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REVIEW OF MONITORING INDICATORS FOR THE BANC-DES-AMÉRICAINS MARINE PROTECTED AREA, VALIDATION OF THE CHOICE OF MEASURES AND STATE OF KNOWLEDGE

Banc-des-Américains cliff. Photo: DFO, ROPOS (CSSF), Oceana Canada

Context:

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 a dual protection status, namely the Marine Protected Area under Canada's Oceans Act *(Regulation SOR/2019-50) and the status of a proposed aquatic reserve under Quebec's* Natural Heritage Conservation Act*. Following the designation of federal status, an ecological monitoring plan must be developed and monitoring implemented to provide information on the achievement of the three conservation objectives (COs) of this 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). A draft ecological monitoring plan was submitted for peer review in 2018 and specified an initial list of direct, indirect and pressure indicators (DFO 2019). Following this peer review, a scientific monitoring committee (SMC-BDA) was established to finalize the choice of indicators and associated measures, calculate the results, and specify the methods to assess the status and trends of the MPA.*

This Science Advisory Report is from the April 27–29, 2021 Review of Monitoring Indicators for the Banc-des-Américains Martine Protected Area, Validation of the Choice of Measures and State of Knowledge. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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SUMMARY

- Priority issues were identified to link the conservation objectives (COs) with the choice of pressures. Priority issues also help to clarify the direction of the changes expected to assess the status of the indicators and measures.

Conservation priorities, pressures and indicators

- The 15 conservation priorities, 12 pressures, and 44 indicators were reorganized from the 2018 list and, in some cases, slightly modified to better reflect the databases used.
- Five indicators were removed from the 2018 list, and three pressures and five indicators were added regarding competitors/predators (grey seal), scientific activities, fishing violations, new pressures and ghost gear. As a result of the review, acidification and dissolved oxygen become two separate indicators from Pr2 to allow for a more appropriate interpretation.

Method for assessing the status of measures and indicators

- Two methods are proposed for assessing the status of the measures and indicators presented: anomaly and fixed threshold. Other approaches may be considered for indicators not presented.
    - **Anomaly method**: Anomalies (deviation from the standardized mean) are used to highlight the variation of a measure against a reference period.
    - **Fixed-threshold method**: Thresholds are used instead of anomalies when threshold values with known biological effects from the scientific literature are available. Known thresholds have been used for measures relating to herring, dissolved oxygen and acidification.
- The data used must be properly processed according to their nature and statistical properties (e.g., data transformations) before the anomaly is calculated.
- The status assessment can be (1) **directional** when the change has an *a priori* favourable or unfavourable direction or (2) **bidirectional** when there is no anticipated direction to the change. In this case, it is the magnitude of the change that is assessed.
- Three status categories are used, and each category is assigned a score from 1 to 3. Data may be presented without an its status evaluated due to a lack of information, in which case the “Not assessed” category is used.
- The status of the indicator is the sum of the anomalies of each of its measures or, when thresholds are used, the sum of the scores associated with each measure.
- An oceanographic area and a benthic area wider than the MPA boundary were defined in order to calculate measures for eight indicators.

Measures and state of knowledge

- For each of the 27 indicators with a processed database, measures were selected, described and calculated according to a reference period in order to produce the state of knowledge for the available time series.
- The relevance of the grouping of measures considered for an indicator was reviewed and commented upon.

- A confidence level was established for each of the 27 indicators, based on the quality and quantity of the data used.
- The following indicators could not be assessed: BD2–Warm water indicator species, EP2–Atlantic wolffish bycatch, EP6–Cetacean mortality/accidents, Pr8–Intensity of observation and recreational activities, Pr10–Number of entanglements, and Pr18–Number of new pressures. A basic portrait is nevertheless presented for these indicators.
- The final status (overall rating) of the indicators will be produced in the monitoring reports after a few years have passed since the establishment of the MPA status. In this report, only changes in the status of the indicators over the time series are presented.

Priority indicators

- Priority indicators have been identified for the production of interim reports, which are more succinct than full monitoring reports, every 3 years. These indicators focus on direct pressures and a few key indicators related to CO1 (conserve and protect benthic habitats) and CO3 (promote the recovery of at-risk whales and wolffish).

BACKGROUND

Ecological monitoring

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. For each CO, conservation priorities and related pressures are identified (Figure 1). Indicators are then selected to monitor each of these elements. It is also necessary to specify the measures used to assess each indicator (Figure 1).

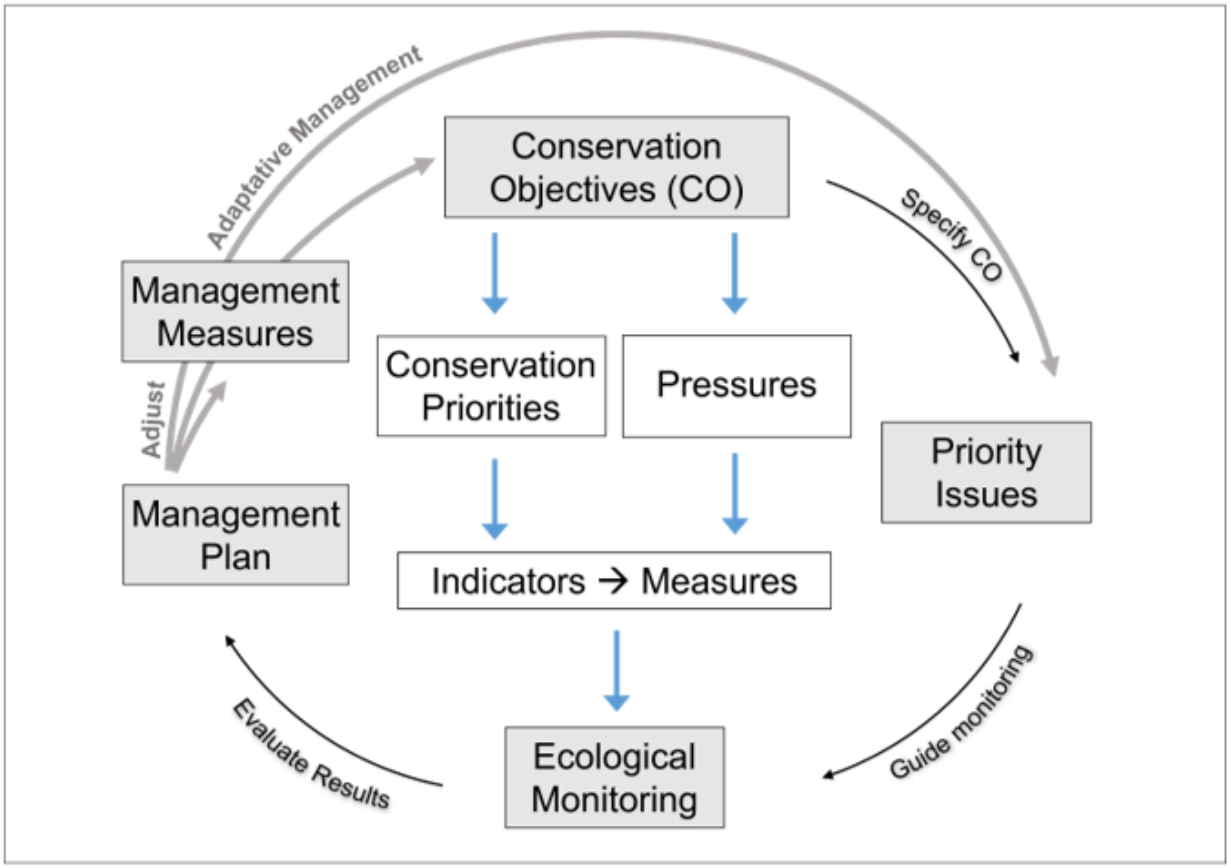
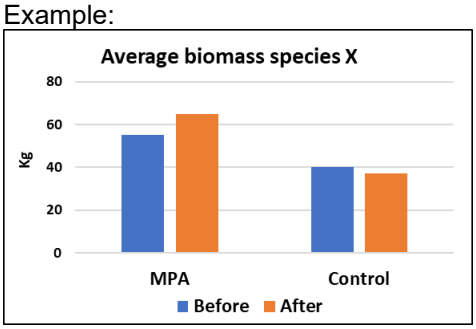


Figure 1. Hierarchy of the various elements used for the DFO ecological monitoring plan for the Banc-des-Américains MPA (blue arrows and white boxes) and key steps in the monitoring process (black arrows and grey boxes) to enable adaptive management of the MPA (grey arrows).

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 2019). 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 DFO monitoring program for the Banc-des-Américains MPA will be divided into two main components: (1) assessment of the MPA's status and trends and (2) assessment of the MPA's performance (Table 1). The ecological monitoring thus implemented will allow to inform the Marine Planning and Conservation (MPC) Directorate with the results obtained for the indicators and will guide the management plan (Figure 1). This information can be used to make any necessary adjustments to management measures and COs and thus enabling adaptive management of the MPA (Figure 1).

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

<table>
<tr><th></th><th colspan="2">Main monitoring elements</th></tr>
<tr><th></th><th>1) Assessing MPA status and trends</th><th>2) Assessing the ecological performance of the MPA</th></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.

Example dissolved O2:
<table><tr><th>State</th><th>Fixe 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
Example:
 
</td></tr>
<tr><td>What questions will be answered?</td><td>Did the biomass of species X change over time?

Has bottom oxygen decreased over the time series?

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>

Priority issues related to conservation objectives

For the Banc-des-Américains MPA, three 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). Because these three objectives are so broad, priority issues were developed to more specifically guide indicator assessment and MPA monitoring:

OC1 Conserve and protect benthic habitats

Priority issues:

- 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

OC2 Conserve and protect pelagic habitats and forage species

Priority issue:

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

OC3 Promote the recovery of at-risk whales and wolffish

Priority issue:

- 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.

ASSESSMENT

Update of conservation priorities, indicators and pressures

Following discussion by the DFO scientific monitoring committee (DFO-SMC), the conservation priorities and indicators identified in the 2018 peer review (Faille *et al.* 2019; DFO 2019) 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.” Following this revision, three pressures and five associated indicators were added to the list, and four indicators were removed (Tables 2 and 3). When the results were presented to the peer review, one additional indicator was removed (BD4), and indicator Pr2 was subdivided into three (Pr2, Pr19 and Pr20). Thus, a total of 44 indicators were selected to assess the 15 conservation priorities and 12 pressures. Tables 4 and 5 present all of these elements, the main surveys that were used or will be used to calculate the indicators (Appendix 1), and the data analysis status as of April 2021 (processed, not processed, not available). For 27 indicators, data were analyzed, and measures were calculated to provide a historical and initial portrait. For six indicators, data exist but could not be analyzed for this process. Finally, no results could be presented for 11 indicators, as data were not available or were insufficient.

Table 2. Indicators added to the 2018 list for DFO's ecological monitoring of the Banc-des-Américains MPA and rationale for their addition.

Pressures added	Indicators added	Comment–justification
Competitors/predators	Pr4) Grey seal	The competitor/predator pressure could have significant effects on the existing benthic and demersal communities and thus affect the general goal of the MPA. The grey seal was identified as an element that could affect the demersal communities through predation pressure.
-	Pr13) and Pr17) Footprint and biomass harvested by scientific activities	Scientific activities presently occur at a low frequency and are managed by an activity plan, thus posing a low risk of impact on the achievement of the COs. From a transparency perspective, it is important to report on scientific activities.
-	Pr14) Fishing activity violation	Add 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 could impede on the achievement of CO1.
New pressure	Pr18) Number of new pressures	Add to track and identify any new activity in the MPA that have the potential to impede the CO (e.g., native fishing, tourism, etc.).
Ghost Gear	-	The presence of fixed gear (traps and longline) fisheries in the MPA. pose a risk of gear loss (past and future). Ghost gear may primarily affect the achievement of CO3.

Table 3. Indicators removed from the 2018 list for DFO's ecological monitoring of the Banc-des-Américains MPA and rationale for their removal.

2018 Indicators eliminated	Comment - justification
O2) Internal current, wave and tidal dynamics	The available data come 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) Abundance and taxonomy of species	No data available from existing surveys for the area. The expertise of a specialized taxonomist would be required to produce data for the area. This represents a considerable expense for which the projected cost-benefit ratio is too low, considering that this indicator is indirect and such precision is not needed.
P7) Biomass and abundance from the mackerel stock assessment	Data from the stock assessment is measured at the scale of northeastern North America (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	

Table 4. List of updated indicators related to the conservation priorities and the main surveys (Appendix 1) used to monitor them. The type of indicator—direct (D) or indirect (I)—is specified. The analysis status indicates whether (1) the data have been processed and results are presented (P), (2) the data are available but have not been processed (NP), or (3) the data are not available (NA).

Conservation Priorities	Indicators version 2021	Type	Main Survey(s)	Analysis status
CO1 Conserve and protect benthic habitats (benthic and demersal (BD))				
Indicator species of benthic and demersal communities	BD1) Cold water indicator species	I	R10-Multi sGSL	P
	BD2) Warm water indicator species	I	R10-Multi sGSL	P
	BD3) Dominant/key species	I	R10-Multi sGSL	P
	*BD4) Biomass of invertebrates**	-	R10-Multi sGSL	P
Epibenthic communities	BD5) Epibenthic community A: Rocky ridge	D	RD1-Imagery	NA
	BD6) Epibenthic community B: Mixed ridge	D	RD1-Imagery	NA
	BD7) Epibenthic community C: Mixed plain	D	RD1-Imagery	NA
	BD8) Epibenthic community D: Soft plain	D	RD1-Imagery	NA
Demersal communities	BD9) Demersal fish community on the plain	I	R10-Multi sGSL	P
	BD10) Demersal fish on the ridge	I	RD6-Bait. Imagery	NA
Benthic and demersal commercial species	BD11) Snow Crab	D	R13-Snow Crab sGSL	P
	BD12) Harvested groundfish	I	R10-Multi sGSL	P
Substrate characteristics	BD13) Sediments	D	RD1-Imagery	NA
Endobenthic communities	*na*	-	RD2-Grab	NA
Suprabenthic communities	*na*	-	*na*	NA

Conservation Priorities	Indicators version 2021	Type	Main Survey(s)	Analysis status
CO2 Conserve and protect pelagic habitats and forage species (Pelagic (P))				
Nutrients	P1) Nutrients	I	R1-AZMP and R10-R11-Multi n/sGSL	P
Phytoplancton	P2) Chlorophyll *a*	I	R1-AZMP and R10-R11-Multi n/sGSL	P
Zooplancton	P3) Zooplancton	I	R1- AZMP	P
Krill	P4) Krill biomass	I	R7-Krill and R10-R11-Multi n/sGSL	NP
Herring	P5) Herring stock biomass sGSL	I	R8-Herring sGSL	P
Capelin	*na*	-	*na*	NA
CO3 Promote the recovery of at-risk whales and wolffish (EP)				
Atlantic Wolffish	EP1) Atlantic Wolffish	D	RD4-Scuba diving and RD5-DNAe	NA
	EP2) Atlantic Wolffish bycatch	D	R10-Multi sGSL, R13-Snow Crab sGSL, R15-Observers	P
Whales	EP3) Fin whale	I	R21-PAM	NP
	EP4) Blue whale	I	R21-PAM	NP
	EP5) North Atlantic right whale	I	R21-PAM	NP
	EP6) Cetacean mortality/accidents	D	R17-QMMERN	P

**Indicator removed following peer review of results; results are still presented in the research document.*

Table 5. List of updated indicators related to the pressures and the main surveys used to monitor them. The type of indicator—direct (D) or indirect (I)—is specified. The analysis status indicates whether (1) the data have been processed and results are presented (P), (2) the data are available but have not been processed (NP), (3) the data are available and partially processed (PP), or (4) the data are not available (NA).

Pressures (Pr)	Indicators version 2021	Type	Main Survey(s)	Status of analysis
Climate changes	Pr1) Physical conditions of the pelagic habitat	I	R1-AZMP, R3-Ice, R4-SST, R6-Helicoptered and R10-R11-Multi n/sGSL	P
	Pr2) Physical conditions of the benthic habitat (>100m)	I	R10-R11-Multi n/sGSL	P
	Pr19) Acidification	I	R1-AZMP and R10-R11-Multi n/sGSL	P
	Pr20) Dissolved oxygen	I	R1-AZMP and R10-R11-Multi n/sGSL	P
Invasive Species (AIS)	Pr3) Presence of AIS	I	RD5-eDNA	NA
Competitors/predators	Pr4) Grey Seal	I	RD7-Haulouts	NA
	Pr5) Lobster on the ridge	D	RD4-Scuba diving and RD6-Bait. Imagery	NA
Noise	Pr6) Anthropogenic noise	D	R21-PAM	NA
	Pr7) Traffic intensity	D	R18-AIS	P
Disturbance	Pr8) Intensity of observation and recreational activities	D	R22-Act. report and R18-AIS	PP
Collisions	Pr21) Number of collisions	D	*na*	NP
	Pr9) Vessel speed	D	R18-AIS	P
Entanglements	Pr10) Number of entanglements	D	R17-QMMERN	P
Physical disturbance of the bottom	Pr11) Relative footprint of the Snow Crab fishery	D	R14-ZIFF	P
	Pr12) Relative footprint of the groundfish fishery	D	R14-ZIFF	P

Pressures (Pr)	Indicators version 2021	Type	Main Survey(s)	Status of analysis
	Pr13) Footprint of scientific activities	D	R10Multi sGSL, R13-Snow Crab sGSL and RD1-Imagery	P
	Pr14) Fishing activities–violations	D	*na*	NP
Biomass removal	Pr15) Snow Crab fishery	D	R14-ZIFF and R13-Snow Crab sGSL	P
	Pr16) Groundfish fishery	D	R14-ZIFF	P
	Pr17) Fishing done by scientific activities	D	R10-Multi sGSL, R13-Snow Crab sGSL	P
New pressure	Pr18) Number of new pressures	-	*na*	NA
Ghost gear	*na*	-	*na*	NA
Pollution	*na*	-	*na*	NA

**Indicators separated from indicator Pr2 following peer review*

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 managers and the public 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. 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. It is important to note that aggregation of measures can attenuate or mask signals from important individual measures, which can lead to simplistic conclusions or inappropriate management actions. Thus, it is suggested that the status of each measure be presented in conjunction with the status of the indicators to optimize interpretation of the results. In addition, given the diversity of the indicators and measures, the use of two methods, anomaly and threshold, is proposed.

It was decided to use three categories of indicator status or change, with scores ranging from 1 (poor status or high change) to 3 (good status or low change; Table 1). Data may be presented without the status being assessed because of a lack of information, in which case the “Not assessed” category is used.

Anomaly

The anomaly 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) (Galbraith *et al.* 2022; Blais *et al.* 2021) 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. 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 (Table 6). For example, for marine traffic intensity, the more positive the anomaly is, the more the status of this pressure is “High” (Table 6).
- **Bidirectional**: Sometimes the direction of the change (positive or negative) cannot be interpreted as good or bad. 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 7).

Thresholds

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, for indicators related

to dissolved oxygen and acidification, physiological/ecological thresholds are known below which the growth, reproduction and even survival of one or more species are compromised (Table 6). 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 6).

Table 6. Methods for assessing the status of the measures and indicators for conservation priorities and pressures: (1) directional anomaly calculated based on 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 SE or higher	Average of the reference period ± 1 SE or lower	> 70%	> 2	> USR
Medium/Medium (2)	- 1 SE to - 2 SE	+ 1 to + 2 SE	30–70%	1–2	> LRP and < USR
Poor/High (1)	< - 2 SE	> 2 SE	< 30%	< 1	< LRP
Not assessed	Insufficient data				

Table 7. Method for assessing the status of measures and indicators of conservation priorities and pressures using bidirectional 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 SE
Moderate change (2)	± 1 to 2 SE
Important change (1)	> or < 2 SE
Not assessed	Insufficient data

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 8).

In this document, these methods are applied to provide an initial portrait of 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 be presented when at least 3 years have elapsed since the MPA was established. It will then be weighed 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-SMC. The quantity of the data (e.g., frequency, time series, seasonal and spatial coverage) and their quality (e.g., gear selectivity, taxonomic accuracy) were considered for this assessment.

Table 8. Calculation of indicator status based on the scores of each measure for the threshold method.

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		

Spatial scales for the calculation of measures

Not all indicators and associated measures are assessed at the same spatial scale (Tables 9 and 10). The Banc-des-Américains MPA is subdivided into two main areas. Area 1, corresponding mostly to the ridge, is subject to stricter conservation measures than Area 2 (a and b), which includes the northeast and southwest plains (*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).

The indicators (BD1, BD2, BD3, BD4, BD9 and BD12), calculated from the DFO sGSL multispecies survey (R10-Multi sGSL; Appendix 1), are based on all tows in stratum 416, including the MPA. The number of tows in the MPA alone is insufficient to adequately assess the status of these indicators, hence the decision to expand the spatial scale to stratum 416. 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. An area larger than the MPA was also delineated to calculate oceanographic indicators related to benthic habitat (Pr2, Pr19 and Pr20; 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).

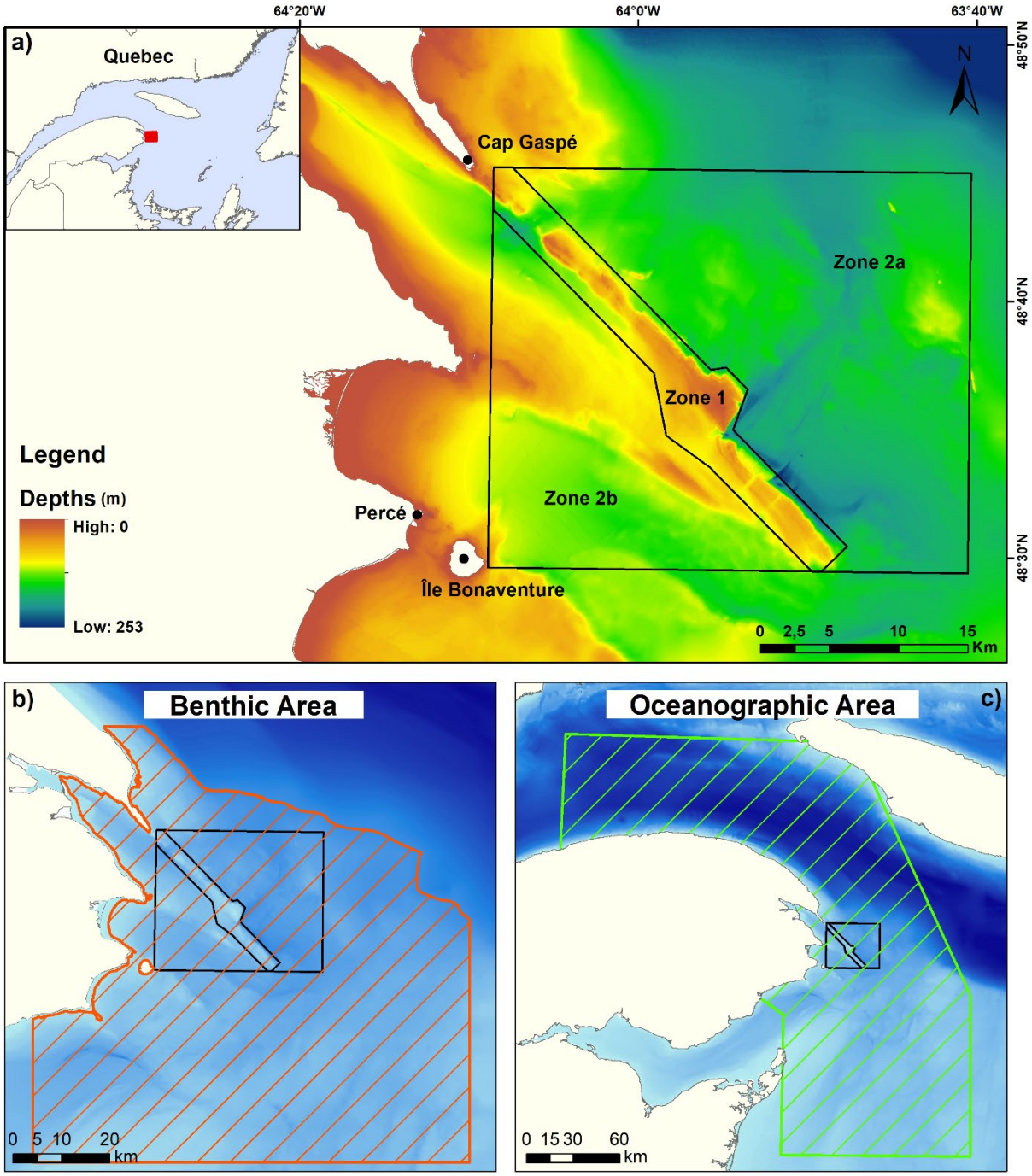


Figure 2. (a) Boundaries of the Banc-des-Américains MPA and the two regulatory areas present, Area 1 and Area 2 (a and b); (b) boundary of the benthic area used to calculate indicators Pr2, Pr19 and Pr20; (c) boundary of the oceanographic area used to calculate indicators P1, P2, P3, P4 and Pr1.

Selection of measures and state of knowledge for conservation priorities

Indicator species of benthic and demersal communities

Species of cold-water or warm-water stenothermic fishes (22 taxa) and invertebrates (8 taxa) were selected based on their preferred thermal thresholds to calculate indicators BD1–Cold water indicator species and BD2–Warm water indicator species. These species were selected because they can show a rapid response to thermal changes. Four measures were selected for each indicator, and status was assessed based on the R10-Multi sGSL survey data (Appendix 1) for the 1986–2020 (fish) and 2004–2020 (invertebrates) time series using bidirectional anomaly. For indicator BD1, the biomass of the most abundant taxa is used as a measure, while for less-frequent species, the measure used is the proportion of tows with catches. The status of indicator BD1 has been fairly stable throughout the historical series, with variations on either side of the mean corresponding mainly to a “Low” level of change (Table 9 and Figure 3). Since 2015, measures have tended to be below the reference period mean. The status of indicator BD2 could not be estimated because of the lack of data, since very few specimens of warm-water indicator species were captured (Table 9). This indicator was nevertheless retained and will be reassessed in future monitoring reports.

For indicator BD3-Dominant/key species, the most abundant and key taxa for the sector were selected from the R10-Multi sGSL survey biomass (kg) and occurrence data (Appendix 1). The status of the measures was assessed for the 1986–2020 (fish) and 2004–2020 (invertebrates) time series using directional anomaly. A decrease in the biomass of these dominant species is not desirable, since the objective is to maintain or improve the baseline state of the benthic habitat at the time the MPA was established. Following the review, three measures related to demersal species (*Pandalus*, American Plaice and Greenland Halibut) were retained, and three measures related to key invertebrate species were removed from this indicator (Table 9). As the bottom trawl used does not capture some benthic taxa well, the data used were not sufficiently representative. In addition, as the spatial scale was expanded to stratum 416 of the R10 Multi sGSL survey rather than the MPA, the data on low-mobility invertebrates collected in this way are not very informative with regard to the taxa actually present in the MPA. For the same reason, indicator BD4–Biomass of invertebrates was not retained following the revision of the results. Considering the removal of these three measures, the name of indicator BD3 becomes Dominant species only. The status of indicator BD3 was “Healthy” throughout the historical series. A more pronounced increase from the reference mean was observed in 2020 (Table 9 and Figure 3).

Demersal communities

During the peer review, only indicator BD9–Demersal fish community on the plain was assessed using five measures (Table 9). The monitoring of these measures contributes to an overall portrait of the evolution of the demersal fish community on the plains. The status of the indicator was assessed for the historical series from 1986 to 2020 using the R10-Multi sGSL survey data (Appendix 1) and is presented as a directional anomaly. Maintenance or improvement in demersal fish community diversity and maintenance or increase in abundance are targeted. The status of indicator BD9 has remained “Good” throughout the historical series. The indicator has fluctuated from the reference mean slightly but frequently, with a below-mean trend over the past 10 years (Table 9 and Figure 4).

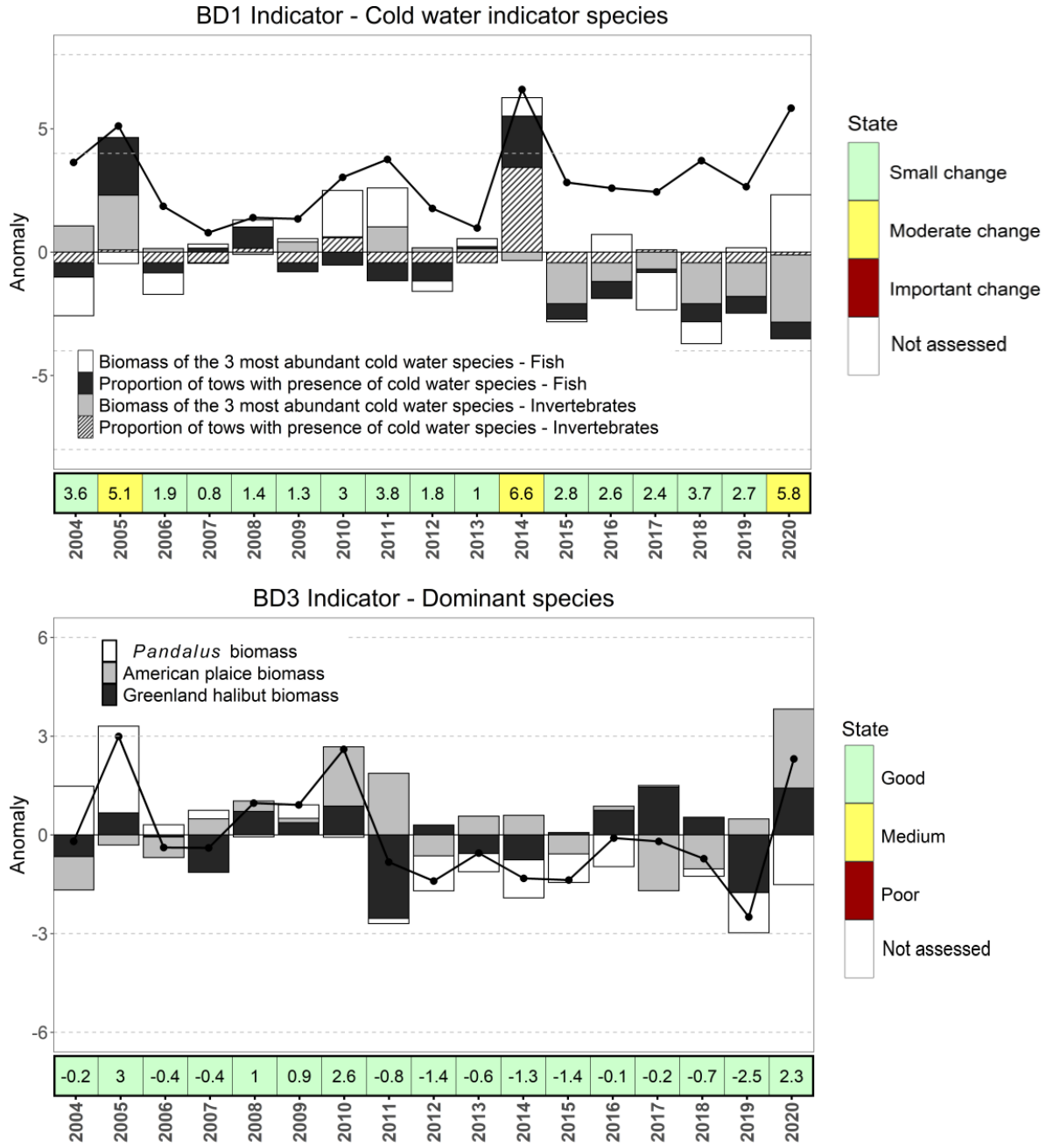


Figure 3. Status and trend of the time series for indicators BD1 (top figure) and BD3 (bottom figure), associated with the conservation priority Indicator species of benthic and demersal communities. The vertical bars represent the standardized measures (anomaly), and the black line symbolizes the sum of the anomalies (as an absolute value for BD1), which is used to assign an annual status to the indicator. This status is colour coded on the horizontal band below the graph.

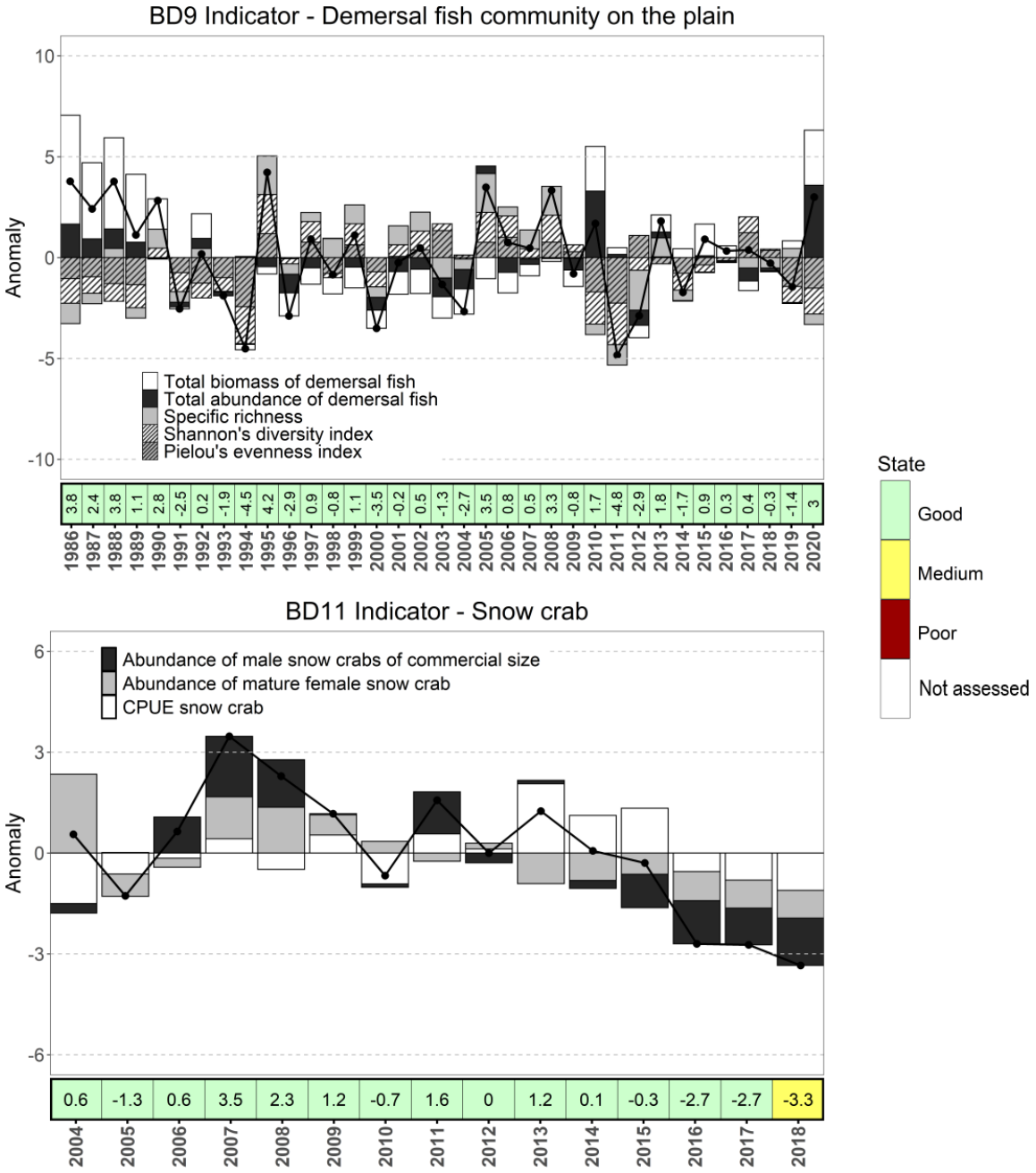


Figure 4. Status and trend of the time series for indicators BD9 (top figure) and BD11 (bottom figure), associated with the conservation priorities Demersal communities and Benthic and demersal commercial species, respectively. The vertical bars represent the standardized measures (anomaly), and the black line symbolizes the sum of the anomalies, which is used to assign an annual status to the indicator. This status is colour coded on the horizontal band below the graph.

Benthic and demersal commercial species

The status of indicators BD11–Snow Crab and BD12–Harvested groundfish (Atlantic Halibut and Atlantic Cod) were assessed using three measures each. The measures were calculated for the available historical series from 2004 to 2018 using data from the R13-Snow Crab sGSL

and R10-Multi sGSL surveys (Appendix 1); the results are presented as a directional anomaly. A decrease in the biomass of these commercial species is not desirable, since the objective is to maintain or improve the status of the commercial resources at the time the MPA was implemented. For indicator BD11, the status was “Good” throughout the historical series, except in 2018, when it was “Medium.” However, since 2013, a downward trend in the indicator has been observed (Table 9 and Figures 4). For indicator BD12, the condition has remained “Good” throughout the historical series, but a general upward trend has been observed (Table 9 and Figures 5). Prior to 2011, the anomalies were negative, while thereafter they were all positive. Since no longline fishing was recorded in the MPA in 2004 and 2006, the measure related to CPUE was not calculated and the status could not be assessed for these years.

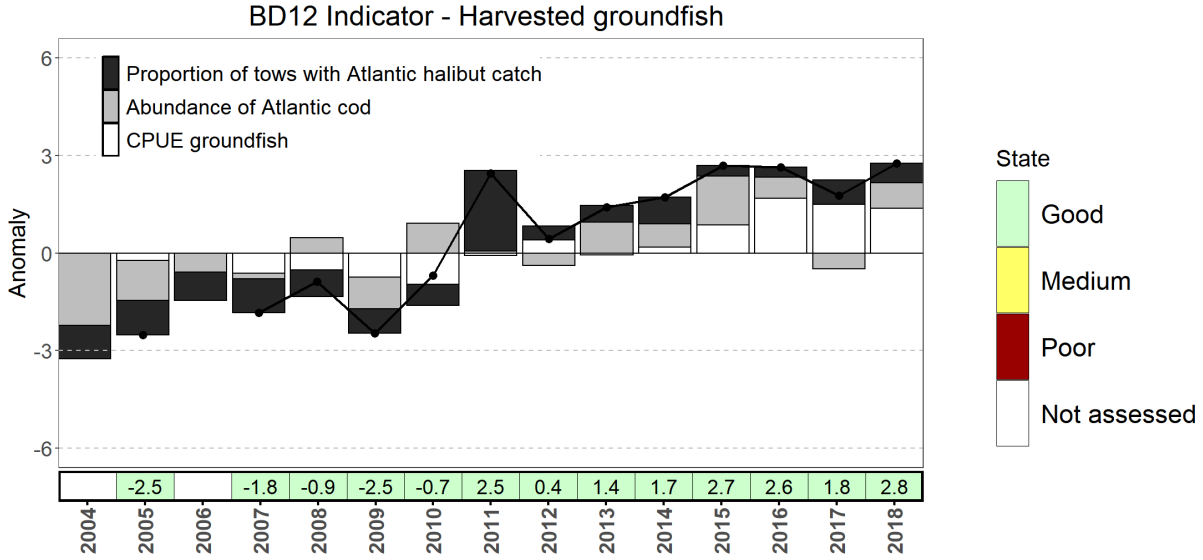


Figure 5. Status and trend of the time series for indicator BD12, associated with the conservation priority Benthic and demersal commercial species. The vertical bars represent the standardized measures (anomaly), and the black line symbolizes the sum of the anomalies, which is used to assign an annual status to the indicator. This status is colour coded on the horizontal band below the graph. Since there was no fishing in the MPA in 2004 and 2006, no status could be calculated.

Nutrients

The indicator P1–Nutrients was assessed based on three measures at two depth strata (0–50 m and 50–150 m). The status of this indicator was assessed based on AZMP data and the multispecies surveys (R1-AZMP and R10-R11-Multi n/sGSL, Appendix 1) for the 1999–2020 time series and is presented as a bidirectional anomaly. The status fluctuated frequently between a “Small” and “Moderate” change. Since 2016, the indicator has been more stable and close to the reference mean, except in 2020 when the level of change was “Moderate” because of high nitrate concentrations in the intermediate layer (Table 9 and Figure 6).

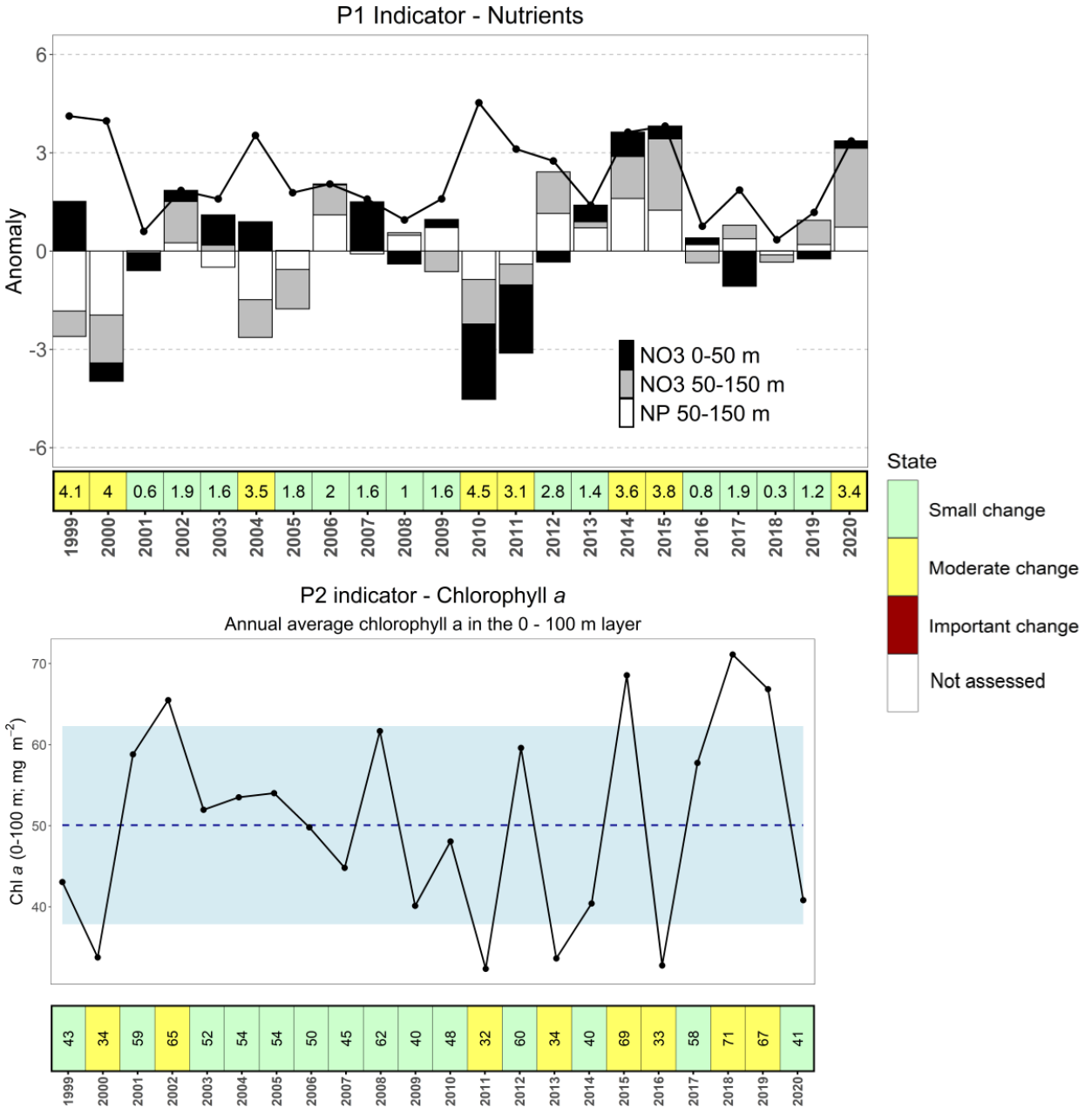


Figure 6. Status and trend of the time series for indicators P1 and P2, associated with the conservation priorities Nutrients and Phytoplankton, respectively. For indicator P1 (top panel), the vertical bars represent three standardized measures (anomaly), and the black line symbolizes the sum of the anomalies as an absolute value, which is used to assign an annual status to the indicator. For indicators P2 (bottom panel), only one measure is retained, which is represented directly by the raw value. The blue hatched line represents the average conditions during the reference period (1999–2018), and the blue shading represents ± 1 standard deviation around this average. Below the graphs, the condition is colour coded.

Phytoplankton

Indicator P2–Chlorophyll *a* was assessed based on a single measure, the annual average of chlorophyll *a* in the layer between 0 and 100 m. The status of this indicator was assessed based on AZMP data and the multispecies surveys (R1-AZMP and R10-R11-Multi n/sGSL, Appendix 1) for the 1999–2020 time series and is presented as a bidirectional anomaly. Following a relatively stable period from 1999 to 2010, the status underwent greater oscillations from 2011 onwards, corresponding mainly to a “Moderate” change level (Table 9 and Figure 6).

Zooplankton

Indicator P3-Zooplankton was assessed using four measures related to mesozooplankton. The status of this indicator was assessed using the R1-AZMP survey data (Appendix 1) for the 2001–2020 time series and is presented as a bidirectional anomaly. In the first half of the historical series, the level of change was “Small.” From 2012 onwards, more pronounced anomalies (“Moderate” change) were observed (Table 9 and Figure 7).

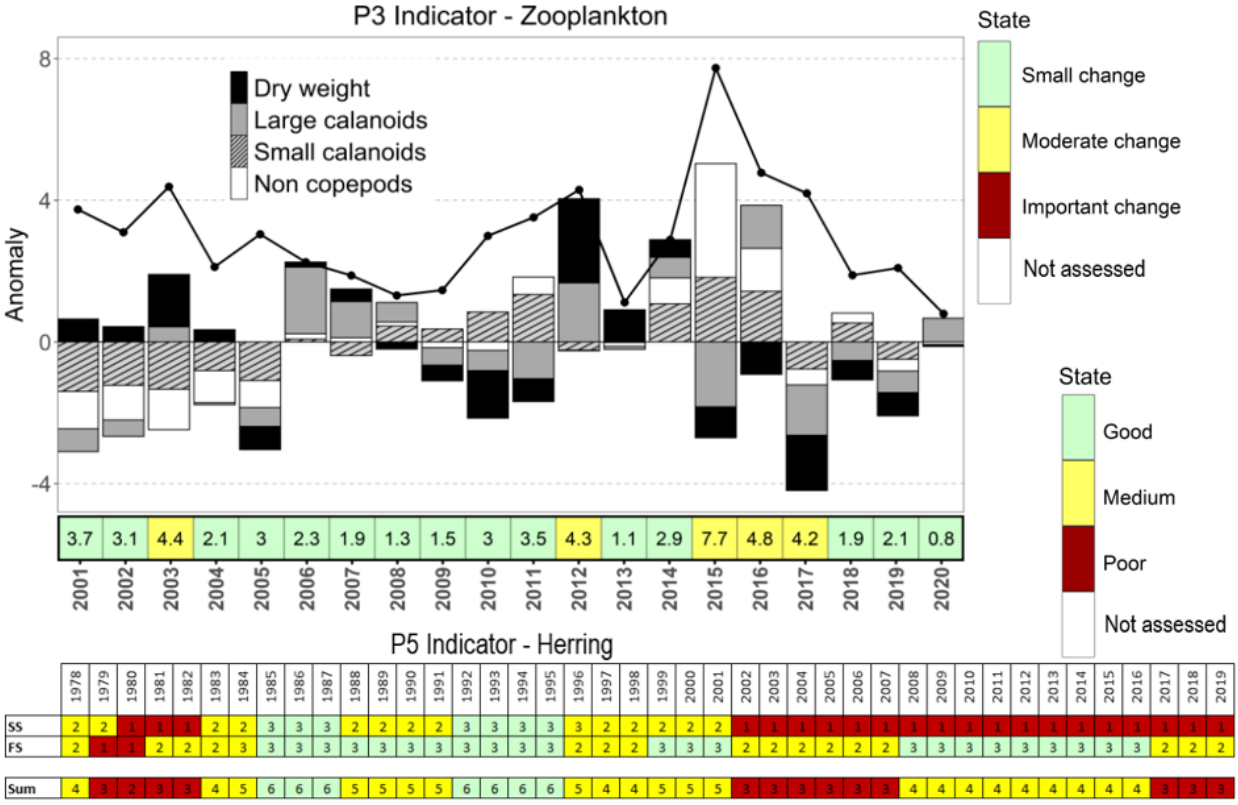


Figure 7. Status and trend of the time series for indicators P3 and P5, associated with the conservation priorities Zooplankton and Herring, respectively. For indicator P3 (top panel), the vertical bars represent the standardized measures (anomaly), and the black line symbolizes the sum of the anomalies as an absolute value, which is used to assign an annual status to the indicator. This status is colour coded on the horizontal band below the graph. For indicator P5 (bottom panel), a fixed threshold is used to assess the status represented by the sum of the status of the two measures, spring spawners (SS) and fall spawners (FS).

Krill

The status of indicator P4–Krill biomass was not assessed because of a lack of processed data, but the three measures to be used in the future were described (Table 9).

Herring

To determine the status of indicator P5–Herring stock biomass sGSL, two measures from the southern Gulf herring stock assessment were used. The status of this indicator was estimated for the 1978–2019 time series and is presented as a directional anomaly using thresholds defined with the precautionary approach for herring stocks. Status ranged from “Poor” in the early 1980s to between “Good” and “Medium” in the late 1980s and 1990s (Table 9 and Figure 7). Since 2002, the status has deteriorated and has ranged from “Medium” to “Poor,” mainly because of the decline in spring-spawning herring.

Atlantic wolffish

Data were analyzed only for indicator EP2–Atlantic wolffish bycatch, which was divided into two measures (Table 9). However, the status of this indicator could not be assessed because there was insufficient data, and the interpretation of the results remains to be clarified. If bycatch is increasing, this change can be considered negative, as more fish are being harvested. Conversely, the change can be interpreted as positive, since an increase in bycatch would reflect a larger population.

Whales

During the peer review, only one of the four indicators identified for the “Whales” conservation priority was presented. Indicator EP6–Cetacean mortality/accidents was revised to include two measures, one for species at risk and one for other marine mammal species (Table 9). The status of indicator EP6 could not be assessed, because there are too many uncertainties associated with the QMMERN data (R17-QMMERN, Appendix 1) to allow for a meaningful assessment. These data are essentially based on voluntary observations and are not reported systematically. As such, the proportion may fluctuate over time (public awareness). In addition, carcasses tend to sink rather than drift, so not all are counted. However, the indicator was retained because it remains informative and can help in the interpretation of other indicators.

Choice of measures and state of knowledge for pressures

Climate change

Indicator Pr1–Physical conditions of the pelagic habitat was estimated using three sub-indicators: physical conditions of the surface layer (three measures), ice conditions (three measures) and physical conditions of the cold intermediate layer (three measures). The data used are from the R1-AZMP survey (Appendix 1) as well as from other surveys collecting oceanographic data (R3-Ice, R4-SST, R6-Helicoptered and R10-R11-Multi n/sGSL). An annual status was first assigned to each of the three sub-indicators based on the sum of the absolute anomaly values (bidirectional anomaly). This sum per sub-indicator was then summed to characterize the annual status of the indicator between 1987 and 2020 (Table 10 and Figure 8). The status has mostly remained at a “Small” level of change over the historical series. Stronger anomalies were observed in the early 1990s, which were related to colder conditions, as well as starting in 2010, related to warmer conditions (Table 10 and Figure 8).

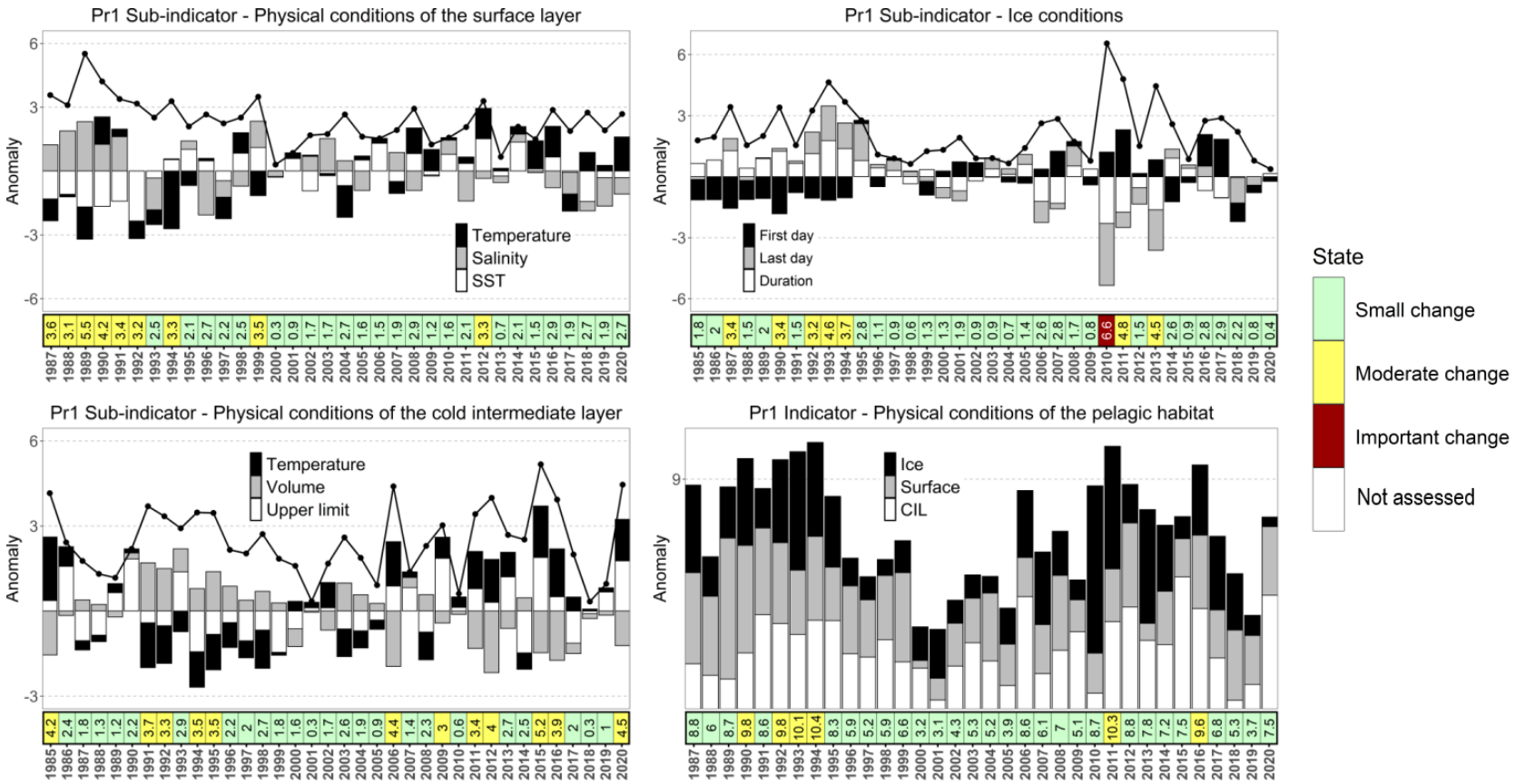


Figure 8. Status and trend of the time series for the three sub-indicators of indicator Pr1 and indicator Pr1-Physical conditions of pelagic habitat, associated with the pressure Climate change. The black line corresponds to the sum of the absolute values of the anomalies that assign an annual status to the sub-indicators of Pr1, which is colour coded on the horizontal band below each graph.

Indicator Pr2–Physical conditions of benthic habitat (> 100 m), as presented in the peer review, included measurements of temperature, salinity, acidification and dissolved oxygen. In order to properly interpret the observed changes, it was decided to split the indicator into three, with one indicator for acidification and one for dissolved oxygen. Indicator Pr2 was assessed based on the data collected by surveys R10-R11-Multi n/sGSL (Appendix 1), and its status is presented as a bidirectional anomaly for the 1987–2020 time series. Two measures were used to provide a general portrait of near-bottom physical conditions, as temperature and salinity can directly influence the metabolism of some benthic organisms. The observed level of change has generally been “Small” since 1996. Prior to that date, the change was more “Moderate” and was related to colder conditions and lower salinity. The summer temperature near the bottom (> 100 m) was at its minimum in the late 1980s and early 1990s. The temperature then gradually increased over time (Table 10 and Figure 9).

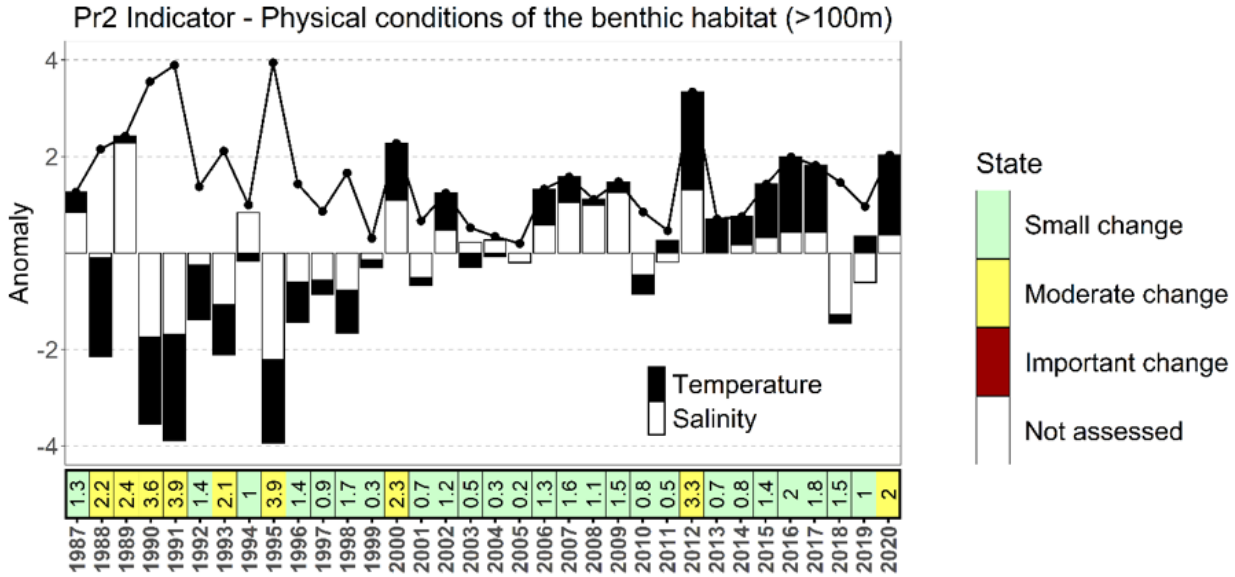


Figure 9. Status and trend of the time series for indicator Pr2, associated with the pressure Climate change. The vertical bars represent the standardized measures (anomaly), and the black line corresponds to the sum of the absolute values of the anomalies, which makes it possible to assign an annual status to the indicator. This status is colour coded on the horizontal band below the graph.

Indicator Pr19–Acidification was retained to assess whether conditions are becoming more acidic for near-bottom benthic organisms in areas deeper than 100 m. Two measures were calculated since 2017, as well as for 2011, using the data from R1-AZMP (Appendix 1) as well as other surveys collecting oceanographic data (R10-R11-Multi n/sGSL). The status of the indicator was assessed using fixed thresholds (Table 6). The pressure level was “High” for the entire historical series, primarily because the aragonite saturation rate was below the threshold of 1 (Table 10 and Figure 10).

Using the same databases, the status of indicator Pr20–Dissolved oxygen was assessed using a single measure for the 2002–2020 time series and was estimated using fixed thresholds (Table 6). Indicator Pr20 was used as an index to monitor the pressure of O_2 levels on benthic and demersal organisms (one measure). Throughout the historical series, the pressure level was fairly stable and qualified as “Medium,” with dissolved O_2 values varying between 46% and 68% saturation (Table 10 and Figure 10).

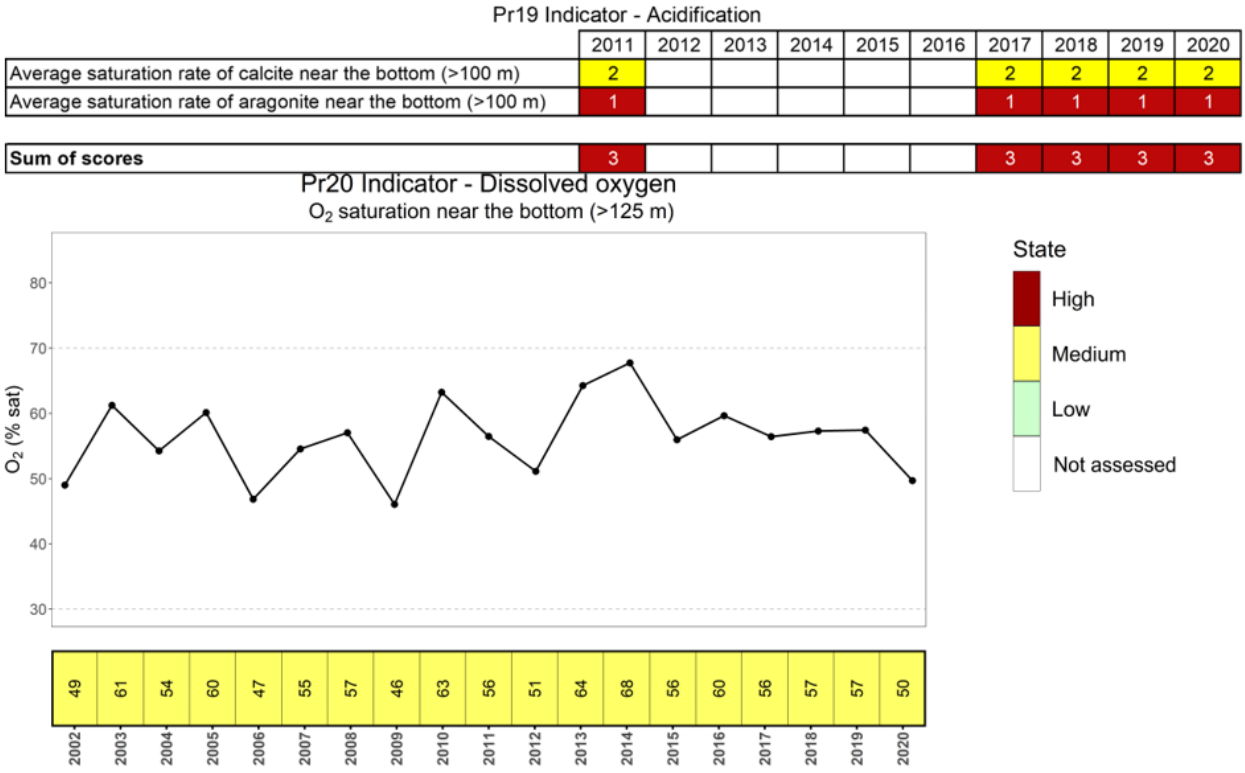


Figure 10. Status and trend of the time series for indicators Pr19 and Pr20, associated with the pressure Climate change. In the top panel, the sum of the saturation rates is used to assign an annual status to the indicator, which is colour coded in the centre panel. The grey hatched lines in the bottom panel represent the boundaries of the intervals associated with the different statuses (Pr20). On the band below the graph, the value obtained each year is colour coded according to a known threshold criterion.

Noise

In the peer review, only indicator Pr7-Traffic intensity was assessed using data collected by the R18-AIS survey (Appendix 1), and its status is presented as a directional anomaly for the 2013–2019 time series. Traffic intensity is used to indirectly assess the potential noise disturbance to cetaceans and other marine mammals. Two measures were selected and calculated for indicator Pr7 : one for commercial traffic and one for traffic related to marine operations (e.g., tugboat, dredger, research, Canadian Coast Guard, icebreaker, military). The other two measures calculated for the transit time in the MPA for each type of vessel were eliminated. These measures are difficult to interpret, considering the speed limits established for right whales since 2017. Slowing down vessels in the MPA can potentially help decrease noise levels and collision risk but increases transit time, which increases cetacean disturbance. The pressure level was “Low” throughout the historical series, except in 2019 when it was “High” because of the increase in commercial traffic, representing about 100 more passages than the annual average (Table 10 and Figure 11). Also, the number of transits for marine operations increased markedly in 2019.

Disturbance

Indicator Pr8–Intensity of observation and recreational activities was assessed using four measures related to marine observation activities (Table 10). For this indicator, little historical data was available, so only a partial portrait was provided. Thus, the status of the

indicator could not be assessed in this document. Measures will be assessed at a later date once commercial tourism activities in the MPA have been monitored more precisely over several years.

Collisions (traffic)

To provide information on collision risk to marine mammals, indicator Pr9-Vessel speed was assessed using three selected measures. The status of the indicator was assessed for the available historical series from 2013 to 2019 and is presented as directional anomalies, since an increase in speed can increase the risk of collision. The data used was collected by the R18-AIS survey (Appendix 1). The status has improved from a “Medium” pressure level in 2013 to a “Low” level since 2014 (Figure 11 and Table 10). A steady decrease of average speeds for commercial and marine operations vessels was observed since 2017. This decline can be explained by the slowdown measures related to the Right Whale. Indicator Pr9 could be modified based on the work done by the Saguenay–St. Lawrence Marine Park, which uses a probability index integrating the risk of collisions and the number of vessels according to speed.

Entanglements

Indicator Pr10–Entanglements was calculated using a single measure, the number of cetacean entanglements based on data collected between 2012 and 2020 by the QMMERN (R17-QMMERN; Appendix 1) for the Gaspé and Percé sectors (Table 10). As with indicator EP6, the status could not be assessed because the data were insufficient and presented several uncertainties. However, the indicator was retained, and the raw data will continue to be presented in future monitoring reports.

Physical disturbance of the bottom

Indicators Pr11–Relative footprint of the Snow Crab fishery and Pr12–Relative footprint of the groundfish fishery were each assessed using two measures. The method used to calculate the relative spatial footprint of commercial fisheries is an approximation and may overestimate the disturbed area, which should be considered during interpretation of the results. Further assessment of the method will be required to develop a more optimal approach. For these indicators, status was assessed for the available time series, from 2004 to 2018, based on the R14-ZIFF survey data (Appendix 1). Both indicators were presented as directional anomalies as increasing the fishing footprint may affect a greater proportion of benthic communities, which is contrary to CO1. For indicator Pr11, the pressure level was generally “Low” between 2004 and 2017 and increased to “Medium” in 2018 (Figure 12 and Table 10).

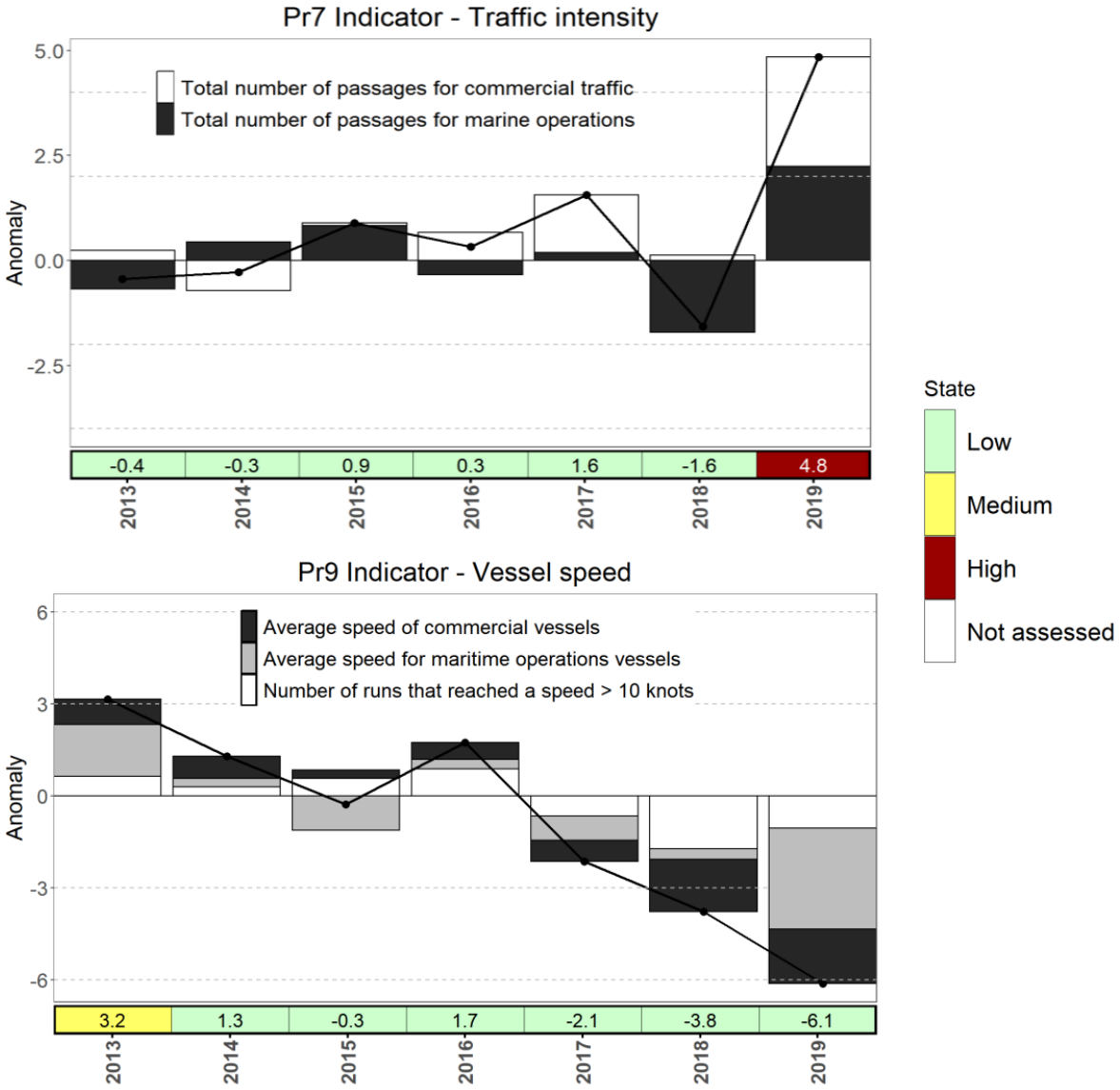


Figure 11. Status and trend of the time series for indicators Pr7 (top panel) and Pr9 (bottom panel), associated with the pressures Noise and Collisions, respectively. The black line on each graph corresponds to the sum of the actual values of the anomalies, which are used to assign an annual status to the indicator. This status is colour coded on the horizontal band below the graph.

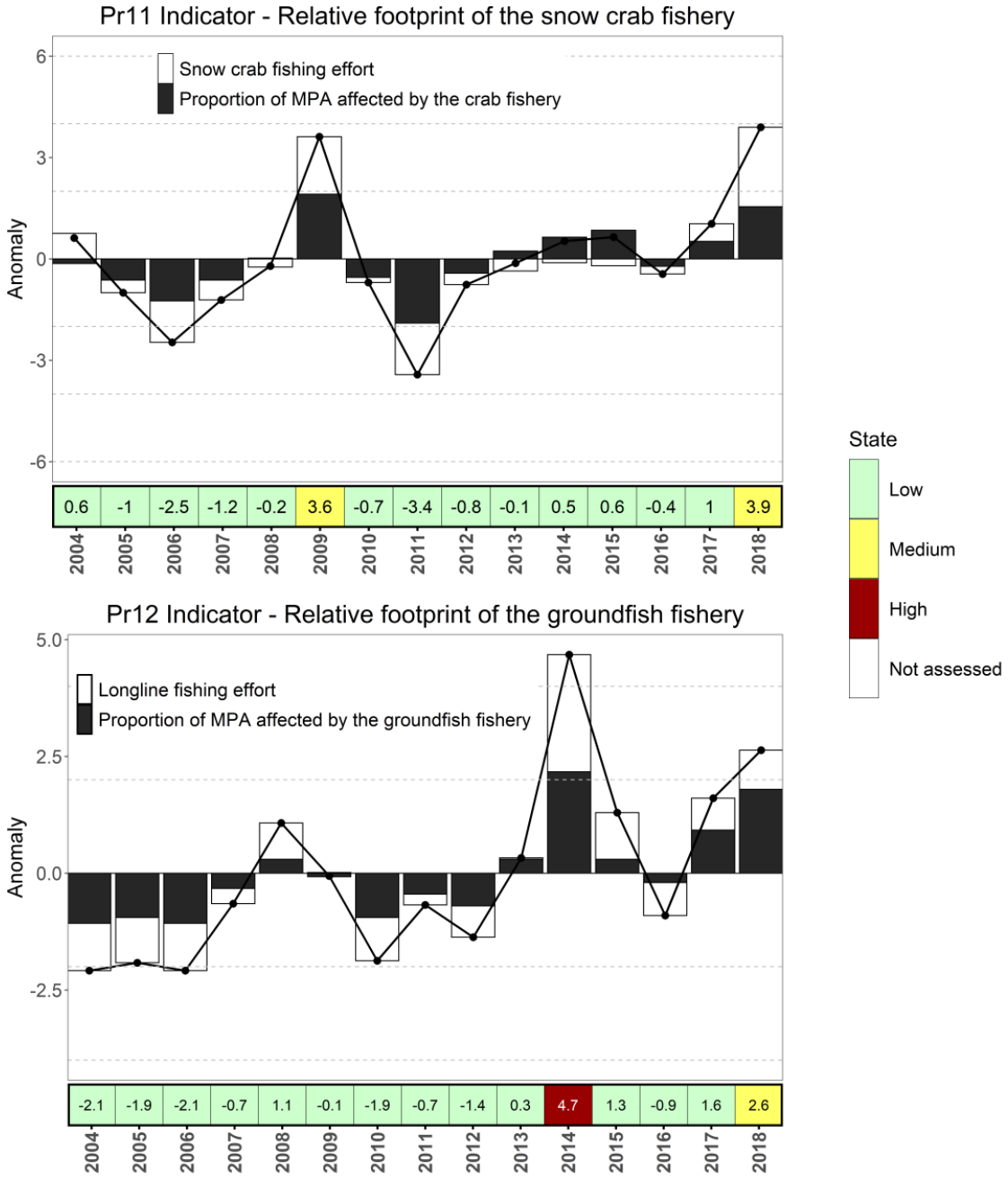


Figure 12. Status and trend of the time series for the indicators associated with the pressure Physical disturbance of the bottom (Pr11 and Pr12). The black line on each graph is the sum of the actual values of the anomalies that are used to assign an annual status to indicators Pr11 (top panel) and Pr12 (bottom panel), which is colour coded on the horizontal band below each graph.

For indicator Pr12, the pressure level has remained “Low” throughout the series, except in 2014 when the level increased to “High” and in 2018 when it was “Medium” (Figure 12 and Table 10). These increases are related to increases in fishing effort and the proportion of the MPA affected by fishing. There was no longline fishing recorded in the MPA in 2004 and 2006. Note that the average for the reference period is still very low (less than 1% of the MPA). Also, the time series

used (2004–2018) represents a low level of fishing compared to the 1980s and 1990s. As there were too few geo-referenced data for the latter period, comparison over a longer reference period was not possible.

Indicator Pr13–Footprint of scientific activities was assessed using a measure for the 1986–2020 time series from the R10-Multi sGSL, R13-Snow-Crab sGSL and RD1-Imagery data (Appendix 1). As suggested for this indicator in the peer review, the data were presented without a status assessment, since no assessment method was selected (Figure 13 and Table 10).

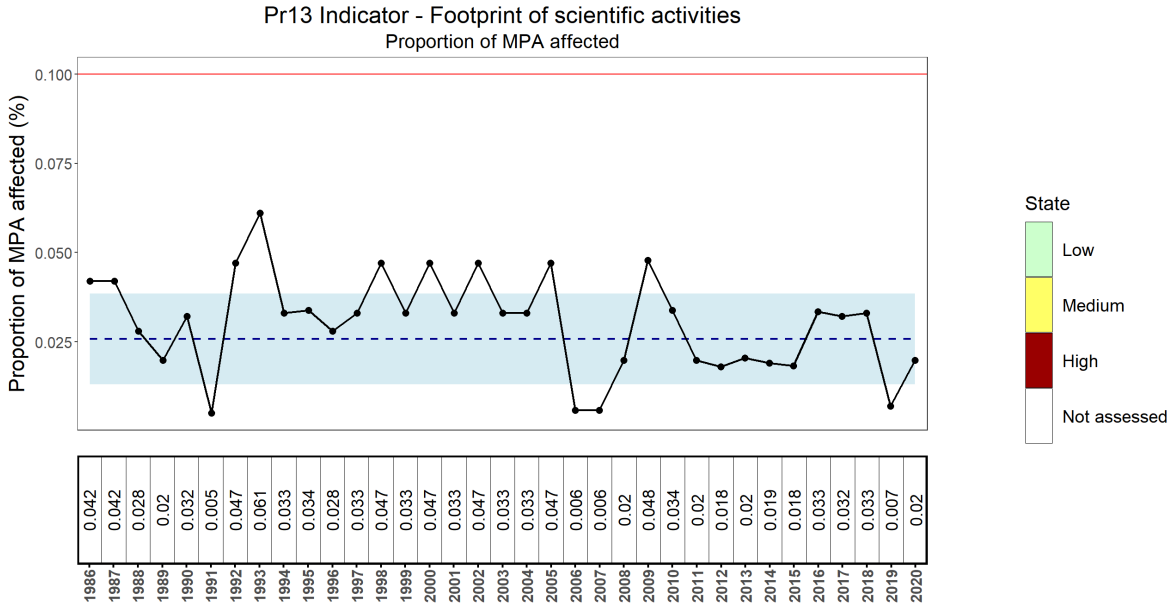


Figure 13. Status and trend of the time series for indicator Pr13, associated with the pressure Physical disturbance of the bottom. The blue hatched line represents the average conditions during the reference period (2004–2018), and the blue shading represents ± 1 standard deviation around this average. The annual proportion of the MPA covered by the science surveys is presented on the band below the graph. The red line represents 0.1% of the total MPA area.

Biomass sampling

Indicator Pr15–Snow Crab fishery was assessed using two measures, while one measure was used for indicator Pr16–Groundfish fishery. The status of the indicators was estimated for the available historical series, from 2004 to 2018, based on the same surveys used for the pressure Physical disturbance of the bottom. The status of each indicator was presented as a directional anomaly, as too much biomass removal is not desirable for the MPA; the goal is to maintain or improve the status of the fisheries resources present at the time the MPA was established. For indicator Pr15, the pressure level was generally “Low” over the time series with the exception of 2009, 2017 and 2018, where the pressure level increased to “Medium” (Table 10 and Figure 14). For indicator Pr16, the pressure level of the indicator was “Low” until 2013 and became mostly “Medium” from 2014 onwards, showing a slight increase in landings.

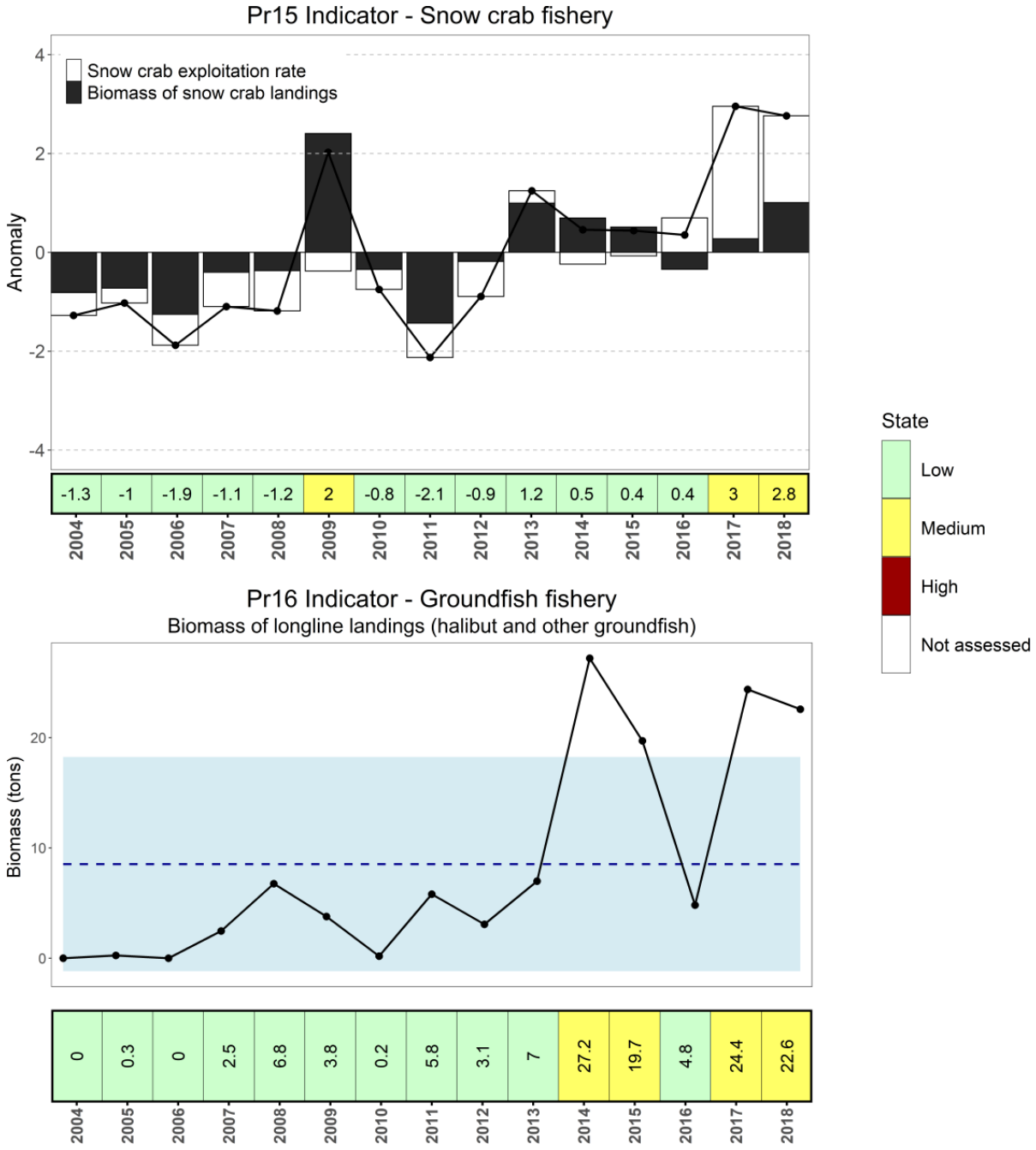


Figure 14. Status and trend of the time series for the indicators associated with the pressure Biomass removal (Pr15 and Pr16). The black line on the top graph is the sum of the actual values of the anomalies that assign an annual status to the indicator Pr15, which is colour coded on the horizontal band below the graph. The blue hatched line in the bottom figure represents the average conditions over the reference period (2004–2018), and the blue shading represents ± 1 standard deviation around this average. On the band below the graph, the value obtained each year is colour coded according to the magnitude and direction of the observed change from the baseline period (directional anomaly). Note the absence of longline fishing in 2004 and 2006.

Indicator Pr17–Fishing done by scientific activities was assessed using biomass harvested by the R10–Multi sGSL and R13-Snow Crab sGSL scientific surveys (Appendix 1). The indicator data are presented for the historical series from 1986 to 2020 as a directional anomaly, as too much biomass removal is not desirable for the MPA. No status was established, since the assessment method could not be specified. However, the pressure is considered very low throughout the time series, with less than 0.5 t of biomass harvested per year, except between 1986 and 1988 and in 1992 (Table 10 and Figure 15).

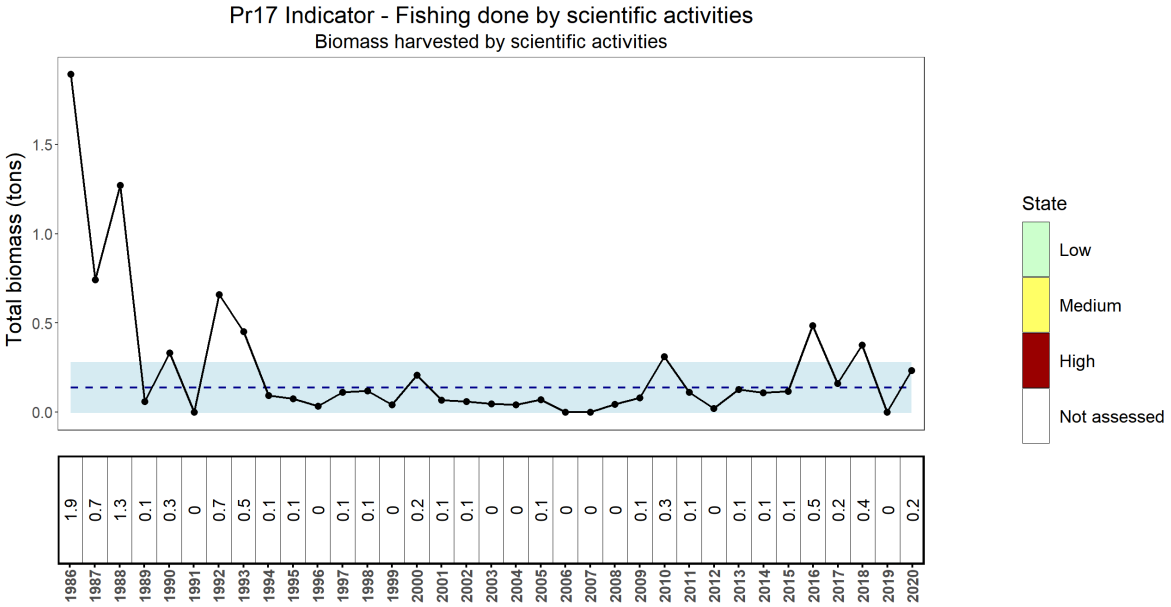


Figure 15. Status and trend of the time series for indicator Pr17, associated with the pressure Fishing done by scientific activities The blue hatched line represents the average conditions during the reference period (2004–2018), and the blue shading represents ± 1 standard deviation around this average. The value obtained each year is presented on the band below the graph.

Table 9. Description of the measures used for each indicator, confidence level of the available data and status of the historical series. Specification of the spatial scale, reference period and assessment method (Directional anomaly: dir.; Bidirectional anomaly: bidir.; and fixed threshold) used to calculate the measures.

Indic.	Spatial scale	Reference period	Evaluation method	Confidence level	Measures	Status assessment for the historical series
CO1 Conserve and protect benthic habitats						
BD1) Cold water indicator species	Strata 416	2004–2018	Bidir. anomaly	Good	Biomass of the 3 most abundant cold water stenotherm species–Fish Biomass of the 3 most abundant cold water stenotherm species–Invertebrates Proportion of tows with presence of cold water stenotherm species–Fish Proportion of tows with presence of cold water stenotherm species–Invertebrates	Status was fairly stable throughout the historical series with variations on either side of the mean and a mostly "Small" level of change. Over the past 6 years, measures have tended to be below the baseline period average.
BD2) Warm water indicator species	Strata 416	2004–2018	Bidir. anomaly	Good	Biomass of the 3 most abundant warm water stenotherm species–Fish Biomass of the 3 most abundant warm water stenotherm species–Invertebrates Proportion of tows with presence of warm water stenotherm species–Fish Proportion of tows with presence of warm water stenotherm species–Invertebrates	**Status not assessed** Very limited number of individuals detected. Data are insufficient to assess status and to interpret and describe the historical picture. It is suggested that monitoring be maintained to detect a sudden appearance in the MPA.
BD3) Dominant/key species	Strata 416	2004–2018	Dir. anomaly	Good	*Total biomass of fixed and erect taxa** *Sea Urchin biomass** *Predatory Starfish biomass** *Pandalus* biomass American Plaice biomass Greenland Halibut biomass	The status was "Good" throughout the historical series. A steeper increase from the baseline average was observed in 2020.
BD9) Demersal fish community on the plain	Strata 416	2004–2018	Dir. anomaly	Good	Total biomass of demersal fish Total abundance of demersal fish Specific richness Shannon's diversity index Pielou's evenness index	The status has remained "Good" throughout the historical series. The indicator has fluctuated slightly, but frequently, from the baseline average.

Indic.	Spatial scale	Reference period	Evaluation method	Confidence level	Measures	Status assessment for the historical series
BD11) Snow Crab	BDA	2004–2018	Dir. anomaly	*na*	Abundance of male Snow Crabs of commercial size Abundance of mature female Snow Crab Snow Crab CPUE	The status was "Good" throughout the historical series except in 2018 when it changed to "Medium". Since 2013, there has been a downward trend.
BD12) Harvested groundfish	Strata 416	2004–2018	Dir. anomaly	*na*	Proportion of tows with Atlantic Halibut catch Abundance of Atlantic Cod Groundfish CPUE	The status has remained "Good" throughout the historical series. A general upward trend was observed during this period. Prior to 2011, negative anomalies were observed while thereafter they all remained positive. No longline fisheries were conducted in the MPA in 2004 and 2006.
CO2 Conserve and protect pelagic habitats and forage species						
P1) Nutrients	Oceano area	1999–2018	Bidir. anomaly	Good	Winter average nitrate in the surface layer (0-50 m) Average annual nitrate in the middle layer (50-150 m) Average annual N:P ratio in the middle layer (50-150 m)	The status has frequently fluctuated between a "Small" and "Moderate" change. Since 2016, the indicator was more stable and close to the baseline average, except in 2020 when the level of change was "Moderate" due to high nitrate concentrations in the middle layer.
P2) Chl *a*	Oceano area	1999–2018	Bidir. anomaly	Good	Annual average chlorophyll a in the 0–100 m layer	After a relatively stable period from 1999 to 2010, the status underwent major oscillations from 2011 onwards and corresponded mainly to a "Moderate" change.
P3) Zooplancton	Oceano area	2001–2018	Bidir. anomaly	Good	Average annual dry weight of mesozooplankton Average annual abundance of small calanoid species Average annual abundance of large calanoid species Average annual abundance of non-copepod species	During the first half of the historical series, the level of change was "Small". Starting in 2012, more pronounced anomalies (Moderate change) were observed.

Indic.	Spatial scale	Reference period	Evaluation method	Confidence level	Measures	Status assessment for the historical series
P4) Krill biomass	Oceano area	2008–2018	*na*	*na*	Wet weight of krill Wet weight of *Thysanoessa raschii* Wet weight of *Meganyctiphanes norvegica*	No data were presented in the peer review.
P5) Herring stock biomass sGSL	sGSL	*na*	Fixed threshold	Good	Spring herring SSB from sGSL Fall herring SSB from sGSL	The status ranged from " Poor" in the early 1980's to a status varying between " Good" and " Moderate" in the late 1980's and 90's. Since 2002, condition has deteriorated and varied between " Moderate " and " Poor ".
CO3 Promote the recovery of at-risk whales and wolffish						
EP2) Atlantic Wolffish bycatch	BDA and strata 416	2004–2018	*na*	Poor	Proportion of commercial fishing events with Atlantic wolffish bycatch Proportion of trawl with catches of Atlantic wolffish by scientific surveys	**Status not assessed** Too few data are available. It is suggested that monitoring be maintained to detect marked changes over time.
EP6) Cetacean mortality/accidents	Gaspé and Percé sector	2004–2018	*na*	Poor	Total number of reports of sick, injured, stranded individuals and carcasses for Species at Risk Total number of reports of sick, injured, stranded individuals and carcasses for other species (large MM, dolphin, porpoise)	**Status not assessed** There are too many uncertainties associated with the data to interpret a historical average. It is recommended that the indicator be retained to assist in the interpretation of other indicators such as vessel traffic.

* Measures not retained in the peer review.

Table 10. Description of the measures used for each pressure indicator, confidence level of the available data and status of the historical series. Specification of the spatial scale, reference period and assessment method (Directional anomaly: dir.; Bidirectional anomaly: bidir.; and fixed threshold) used to calculate the measures.

Indic.	Spatial scale	Reference period	Evaluation method	Confidence level	Measures	Status assessment for the historical series
Pr1) Physical conditions of the pelagic habitat	Oceano area	1989–2018	Bidir. anomaly	Good	Mean surface temperature (May-Nov) derived from satellite data (SST)	The status has remained mostly at a "Small" level of change over the historical series. Stronger anomalies were observed in the early 1990s related to particularly cold conditions, while strong anomalies were observed starting in 2010 related to warmer conditions.
					Average summer temperature (August-September) at the surface (0–30m)	
					Average summer salinity (August-September) at surface (0–30m)	
	Oceano area	1989–2018	Bidir. anomaly	Good	First day of ice	
					Last day of ice	
					Duration of the ice season	
	Oceano area	1989–2018	Bidir. anomaly	Good	Average summer temperature (August-September) in the cold intermediate layer (CIF; 40–100 m)	
					Depth of the upper limit of the cold intermediate layer (CIF; 2°C)	
					Volume of the cold intermediate layer (CIF; 1°C)	
Pr2) Physical conditions of the benthic habitat (>100m)	Benthic area	1989–2018	Bidir. anomaly	Good	Average temperature (August-September) near the bottom (> 100 m)	The level of change observed was generally "Small" since 1996. Prior to that date, the change was more "Moderate" and was related to colder conditions. Summer temperatures near the bottom (> 100 m) were at their lowest in the late 1980s and early 1990s. The temperature then gradually increased over time.
					Average salinity (August-September) near the bottom (> 100 m)	
Pr19) Acidification	Benthic area	*nd*	Fixe threshold	Poor	Average saturation rate of calcite near the bottom (> 100 m)	The pressure level was "High" for the entire historical series mainly due to the saturation level of the aragonite which is below the threshold of 1.
					Average saturation rate of aragonite near the bottom (> 100 m)	

Indic.	Spatial scale	Reference period	Evaluation method	Confidence level	Measures	Status assessment for the historical series
Pr20) Dissolved oxygen	Benthic area	*na*	Fixe threshold	Good	Dissolved oxygen saturation value near the bottom (> 125 m)	Throughout the historical series, the pressure level has been fairly stable and described as "Medium", with dissolved O_2 values ranging from 46% to 68% saturation.
Pr7) Traffic intensity	BDA	2012–2018	Dir. anomaly	Good	Total number of passages for commercial traffic Total number of passages for marine operations *Total transit duration in the BDA for commercial traffic** *Total transit duration in the BDA for maritime operations**	The pressure level was "Low" throughout the historical series except in 2019 when the increase in commercial traffic, but also in marine operations, led to a "High" level.
Pr8) Intensity of observation and recreational activities	BDA + Gaspé sector	*na*	*na*	Good	Total number of observation trips at sea Average duration of the trips Number of observation boats at sea Duration of the season of observation at sea	**Status not assessed** Data are insufficient to assess status and to interpret and describe the historical picture. More accurate data collection is planned.
Pr9) Vessel speed	BDA	2012–2018	Dir. anomaly	Good	Average speed of commercial vessels Average speed for maritime operations vessels Number of runs that reached a speed > 10 knots	Status has trended upward from a "Medium" pressure level in 2013 to "Low" since 2014. An increasing decrease in average vessel speeds has been observed since 2017 related to speed limits implemented to protect the Right Whale.
Pr10) Number of entanglements	Gaspé and Percé sector	2004–2018	Dir. anomaly	Poor	Number of cetacean entanglements	**Status not assessed** Data are insufficient to assess the status and to interpret and describe the historical picture. Raw data will continue to be presented in future monitoring reports.
Pr11) Relative footprint of the Snow Crab fishery	BDA	2004–2018	Dir. anomaly	Good	Snow Crab fishing effort (number of traps hauled) Proportion of MPA affected by the Crab fishery	The pressure level was generally "Low" between 2004 and 2017. A slight upward trend was observed from 2011 to reach a "Medium" level in 2018.

Indic.	Spatial scale	Reference period	Evaluation method	Confidence level	Measures	Status assessment for the historical series
Pr12) Relative footprint of the groundfish fishery	BDA	2004–2018	Dir. anomaly	Good	Longline fishing effort (total number of hooks) Proportion of MPA affected by the groundfish fishery (area affected)	The pressure level has remained "Low" throughout the series, with the exception of 2014 when the level increased to "High" and then to a "Medium" level in 2018. These increases are related to increases in fishing effort and the proportion of the MPA affected by fishing. Note that the baseline period average is still at a very low level (less than 1% of the MPA).
Pr13) Footprint of scientific activities	BDA	2004–2018	*na*	Good	Science activities footprint (proportion of MPA affected)	**Status not assessed** No status has been established since the evaluation method could not be specified. The pressure is still considered to be very low throughout the time serie (less than 0.1% of the MPA).
Pr15) Snow Crab fishery	BDA	2004–2018	Dir. anomaly	Good	Snow Crab exploitation rate Biomass of Snow Crab landings	The pressure level was generally "Low" over the time series with the exception of 2009, 2017, and 2018 where the pressure level changed to "Medium". The change observed in 2009 is related to an increase in landings while in 2017 and 2018, the change is related to an increase in the exploitation rate of Snow Crab.
Pr16) Groundfish fishery	BDA	2004–2018	Dir. anomaly	Good	Biomass of longline landings (Halibut and other groundfish)	The pressure level of the indicator was "Low" until 2013 and becomes predominantly "Medium" from 2014 onwards demonstrating a slight increase in landings. It should be noted that the reference period is from 2004 to 2018, which is after the collapse of the groundfish fishery. The average used is therefore very low compared to the landings of the 80s and 90s in the region.
Pr17) Fishing done by scientific activities	BDA	2004–2018	Dir. anomaly	Good	Biomass harvested by scientific activities	**Status not assessed** No status was established since the assessment method could not be specified. However, the pressure is considered to be very low throughout the time series (less than 0.5 t except between 1986 and 1988).

* Measures not retained in the peer review.

Interim reports and priority indicators

It is proposed that an interim report be produced at a higher frequency (e.g., every 3 years), which would be more succinct than a full monitoring report and would group together a few priority indicators. 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 (e.g., benthic communities) and for which data are not available annually, it would not be relevant to present results frequently. 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.

To select priority indicators, three criteria were considered: (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. Some pressure indicators meet these three criteria and are proposed for the interim reports (Table 11). 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 in the future depending on the availability of new data, such as on anthropogenic noise. A complete monitoring report with an update of all indicators would be produced at a lower frequency (e.g., every 6–10 years) and should be linked to the revision of the management plan so that the information is available in a timely manner and can be easily interpreted.

Table 11. List of priority indicators retained for interim monitoring reports.

	Proposed priority indicators
Conservation Priorities	
Benthic and demersal commercial species	BD11) Snow Crab
	BD12) Harvested groundfish
Whales	EP6) Cetacean mortality/accidents
Pressures	
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
	Pr12) Relative footprint of the groundfish fishery
	Pr13) Footprint of scientific activities
	Pr14) Fishing activities–violations
Biomass removal	Pr15) Snow Crab fishing
	Pr16) Groundfish fishing
	Pr17) Biomass removal by scientific activities
New pressure	Pr18) Number of new pressures

Sources of uncertainty

Some of the available databases were analyzed at a spatial scale larger than the MPA, which may result in the detection of a different signal from what is actually occurring within the protected area. For example, for the oceanographic indicators (Pr1, Pr2, Pr19 and Pr20) and pelagic habitat indicators (P1, P2, P3 and P4), averages were calculated over large areas (oceanographic and benthic area) relative to that of the MPA in order to represent trends at a regional/area spatial scale. However, some phenomena that are more specific temporally or spatially within the MPA may not be detected. Also, in the case of the indicator P5–Herring stock biomass sGSL, the data used come from the stock assessment and represent a portrait of the population in the entire southern Gulf of St. Lawrence, which does not allow their distribution to be discerned locally in the MPA. For the monitoring of marine mammal mortalities and entanglements (EP6 and Pr10), the data are also analyzed on a larger scale than the MPA. The data are counted for the municipalities of Gaspé and Percé, given that injured or sick cetaceans continue to travel and carcasses may sink or drift from the point of origin, which makes it impossible to indicate the exact time and place of the incident. The data used in this analysis correspond to the cases reported to the QMMERN. However, it is important to note that these data underestimate the actual number of incidents that occurred in the sector. Because of the lack of data collected directly in the MPA and considering the mobile nature of the species, the indicators related to the DFO multispecies bottom trawl survey in the southern Gulf (BD1, BD2, BD3, BD9 and BD12) were assessed for all of survey stratum 416. Thus, the results must be interpreted with consideration for the spatial scale covered.

The taxonomic resolution of the DFO southern Gulf multispecies bottom trawl survey may impact the outcome of some indicators (BD1, BD2 and BD9). Measures regarding diversity and those targeting rarer species, some of which are stenotherms, are directly influenced by the taxonomic resolution, which has varied over time. This bias must be considered, and accurate taxonomic identification is paramount for this survey in the future.

Some databases are used for their informational value although they contain little information about the spatial and temporal variability of the indicator/monitoring measure and must therefore be interpreted according to this limitation. For example, the assessment of Atlantic wolffish bycatch (EP2) by commercial fisheries is uncertain, since the information collected through the at-sea observer program covers only a small percentage of fishing activities and few fishing activities are observed annually in the MPA/area. Fishers are required to report bycatch of species at risk, such as wolffish, but this requirement is not verified by any legal authority, so the consistency of this data is uncertain.

For indicator Pr17–Fishing done by scientific activities, a data source could be added to assess the indicator, namely the total catches in the Snow Crab scientific survey, but these data were not available at the time this report was written.

Another source of uncertainty is the use of incomplete databases. For example, the ZIFF data used to assess the pressure indicators related to commercial fishing (indicators Pr11, Pr12, Pr15 and Pr16) in the MPA contain a significant proportion of non-georeferenced observations and provide only a partial portrait of these indicators. The monitoring of marine mammal mortalities and entanglements (EP6, Pr10) must also be considered incomplete as not all events are reported, particularly because some carcasses sink very quickly following an accident. For indicator Pr19–Acidification, very few data were available, and this limitation must be considered when interpreting the results obtained.

Finally, uncertainties related to the positioning of commercial fishing activities may influence the calculation of some indicators (Pr11, Pr12, Pr15 and Pr16). It is difficult to properly assess the

footprint and intensity of fishing events, since only one position (latitude-longitude) is provided for a landing that may correspond to several gears deployed (trap or longline). Thus, what is calculated is an approximation of the actual fishing activity in the MPA.

CONCLUSIONS AND ADVICE

To help complete the DFO ecological monitoring plan for the Banc-des-Américains MPA, the indicators identified in 2018 were reviewed, and an updated list of conservation priorities (15), pressures (12) and associated indicators (44) was produced. This update added five indicators relating to competitors/predators (grey seal), scientific activities, fishing violations, new pressures and ghost gear. As a result of the review, acidification and dissolved oxygen become two separate indicators of Pr2-Physical conditions of the benthic habitat (> 100 m) to allow for a more appropriate interpretation.

Priority issues were selected to guide the assessment of indicators and to link conservation objectives and the choices of pressures. Thus, the priority issues help guide the monitoring and interpretation of results. Two methods were used to summarily and informally assess the status: anomaly, 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. 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.

For each of the 27 indicators with a processed database, measures were selected, described and calculated according to a reference period to produce the state of knowledge for the available time series. The choice of measures was guided in part by the information obtained from the available databases. A confidence level was established for each of the 27 indicators, based on the quality and quantity of the data used, but will have to be reviewed in detail by the DFO-SMC. The spatial and temporal scales for calculating the measures were also specified and revised. Six of the indicators for which data were revised, could not be assessed for various reasons, such as too little data available, too much uncertainty in the data, or lack of an assessment method.

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 CSS-BDA. 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.

Priority indicators have been identified for presentation in the interim summary reports that will be produced every 3 years, between assessments and full monitoring reports. These indicators focus on direct pressures and three key indicators linked to conservation objectives OC1 (Conserve and protect benthic habitats) and OC3 (Promote the recovery of at-risk whales and wolffish). In this report, the time series of the indicator status are presented. The final status (overall rating) of the indicators will be produced 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 of the available data set for each of the indicator measures. This review presented part of the state of knowledge at the time the MPA was established and provided a portrait of the historical data for the area.

OTHER CONSIDERATIONS

There is currently no national DFO framework for assessing the status of indicators and reporting results. The methods proposed here may be reviewed and adjusted in light of new knowledge or new DFO guidelines for standardized reporting of its MPAs.

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SOURCES OF INFORMATION

This Science Advisory Report is from the Regional Advisory meeting on April 27–29, 2021 Review of Monitoring Indicators for the Banc-des-Américains Martine Protected Area, Validation of the Choice of Measures and State of Knowledge. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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APPENDIX 1: SCIENTIFIC SURVEYS

Table 12. List of surveys used or under development for DFO's ecological monitoring of the Banc-des-Américains MPA.

#	Surveys/Database	Names used	Manager	Frequency
Existing				
R1	Atlantic Zone Monitoring Program (AZMP)	R1-AZMP	DFO–Science	bi-annual
R2	Oceanographic Buoy network (Viking)	R2-Viking	DFO–Science	Continuous summer
R3	Ice cover monitoring	R3-Ice	Canadian Ice Service	Continuous winter
R4	Remote sensing of water surface temperature	R4-SST	DFO–Science	Continuous
R5	Thermograph Network	R5-Thermograph	DFO–Science	Continuous summer
R6	Monitoring winter water masses–helicoptered mission	R6-Helicoptered	DFO–Science	Annual
R7	Pelagic acoustic survey of the estuary and northwestern Gulf	R7-Krill	DFO–Science	Annual
R8	Annual acoustic survey of herring (sGSL)	R8-Herring sGSL	DFO–Science	Annual
R10	Multispecies southern Gulf of St. Lawrence bottom trawl survey	R10-Multi sGSL	DFO–Science	Annual
R11	Multispecies in the estuary and northern Gulf of St. Lawrence bottom trawl survey	R11-Multi nGSL	DFO–Science	Annual
R13	Southern Gulf of St. Lawrence Snow Crab bottom trawl survey	R13-SnowCrab sGSL	DFO–Science	Annual
R14	Fishing data from ZIFF statistics	R14-ZIFF	DFO–Fisheries Management	Continuous summer
R15	At-sea observer program	R15-Observers	DFO–Fisheries Management	Continuous summer
R17	Quebec Marine Mammal Emergency Response Network (QMMERN)	R17-QMMERN	QMMERN	Continuous summer
R18	Monitoring of maritime traffic via a navigation information system (AIS)	R18-AIS	Canadian Coast Guard	Continuous
R21	Passive acoustics monitoring–hydrophone	R21-PAM	DFO–Science	Continuous
R22	Monitoring of MPA activity reports	R22-Act. report	DFO–MPCD	Continuous
In development or to be developed				
RD1	Benthic community survey by imagery	RD1-Imagery	DFO–Science	-
RD2	Benthic community survey with grab	RD2-Grab	DFO–Science	-
RD4	Scuba diving	RD4-Scuba diving	DFO–Science	-
RD5	Environmental DNA	RD5-eDNA	DFO–Science	-
RD6	Baited imagery survey	RD6-Bait. Imagery	DFO–Science	-
RD7	Monitoring of seal haulouts, AGHAMM and Forillon National Park	RD7-Haulouts	DFO–MPCD and partners	-

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