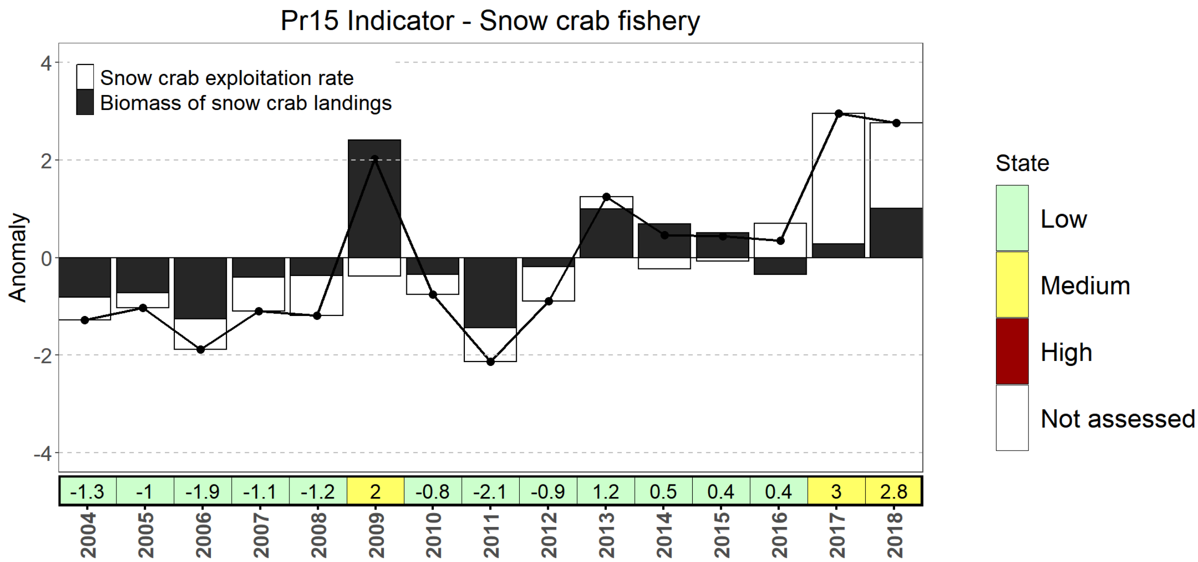



*Figure 58. Time series of anomaly values for each of the measures associated with the Pr15 pressure indicator (Snow crab fishery). The black line corresponds to the sum of the actual values of the anomalies that are used to assign an annual status to the indicator, which is shown in the horizontal strip below the graph, colour coded according to its status.*

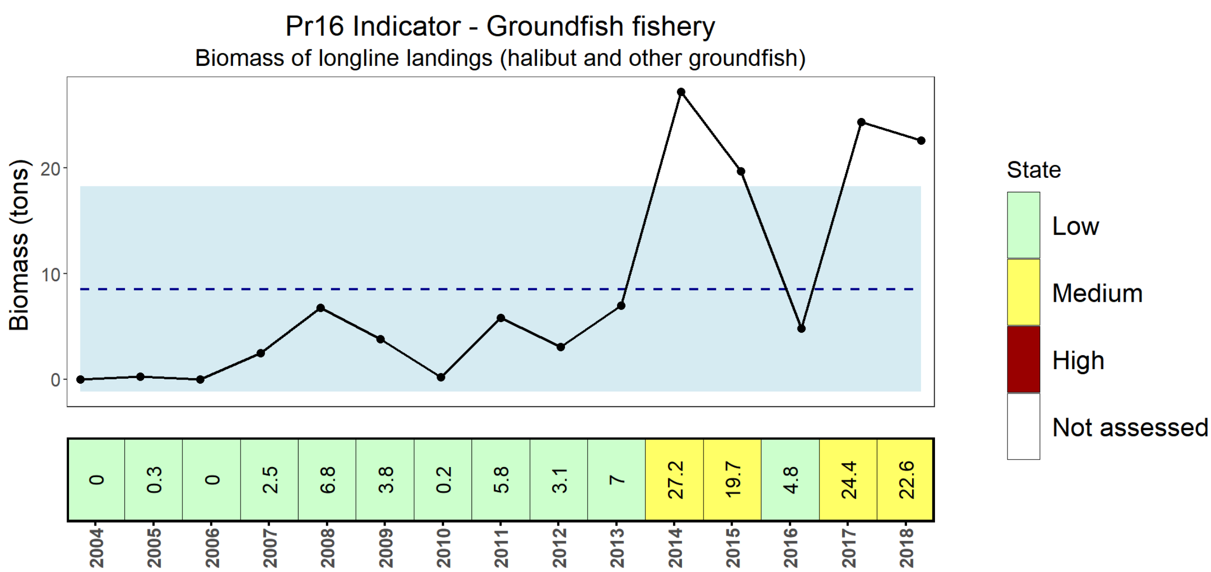



*Figure 59. Time series of the values of the measure associated with the Pr16 pressure indicator (Groundfish fishery). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The strip below each graph shows the value obtained for each year, colour-coded according to the magnitude and direction of the change observed in relation to the reference period (directional anomaly).*

## 8.9.3. Pr17) Fishing by scientific activities

### 8.9.3.1. Surveys

The data used for this indicator were obtained from the multi-species bottom trawl survey (R10-Multi sGSL; Appendix E). For more details, see section 5.1.1. Eventually, biomass data from the sGSL snow crab bottom trawl survey (R13-Snow crab sGSL; Appendix E) will be used in the calculation of total biomass harvested by scientific activities.

#### 8.9.3.2. Data processing

Total biomass corresponds to the weight (in kg) of all taxa (fish and invertebrates) caught per tow per year. For this measure, the actual biomass harvested (raw biomass) is used, rather than standardized biomass as in the other measures.

The reference period used is from 2004 to 2018. The entire time series is presented, i.e. from 1986 to the present. The status of the Pr17 indicator was not assessed since, given the very low biomass values, the anomaly method cannot logically be used, and no fixed thresholds were identified.

#### 8.9.3.3. Measures retained and state of knowledge

*Measure 1: Biomass harvested by scientific activities*

This measure is used as an indicator of biomass removal in the MPA, like indicators Pr15 and Pr16. For this first report, the status of the Pr17 indicator was assessed solely on the basis of data from the sGSL multi-species bottom trawl survey. Eventually, data from the snow crab research survey (R13-Snow crab sGSL) could be integrated in the assessment of the indicator.

*Results*

Biomass removed by scientific activities fell drastically at the beginning of the time series and then stabilized between 1994 and 2015, hovering around the reference period mean of 0.2 tonnes/year (Figure 60); during this period, the value of removals from the MPA remained mostly below the reference period mean. From 2016 onwards, the magnitude of the fluctuations increased. No biomass was removed from the MPA in 1991, 2006, 2007 and 2019, as no tows in the MPA were performed in the sGSL multi-species bottom trawl survey (Figure 60 and Table 20).

*Status and trend*

In 1986–1988, 1992–1993, and 2016, larger quantities of biomass were removed. However, the state of Pr17 indicator is still considered to be very low throughout the time series (less than 0.5 t, except between 1986 and 1988). The indicator was more variable at the beginning of the time series, as well as towards the end (i.e. from 2016 onwards), when the fluctuations in biomass were of greater magnitude. It is important to note that, for the time series as a whole, the total amount of biomass harvested in annual scientific activities was much lower than that recorded in the commercial fisheries (Figure 60).

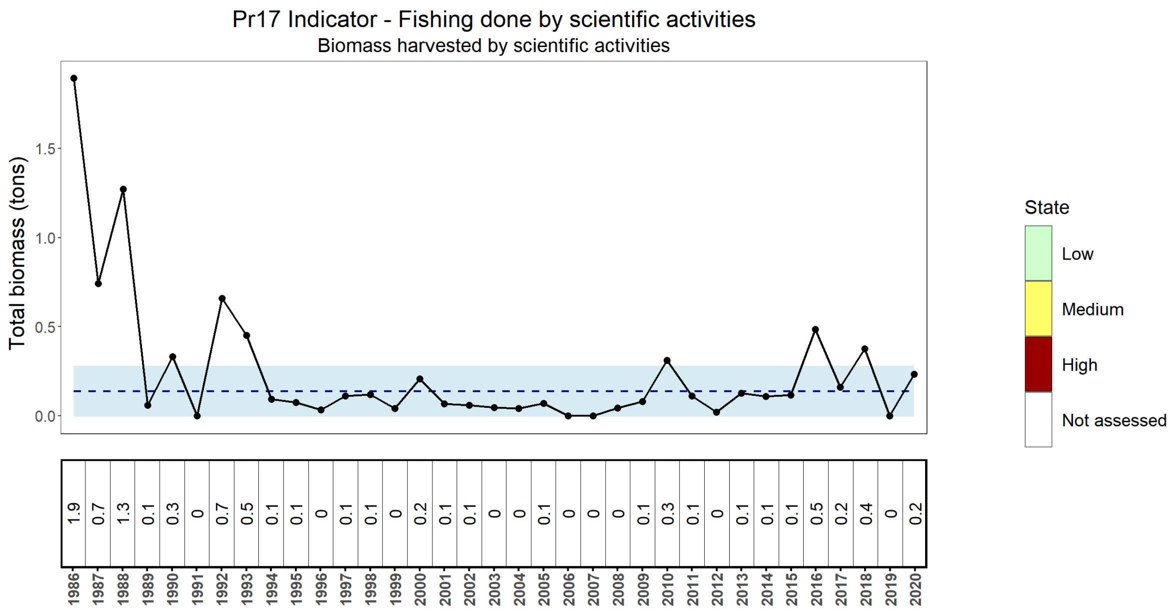



*Figure 60. Time series of the values of the measure associated with the Pr17 pressure indicator (Fishing by scientific activities). The blue dashed line represents the mean conditions during the reference period (2004–2018), and the blue shading, the ± 1 standard deviation around this mean. The indicator's status was not assessed.*

#### 8.9.3.4. Limitations

A major effort should be made to validate and standardize the bycatch data from the database produced from the snow crab bottom trawl survey (R13-Snow crab sGSL), before integrating these data in the calculation of the biomass harvested by scientific activities.

## 8.10. NEW PRESSURES

### 8.10.1. Pr18) Number of new pressures

This indicator was added in order to ensure that new pressures emerging in the MPA over the long term are monitored, even if these activities are not targeted by other indicators. No specific surveys are associated with this indicator, but activity plan applications submitted to the MPCD may, among other things, help in gathering information on this issue.

## 8.11. GHOST GEAR AND POLLUTION

At present, no indicators have been defined for these two pressures, since no data have been analyzed to date. A basic characterization is needed to validate the relevance of monitoring these pressures and inform the choice of indicators and measures.

# 9. PRIORITY INDICATORS AND NEXT STEPS

Producing results for all the indicators is a large-scale exercise that cannot be carried out at high frequency. In addition, for several indicators that are not likely to fluctuate rapidly, such as benthic communities, long-term data will be needed to discern any changes. It is more important to frequently produce results for indicators that are considered likely to change rapidly and that can lead to changes in management actions in the short term. It is therefore proposed that an interim report be produced at a higher frequency, which would be more succinct than a full monitoring report and would group together a few priority indicators. These interim reports could be in the form of short CSAS Science Responses, similar to what is done for some stock assessments. It is envisaged that these interim reports will be produced every three years. In this way, priority information would be made available, enabling management to react quickly to any significant changes. A complete monitoring report with an update of all indicators could be produced more frequently (to be determined) and its publication should be synchronized with the review of the management plan (MPCD) so that the information is available in a timely manner and can be easily interpreted.

Priority indicators should be closely linked to pressure indicators and be highly informative about the status of the MPA. Selection of the indicators to be included in the interim reports was based on:

1. the ease of producing results (data accessible annually and simple analyses);
2. their specificity to the MPA (favouring direct indicators); and
3. their capacity to trigger management action in response to a change observed in the short term.

Only some pressure indicators meet these three criteria and are proposed for the interim reports (Table 21). In addition, three indicators related to conservation objectives CO1 and CO3 that partially meet these criteria were retained to provide minimal information on these conservation priorities. None of the indicators for CO2 (pelagic) were retained, because they relate to a very large area in relation to the MPA and their variation could not lead to concrete management measures (indirect indicators). This list may be reviewed as needed.

*Table 21. List of priority indicators proposed for inclusion in the interim monitoring reports.*

**Indicators for conservation priorities**

| **Conservation priorities** | **Proposed priority indicators** |
|---|---|
| Benthic and demersal commercial species | BD11) Snow crab<br>BD12) Harvested groundfish |
| Whales | EP6) Cetacean mortality/accidents |

**Indicators for pressures pressions**

| **Pressures** | **Proposed priority indicators** |
|---|---|
| Noise | Pr7) Traffic intensity |
| Disturbance | Pr8) Intensity of observation and recreational activities |
| Collisions | Pr9) Vessel speed |
| Physical disturbance of the bottom | Pr11) Relative footprint of the snow crab fishery<br>Pr12) Relative footprint of the groundfish fishery<br>Pr13) Footprint of scientific activities<br>Pr14) Fishing activities – violations |
| Biomass removal | Pr15) Snow crab fishing<br>Pr16) Groundfish fishing<br>Pr17) Biomass removal by scientific activities |
| New pressure | Pr18) Number of new pressures |

## 10. CONCLUSION

Following updates to DFO's ecological monitoring plan for the Banc-des-Américains MPA, 44 indicators are presented in this document: 23 indicators associated with 15 conservation priorities and 21 indicators associated with 12 pressures. Measures were selected, described and calculated for the 27 indicators for which a database of validated information is available. These measures were calculated using a reference period in order to generate the state of knowledge on each indicator for the time series available. The spatial and temporal scales at which the measures were calculated were also described and reviewed. Because of the lack of data collected directly in the MPA, the indicators evaluated using data from DFO's sGSL multi-species bottom trawl survey were estimated for all of stratum 416. Consequently, the results must be interpreted by taking the spatial scale covered into account. In addition, the data were reviewed for six indicators, whose status could not be assessed due to the lack of available data, too much uncertainty surrounding the data, or simply the lack of an assessment method.

Priority issues were selected to guide the assessment of indicators and to link conservation objectives and the choice of pressures. The priority issues help clarify the direction of the expected changes, in order to assess the status of the indicators and measures. Two methods were retained: anomaly (the deviation from the reference period mean), which can be interpreted in a directional or bidirectional manner, and fixed threshold. Three condition categories were retained, as well as the "Not assessed" category. The status of the indicator was defined as corresponding to the sum of the anomalies of each of its associated measures or, when the threshold method was used, the sum of the scores for each measure. This methodology will provide a framework for the production of future monitoring reports and ensure a clear interpretation of the results in order to adequately inform management (MPCD).

For indicators that could not be presented in this process because of a lack of data or because the databases were not analyzed, the next steps will be prioritized by the BDA SMC. For indicators related to epibenthic communities, an imaging sampling protocol is being developed and will be presented in a technical report. This report will also specify the measures to be used and will provide an overview of existing data. In addition, the measures selected for benthic and demersal communities could be improved through the ecosystem approach (Quebec Region), which will specify trophic guilds and ecological indices that could be used.

Interim reports, which are more succinct than a full monitoring report, will be produced more frequently (e.g. every three years). Priority indicators have been selected for presentation in these reports between the assessments and the full monitoring reports. These indicators focus on direct pressures and three key indicators linked to conservation objectives CO1 (Conserve and protect benthic habitats) and CO3 (Promote the recovery of at-risk whales and wolffish). In this report, the status of the indicators over their respective time series was presented. The final status, or overall rating of the indicators, will be assessed and presented in future monitoring reports when a few years have passed since the establishment of the MPA. This overall rating will be weighted according to the confidence level associated with the available dataset for each of the indicator measures. This review presents a portion of the state of knowledge at the time the MPA was established and provides a portrait of the historical data for the area.

## AKNOWLEDGEMENTS

We would like to thank all the members of DFO's Scientific Monitoring Committee for the Banc-des-Américains MPA (BDA SMC), including Denis Chabot, Bernard Sainte-Marie, Marilyn Thorne, Valérie Harvey and Jacinthe Beauchamp, who have worked for nearly two years on developing the monitoring plan, sharing their expertise and reviewing this document. We are very grateful to Tobie Surette, Denis Gagnon and Nicolas Rolland for their help in sharing the databases from the Gulf region. This document was also made possible by the sharing of databases from Fisheries Management (provided by Alexandre McCutcheon, Julie Aucoin, Élaine Bouchard and Jean-François Bolduc) and from the QMMERN (provided by Méduline Chailloux and Robert Michaud). We would also like to highlight the excellent work done by Tom

Bermingham and Vincent Lamarre in analyzing and formatting certain databases. We are also grateful for the invaluable contributions of many scientists, such as Samuel Turgeon (DFO), Virginie Roy, Marie-Julie Roux and Stéphane Plourde, who took part in special meetings and workshops on specific themes.

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# APPENDICES

*Appendix A. Acronyms*

| Acronym | Definition |
|---|---|
| ADCP | Acoustic Doppler Current Profiler |
| AIS | Automatic Identification System |
| AIS | Aquatic invasive species |
| AOI | Area of interest |
| AZMP | Atlantic Zone Monitoring Program |
| BACI | Before after controls impact analyses |
| BDA | Banc-des-Américains |
| CIL | Cold intermediate layer |
| CO | Conservation objective |
| COSEWIC | Committee on the Status of Endangered Wildlife in Canada |
| CPUE | Catch per unit of effort |
| DFO | Fisheries and Oceans Canada |
| EBSA | Ecologically and Biologically Significant Area |
| ECCC | Environment and Climate Change Canada |
| eDNA | environmental DNA |
| GREMM | Group for Research and Education on Marine Mammals |
| MICS | Mingan Island Cetacean Study |
| MLI | Maurice Lamontagne Institute |
| MMON | Marine Mammal Observation Network |
| MPA | Marine protected area |
| MPCD | Marine Planning and Conservation Division |
| NAFO | Northwest Atlantic Fisheries Organization |
| nGSL | Northern Gulf of St. Lawrence |
| PAM | Passive acoustic monitoring |
| QMMERN | Quebec Marine Mammal Emergency Response Network |
| ROPOS | Remotely Operated Platform for Ocean Sciences |
| RV | Research vessel |
| SARA | Species at Risk Act |
| sGSL | Southern Gulf of St. Lawrence |
| SLAP | St. Lawrence Action Plan |
| VMS | Vessel monitoring system |
| ZIFF | Zonal interchange file format |

*Appendix B. Members of DFO's Scientific Monitoring Committee for the Banc-des-Américains MPA (BDA SMC) as of May 2021.*

**Active members**

| Name | Division | DFO Region |
|---|---|---|
| Geneviève Faille | DSDB | Quebec |
| Denis Chabot | DSDB | Quebec |
| Bernard Sainte-Marie | DSDB | Quebec |
| Marilyn Thorne | DSDB | Quebec |
| Geneviève Côté | DSDB | Quebec |
| Marjolaine Blais | DSPE | Quebec |
| Valérie Harvey | DSPE | Quebec |
| Jean-Martin Chamberland | DSPE | Quebec |
| Renée Gagné | DPCM | Quebec |
| Natasha Dazé Querry | DPCM | Quebec |
| Catherine Marcil | DPCM | Quebec |
| Jacinthe Beauchamp | DPCM | Quebec |
| Denise Méthé | - | Gulf |

**Former members**

| Name | Division | DFO Region |
|---|---|---|
| Daniel Ricard | POISSMA | Gulf |
| Sylvain Hurtubise | DAISS | Quebec |
| Pascale Tremblay | DPCM | Quebec |

*Appendix C. List of indicators retained during the 2018 peer review (MPO 2019a) and the corresponding indicators retained in the 2021 update. The list is presented in the same order as in 2018. The indicators that were eliminated are presented in greater detail in Appendix D, along with the rationale for their removal.*

**Physical and chemical oceanography (O)**

| Ecosystem components | Indicators 2018 | Update 2021 |
|---|---|---|
| Physico-chemical properties of the water | 1) Temperature, salinity, nutrients, dissolved oxygen, pH, turbidity, in different water layers (surface, CIF, bottom, etc.) | : Pr1) Physical conditions of the pelagic habitat,<br>Pr2) Physical conditions of the benthic habitat (> 100 m),<br>Pr19) Acidification,<br>Pr20) Dissolved oxygen, and<br>P1) Nutrients |
| | O2) Internal current, wave and tidal dynamics | Removed |
| | O3) Ice cover | Included in Pr1) Physical conditions of the pelagic habitat |

**Pelagic (P)**

| Ecosystem components | Indicators 2018 | Update 2021 |
|---|---|---|
| Phytoplankton | P1) Chlorophyll a biomass | P2) Chlorophyll a |
| | P2) Abundance and taxonomy of species | Removed |
| Zooplankton | P3) Total biomass of zooplankton | P3) Zooplankton |
| | P4) Abundance of different dominant/key species | Included in P3) Zooplankton |
| Krill | P5) Krill biomass | P4) Krill biomass |
| Herring | P6) Biomass from herring stock assessment | P5) Herring stock biomass sGSL |
| Mackerel | 7) Biomass and abundance from the mackerel stock assessment | Removed |
| | P8) Mackerel egg abundance | Removed |

**Benthic and demersal (BD)**

| Ecosystem components | Indicators 2018 | Update 2021 |
|---|---|---|
| Epibenthic communities | 1) Presence, relative abundance and size of fixed erected organisms (sponges and other species) | BD3) Dominant species |
| | 2) Composition of epibenthic communities: richness, diversity, abundance, density, biomass of species or taxa | Remodeled into:<br>BD4) Biomass of invertebrates (Removed)<br>BD5) Epibenthic community A: Rocky ridge<br>BD6) Epibenthic community B: Mixed ridge<br>BD7) Epibenthic community C: Mixed plain<br>BD8) Epibenthic community D: Soft plain |
| | 3) Biomass, abundance, size structure of indicator/dominant species | |
| Demersal communities | 4) Composition of demersal communities: richness, diversity, abundance, density, biomass of species or taxa | Remodeled into:<br>BD1) Cold water indicator species<br>BD2) Warm water indicator species<br>BD9) Demersal fish community on the plain<br>BD10) Demersal fish on the ridge |
| | 5) Presence, size and abundance classes of indicator species | |
| Commercial benthic and demersal species | BD6) Biomass and abundance of species | Remodeled into:<br>BD11) Snow crab<br>BD12) Harvested groundfish |
| | BD7) Size structure, sex and maturity of commercial species | |
| | BD8) Lobster abundance on the ridge | Pr5) Lobster on the ridge |
| Substrates characteristics | BD9) Type of sediment and granulometry | BD13) Sediments |

**Species-at-risk (EP)**

| Ecosystem components | Indicators 2018 | Update 2021 |
|---|---|---|
| Atlantic Wolffish | EP1) Presence/absence on the ridge | Merged into EP1) Atlantic wolffish |
| | 2) Occupancy and potential habitat availability (number of burrows) | |
| | EP3) Bycatch (commercial fishing/scientific surveys) | EP2) Atlantic Wolffish bycatch |
| Whales | 4) Presence of species at risk: Fin Whale, Blue Whale, Humpback Whale and Right Whale | EP3) Fin whale<br>EP4) Blue whale<br>EP5) North Atlantic right whale<br>EP6) Cetacean mortality/accidents |

**Pressures (Pr)**

| Ecosystem components | Indicators 2018 | Update 2021 |
|---|---|---|
| Aquatic invasive species (AIS) | PA1) Presence/absence of AIS in the proposed MPA | Pr3) Presence of AIS |
| Noise | PA2) Measurement of anthropogenic noise | Pr6) Anthropogenic noise |
| | PA3) Intensity of commercial traffic | Pr7) Traffic intensity |
| Disturbance | PA4) Intensity of observation and recreational activities | Pr8) Intensity of observation and recreational activities |
| Collisions | PA5) Speed of commercial vessels | Pr9) Vessel speed |
| | PA6) Number of reported accidents (collisions) | Pr21) Number of collisions |
| Entanglement | 7) Number of accidents (entanglement) reported in and around the proposed MPA | Pr10) Number of entanglements |
| Commercial fishing | 8) Commercial fishing effort for all fish and invertebrates (total landings) | Remodeled into:<br>Pr15) Snow crab fishery<br>Pr16) Groundfish fishery<br>Pr17) Fishing done by scientific activities<br>Pr11) Relative footprint of the snow crab fishery<br>Pr12) Relative footprint of the groundfish fishery<br>Pr13) Footprint of scientific activities<br>Pr14) Fishing activities – violations |
| | 9) Distribution of fishing effort from vessel monitoring system (VMS data) and logbooks | |

*Appendix D. List of eliminated indicators evaluated according to criteria and justifications.*

| Eliminated 2018 indicators | Main Survey(s) | Criteria | | | | | | Comment |
|---|---|---|---|---|---|---|---|---|
| | | **Theoretical basis** | **Sensitivity** | **Measurable** | **Cost-benefit ratio** | **Interpretable** | **Sustainability** | |
| O2) Internal current, waves and tidal dynamics | *nd* | • | | | | | | The available data are from a single Viking buoy located in the MPA and are therefore not representative of the entire area. If a more complete baseline characterization of the currents becomes available, the relevance of this indicator may be re-evaluated. |
| P2) Abondance and taxonomy of phytoplankton species | *nd* | • | | | | • | | No data available for the area from existing surveys. To produce data for the area, a specialized taxonomist would be required and this work would be very expensive. It is estimated that the cost-benefit ratio is not high enough since this indicator is indirect and very precise. |
| P7) Biomass and abundance from the mackerel stock assessment | Stock assessment | • | | • | • | | • | Data from the stock assessment measured at the northeastern North American scale (NAFO Regions 3-4). This scale is considered too large for the indicators to be informative of the status of mackerel in the MPA. Changes in these indicators would not be interpretable in the context of the MPA. |
| P8) Mackerel egg abundance | Mackerel egg survey | • | | • | • | | • | |
| PA6) Number of reported accidents (collisions) | *nd* | • | • | | • | | • | Collisions are not necessarily reported consistently, so this uncertainty would make it difficult to track over time and interpret changes in the indicator. |

*Appendix E. List of surveys currently used in the monitoring plan, based on the list in CSAS 2019 (Faille et al. 2019).*

**Existing**

| # | Surveys/Database | Names used |
|---|---|---|
| R1 | Atlantic Zone Monitoring Program (AZMP) | R1-AZMP |
| R2 | Oceanographic Buoy network (Viking) | R2-Viking |
| R3 | Ice cover monitoring | R3-Ice |
| R4 | Remote sensing of water surface temperature | R4-SST |
| R5 | Thermograph Network | R5-Thermograph |
| R6 | Monitoring winter water masses – helicoptered mission | R6-Helicoptered |
| R7 | Pelagic acoustic survey of the estuary and northwestern Gulf | R7-Krill |
| R8 | Annual acoustic survey of herring (SGSL) | R8-Herring sGSL |
| R10 | Multi-species southern Gulf of St. Lawrence bottom trawl survey | R10-Multi sGSL |
| R11 | Multi-species in the estuary and northern Gulf of St. Lawrence bottom trawl survey | R11-Multi nGSL |
| R13 | Southern Gulf of St. Lawrence snow crab bottom trawl survey | R13-Snow crab sGSL |
| R14 | Fishing data from ZIFF statistics | R14-ZIFF |
| R15 | At-sea observer program | R15-Observers |
| R17 | Quebec Marine Mammal Emergency Response Network (QMMERN) | R17-QMMERN |
| R18 | Monitoring of maritime traffic via a navigation information system (AIS) | R18-AIS |
| R21 | Passive acoustics monitoring – Hydrophone | R21-PAM |
| R22 | Monitoring of MPA activity reports | R22-Act. report |

**Under development or to be developed**

| # | Surveys/Database | Names used |
|---|---|---|
| RD1 | Benthic community survey by imagery | RD1-Imagery |
| RD2 | Benthic community survey with grab | RD2-Grab |
| RD4 | Scuba diving | RD4-Scuba diving |
| RD5 | Environmental DNA | RD5-eDNA |
| RD6 | Baited imagery survey | RD6-Bait. Imagery |
| RD7 | Monitoring of seal haulouts, AGHAMM and Parc Forillon | RD7-Haulouts |

*Appendix F. Details on the measures used to calculate each indicator associated with the conservation priorities (Table 2). The units involved, the surveys that served as sources of data, the spatial and temporal scales (reference period and time series) used to calculate the indicator, and the method utilized to assess the status of the indicator are specified. The list of surveys is presented in Appendix E.* These data were collected sporadically over the period in question. ** Indicators or measures not retained during the peer review.*

**CO1 Conserve and protect benthic habitats (Benthic and demersal (BD))**

| Indicators | Measures | Units | Surveys | Spatial scales | Reference period | Historical series | Method | Confidence level |
|---|---|---|---|---|---|---|---|---|
| BD1) Cold water indicator species | Biomass of the 3 most abundant cold water stenotherm species – Fish | kg/tow | R10-Multi sGSL | Strata 416 | 2004–2018 | since 1986 | Bidirectional anomaly | Good |
| | Biomass of the 3 most abundant cold water stenotherm species – Invertebrates | kg/tow | | | | | | |
| | Estimated biomass of cold water stenotherm species – Fish | kg/tow | | | | | | |
| | Estimated biomass of cold water stenotherm species – Invertebrates | kg/tow | | | | | | |
| BD2) Warm water indicator species | Biomass of the most abundant warm water stenotherm species – Fish | kg/tow | R10-Multi sGSL | Strata 416 | 2004–2018 | since 1986 | Bidirectional anomaly | Good |
| | Biomass of the most abundant warm water stenotherm species – Invertebrates | kg/tow | | | | | | |
| | Estimated biomass of warm water stenotherm species – Fish | kg/tow | | | | | | |
| | Estimated biomass of warm water stenotherm species – Invertebrates | kg/tow | | | | | | |
| BD3) Dominant/key species | *Total biomass of fixed and erect taxa*** | kg/tow | R10-Multi sGSL | Strata 416 | 2004–2018 | since 1986 | Directional anomaly | Good |
| | *Sea urchin biomass*** | kg/tow | | | | | | |
| | *Predatory starfish biomass*** | kg/tow | | | | | | |
| | *Pandalus* biomass | kg/tow | | | | | | |
| | American plaice biomass | kg/tow | | | | | | |
| | Greenland halibut biomass | kg/tow | | | | | | |
| *BD4) Biomass of invertebrates*** | *Total invertebrate biomass*** | kg/tow | R10-Multi sGSL | Strata 416 | 2004–2018 | since 1986 | Bidirectional anomaly | *nd* |
| BD5) Epibenthic community A: Rocky ridge | *Pending* | *Nd* | RD1-Imagery | Monitoring sites comm. A | *nd* | 2012–2020* data | *nd* | *nd* |

| Indicators | Measures | Units | Surveys | Spatial scales | Reference period | Historical series | Method | Confidence level |
|---|---|---|---|---|---|---|---|---|
| BD6) Epibenthic community B: Mixed ridge | *Pending* | *nd* | RD1-Imagery | Monitoring sites comm. B | *nd* | 2012–2020* data | *nd* | *nd* |
| BD7) Epibenthic community C: Mixed plain | *Pending* | *nd* | RD1-Imagery | Monitoring sites comm. C | *nd* | 2012–2020* data | *nd* | *nd* |
| BD8) Epibenthic community D: Soft plain | *Pending* | *nd* | RD1-Imagery | Monitoring sites comm. D | *nd* | 2012–2020* data | *nd* | *nd* |
| BD9) Demersal fish community on the plain | Total biomass of demersal fish | kg/trait | R10-Multi sGSL | Strata 416 | 2004-2018 | since 1986 | Directional anomaly | Good |
| | Total abundance of demersal fish | ind/trait | | | | | | |
| | Specific richness | Nb species | | | | | | |
| | Shannon's diversity index | - | | | | | | |
| | Pielou's evenness index | - | | | | | | |
| | *Pending (Stomach filling [weight])* | - | R10-Multi sGSL | BDA | *nd* | *nd* | *nd* | *nd* |
| | *Pending (measures by trophic guild)* | - | | | | | | |
| BD10) Demersal fish on the ridge | *Pending* | *nd* | RD6-Bait. Imagery | BDA-ridge | *nd* | none | *nd* | *nd* |
| BD11) Snow crab | Abundance of male snow crabs of commercial size | ind/km² | R13-Snow crab sGSL | BDA | 2004–2018 | since 1989 | Directional anomaly | *nd* |
| | Abundance of mature female snow crabs | ind/km² | | | | | | |
| | Snow crab CPUE | kg/raised trap | | | | | | |
| BD12) Harvested groundfish | Estimated biomass of Atlantic halibut catch | kg/tow | R10-Multi sGSL | Strata 416 | 2004–2018 | since 1986 | Directional anomaly | *nd* |
| | Abundance of Atlantic cod | ind/tow | | | | | | |
| | Groundfish CPUE | kg/hook | | | | | | |
| BD13) Sediments | *Pending* | *nd* | RD1-Imagery | BDA | *nd* | none | *nd* | *nd* |

**CO2 Conserve and protect pelagic habitats and forage species (Pelagic (P))**

| Indicators | Measures | Units | Surveys | Spatial scales | Reference period | Timel series | Method | Confidence level |
|---|---|---|---|---|---|---|---|---|
| P1) Nutrients | Winter average nitrate in the surface layer (0–50 m) | mmol $m^{-2}$ | R1-AZMP, R6-R10-R11-Multi n/sGSL | Oceano area | 1999–2018 | Since 1999 | Bidirectional anomaly | Good |
| | Average annual nitrate in the middle layer (50–150 m) | mmol $m^{-2}$ | | | | | | |
| | Average annual N:P ratio in the middle layer (50–150 m) | - | | | | | | |
| P2) Chlorophyll *a* | Annual average chlorophyll a in the 0–100 m layer | mg $m^{-2}$ | R1-AZMP, R10-R11-Multi n/sGSL | Oceano area. | 1999–2018 | Since 1999 | Bidirectional anomaly | Good |
| P3) Zooplankton | Average annual dry weight of mesozooplankton | g $m^{-2}$ | R1-AZMP | Oceano area | 2001–2018 | Since 2001 | Bidirectional anomaly | Good |
| | Average annual abundance of small calanoid species | ind/$m^2$ | | | | | | |
| | Average annual abundance of large calanoid species | ind/$m^2$ | | | | | | |
| | Average annual abundance of non copepod species | ind/$m^2$ | | | | | | |
| P4) Krill Biomass | Wet weight of krill<br>Wet weight of *Thysanoessa raschii*<br>Wet weight of *Meganyctiphanes norvegica* | g $m^{-2}$ | R7-Krill, R10-R11-Multi n/sGSL | Oceano area | 2008–2018 | Since 2008 | *nd* | *nd* |
| P5) sGSL herring stock biomass | SSB of spring herring from sGSL<br>SSB of fall herring from sGSL | ton (kt) | R8-Herring sGSL | sGSL | - | 1980–2018 | Fixed threshold | Good |

**CO3 Promote the recovery of at-risk whales and wolffish (EP)**

| Indicators | Measures | Units | Surveys | Spatial scales | Reference period | Time series | Method | Confidence level |
|---|---|---|---|---|---|---|---|---|
| EP1) Atlantic wolffish | *Pending* | *nd* | RD4-Scuba diving<br>RD5-eDNA | BDA-ridge | *nd* | *nd* | *nd* | *nd* |
| EP2) Atlantic wolffish bycatch | Proportion of commercial fishing events with Atlantic wolffish bycatch | % | R15-Observers | BDA | 1996–2018 | 1996–2020 | *nd* | *Poor* |
| | Estimated biomass of Atlantic wolffish by scientific surveys | kg/tow | R10-Multi sGSL,<br>R13-Snow crab sGSL | Strata 416 | 2004–2018 | 1985–2018 | *nd* | *Poor* |
| EP3) Fin whale | *Pending* | *nd* | R21-MPA | Area covered by the MPA | *nd* | *nd* | *nd* | *nd* |
| EP4) Blue whale | *Pending* | *nd* | R21-MPA | Area covered by the MPA | *nd* | *nd* | *nd* | *nd* |
| EP5) North Atlantic right whale | *Pending* | nd | R21-MPA | Area covered by the MPA | *nd* | *nd* | *nd* | *nd* |
| EP6) Cetacean mortality/accidents | Total number of reports of sick, injured, stranded individuals and carcasses for Species at Risk | Nb | R17-QMMERN | Gaspé and Percé sector | 2004–2018 | Since 2004 | *nd* | Poor |
| | Total number of reports of sick, injured, stranded individuals and carcasses for other species (large MM, dolphin, porpoise) | Nb | R17-QMMERN | Gaspé and Percé sector | 2004–2018 | Since 2004 | *nd* | Poor |

*Appendix G. Details on the measures used to calculate each pressure indicator (Table 3). The units involved, the surveys that served as sources of data, the spatial and temporal scales, and the method utilized to assess the status of the indicator are specified. The list of surveys is presented in Appendix E.*

| Indicators | Measures | Units | Surveys | Spatial scales | Reference period | Time series | Method | Confidence level |
|---|---|---|---|---|---|---|---|---|
| Pr1) Physical conditions of the pelagic habitat | Mean surface temperature (May-Nov) derived from satellite data (SST) | °C | R4-SST | Oceano area | 1989–2018 | Since 1985 | Bidirectional anomaly | Good |
| | Average summer temperature (Aug.–Sept.) at the surface (0–30 m) | °C | R10-R11-Multi n/sGSL | Oceano area | 1989–2018 | Since 1985 | Bidirectional anomaly | Good |
| | Average summer salinity (Aug.—Sept.) at surface (0–30 m) | - | | | | | | |
| | First day of ice; Last day of ice; Duration of the ice season | day | R3-Ice | Oceano area | 1989–2018 | Since 1969 | Bidirectional anomaly | Good |
| | Average summer temperature (Aug.–Sept.) in the cold intermediate layer (CIF; 40–100 m) | °C | R10-R11-Multi n/sGSL | Oceano area | 1989–2018 | Since 1985 | Bidirectional anomaly | Good |
| | Depth of the upper limit of the cold intermediate layer (CIF; 2°C) | m | | | | | | |
| | Volume of the cold intermediate layer (CIF; 1°C) | $km^3$ | | | | | | |
| Pr2) Physical conditions of the benthic habitat (> 100 m) | Average temperature (Aug.–Sept.) near the bottom (> 100 m) | °C | R10-R11-Multi n/sGSL | Benthic area | 1989–2018 | Since 1985 | Bidirectional anomaly | Good |
| | Average salinity (Aug.–Sept) near the bottom (> 100 m) | - | | | 1989–2018 | Since 1987 | | |
| Pr19) Acidification of the benthic habitat (> 100 m) | Average saturation rate of calcite near the bottom (> 100 m) | Saturation rate | R1-AZMP, R10-R11-Multi n/sGSL | Benthic area | - | - | Fixed threshold | Poor |
| | Average saturation rate of aragonite near the bottom (> 100 m) | Saturation rate | | | | | | |
| Pr20) Dissolved oxygen in the benthic habitat (> 125 m) | Dissolved oxygen saturation value near the bottom (> 125 m) | % sat. | R1-AZMP, R10-R11-Multi n/sGSL | Benthic area | | Since 2002 | Fixed threshold | Good |
| Pr3) Presence of AIS | *Pending* | *nd* | RD5-eDNA | BDA | *nd* | none | *nd* | *nd* |
| Pr4) Grey seal | *Pending* | *nd* | RD7-Haulouts | *nd* | *nd* | *nd* | *nd* | *nd* |
| Pr5) Lobster on the ridge | Abundance of lobster | Nb | RD4-Scuba diving, RD6-Bait. imagery | BDA (ridge) | *nd* | none | *nd* | *nd* |
| Pr6) Anthropogenic noise | *Pending* | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* |

| Indicators | Measures | Units | Surveys | Spatial scales | Reference period | Time series | Method | Confidence level |
|---|---|---|---|---|---|---|---|---|
| Pr7) Traffic intensity | Total number of passages for commercial traffic | Nb | R18-AIS | BDA | 2012–2018 | Since 2012 | Directional anomaly | Good |
| | Total number of passages for marine operations | Nb | | | | | | |
| | *Total transit time in the BDA for commercial traffic** | h | | | | | | |
| | *Total transit time in the BDA for marine operations** | h | | | | | | |
| Pr8) Intensity of observation and recreational activities | Total number of observation trips at sea | Nb | R22-Rapport actv. | BDA and Gaspé sector | *nd* | Since 2019 | *nd* | Good |
| | Average duration of the outings | h | | | | | | |
| | Number of observation boats at sea | Nb | | | | | | |
| | Duration of the season of observation at sea | Nb days | | | | | | |
| | *Pending (spatial footprint of cruise passengers)* | *nd* | R18-AIS | BDA | *nd* | *nd* | *nd* | *nd* |
| | *Pending (measures for marinas and boaters)* | *nd* | *nd* | Gaspé and Percé sector | *nd* | *nd* | *nd* | *nd* |
| Pr21) Number of collisions | *Pending* | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* | *nd* |
| Pr9) Vessel speed | Average speed of commercial vessels | Kt | R18-AIS | BDA | 2012–2018 | Since 2012 | Directional anomaly | Good |
| | Average speed for marine operations vessels | Kt | | | | | | |
| | Number of runs that reached a speed > 10 knots | Nb | | | | | | |
| Pr10) Number of entanglements | Number of cetacean entanglements | Nb | R17-QMMERN | Gaspé and Percé sector | 2004–2018 | Since 2004 | Directional anomaly | Poor |
| Pr11) Relative footprint of the snow crab fishery | Snow crab fishing effort (number of traps hauled) | Nb traps hauled | R14-ZIFF | BDA | 2004–2018 | Since 2004 | Directional anomaly | Good |
| | Proportion of MPA affected by the crab fishery | % | | | | | | |

| Indicators | Measures | Units | Surveys | Spatial scales | Reference period | Time series | Method | Confidence level |
|---|---|---|---|---|---|---|---|---|
| Pr12) Relative footprint of the groundfish fishery | Longline fishing effort (total number of hooks) | Nb of hooks | R14-ZIFF | BDA | 2004–2018 | Since 2004 | Directional anomaly | Good |
| | Proportion of MPA affected by the groundfish fishery (area affected) | % | | | | | | |
| Pr13) Footprint of scientific activities | Science activities footprint (proportion of MPA affected) | % | R10-Multi sGSL, R13-Snow Crab sGSL, RD1-Imagery | BDA | 2004–2018 | Since 2004 | *nd* | Good |
| Pr14 Fishing activities – violations | *Pending* | Nb | *nd* | BDA (areas 1 and 2) | *nd* | *Since 2019* | *nd* | *nd* |
| Pr15) Snow crab fishery | Snow crab exploitation rate | % | R14-ZIFF, R13-Snow crab sGSL | BDA | 2004–2018 | Since 2004 | Directional anomaly | Good |
| | Biomass of snow crab landings | Ton | R14-ZIFF | BDA | | | | |
| Pr16) Groundfish fishery | Biomass of longline landings (halibut and other groundfish) | Ton | R14-ZIFF | BDA | 2004–2018 | Since 2004 | Directional anomaly | Good |
| Pr17) Fishing by scientific activities | Biomass harvested by scientific activities | Ton | R10-Multi sGSL, R13-Snow crab sGSL | BDA | 2004–2018 | Since 2004 | *nd* | Good |
| Pr18) Number of new pressures | Number of new pressures | Nb | *nd* | BDA | *nd* | Since *2019* | *nd* | *nd* |

* *Indicators or measures not retained during the peer review.*

*Appendix H. Biomass and distribution of taxa included in indicator BD1 (Cold water indicator species).*

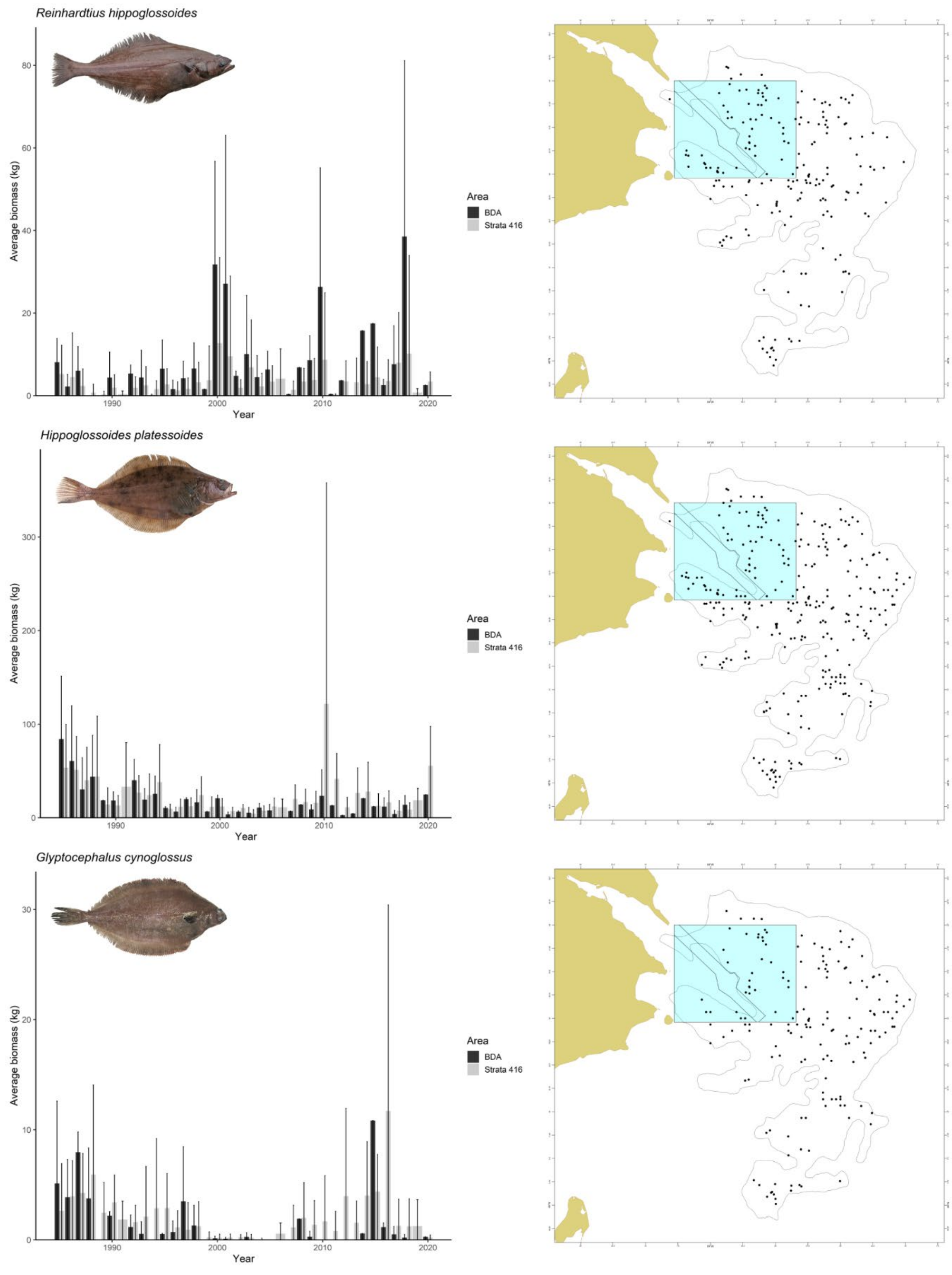


*Figure H1. Biomass and distribution of cold water stenothermic fish in the MPA and benthic buffer zone between 1985 and 2020. Top: Greenland Halibut* (Reinhardtius hippoglossoides); *centre: American Plaice* (Hippoglossoides platessoides)*; bottom: Witch Flounder* (Glyptocephalus cynoglossus).

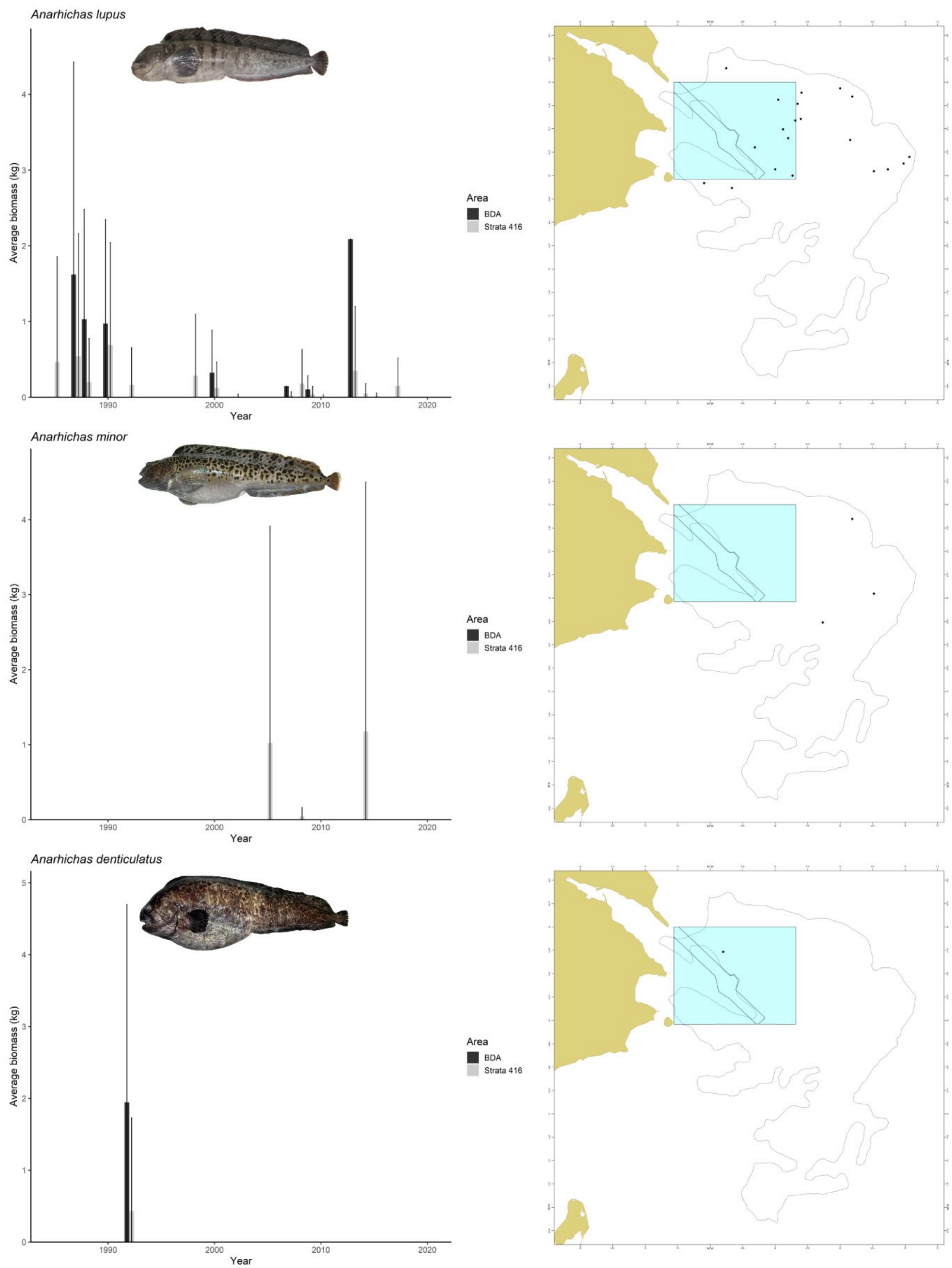


*Figure H2. Biomass and distribution of cold water stenothermic fish in the MPA and benthic buffer zone between 1985 and 2020. Top: Atlantic Wolffish* (Anarhichas lupus)*; center: Spotted Wolffish* (Anarhichas minor); *bottom: Northern Wolffish* (Anarhichas denticulatus).

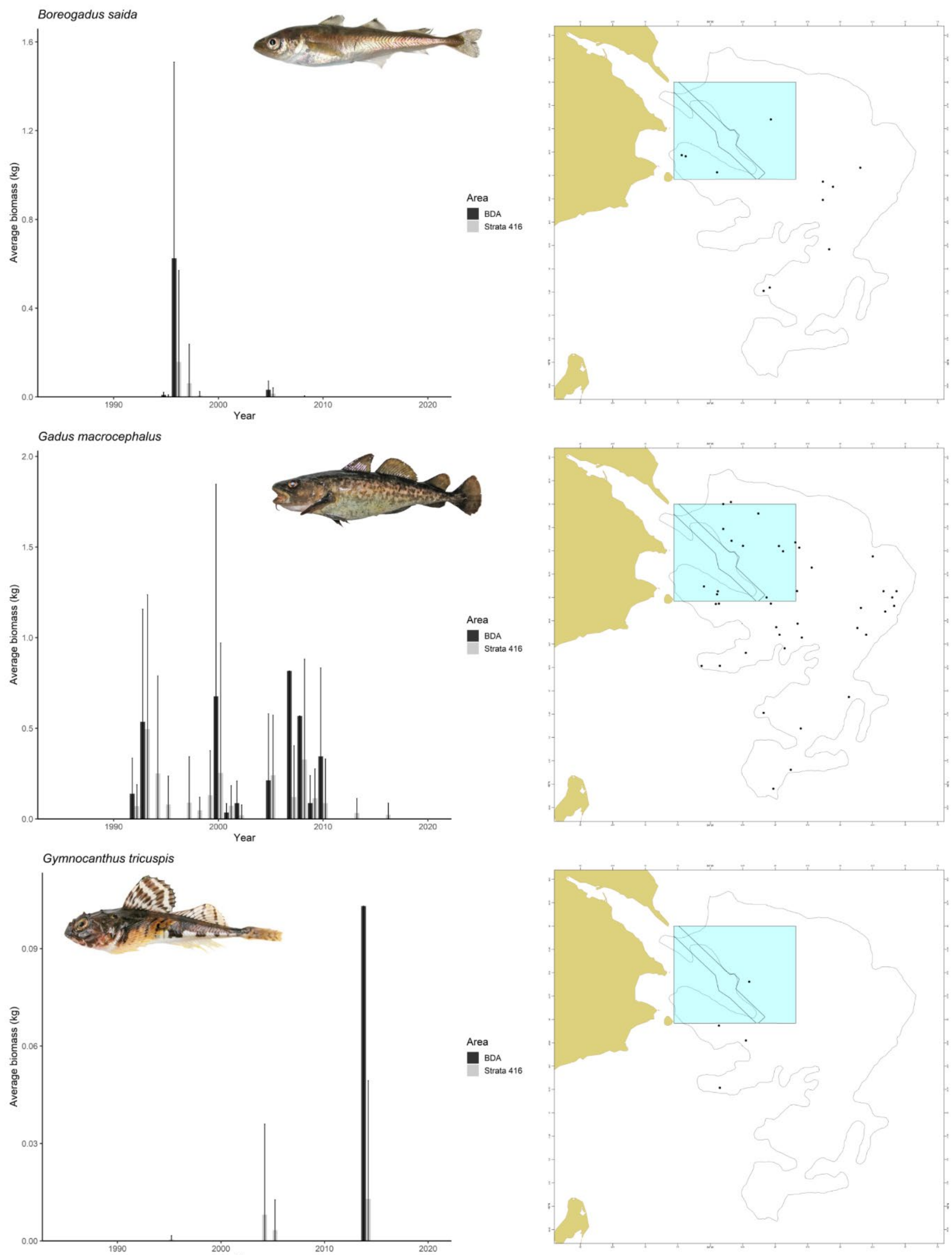


*Figure H3. Biomass and distribution of cold water stenothermic fish in the MPA and benthic buffer zone between 1985 and 2020. Top: Arctic Cod* (Boreogadus saida); *centre: Pacific Cod* (Gadus macrocephalus); *bottom: Arctic Staghorn Sculpin* (Gymnocanthus tricuspis).

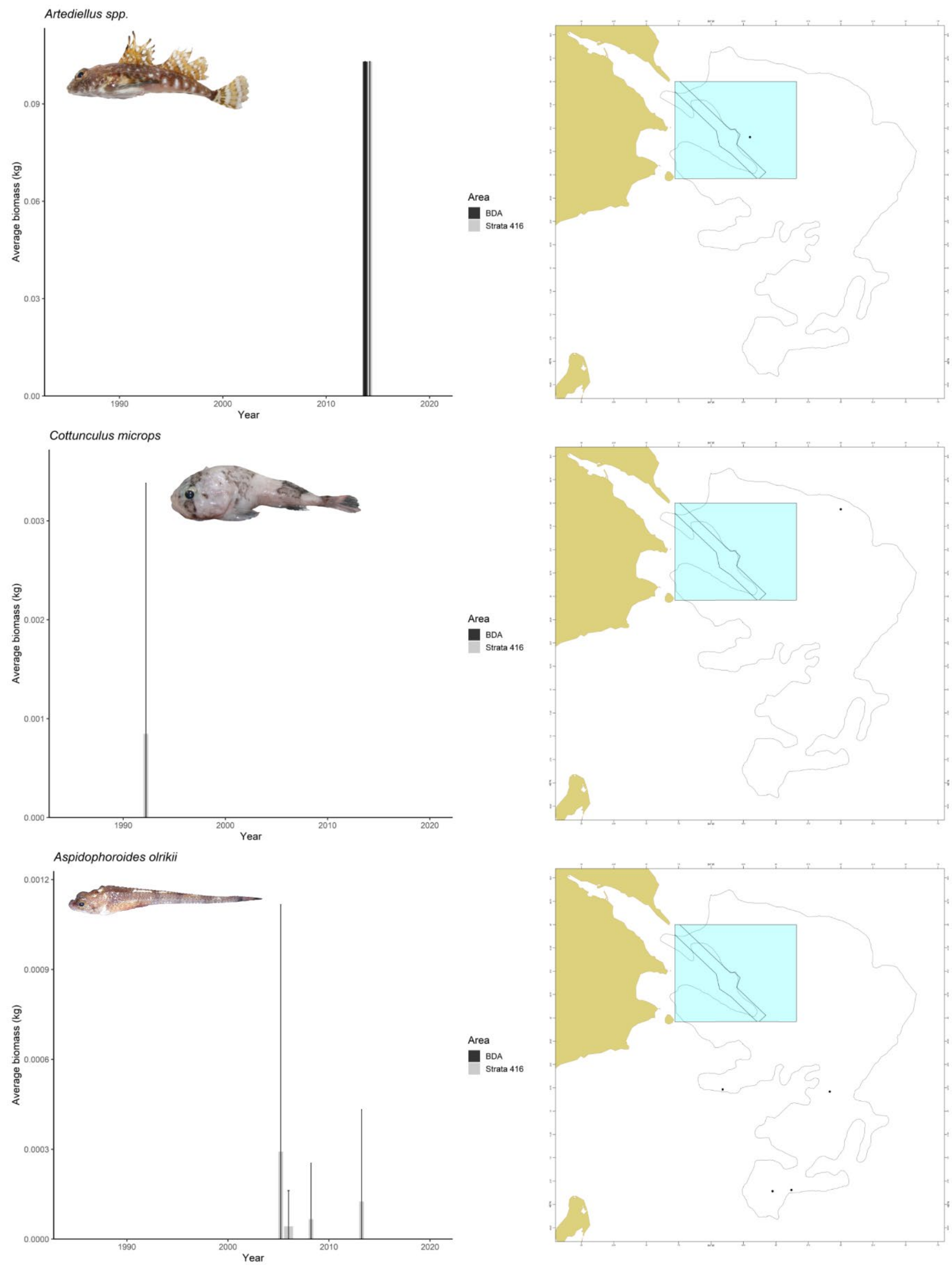


*Figure H4. Biomass and distribution of cold water stenothermic fish in the MPA and benthic buffer zone between 1985 and 2020. Top: Sculpin* (Artediellus *sp.*)*; centre: Polar Sculpin* (Cottunculus microps); *bottom: Arctic Alligatorfish* (Aspidophoroides olrikii).

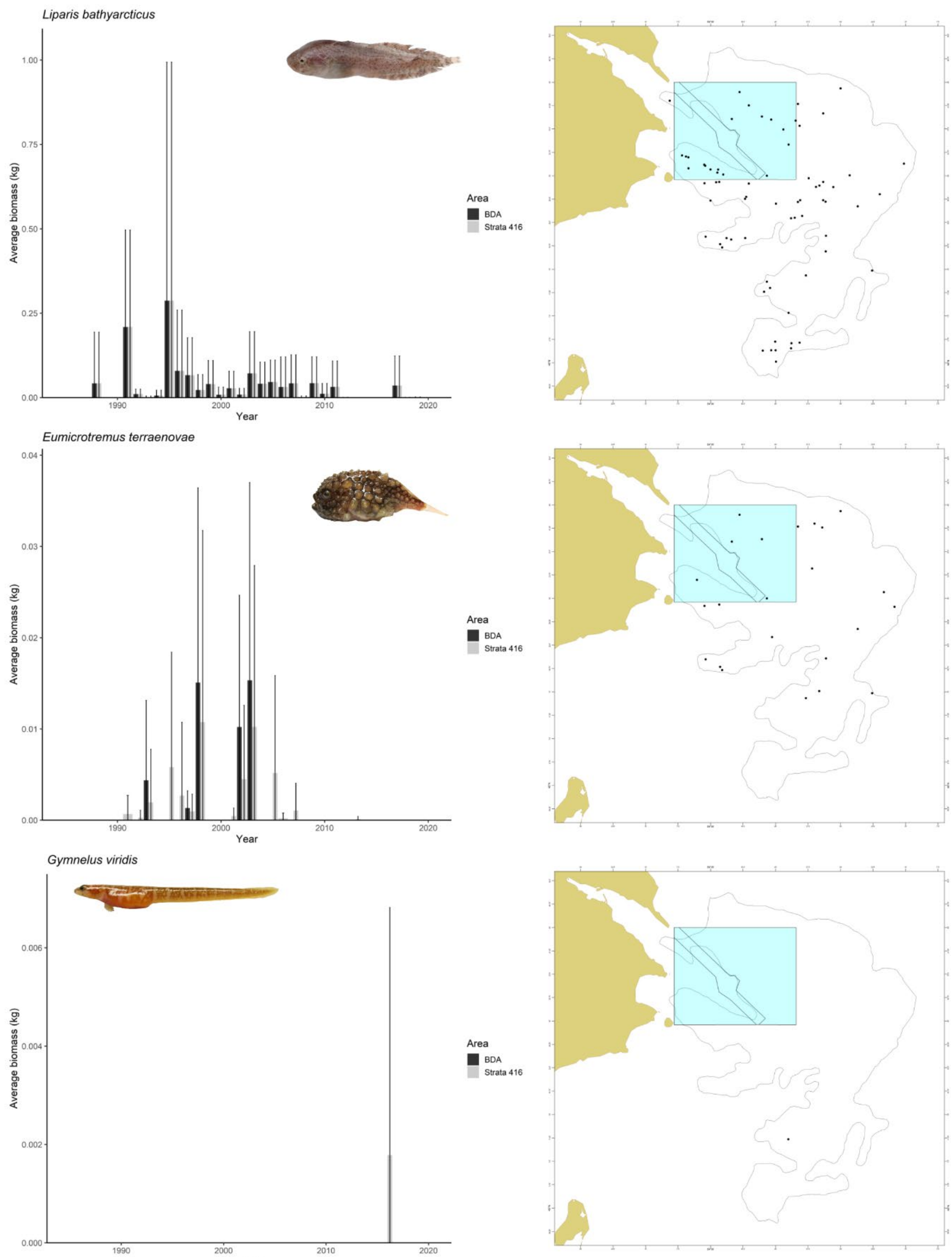


*Figure H5. Biomass and distribution of cold water stenothermic fish in the MPA and benthic buffer zone between 1985 and 2020. Top: Nebulous Snailfish* (Liparis bathyarcticus); *centre: Newfoundland Spiny Lumpsucker* (Eumicrotremus terraenovae); *bottom: Fish Doctor* (Gymnelus viridis). *Note that no catches of Nebulous Snailfish have been recorded in stratum 416 since 1985.*

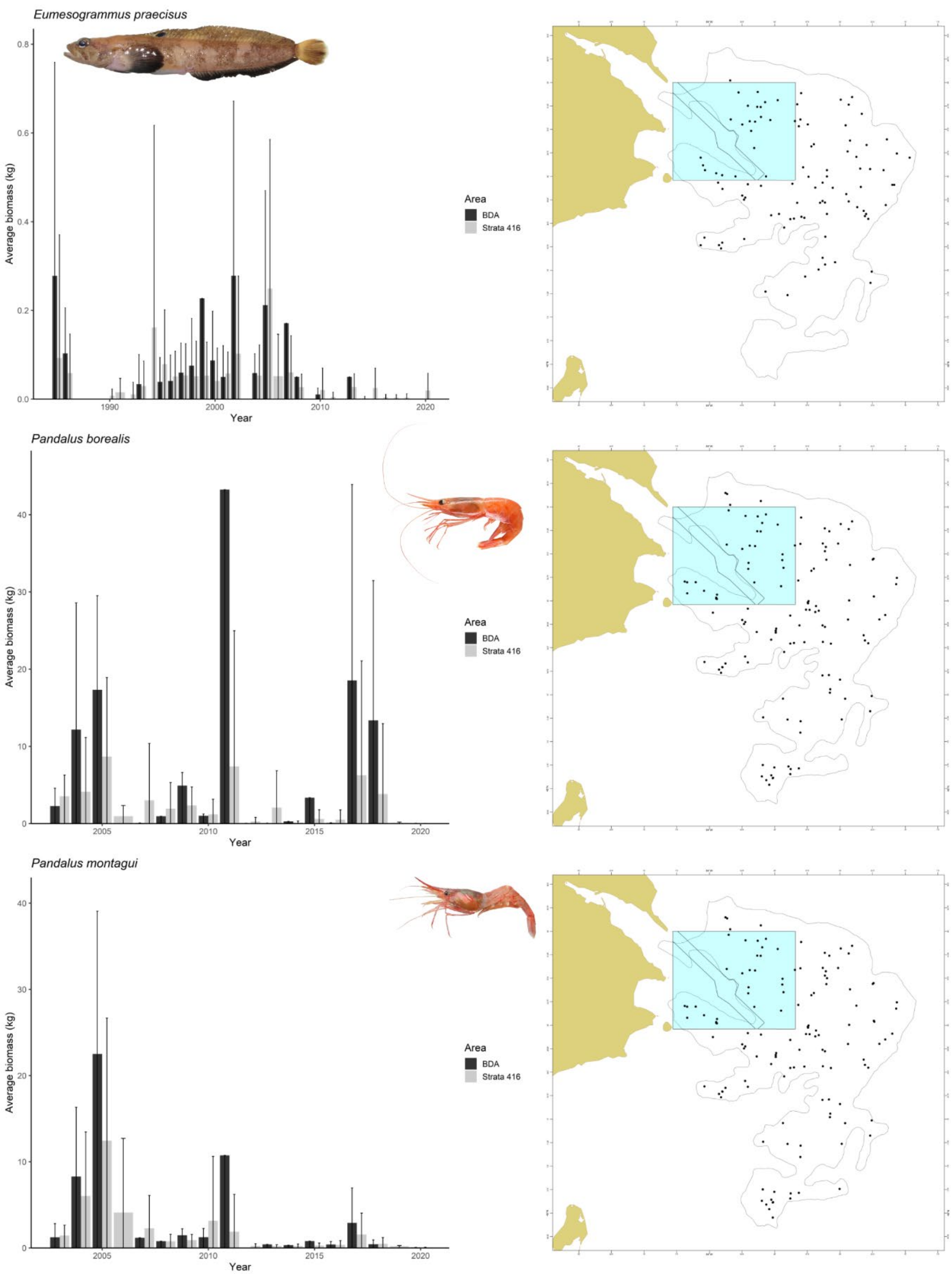


*Figure H6. Biomass and distribution of cold water stenothermic taxa in the MPA and benthic buffer zone between 1985 and 2020. Top: Fourline Snakeblenny (*Eumesogrammus praecisus*); centre: Northern Shrimp (*Pandalus borealis*); bottom: Striped Shrimp* (Pandalus montagui*).*

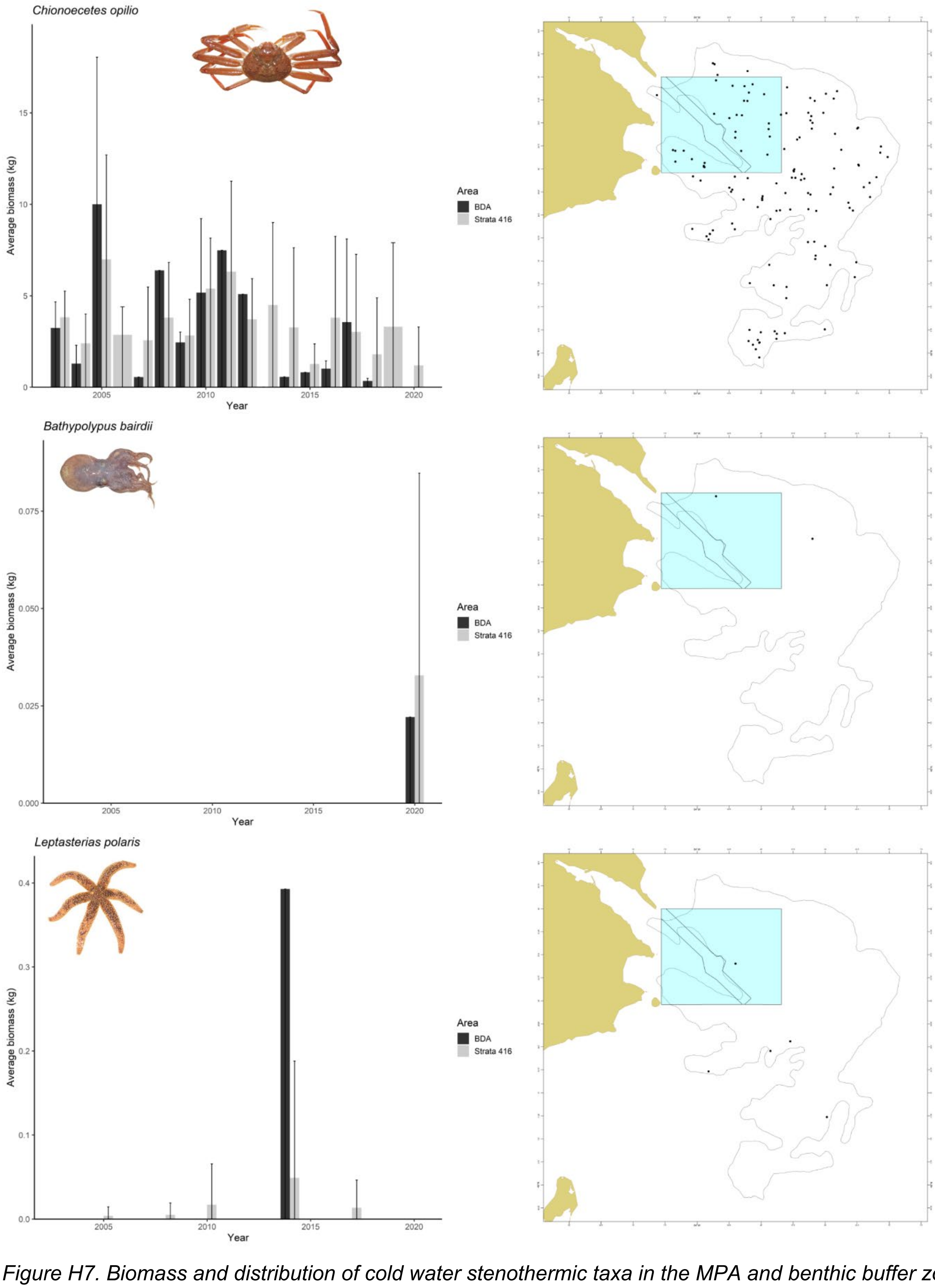


*Figure H7. Biomass and distribution of cold water stenothermic taxa in the MPA and benthic buffer zone between 1985 and 2020. Top: Snow Crab* (Chionoecetes opilio); *centre: Baird's Spoonarm Octopus* (Bathypolypus bairdii); *bottom: Polar Sea Star* (Leptasterias polaris).

*Appendix I. Biomass and distribution of taxa included in indicator BD2 (Warm water indicator species).*

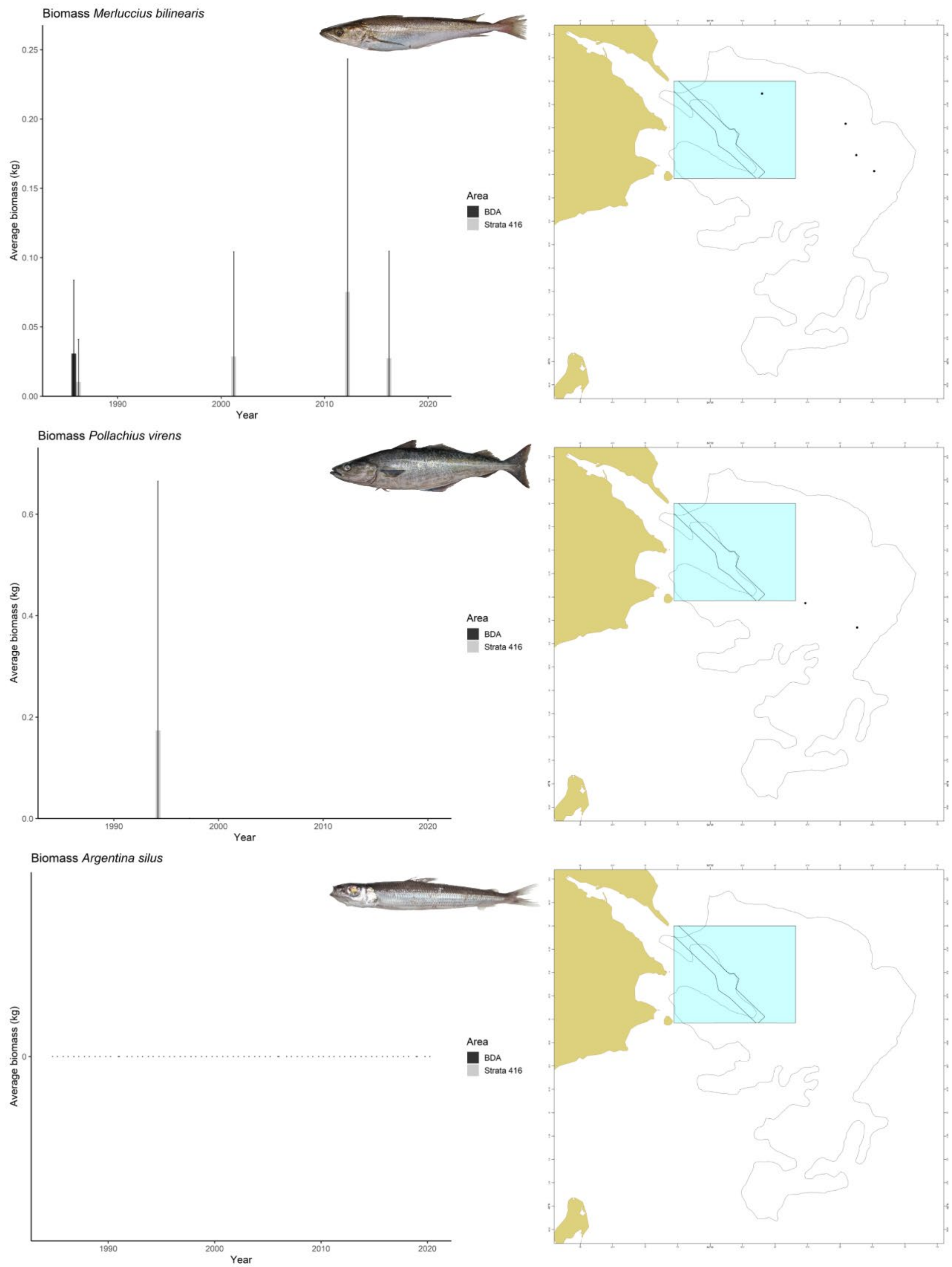


*Figure I1. Biomass and distribution of warm water stenothermic fish in the MPA and benthic buffer zone between 1985 and 2020. Top: Silver Hake* (Merluccius bilinearis); *centre: Pollock* (Pollachius virens); *bottom: Atlantic Argentine* (Argentina silus). *Note that no catches of Atlantic Argentine have been recorded in stratum 416 since 1985.*

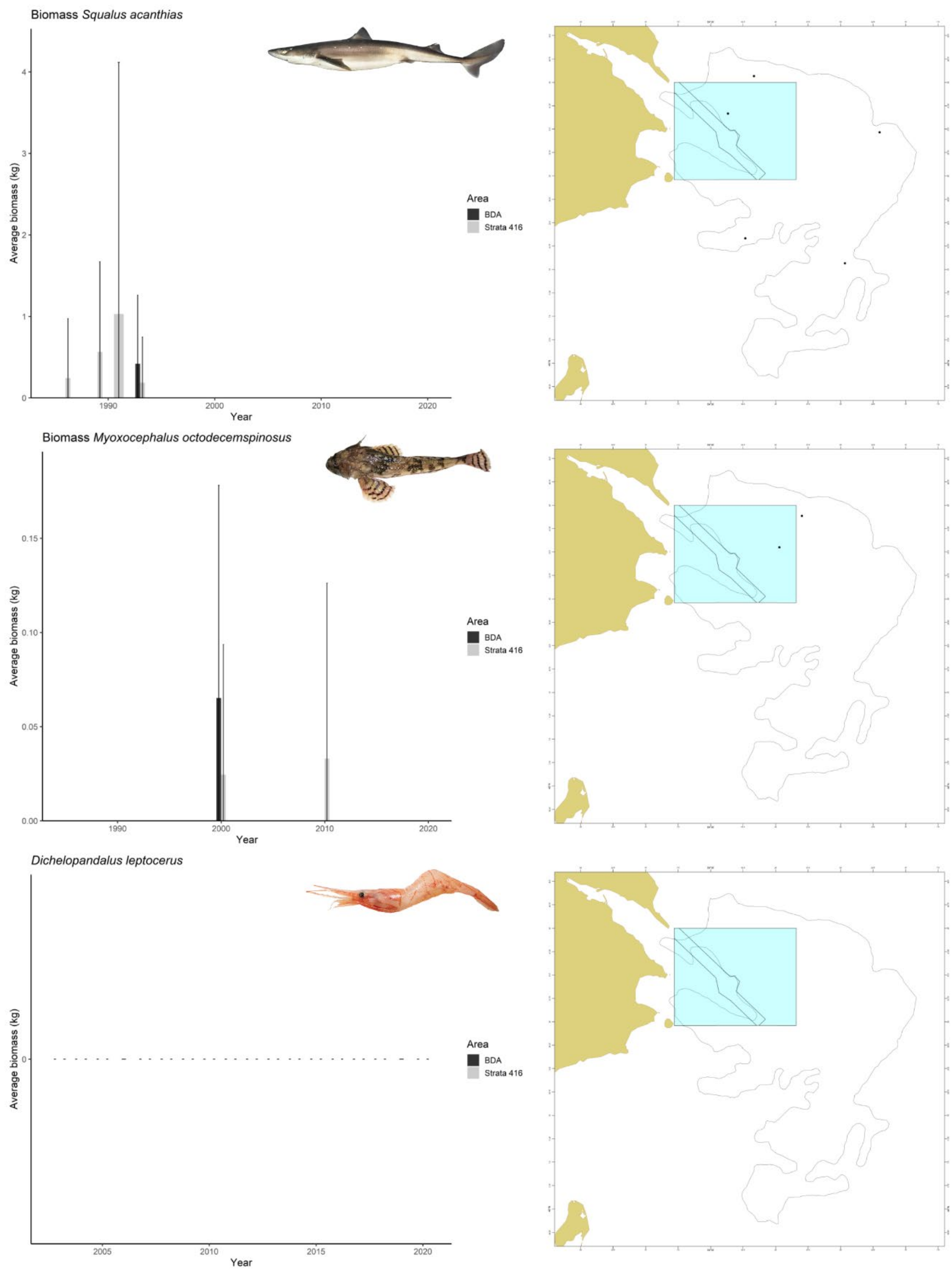


*Figure I2. Biomass and distribution of warm water stenothermic fish in the MPA and benthic buffer zone between 1985 and 2020. Top: Spiny Dogfish* (Squalus acanthias); *centre: Longhorn Sculpin* (Myoxocephalus octodecemspinosus); *bottom: Bristled Longbeak* (Dichelopandalus leptocerus). *Note that no catches of Bristled Longbeak have been recorded in stratum 416 since 1985.*

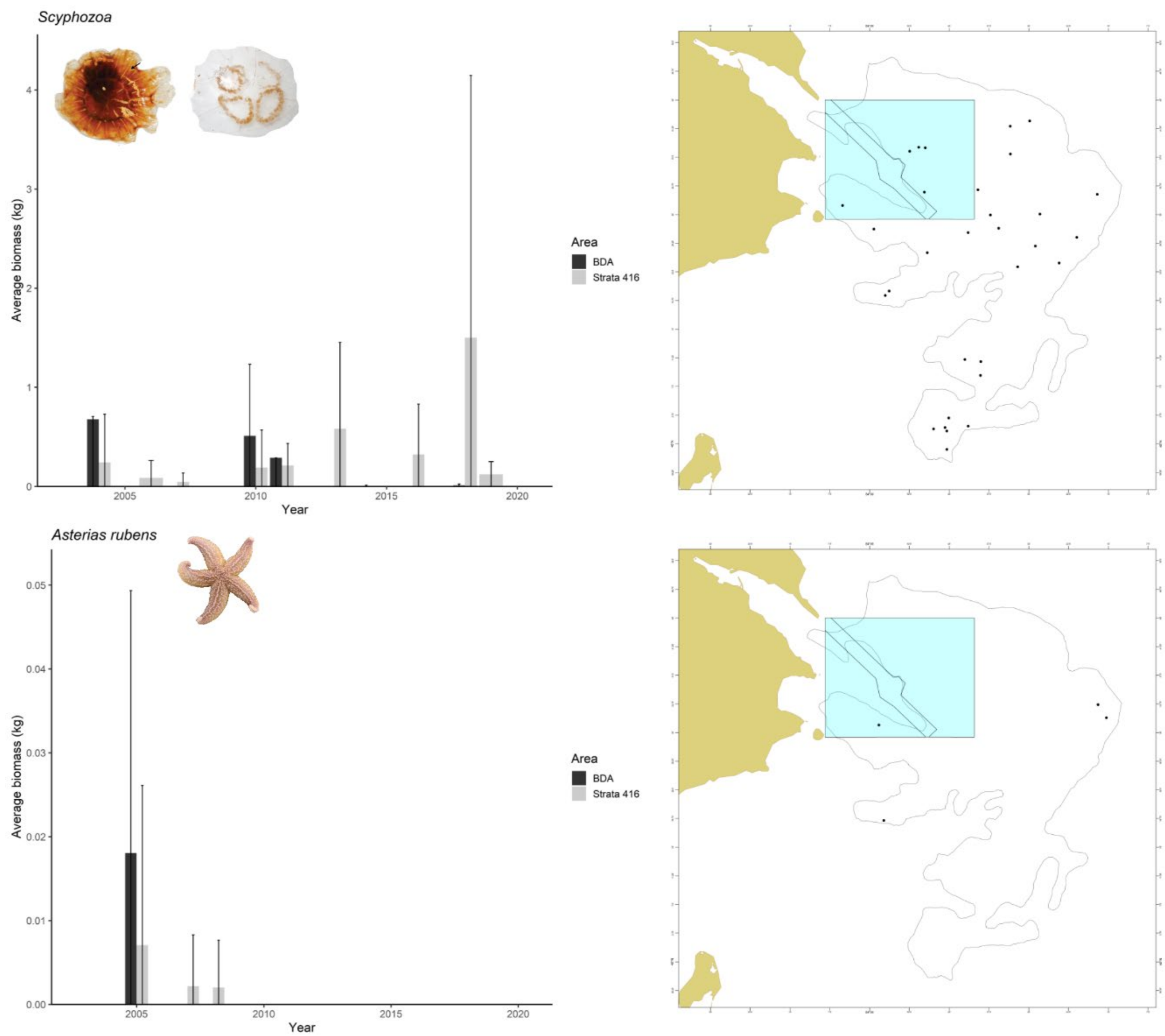


*Figure I3. Biomass and distribution of warm water stenothermic invertebrates in the MPA and benthic buffer zone between 1985 and 2020. Top: Jellyfish (Scyphozoa); bottom: Common Sea Star* (Asterias rubens).

*Appendix J Example of a data entry form for marine life observation activities authorized by a DFO activity plan in the Banc-des-Américains MPA.*

## Data entry form for marine life observation activities (MLOA) in the Banc-des-Américains MPA

The data entry form is a logbook in which the person responsible for recording data (either the captain or the naturalist/guide interpreter) can record all the elements deemed relevant during a marine mammal observation tour.

This form is not mandatory for these activities, but is intended as a user-friendly tool to facilitate the compilation of marine mammal observation data. The data collected will also be useful in preparing the activity report, which must be submitted within 90 days of the end of an activity approved in an approved activity plan, in accordance with the *Banc-des-Américains Marine Protected Area Regulations*. They may also be used for monitoring purposes in the management of the MPA.

For **each trip**, the person in charge of recording data can take note of the following:[5]

- Date*
- Name of the person responsible for recording the data
- Start time (local) and end time of trip
- Number of passengers on board

All observations made during the tour can be noted and will be useful for monitoring purposes, but **observations inside the boundaries of the Banc-des-Américains MPA should be prioritized**. This may be an observation made while moving between two locations or the direct observation of marine mammals. An observation is considered to be direct when the vessel is stationary, at reduced speed, or performing manoeuvres to observe a marine mammal.

When a marine mammal is observed, the person responsible for recording the data can take note of the following data (Table J1):

- Time (local) and duration of observation
- Species
- Number of adult animals
- Number of calves
- Geographic coordinates* of the vessel
- Type of observation (direct or while moving)
- Observed behaviours (resting, feeding, free swimming, breaching, flipper slapping, lob tailing, etc.)
- Any incident that occurred*

If the vessel is equipped with an Automatic Identification System (AIS), it would be very useful to record the time of the observation, so as to be able to subsequently obtain its position and the place where the activity took place.

To find out the frequentation rate of vessels used for marine life observation tours in the Banc-des-Américains MPA, the following information can also be noted:

Number of vessels present at an observation site within an approximate radius of one kilometre
Type of vessel (e.g. zodiac, small craft)

For each date on which a tour takes place, the data entry form (next page) can be completed. For the next date, it is important to start taking notes on a new form.

[5] Data marked with an asterisk (*) **must** be provided in the activity report, in accordance with section 11(1) of the *Banc-des-Américains Marine Protected Area Regulations*.

**Data entry form for marine life observation activities (MLOA) in the Banc-des-Américains MPA**[6]

**Name of person in charge**:______________________________________________Date of trip:___________________
(captain and/or naturalist/guide interpreter)

**Start time (trip)**:_______ **End time (trip)**:___________________ Number of passengers:______

*Table J1. At-sea observation data*

| **Time and duration of observation** | Species | Number of adult animals | Number of calves | **Coordinates* (lat./long.)** | Type of observation (direct or while moving) | Behaviours (resting, feeding, breaching, swimming, etc.) | Number of vessels | Type of vessel | **Incident that occurred*** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
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Comments:______________________________________________________________________________
_______________________________________________________________________________________

[6] Data marked with an asterisk (*) **must** be provided in the activity report, in accordance with section 11(1) of the *Banc-des-Américains Marine Protected Area Regulations*.