ENVIRONMENT, SOCIETY
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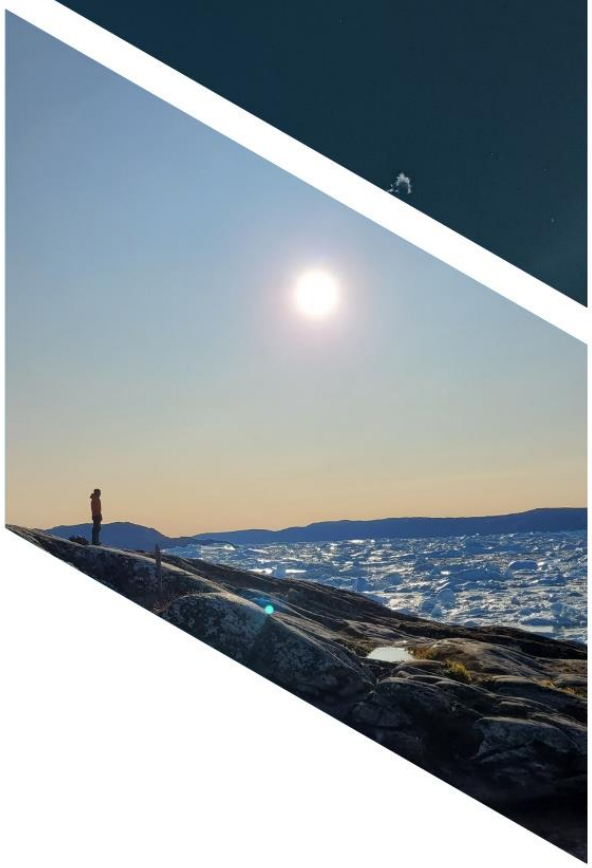

UN DECADE OF OCEAN SCIENCE FOR SUSTAINABLE DEVELOPMENT

"A SAFE OCEAN" BENCHMARKING REPORT

PREPARED FOR FISHERIES AND OCEANS CANADA

2024

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NOTICES

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Photos on cover page: Lana Dolgova (top) and Jean Holloway (bottom).

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EXECUTIVE SUMMARY

The United Nation Decade of Ocean Science (herein referred to as the Ocean Decade) was declared for 2021-2030 to generate and share knowledge that directly contributes to meeting the goals of the 2030 Agenda for Sustainable Development by using transformative ocean science solutions. Seven desirable outcomes were established as part of the Ocean Decade, one of which is the 'Safe Ocean' outcome, which encompasses "where life and livelihoods are protected from ocean-related hazards". The Government of Canada, having adopted these Ocean Decade outcomes, is establishing Canada's vision for a 'Safe Ocean', and research priorities to achieve this vision. To support this, we used an adapted Delphi methodology in a three-phase approach ('Collection', 'Convergence', and 'Consensus') to: inventory relevant projects, programs, and experts across Canada; identify key research priority areas for the Ocean Decade; and, develop findings that will inform a strategic plan for the Safe Oceans theme during the decade.

Phase 1, 'Collection', included a *Scene Survey* to gather baseline information on existing research and programs, identify stakeholders and rightsholders, reveal existing knowledge gaps, and determine desired impacts and outcomes. This database was composed of 664 government scientists and policymakers, academics, non-governmental organizations (NGOs), and Indigenous governments and organizations from across Canada. Phase 1 also included a focus group (*Delphi Round 1*) with relevant experts at the Oceans Research in Canada Alliance (ORCA) 2023 meeting.
Phase 2, 'Convergence', was composed of *Delphi Round 2* and *Delphi Round 3*. Near 100 participants (from the list of stakeholders and rightsholders identified in Phase 1) contributed to *Delphi Round 2*, which included developing a list of key knowledge gaps, desired outcomes, and research priorities for the Ocean Decade. Responses were analyzed and organized into themes using constant comparison. 62 research priorities and knowledge gaps were identified, divided into six thematic categories:

1. Shipping and Safe Navigation
2. Fisheries, Marine Economies, and Well-Being
3. Climate Change: Impacts, Risks and Adaptation
4. Weather, Water, Ice, and Ocean Conditions
5. Governance, Policy, and Planning
6. Technology and Innovation

These results were then organized into *Delphi Round 3*, where a smaller group of participants were asked to evaluate and prioritize research priorities with the following criteria: (i) priority; (ii) feasibility (i.e., combination of affordability and achievability); and (iii) timeframe to achieve.

Phase 3, 'Consensus', involved statistical analysis of *Delphi Round 3* results, focusing on identifying the point of agreement and the level of consensus among the respondent

groups for each of the 62 research priorities and among each of the evaluation criteria, enabling the prioritization of priority research areas. 12 research priorities emerged as the highest-ranked, which we suggest targeting first within the Ocean Decade, including:

1. Conduct a comprehensive risk assessment for changing shipping activities across Canada (enabling national, regional, and sub-regional level evaluations);
2. Produce a comprehensive set of flood inundation and flood risk maps related to storm surge and sea level rise for all coastal areas across Canada (national, regional, and localized);
3. Monitor and model the release of ship-based contaminants, emissions, and pollutants in Canadian ocean regions;
4. Evaluate readiness for responding to major ocean-based pollution events from anthropogenic sources that stem from within and also outside of Canada;
5. Evaluate the environmental, economic, social, and cultural implications of increased shipping in Arctic waters;
6. Examine the potential impacts of marine hazards on Indigenous and coastal communities including those dependent on marine resources for their livelihoods and well-being;
7. Evaluate the potential for and risks of ‘green fuel’ technologies (i.e., hydrogen, wind, solar);
8. Evaluate the level of climate readiness and what climate change adaptations are needed to ensure safe and sustainable coastal community infrastructure;
9. Identify and monitor significant marine areas (ecological, biological, and cultural) and consider voluntary shipping measures in these areas, such as speed reductions, no anchor areas, and others;
10. Engage in comprehensive habitat mapping and risk assessments for vulnerable and economically important marine species;
11. Enhance mapping and baseline information on coastal regions to enable monitoring of climate change (and human use) impacts; and,
12. Enhance bathymetric charting and modern digital charting in all regions but especially in northern latitudes.

These findings will support the development of a Strategic Science Plan for the Safe Oceans Theme during the Ocean Decade and provide resources upon which the Government of Canada’s ‘Safe Ocean’ vision can be operationalized.

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1.0 INTRODUCTION

1.1 BACKGROUND AND CONTEXT

The United Nations General Assembly declared 2021-2030 the "Decade of Ocean Science for Sustainable Development" as a framework for creating and strengthening connections among communities that are working to study, conserve, and sustainably use the ocean and its resources. The "Ocean Decade" aims to focus global scientific capacity to generate and share knowledge that directly contributes to meeting the goals of the 2030 Agenda for Sustainable Development and other relevant global legal and policy frameworks. Within the Ocean Decade initiative, seven Outcomes and ten Key Challenges (see https://oceandecade.org/challenges/) were identified. To support Canada's efforts towards achieving the outcomes and in facing the key challenge areas, the Government of Canada's Department of Fisheries and Oceans (DFO) established a group of 'Champions' linked to each Outcome.

Outcome 5 (Champion - Dr. Jackie Dawson) is 'A Safe Ocean - where life and livelihoods are protected from ocean-related hazards'. Dr. Dawson has established a small working group of Canadian scholars and a larger advisory group of academics, experts, stakeholders, and rights holders to support Canada's Ocean Decade activities under this theme. The working group aims to unite Decade partners in collective action (at global, regional, national, and local levels - with an enhanced focus on national and local) in specifically (directly or indirectly) advancing four of the ten Key Challenge Areas, including to understand and beat marine pollution, to protect and restore ecosystems and biodiversity, to develop a sustainable and equitable ocean economy, and to increase community resilience to ocean challenges.

1.2 OBJECTIVES

The purpose of this report is to be a benchmark of 'where we are at' and 'what we want to achieve' within the Ocean Decade Safe Oceans theme in Canada to support larger UN and international initiatives. This report was designed to be used to identify key research priority areas and evaluate our achievements at the end of the Ocean Decade period.

The specific project objectives are to:

- Inventory relevant projects, programs, and experts across Canada that are already engaging in research related to the 'safe oceans' theme;
- Engage relevant experts, stakeholders, and rights holders to a) identify key knowledge gaps and b) prioritize research priority areas; and
- Develop a basic strategic research plan for the Safe Oceans theme that can be considered for implementation during the Ocean Decade.

1.3 DEFINING 'SAFE OCEAN'

The UN Ocean Decade has defined 'Safe Ocean' as "where life and livelihoods are protected from ocean-related hazards" (see https://oceandecade.org/vision-mission/). The focus of the Safe Oceans working group in Canada involves, 'supporting safe and sustainable transportation and navigation of the ocean' - encompassing the Atlantic, Arctic, and Pacific regions of the Ocean around Canada. For the purposes of this study, we excluded marine areas outside of Canada.

2.0 METHODS

2.1 IDEA GENERATING STRATEGY – POLICY DELPHI

In this study, we employed a well-established framework developed by the United Nations Environment Program (UNEP) (UNDP, 2005; UNEP, 2008) to support the project aim, objectives, and activities. The framework has previously been used to identify and prioritize knowledge gaps and research needs for global challenge area related such as, climate change, parks and protected areas planning, and tourism development, among others (Lemieux & Scott, 2011; Dawson et al., 2015; Mukherjee et al., 2015; Dawson et al., 2017). The framework follows a focused process of engaging stakeholders (and rights holders), defining the knowledge gaps or challenge areas in need of solutions, revealing desired outcomes, and evaluating feasibility and prioritization of potential outcomes by using an adapted Delphi methodology (Figure 1).

A Delphi is a group-oriented Idea Generating Strategy (IGS) that aims to uncover consensus and/or disagreement on strategies for dealing with a particular challenge (i.e., in this case advancing research and understandings to achieve Ocean Decade Safe Ocean's outcomes) (de Loë & Wojtanowski 2001; Linstone & Turoff 2002; Donohoe & Needham 2009; Lemieux & Scott, 2011). Through anonymized participation, this methodological approach provides a forum for constructive group interactions which elicit a wide range of responses on activities and options (Needham & de Loë 1990; Lemieux & Scott, 2011). Furthermore, the approach provides a structured participatory process to address complex multi-scale and multi-stakeholder problems where views on potential solutions for a particular challenge(s) may differ (Linstone & Turoff, 2002; Donohoe & Needham, 2009). By design, participants are provided the freedom to outline and contest varying viewpoints, to think independently between survey iterations, and most importantly, to bring their unique experiences and deep understandings of the issues of concern without fear of repercussion or humiliation (Lemieux & Scott, 2011). The idea is to make effective use of participants' diverse judgements, opinions, and expertise to identify and investigate the strategies available for a particular challenge or area of focus (ibid).

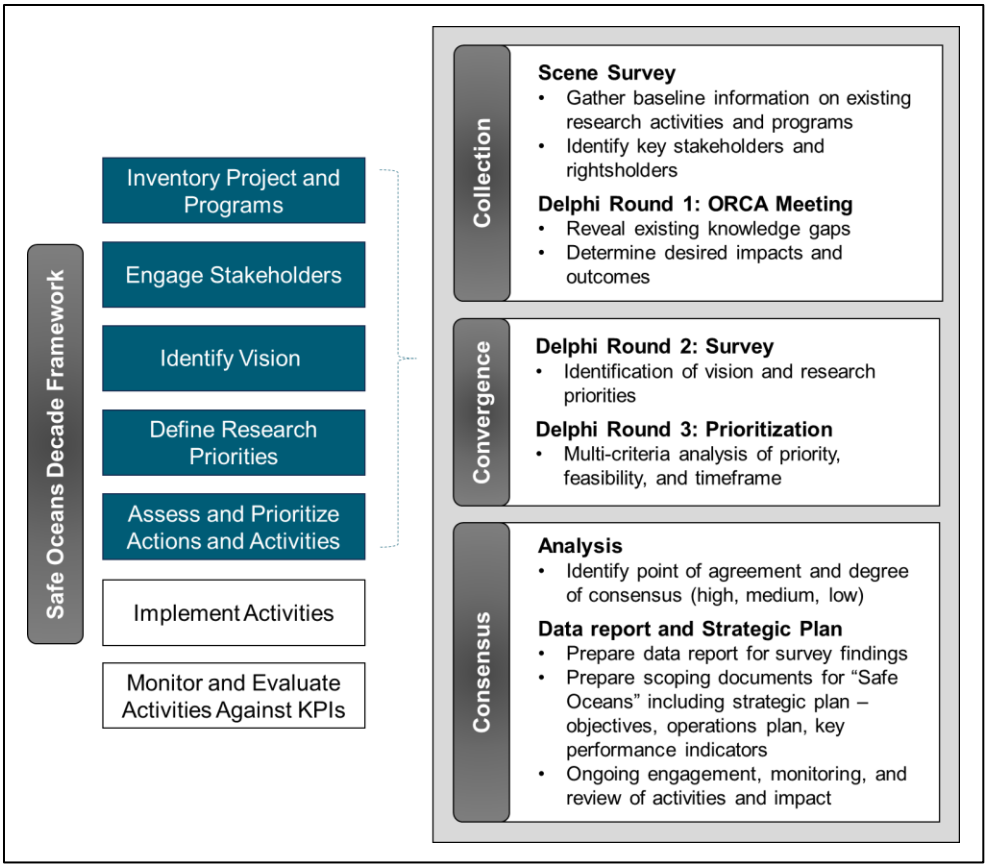


Figure 1: Summary of project approach and methods.

2.2 THREE-PHASED ITERATIVE POLICY DELPHI APPROACH

The Policy Delphi approach used within this project involved three-phases focused on: 1) collection, 2) convergence, and 3) consensus (Figure 1). During the **collection phase**, initial desk-based work was completed to conduct a *Scene Survey* of programs, projects, and experts working on research relevant to the 'Safe Ocean' theme that was then used as a database of stakeholders and rightsholders for the next phases. The established database included 664 government scientists and policymakers, academics, non-governmental organizations (NGOs), and Indigenous governments and organizations from across Canada. The project team strived to be as inclusive as possible and to document a diversity of rights holders and stakeholders. During this phase, *Delphi Round 1* was also completed, which involved engaging relevant experts through a facilitated focus group brainstorming exercise to begin establishing a) key knowledge gaps, and b) desired outcomes for the Ocean Decade. This focus group took place at the Oceans Research in Canada Alliance (ORCA) 2023 meeting in St. John's, NF (June 1-2, 2023), facilitated by DFO and Memorial University, among a small collection of knowledge holders and experts (primarily government scientists, academics, and NGOs). Group brainstorming results were recorded and used as the basis for the iterative survey aimed at further identifying knowledge gaps and research priority areas.

The **convergence phase** included two iterative surveys (*Delphi Round 2* and *Delphi Round 3*) in both French and English that built on *Delphi Round 1* and involved engaging a set of targeted experts from the database established during the *Scene Survey*. Through *Delphi Round 2*, 114 participants further revealed a list of key knowledge gaps, desired outcomes, and research priorities for the Ocean Decade. Incomplete responses were removed (n=11), as were responses where participants answered “N/A” for all the main data questions (this was done so that these responses didn’t bias the demographic data; (n=9), leaving 94 complete responses.

A constant comparison analysis was performed on results of the first survey and thematic areas were identified, revealing relevant categories and enabling syntheses of responses into manageable options (Lewis-Beck et al., 2004). Following this analysis, a total of 62 research priorities were identified, divided among six thematic categories:

1. Shipping and Safe Navigation;
2. Fisheries, Marine Economies, and Well-Being;
3. Climate Change; Impacts, Risks and Adaptation;
4. Weather, Water, Ice, and Ocean Conditions;
5. Governance, Policy, and Planning; and
6. Technology and Innovation.

These results were then organized into a second survey (*Delphi Round 3*) where a smaller panel of experts who had participated in *Delphi Round 2* were asked to evaluate and prioritize responses using a pre-established rubric (Table 1). Experts were given a clear set of criteria (i.e., rubric) across a 4-point Likert scale (adapted from Lemieux and Scott 2011 and Dawson et al. 2016) for evaluating each research priority based on the following criteria:

1. priority;
2. feasibility (i.e., combination of affordability and achievability); and
3. timeframe needed to achieve the priority.

For *Delphi Round 3*, 39 participants began the questionnaire. Responses where less than 20% of the questionnaire was completed were removed (n=7), leaving 32 total responses.

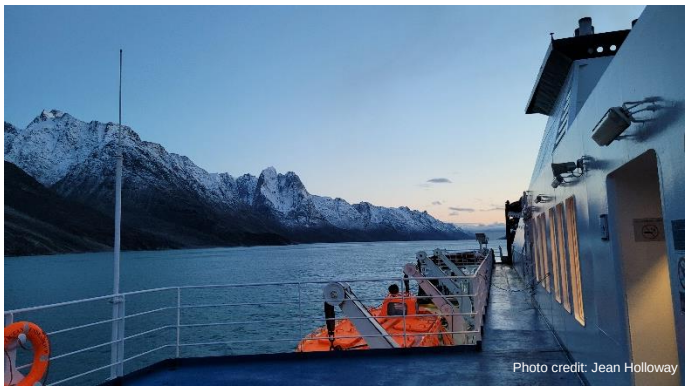


Photo credit: Jean Holloway


Photo credit: Lana Dolgova

Table 1: Rubric to evaluate Delphi Round 3. Adapted from Lemieux and Scott 2011 and Dawson et al. 2016.

Evaluation Criteria	Rating 1	Rating 2	Rating 3	Rating 4
Priority	**First order priority**; a clear research need; addresses key knowledge gap(s); if resolved will make important progress.	**Second order priority**; a research need; may addresses key knowledge gap(s); if resolved may make some progress.	**Third order priority;** potentially a research need; may or may not address key knowledge gap(s); no urgent need to investigate.	**No priority**; not a research need; does not respond to key knowledge gap(s); no need to investigate.
Feasibility 1: Affordability	**Definitely affordable**; can be achieved with current fiscal realities. AND/OR High cost sharing possibilities.	**Probably affordable**; might be achieved with current fiscal realities. AND/OR Some cost sharing opportunities.	**Maybe not affordable**; additional monetary resources or reallocation required to achieve. AND/OR Low cost sharing opportunities.	**Definitely not affordable**; priority cannot be achieved within current fiscal realities AND/OR No cost sharing opportunities exist.
Feasibility 2: Achievability	**Definitely achievable** No non-financial barriers exist (e.g., legal, political, institutional, social, etc.) AND/ OR barriers that do exist can easily be overcome.	**Probably achievable;** Some non-financial barriers exist (e.g. legal, political, institutional, social, etc.) AND/OR barriers that do exist can be overcome with some effort.	**Probably not achievable;** Non-financial barriers exist (e.g. legal, political, institutional, social, etc.) AND/OR barriers may be too significant to overcome.	**Definitely not achievable;** Major non-financial barriers (e .g. legal, political, institutional, social, etc.) AND/OR barriers can not be overcome.
Timeframe	**Short-term** (within 2 years)	**Medium-term** (between 2-7 years from now)	**Long-term** (8 years or longer from now)	

The **consensus phase** of the project involved a statistical analysis of *Delphi Round 3* results, focusing on identifying the point of agreement and the level of consensus among the expert panel for each of the 62 research priorities and among each of the evaluation criteria (refer to Table 1). A point of agreement occurs when the majority of the scores fall on a particular criteria level. Consensus was measured as the degree to which the *Delphi Round 3* participants agreed on the assessment (i.e., point of agreement) for each research priority and for each evaluation criteria (see Table 1). The overall level of consensus was determined through statistical analysis of responses, followed by nominally categorizing the results as high (70% of ratings in one agreement category or 80% in two related categories), medium (60% of ratings in one agreement category or 70% in two related categories), low (50% of ratings in one agreement category or 60% in related categories), and none (less than 60% of ratings in two related categories).

Although it is not necessary to have consensus on suggested research priorities, low or no consensus indicates that the suggestion may be contentious or require additional consideration. Table 2 provides an example/mock research priority to outline the analytical approach to identify points of agreement and levels of consensus.

This analysis enabled the prioritization of research areas including consideration of levels of consensus among the expert community for each priority area. The analysis conducted in this near final stage of the Delphi directly supported the development of our 'Safe Ocean's' Strategic Research Plan for the Ocean Decade in a way that effectively and fairly reflects the expert community across Canada.

2.2 METHODS FOR RANKING RESPONDENT-IDENTIFIED RESEARCH PRIORITIES

In addition to identifying points of agreement and levels of consensus for each of the identified research priorities, a method was used to rank them based on key criteria. This process is simply an analysis exercise and the full level of prioritization rests with decision-makers. The rankings of research priorities outlined here are designed to assist decision-makers in their own internal processes of which other criteria and considerations would certainly be included but which are beyond the scope, capacity, or remit of the research team. In this analysis, ranking the research priorities is a function of both priority and feasibility (i.e., which includes both affordability and achievability). The approach utilized by the research team involved the development of priority-feasibility plots, which are simple visualizations that can help decision-makers quickly and easily see which research areas they might target first. For example, a certain research priority may be rated as a first order priority but with limited feasibility, whereas another may be a second order priority but with high feasibility, and thus the second option may be the one chosen despite its lower overall priority rating. Results are displayed as a simple scatterplot on a four-quadrant grid, with mean priority ratings across the x-axis and mean feasibility ratings across the y-axis (Figure 2). The location of the x- and y-axes were determined based on mean score of all priority ratings (x-axis) and feasibility ratings (y-axis) for each theme. All variables that fall to the right of the y-axis have been rated as having a higher-than average priority within that theme, and the variables that are found above the x-axis have been rated to be above average in terms of feasibility. Thus, the more important and more feasible options are in the top right quadrant of the scatter plot.


Photo credit: Jackie Dawson


Photo credit: Jackie Dawson

Table 2: Example analysis for consensus.

Priority						
	FOP	SOP	TOP	NP	CONSENSUS	POINT OF AGREEMENT
Responses	13	14	2	1	Medium	First order priority to second order priority
% with opinion	44%	30%	19%	4%		
% like categories	74%	48%	22%			

FOP=First order priority; SOP=Second order priority; TOP=Third order priority; NP=No priority.

Affordability						
	DA	PA	MNA	DNA	CONSENSUS	POINT OF AGREEMENT
Responses	14	15	1	0	Low	Definitely affordable to probably affordable
% with opinion	21%	39%	29%	7%		
% like categories	74%	48%	22%			

DA=Definitely affordable; PA=Probably affordable; MNA=Maybe not affordable; DNA=Definitely not affordable.

Achievability						
	DA	PA	PNA	DNA	CONSENSUS	POINT OF AGREEMENT
Responses	18	12	0	0	Medium	Probably achievable
% with opinion	14%	61%	18%	4%		
% like categories	75%	79%	21%			

DA=Definitely achievable; PA=Probably achievable; PNA=Probably not achievable; DNA=Definitely not achievable.

Timeframe					
	ST	MT	LT	CONSENSUS	POINT OF AGREEMENT
Responses	22	9	0	High	Short to medium term
% with opinion	32%	54%	4%		
% like categories	86%	57%			

ST=Short-term; MT=Medium-term; LT=Long-term

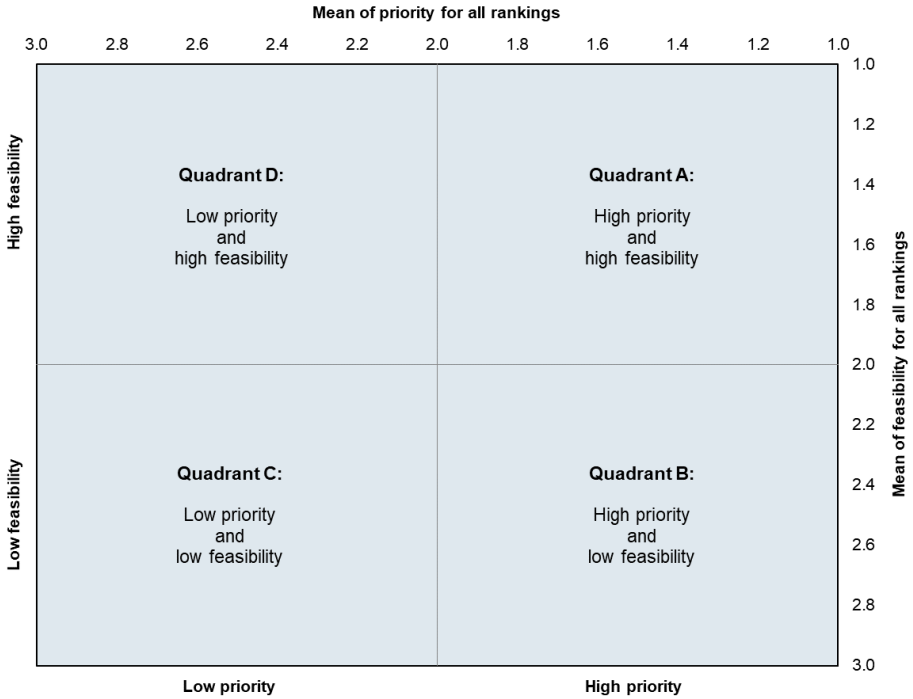


Figure 2: Example priority-feasibility plot

3.0 RESULTS

Section 3.0 presents a synthesis of aggregated results from the three parts of the iterative survey are presented. First, *Delphi Rounds 2 and 3* respondent information (sex- and Indigenous-identity, affiliation, years of experience, involvement with 'Safe Ocean' research/activities, and location), as well as respondent's vision for what a safe ocean would look like by 2030. This is followed by a comprehensive review of the *Delphi Round 3* respondents' assessment of the 62 respondent-identified research priorities. This includes an outline of the highest-ranked priorities, and those that results indicate should be the initial focus of scientific efforts. Next, we describe divergences in opinion of respondents based on their affiliations.

3.1 PARTICIPANT INFORMATION

3.1.1 DELPHI ROUND 2: SURVEY RESPONDENT GROUP

We received a total of 94 complete responses in *Delphi Round 2*, which was designed to identify research priorities for the Ocean Decade. Of the 94 respondents, more than half identified as male (54%), about a third as female (36%), and 1% as non-binary, while 9% would rather not say (Figure 3). 4% of respondents identified as Indigenous, which is very close to the national proportion of Indigenous people in Canada which is 5%. Most respondents live in the maritime provinces (33%), followed by Ontario (23%), Quebec

(17%), and British Columbia (13%), while 4% live in the prairie provinces, another 4% live in territorial/northern Canada, 3% live internationally, and 2% said “other”. In terms of professional affiliation, the majority worked for the federal government (42%) followed by higher education institutions (universities) (37%), while 9% worked for industry, 7% worked for NGOs, 3% worked for Indigenous NGOs, 1% worked for the private sector, and 1% said “other”. Respondents’ years of involvement in topics related to safe oceans ranged from less than one year to over 40 years, but most the common response (29%) was between 11 and 20 years of experience.

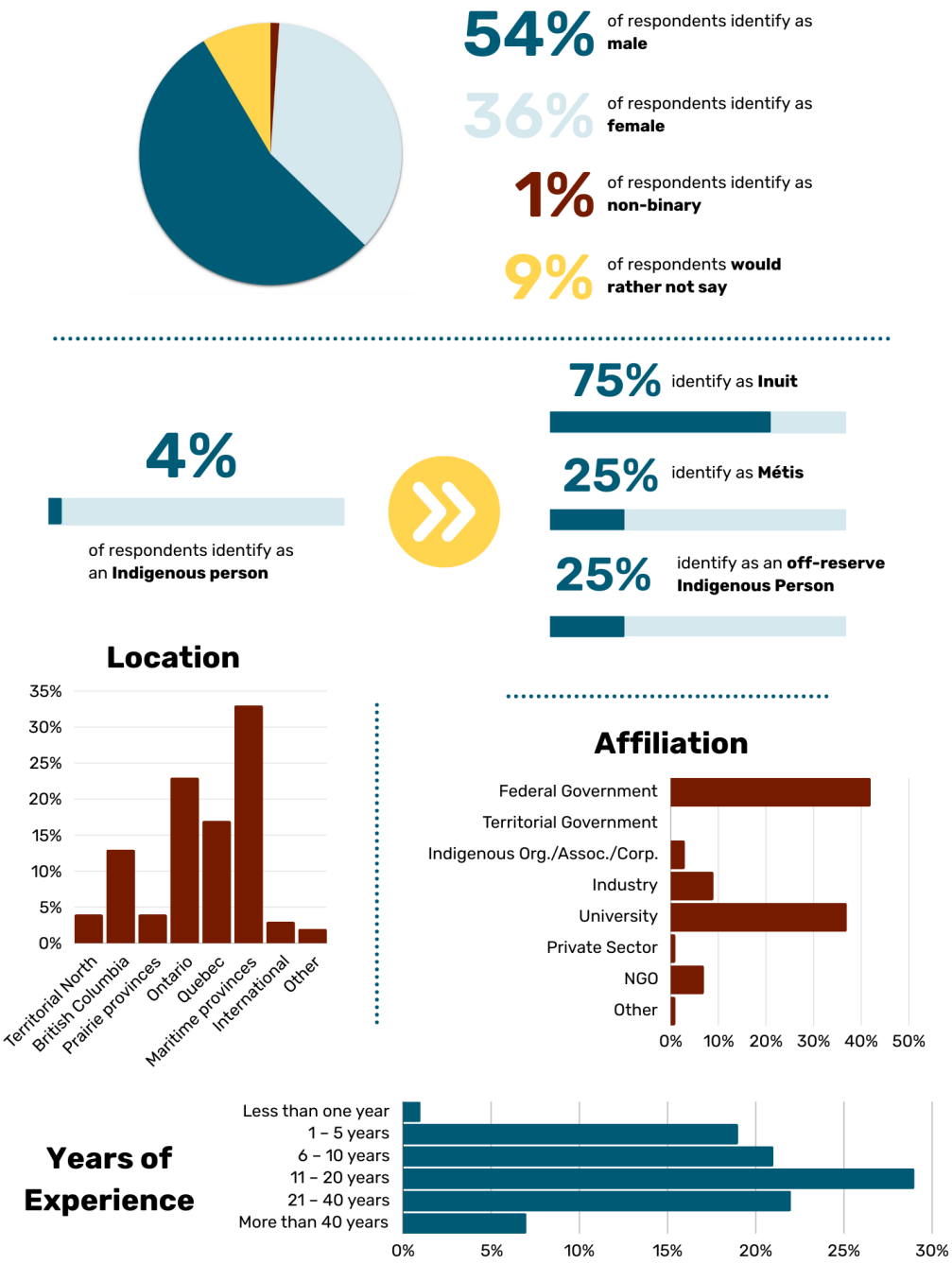


Figure 3: Delphi Round 2 survey respondents’ information.

In terms of the spatial distribution of research activities, the respondent group was highly representative and well spread among the various regions (Figure 4). Respondents were able to select more than one region considering many experts work in multiple regions. When asked what activity related to safe oceans they were most involved in, 64% of respondents said “research/science”, 11% said “other”, 10% said “decision-making”, 9% said “education”, and 6% said “advocacy” (Figure 5A).

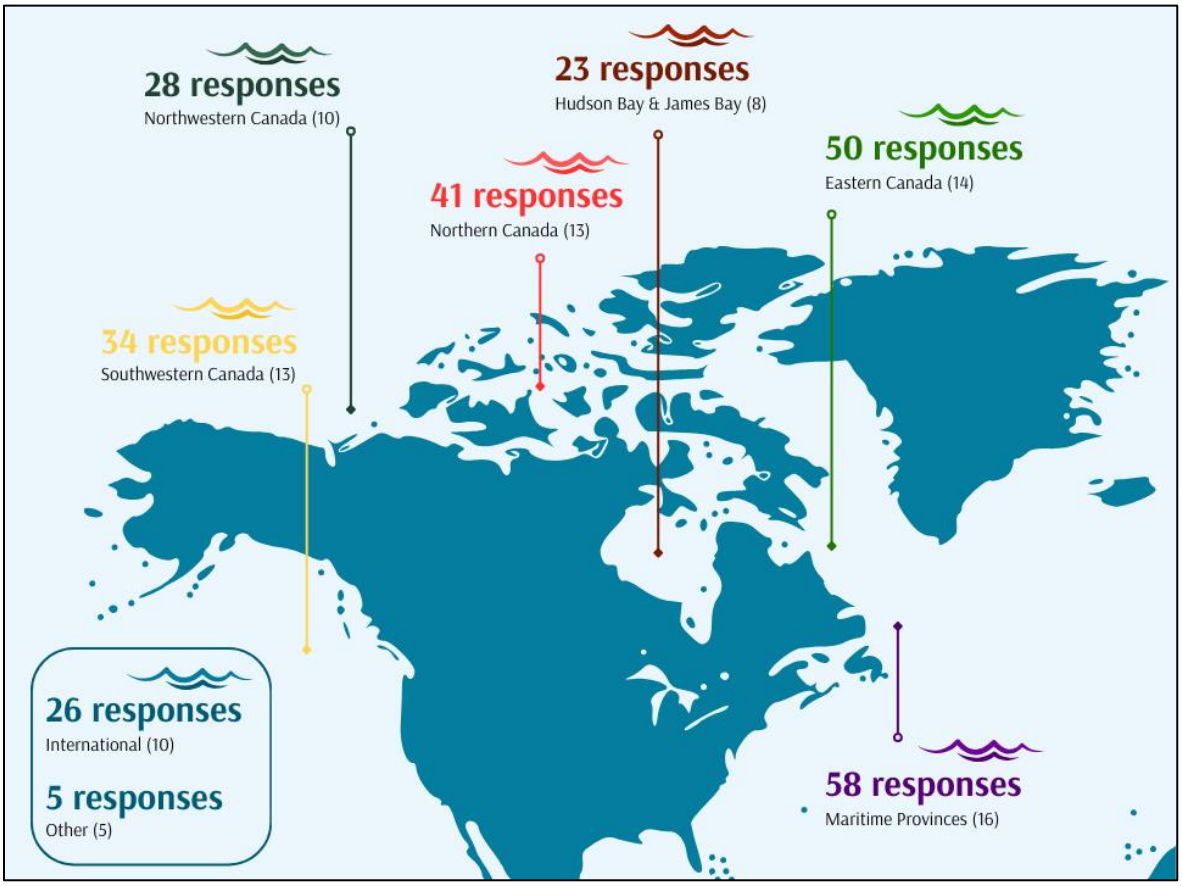


Figure 4: Location in Canada’s oceans where respondents work related to safe oceans takes place. Note that participants were able to select more than one option and all responses have been included. Round 3 responses are indicated in brackets.

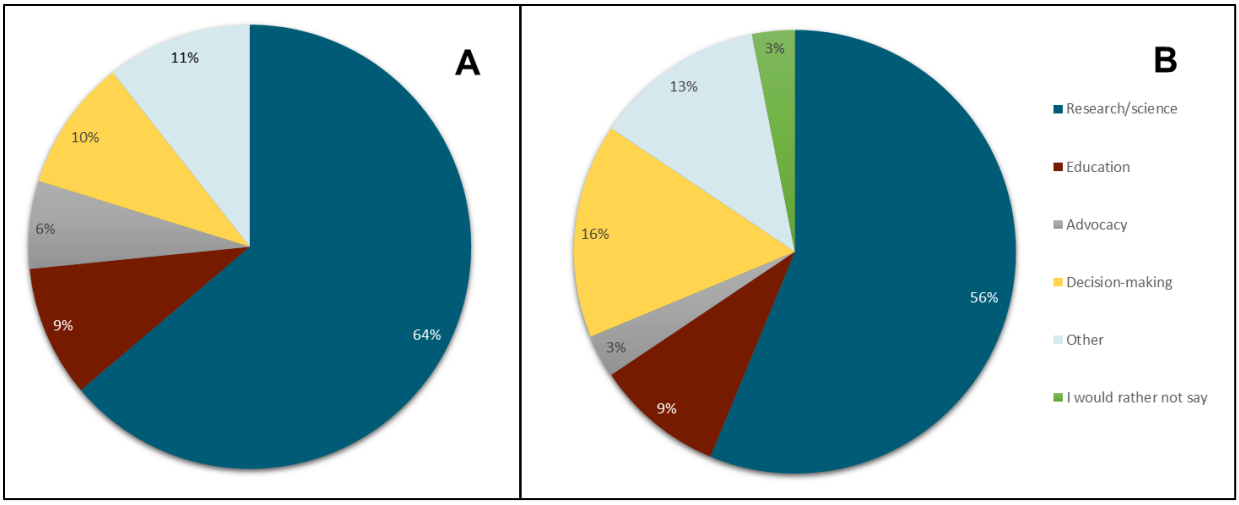


Figure 5: The activity respondents are most engaged in related to their work on safe oceans for Delphi Round 2 (A) and Delphi Round 3 (B).

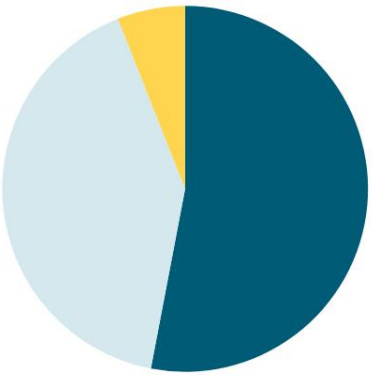
3.1.2 DELPHI ROUND 3: SURVEY RESPONDENT GROUP

A total of 32 respondents participated in *Delphi Round 3*, and information about the respondent group was fairly similar to *Round 2* (Figure 6). Of the total group of respondents, more than half identified as male (53%), closely followed by 41% as female, while 6% would rather not say (Figure 6). Most respondents live in the maritime provinces (34%) and Ontario (26%), followed by Quebec and British Columbia (13% each). In terms of employment industry, most of the expert panel was affiliated with the federal government (47%) followed by higher education institutions (universities) (34%). 34% of respondents indicated they had 11 - 20 years of involvement in topics related to safe oceans. In *Delphi Round 3*, no participants identified as Indigenous. The geographic location and main activities related to respondent's work on safe oceans were also very similar to *Delphi Round 2*. In *Round 3*, slightly fewer respondents (56%) were involved in research/science and slightly more involved in decision-making (16%), while 13% said "other", 9% said "education", 3% said "advocacy", and another 3% would rather not say (Figure 5B). The geographic location of respondents' work in Canada's oceans was very similar to *Round 2* in terms of the proportion and geographic spread were similar (Figure 6).

53% of respondents identify as **male**

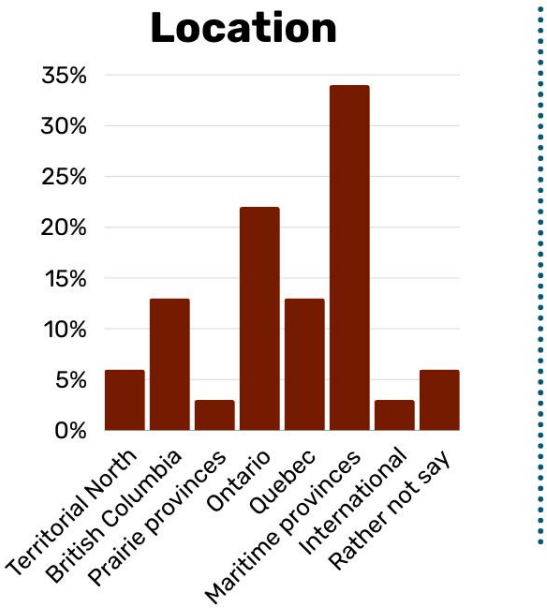
41% of respondents identify as **female**

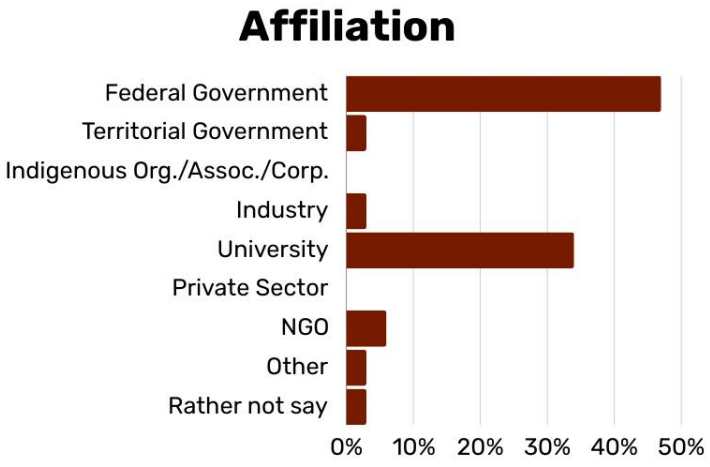
6% of respondents **would rather not say**



0%

No respondents identify as an **Indigenous person**





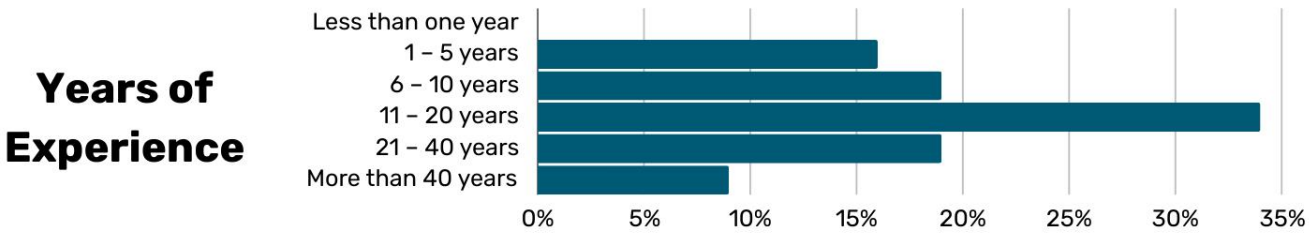


Figure 6: Delphi Round 3 survey respondents' information.

3.2 RESPONDENTS' VISION FOR A SAFE OCEAN BY 2030

Respondents from Delphi Round 2 identified 17 visions for what they feel would lead to a safe ocean in Canada by 2030. The vision statements were:

1. 30% of ocean area protected from human use by 2030 and associated increases in regulations and monitoring within these areas (n=25)
2. Increased use of and easier access to modern digital charting for safe and efficient navigation (n=18)
3. Increased use of Indigenous and local knowledge and governance and management that considered Indigenous self-determination (n=13)
4. Increased investment and research in maritime disaster response, marine safety, and search and rescue (n=19)
5. Increased education and outreach about safe ocean and sustainable human use (n=8)
6. Increased and improved modelling and forecasting of the ocean environment to support safe navigation, science, and other needs (n=12)
7. More sustainable ocean- and resource-use (n=16)
8. Increased regulations and enforcement for national security and sovereignty (n=9)
9. Increased sustainable economic opportunities and support for local livelihoods for coastal communities (n=6)
10. More effective management of existing resources and efficient program planning (n=14)
11. Increased and improved infrastructure (n=7)
12. Business case for private sector investments in marine economy (n=3)
13. Holistic and inter-disciplinary approach to research (n=5)
14. Improved ecosystem and environmental monitoring (n=7)
15. Increased investments in and technological innovations for remote sensing of ocean environments (n=5)
16. Decreased environmental impacts resulting from shipping (n=6)
17. Increased and improved inter-jurisdictional and -national cooperation/communication to support safe ocean operations (n=6)

3.3 DETAILED ASSESSMENT OF IDENTIFIED RESEARCH PRIORITIES

To help achieve some of the visions identified by respondents and outlined above, among others that have been previously identified by the international community via the Ocean Decade initiative and within the Safe Oceans theme area, respondents were asked to outline the research areas that are most urgent. Here we provide a detailed assessment of the respondent-identified research priorities, which were thematically analyzed into six key areas including: 1) shipping and safe navigation, 2) fisheries, marine economies, and well-being, 3) climate change; impacts, risks and adaptation, 4) weather, water, ice, and ocean conditions, 5) governance, policy, and planning, and 6) technology and innovation. We further provide a full assessment of the research priority suggestions within each theme area based on the criteria outlined in Table 2, including the point of agreement and consensus for the priority, affordability, achievability, and timeframe of each of the respondent-identified research priorities.

3.3.1 SHIPPING AND SAFE NAVIGATION

Sixteen research priorities related to Shipping and Safe Navigation were identified and assessed (Table 3). All sixteen research priorities had relatively high consensus, with four having a minimum of three evaluation criteria labelled as “high” consensus, and all priorities having a minimum of two evaluation criteria labelled as “medium” and/or “high” consensus (Table 3). SN-1 demonstrated the highest level of consensus among Shipping and Safe Navigation research priorities, with all four evaluation criteria being labelled as “high” consensus. SN-6, SN-9, SN-10 and SN-11 also show relatively high levels of consensus, with three of the four evaluation criteria being labelled as “high” consensus, and one being labelled as “medium” consensus. Only seven research priorities had a minimum of one evaluation criteria labelled as either “low” consensus and/or as having “none”. SN-14 and SN-15 demonstrate relatively high levels of dissent, with two of the four evaluation criteria being labelled as “low” consensus or “none”, and two being labelled as “medium” or “high”, though this still demonstrates relatively high consensus compared to the other research priority themes.

Table 3: Point of agreement (PA) and consensus (C) on priority, affordability, achievability, and timeframe for Shipping and Safe Navigation research priorities.

Shipping and Safe Navigation						
Research priority			Priority	Affordability	Achievability	Timeframe
SN-1	Evaluate shipping patterns and changes in shipping activity in Canadian oceans	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable	Short to medium term

	including, distance travelled, incidents, accidents, speed, cargo type, passengers, crew, and other attributes	*C*	High	High	High	High
SN-2	Analyze small vessel patterns (non-mandatory AIS vessels) in Canadian oceans to better understand small vessel activity patterns	*PA*	First order to second order priority	Probably affordable to maybe affordable	Probably achievable	Medium term
		C	High	High	Medium	Medium
SN-3	Identify and monitor significant marine areas (ecological, biological, and cultural) and consider voluntary shipping measures in these areas, such as speed reductions, no anchor areas, and others	*PA*	First order priority	Probably affordable to maybe affordable	Definitely achievable to probably achievable	Medium term
		C	Medium	Low	Medium	Medium
SN-4	Enhance bathymetric charting and modern digital charting in all regions but especially in northern latitudes	*PA*	First order priority	Probably affordable to maybe affordable	Probably achievable to probably not achievable	Medium to long term
		C	High	Medium	Medium	High
SN-5	Set up a system that enables crowd sourcing and sharing of bathymetric data using ships of opportunity and social networks	*PA*	Second order to third order priority	Definitely affordable to probably affordable	Probably achievable	Medium to long term
		C	Low	Medium	Medium	Medium
SN-6	Conduct a comprehensive risk assessment for changing shipping activities across Canada (enabling national, regional, and sub-regional level evaluations)	*PA*	First order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Medium term
		C	High	High	High	Medium

SN-7	Establish real-time communication of marine mammal locations with ship operators - especially during migration, calving, and Indigenous hunting seasons	*PA*	First order to second order priority	Probably affordable to maybe affordable	Probably achievable	Medium term
		C	Medium	Low	Medium	High
SN-8	Evaluate the effect of 'light pollution' from ships and ports on marine wildlife and marine ecosystems	*PA*	Second order to third order priority	Probably affordable	Probably achievable	Medium to long term
		C	Low	High	Medium	Medium
SN-9	Observe and model ship-source underwater noise risk for different marine mammal species and by region and identify targeted risk mitigation options	*PA*	First order to second order priority	Probably affordable	Probably achievable	Medium term
		C	High	High	High	Medium
SN-10	Evaluate the environmental, economic, social, and cultural implications of increased shipping in Arctic waters	*PA*	First order priority	Probably affordable	Probably achievable	Medium term
		C	High	High	High	Medium
SN-11	Monitor and model the release of ship-based contaminants, emissions, and pollutants in Canadian ocean regions	*PA*	First order priority	Definitely affordable to probably affordable	Probably achievable	Medium term
		C	High	Medium	High	High
SN-12	Evaluate the impact of shipping emissions on human health in high traffic areas (i.e., Vancouver and Saint Lawrence)	*PA*	Second order priority	Probably affordable	Definitely achievable to probably achievable	Medium to long term
		C	Medium	High	Medium	Medium
SN-13	Measure the level of 'paint-based pollution' emerging from the ablation of hull paint off	*PA*	Second order to third order priority	Probably affordable	Probably achievable	Medium to long term

	vessels (marine-going and icebreaking) in ocean sediments and evaluate potential ecosystem and health impacts	*C*	Low	High	Medium	Medium
SN-14	Evaluate the implications of the upcoming Heavy Fuel Oil Ban in Arctic waters	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	Low	Medium	Medium	Low
SN-15	Evaluate the implications of LNG use among vessels in Canadian waters	*PA*	First order to second order priority	Definitely affordable to probably affordable	Probably achievable	Short to medium term
		C	Low	Medium	High	None
SN-16	Establish linked climate change and socio-economic change models for projecting future maritime trade opportunities through the Northwest Passage	*PA*	Second order priority	Probably affordable	Probably achievable	Medium to long term
		C	Medium	High	Medium	Medium

Figure 7 displays the priority-feasibility plot (see Section 2.3) for research priorities in the Shipping and Safe Navigation theme. Four research priorities (SN-1, SN-6, SN-10 and SN-11) fell into Quadrant A (high priority and high feasibility; see Figure 2). These pertain to predicting and mitigating the impacts of shipping on local ecosystems and livelihoods (SN-6, SN-10, SN-11), and to evaluating trends in shipping patterns and activities (SN-1). This suggests that these should be the initial focus of research efforts. All four of these research priorities could be realized in the short to medium-term, i.e. within the Ocean Decade (Table 3). SN-2, SN-5, SN-8, SN-13, SN-14, SN-15, and SN-16 all fell into Quadrant C (low priority and low feasibility), and thus should not be the initial focus of research efforts unless there is a compelling reason to do so. These pertain to analyzing movement patterns of small-vessels (SN-2), establishing a bathymetric data crowd-sourcing platform (SN-5), evaluating the impacts of ship- and port-based light-pollution (SN-8), quantifying the amount of and evaluating the impacts of ship hull-paint ablation (SN-13), evaluating the impacts of the green fuels transition (including liquid natural gas) (SN-14 and SN-15) and establishing linked climate and socioeconomic change models for opportunities planning in the Northwest Passage (SN-16).

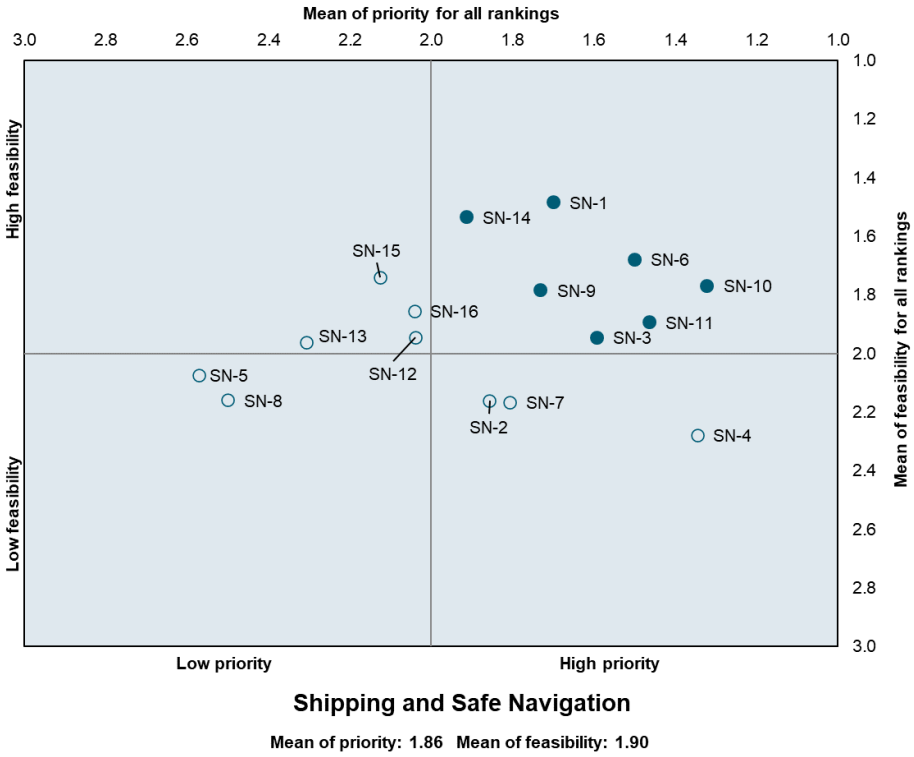


Figure 7: Priority-feasibility plot for research priorities related to Shipping and Safe Navigation. Research priorities in Quadrant A (high priority, high feasibility) have symbols that are filled in, all others are open circles.

3.3.2 FISHERIES, MARINE ECONOMIES, AND WELL-BEING

Twelve research priorities related to Fisheries, Marine Economies, and Well-Being were identified and assessed (Table 4). The research priorities under the theme of Fisheries, Marine Economies, and Well-being had relatively high consensus, with four (of twelve) priorities having a minimum of two evaluation criteria labelled as “high” consensus, and only four having two evaluation criteria labelled as either “low” consensus and/or as having “none” (Table 4). FM-5, FM-6 and FM-7 demonstrated the highest level of consensus, with three of four evaluation criteria being labelled as “high” consensus and one with “medium” consensus. FM-1, FM-11 and FM-12, however, demonstrated the most dissent, with three of the evaluation criteria demonstrating “low” consensus or “none”.

Table 4: Point of agreement (PA) and consensus (C) on priority, affordability, achievability, and timeframe for Fisheries, Marine Economies, and Well-Being research priorities.

Fisheries, Marine Economies, and Well-Being						
Research priority			Priority	Affordability	Achievability	Timeframe
FM-1	Evaluate the plausibility of zero-waste fisheries	*PA*	First order to second order priority	Definitely affordable to probably affordable	Probably achievable to probably not achievable	Medium to long term
		C	None	None	Low	Medium
FM-2	Study the feasibility of cultivating food-grade seaweed through responsible aquaculture	*PA*	Second order to third order priority	Probably affordable	Definitely achievable to probably achievable	Medium to long term
		C	Low	Medium	Medium	Low
FM-3	Analyze existing and underused historic data stored at DFO to support fisheries management	*PA*	First order to second order priority	Definitely affordable	Definitely achievable to probably achievable	Short to medium term
		C	Low	High	Medium	Medium
FM-4	Quantify the role of Canada's marine-based economies (nationally and regionally)	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	Medium	High	High	Medium
FM-5	Quantify the risks and opportunities associated with Arctic cruise tourism in Canada's north	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	Medium	High	High	High
FM-6	Produce a comprehensive set of flood inundation and flood risk maps related to	*PA*	First order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Medium term

	storm surge and sea level rise for all coastal areas across Canada (national, regional, and localized)	*C*	High	High	High	Medium
FM-7	Examine the potential impacts of marine hazards on Indigenous and coastal communities including those dependent on marine resources for their livelihoods and well-being	*PA*	First order priority	Probably affordable	Probably achievable	Medium term
		C	High	High	High	Medium
FM-8	Evaluate how Canadian marine species contribute to food security locally, regionally, nationally, and globally	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	None	Medium	Medium	Low
FM-9	Engage in comprehensive habitat mapping and risk assessments for vulnerable and economically important marine species	*PA*	First order priority	Probably affordable to maybe affordable	Probably achievable	Medium to long term
		C	High	Medium	Medium	Medium
FM-10	Evaluate how ocean-based green energy production activities (e.g., hydrogen, wind, solar, tidal, etc.) affect marine species and ecosystems	*PA*	First order to second order priority	Probably affordable	Probably achievable	Medium term
		C	Medium	High	Medium	Medium
FM-11	Evaluate the role and impact of technology developments (i.e., autonomous vessels, fuel systems, etc.) on pilotage in Canada	*PA*	Second order to third order priority	Probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	Low	Medium	Low	None
FM-12	Track emerging viruses in the marine environment that may have human health implications	*PA*	Second order to third order priority	Probably affordable to maybe affordable	Probably achievable to probably not achievable	Medium to long term
		C	Low	Medium	Low	None

Figure 8 displays the priority-feasibility plot for research priorities in the Fisheries, Marine Economies, and Well-Being theme. Five research priorities (FM-3, FM-4, FM-5, FM-6 and FM-7) fell into Quadrant A (high priority and high feasibility; see Figure 2). These pertain to efficient use of existing data for fisheries management (FM-3), quantifying risks and opportunities related to cruise-based tourism in the Arctic (FM-5), comprehensive flood risk mapping (FM-6) and evaluating the impacts of marine hazards on Indigenous and/or coastal communities (FM-7). This suggests that these should be the initial focus of research efforts under this theme. All five of these research priorities could be realized in the short to medium term, i.e. within the Ocean Decade (Table 4). FM-1 and FM-12 both fell into Quadrant C (low priority and low feasibility), and thus should not be the initial focus of research efforts unless there is a compelling reason to do so. These pertain to evaluating the plausibility of zero-waste fisheries (FM-1) and tracking the emergence of marine-based viruses which could present hazards for humans (FM-12).

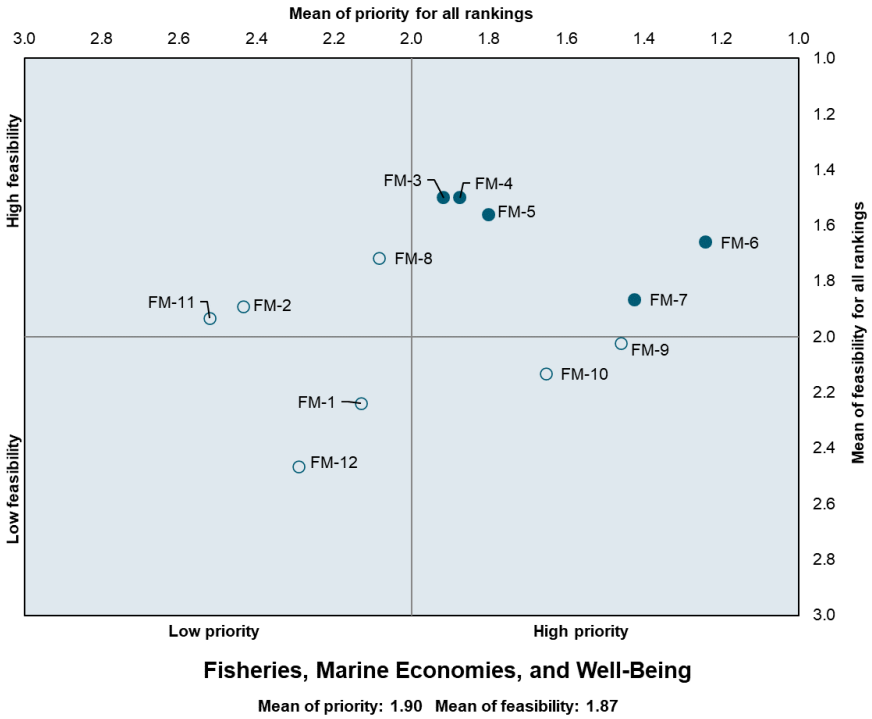


Figure 8: Priority-feasibility plot for research priorities related to Fisheries, Marine Economies, and Well-Being.

3.3.3 CLIMATE CHANGE: IMPACTS, RISKS AND ADAPTATION

Nine research priorities related to Climate Change: Impacts, Risks and Adaptation were identified and assessed (Table 5). The research priorities under the theme of Climate Change: Impacts, Risks and Adaptation had relatively mixed consensus, with five priorities having a minimum of one evaluation criteria labelled as “high” consensus, and four having a minimum of two evaluation criteria labelled as “low” consensus or “none”

(Table 5). CC-1, CC-4 and CC-6 all demonstrated the highest level of consensus, with two of the evaluation criteria being labelled as “high” consensus, and the other two with “medium” consensus. Conversely, CC-2 demonstrated the most dissent, with all evaluation criteria being labelled as “none”. CC-7 demonstrated the second most dissent, with three of the four evaluation criteria being labelled as “low” consensus, and another as “medium”.

Table 5: Point of agreement (PA) and consensus (C) on priority, affordability, achievability, and timeframe for Climate Change: Impacts, Risks and Adaptation research priorities.

Climate Change: Impacts, Risks and Adaptation						
Research priority			Priority	Affordability	Achievability	Timeframe
CC-1	Enhance mapping and baseline information on coastal regions to enable monitoring of climate change (and human use) impacts	*PA*	First order priority	Probably affordable to maybe affordable	Definitely achievable to probably achievable	Medium to long term
		C	High	Medium	Medium	High
CC-2	Evaluate the impact of transgressing individual planetary boundaries for Canada’s marine economy	*PA*	Second order to third order priority	Probably affordable to maybe affordable	Probably achievable to probably not achievable	Medium to long term
		C	None	None	None	None
CC-3	Identify people’s perception of the levels of risk to various ocean-based economic sectors from extreme ocean events and ocean related climate changes	*PA*	Second order to third order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	Low	Medium	Medium	None
CC-4	Evaluate the level of climate readiness and what climate change adaptations are needed to ensure safe and sustainable coastal community infrastructure	*PA*	First order priority	Probably affordable	Probably achievable	Short to medium term
		C	High	High	Medium	Medium
CC-5	Establish better and higher resolution models (coupled to atmospheric drivers)	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Medium term

	of ocean conditions to support more accurate climate change projections and decision making	*C*	Medium	Medium	Medium	High
CC-6	Enhance understanding of the climate change impacts on sea ice (concentration, mobility, thickness, etc.)	*PA*	First order to second order priority	Probably affordable	Probably achievable	Medium term
		C	Medium	High	High	Medium
CC-7	Evaluate and identify options for improving climate-resilient (i.e., adaptation for extreme events and climate change risks) marine supply chains across Canada	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	Low	Medium	Low	Low
CC-8	Track changes in marine mammal movements and migration patterns and evaluate stressors and pressures related to climate change and human activity changes (i.e., shipping, mining, other)	*PA*	First order to second order priority	Probably affordable to maybe affordable	Probably achievable to probably not achievable	Medium to long term
		C	Medium	High	Medium	Low
CC-9	Evaluate the potential carbon sequestration potential of Canada's ocean regions	*PA*	First order to second order priority	Probably affordable	Probably achievable	Medium to long term
		C	Low	Medium	Low	Medium

Figure 9 displays the priority-feasibility plot for research priorities in the Climate Change: Impacts, Risks and Adaptation theme. Five research priorities (CC-1, CC-4, CC-5, CC-6 and CC-7) fell into Quadrant A (high priority and high feasibility; see Figure 2). These pertain to increased baseline information, monitoring and modeling on coastal and sea-ice environments and climate change impacts on them (CC-1, CC-5 and CC-6) and evaluating and identifying readiness of and adaptation options for coastal and marine infrastructure and supply-chains (CC-4 and CC-7). This suggests that these should be the initial focus of research efforts. Three of these research priorities (CC-4, CC-5, CC-6 and CC-7) could be realized in the short to medium-term, i.e. within the Ocean Decade (Table 5). However, CC-1 was believed to be realizable in the medium to long-term and could potentially not be achievable within the Ocean Decade. Conversely, CC-2 and CC-

9 both fell into Quadrant C (low priority and low feasibility), and thus should not be the initial focus of research efforts unless there is a compelling reason to do so. These pertain to evaluating the impact of transgressing planetary boundaries on Canada's marine economies (CC-2) and evaluating the carbon-sequestration potential of Canada's oceans (CC-9).

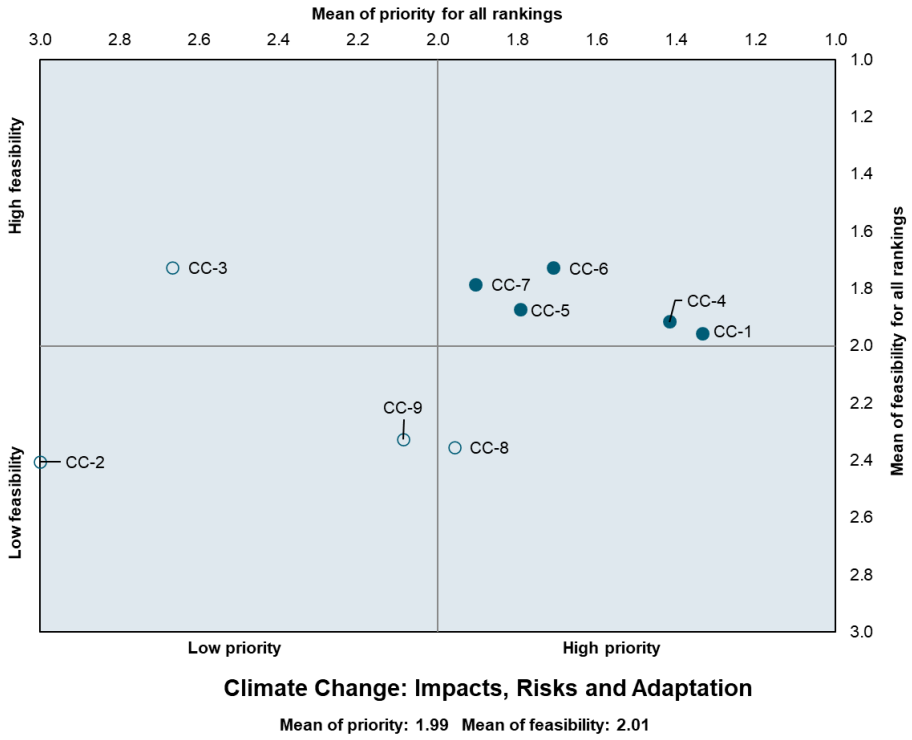


Figure 9: Priority-feasibility plot for research priorities related to Climate Change: Impacts, Risks and Adaptation.

3.3.4 WEATHER, WATER, ICE, AND OCEAN CONDITIONS

Six research priorities related to Weather, Water, Ice, and Ocean Conditions were identified and assessed (Table 6). The research priorities under the theme of Weather, Water, Ice and Ocean Conditions had relatively mixed consensus, with three having a minimum of one evaluation criteria labelled as "high" consensus, and only one having all evaluation criteria labelled as either "low" consensus and/or as having "none" (Table 6). WC-2 demonstrated the highest level of consensus, with two of the four evaluation criteria being labelled as having "high" consensus, one with "medium", and another with "none". WC-5 demonstrated the most dissent, with two of the evaluation criteria being labelled as "low" consensus, and the other two as having "none".

Table 6: Point of agreement (PA) and consensus (C) on priority, affordability, achievability, and timeframe for Weather, Water, Ice, and Ocean Conditions research priorities.

Weather, Water, Ice, and Ocean Conditions						
Research priority			Priority	Affordability	Achievability	Timeframe
WC-1	Evaluate current and future ice-hazards for marine industries (spatial extent and size), particularly given changes to sea-ice extents and glacier calving dynamics	*PA*	First order to second order priority	Definitely affordable to probably affordable	Probably achievable	Medium term
		C	Medium	Low	Medium	Medium
WC-2	Evaluate the question "does better forecasting of weather, water, ice, and climate translate to increased marine safety"	*PA*	Second order to third order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	None	High	High	Medium
WC-3	Increase number of real-time tide (water level) gauges to support monitoring, adaptation, and decision making	*PA*	First order to second order priority	Probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	Low	Medium	High	Medium
WC-4	Establish new systems for the management and integration of weather, water, ice, and climate data (big data, sharing data, etc.)	*PA*	First order to second order priority	Probably affordable to maybe affordable	Definitely achievable to probably achievable	Medium term
		C	Medium	Medium	Medium	Medium
WC-5	Improve and enhance near-time forecasting – hours/days	*PA*	First order to second order priority	Probably affordable to maybe affordable	Definitely achievable to probably achievable	Short to medium term
		C	Low	Low	None	None
WC-6	Increase sampling and analysis of micro and nano plastics in	*PA*	Second order to third order priority	Probably affordable	Definitely achievable to probably achievable	Medium to long term

	Canada's oceans (origin, etc.)	*C*	Low	High	Medium	Low

Figure 10 displays the priority-feasibility plot (see Section 2.3) for research priorities in the Weather, Water, Ice, and Ocean Conditions theme. Two research priorities (WC-1 and WC-2) fell into Quadrant A (high priority and high feasibility). These pertain to evaluating sea ice-based risks to marine industries in the context of climate change (WC-1) and increasing the number of real-time water level gauges to support adaptation and decision making (WC-3). This suggests that these should be the initial focus of research efforts. Both research priorities could also be realized in the short to medium term, i.e. within the Ocean Decade (Table 6). WC-4 and WC-5 should be considered next as they are first to second order priorities, although feasibility is lower. Conversely, no research priorities fell into Quadrant C (low priority and low feasibility).

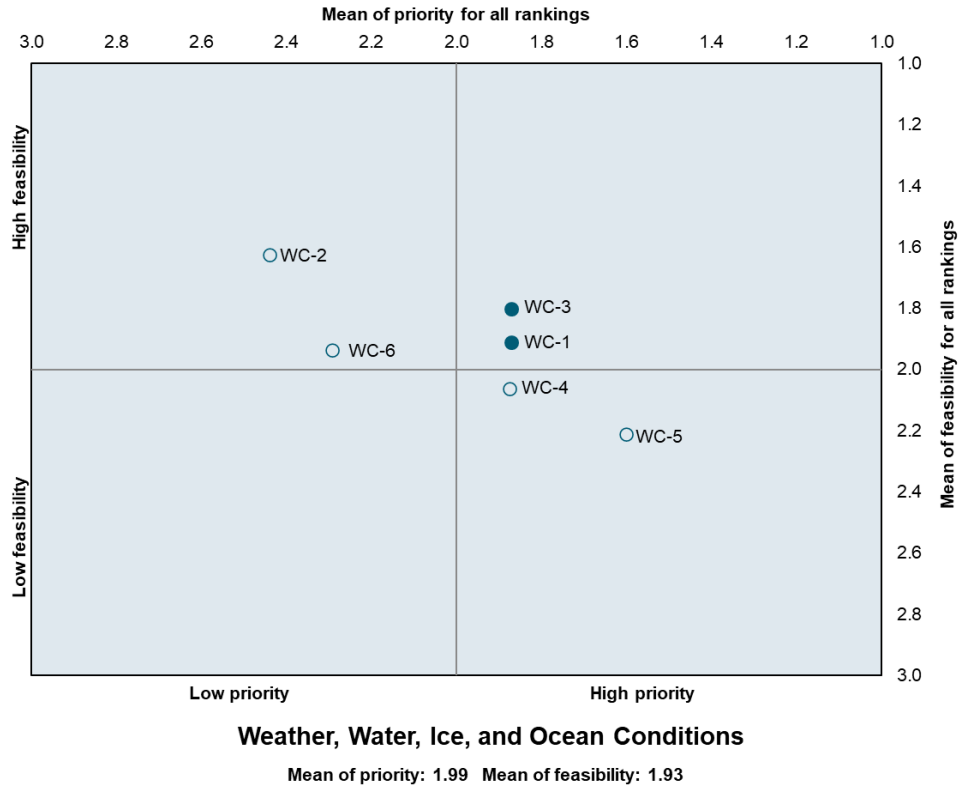


Figure 10: Priority-feasibility plot for research priorities related to Weather, Water, Ice, and Ocean Conditions.

3.3.5 GOVERNANCE, POLICY, AND PLANNING

Ten research priorities related to Governance, Policy, and Planning were identified and assessed (Table 7). All ten research priorities had relatively low consensus, with only one having a minimum of one evaluation criteria labelled as "high" consensus, and six having

all evaluation criteria labelled as either “low” consensus and/or as having “none” (Table 7). GP-6 was rated as having the highest level of consensus, with all four evaluation criteria being labelled as having “high” consensus. GP-1, GP-7 and GP-9 demonstrated significant dissent, with all four evaluation criteria for each research priority being labelled as “none”.

Table 7: Point of agreement (PA) and consensus (C) on priority, affordability, achievability, and timeframe for Governance, Policy, and Planning research priorities.

Governance, Policy, and Planning						
Research priority			Priority	Affordability	Achievability	Timeframe
GP-1	Evaluate Canada’s readiness for autonomous shipping (i.e., policies, mitigation measures, etc.)	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	None	None	None	None
GP-2	Analyze how different levels of government and knowledge systems (i.e., science, Indigenous knowledge, others) can most effectively work together to support safe oceans	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	Low	Medium	Low	Low
GP-3	Identify best practices for marine protected areas design and governance (which consider how Indigenous peoples use the ocean)	*PA*	First order to second order priority	Definitely affordable to probably affordable	Probably achievable	Short to medium term
		C	Medium	Low	Medium	Low
GP-4	Evaluate the role and levels of training among mariners and what human factors contribute to marine industry error, incidents, and accidents	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	None	Medium	Medium	Low
GP-5	Examine engineering and planning solutions for port reception facilities to adequately and efficiently (limit	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term

	ship wait times) deal with wastes and waste streams (regionally specific waste characterization and management capacity)	*C*	Low	None	Low	None
GP-6	Evaluate readiness for responding to major ocean-based pollution events from anthropogenic sources that stem from within and also outside of Canada	*PA*	First order priority	Probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	High	High	High	High
GP-7	Identify and evaluate ocean-based security threats to Canada	*PA*	First order to second order priority	Probably affordable to maybe affordable	Definitely achievable to probably achievable	Short to medium term
		C	None	None	None	None
GP-8	Conduct preliminary impact and opportunity assessments for deep sea mining in Canada's Oceans	*PA*	First order to second order priority	Probably affordable to maybe affordable	Probably achievable to probably not achievable	Short to medium term
		C	None	Low	Low	None
GP-9	Identify the factors affecting human survival time in the ocean, particularly for extended survival situations in the Arctic	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Short to medium term
		C	None	None	None	None
GP-10	Evaluate the best approaches for the decarbonization of ships	*PA*	First order to second order priority	Probably affordable to maybe affordable	Definitely achievable to probably achievable	Short to medium term
		C	Low	Low	Low	None

Figure 11 displays the priority-feasibility plot for research priorities in the Governance, Policy, and Planning theme. Four research priorities (GP-2, GP-3, GP-5 and GP-6) fell into Quadrant A (high priority and high feasibility; see Figure 2). These pertain to understanding how different knowledge systems can contribute to support safe oceans (GP-2), identifying best-practices for MPA management which consider Indigenous use of resources within them (GP-3), evaluating engineering and planning solutions to

expediate ship-based waste management at ports (GP-5), and evaluating Canada's readiness to major domestic and international anthropogenic pollution events (GP-6). This suggests that these should be the initial focus of research efforts. All four of these research priorities could also be realized in the short to medium term, i.e. within the Ocean Decade (Table 7). One research priority (GP-8) fell into Quadrant C (low priority and low feasibility), and thus should not be the initial focus of research efforts unless there is a compelling reason to do so. GP-8 pertains to conducting impact and opportunity assessments for deep-sea mining in Canada's oceans.

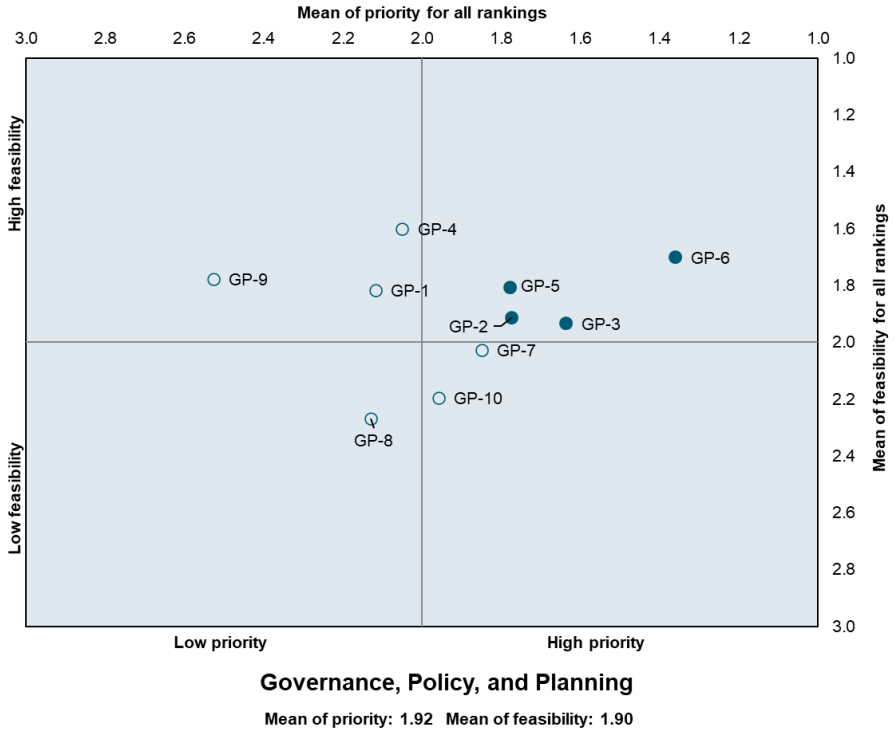


Figure 11: Priority-feasibility plot for research priorities related to Governance, Policy, and Planning.

3.3.6 TECHNOLOGY AND INNOVATION

Nine research priorities related to Technology and Innovation were identified and assessed (Table 8). The research priorities under the theme of Technology and Innovation had relatively low consensus, with only two priorities having a minimum of one evaluation criteria labelled as "high" consensus, and four having all evaluation criteria labelled as either "low" consensus and/or as having "none" (Table 8). TI-1 demonstrated the highest level of consensus, with two of the four evaluation criteria being labelled as having "high" consensus, and the other two being labelled as "medium" consensus. TI-9 demonstrated the highest amount of dissent, with all four evaluation criteria being labelled as "none", having no discernible consensus. TI-5 also demonstrated a high level of dissent, with three evaluation criteria being labelled as "none" and one evaluation criteria labelled as "low" consensus.

Table 8: Point of agreement and consensus on priority, feasibility, and timeframe for Technology and Innovation research priorities.

Technology and Innovation						
Research priority			Priority	Affordability	Achievability	Timeframe
TI-1	Enhance and optimize geospatial technology (satellites, drones etc.), synoptic tools, Artificial Intelligence (AI) to enhance monitoring and forecasting	*PA*	First order to second order priority	Probably affordable to maybe affordable	Definitely achievable to probably achievable	Medium term
		C	High	High	Medium	Medium
TI-2	Improve predictive models and enable finer spatial scales of structure and function of the ocean for greater applicability to decision-making	*PA*	Second order priority	Probably affordable to maybe affordable	Probably achievable to probably not achievable	Medium to long term
		C	High	Low	Low	Medium
TI-3	Establish new techniques (algorithms, scripts, web-scraping, AI, machine learning) for more efficiently analyzing automatic information system (AIS) spatial shipping data (i.e., big data)	*PA*	First order to second order priority	Probably affordable	Probably achievable	Medium term
		C	Medium	Low	Medium	Medium
TI-4	Evaluate the potential for and risks of 'green fuel' technologies (i.e., hydrogen, wind, solar)	*PA*	First order priority	Probably affordable to maybe affordable	Definitely achievable to probably achievable	Medium term
		C	Medium	Low	Medium	Low
TI-5	Evaluate the potential for and risks of using small nuclear reactors (SMRs) to power ships and/or port infrastructure	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Medium to long term
		C	None	None	Low	None
TI-6	Explore innovations in spill response in the ocean and in ice-infested marine waters (e.g., bioremediation, automation / uncrewed equipment, etc.)	*PA*	First order to second order priority	Definitely affordable to probably affordable	Definitely achievable to probably achievable	Medium term
		C	Low	None	Low	Medium
TI-7	Evaluate the utility and benefits of drones/autonomous surface vessels for search and rescue at	*PA*	First order to second order priority	Probably affordable to maybe affordable	Definitely achievable to probably achievable	Short to medium term

	sea, safer navigation, and other in-situ decision making	*C*	Low	Low	Low	Low
TI-8	Establish techniques for detecting ships that turn off AIS transponders (dark ships)	*PA*	First order to second order priority	Probably affordable to maybe affordable	Probably achievable to probably not achievable	Short to medium term
		C	None	Low	Low	None
TI-9	Evaluate the technological feasibility of marine autonomous surface ships	*PA*	Third order to no priority	Probably affordable to maybe affordable	Probably achievable to probably not achievable	Medium to long term
		C	None	None	None	None

Figure 12 displays the priority-feasibility plot for research priorities in the Technology and Innovation theme. Three research priorities (TI-3, TI-4, and TI-6) fell into Quadrant A (high priority and high feasibility). These pertain to developing new techniques and technologies for collecting and processing large amounts of automatic information system (AIS) data (TI-3), evaluating the opportunities and risks associated with using “green” alternatives to fossil fuels on ships (TI-4), and exploring alternative spill response methods effective in ice-infested waters (TI-6). This suggests that these should be the initial focus of research efforts. All three of these research priorities could be realized in the medium term, i.e. within the Ocean Decade (Table 8). TI-5, TI-8 and TI-9 all fell into Quadrant C (low priority and low feasibility), and thus should not be the initial focus of research efforts unless there is a compelling reason to do so. These pertain to evaluating the utility of using Small Modular Reactors (SMRs) on ships (TI-5), establishing techniques for identifying “dark ships”—ships which have purposefully turned-off their automatic information system (AIS) transponders (TI-8), and evaluating the feasibility of autonomous marine surface ships (TI-9).

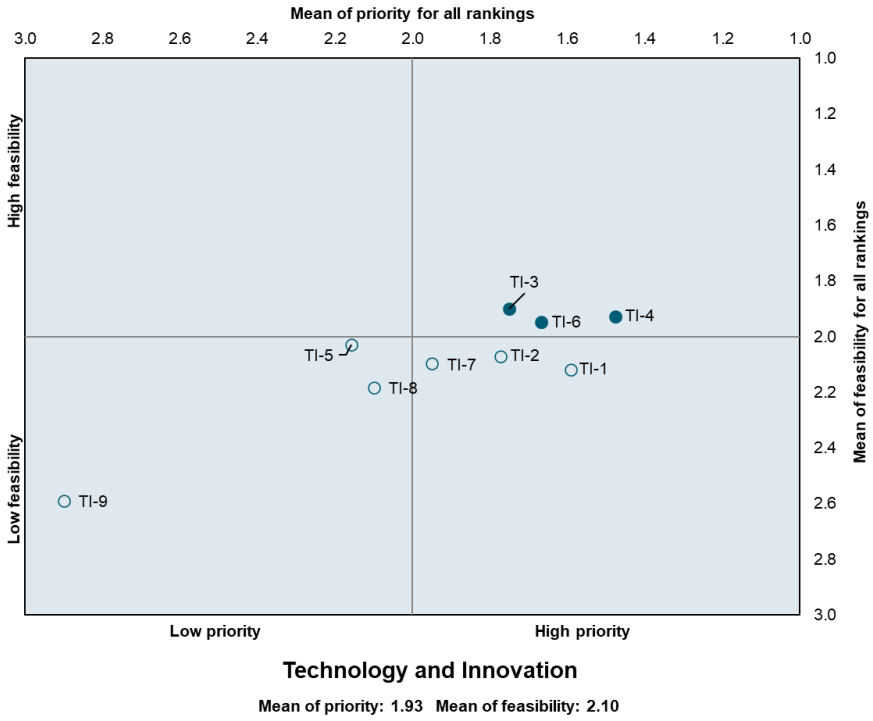


Figure 12: Priority-feasibility plot for research priorities related to Technology and Innovation.

3.4 RANKING OF RESEARCH PRIORITIES

An additional step was taken in our analysis to rank all the research priorities based on the various criteria (including consensus) regardless of themes in order to identify absolute top research needs based on respondent opinion. The methods used to complete this involved determining the final point of agreement (i.e., the rating most often selected by respondents) for priority and for feasibility and assigning each a 'score' between 1 and 8 based on the points of agreement (Table 9). The research priorities were then sorted by the scores, first by priority, and then by feasibility. Consideration was then given to the level of consensus among respondents, whereby low-consensus items were ranked lower compared to those with higher-consensus. Research priorities achievable within the Ocean Decade (i.e., within the short to medium-term) were also prioritized.

The highly ranked priorities are presented below (section 3.4.1) and medium to low ranked priorities can be found in Appendix B.

Table 9: Scoring rubric for ranking system.

Score*	Priority	Feasibility
1	First order priority	Definitely feasible
1.5	First order to second order priority	Probably feasible
2	Second order priority	Probably feasible
2.5	Second order to third order priority	Probably feasible
3	Third order priority	Probably feasible
3.5	Third order to no priority	Probably feasible
4	No priority	Neutral
4.5		Neutral
5		Neutral
5.5		Probably not feasible
6		Probably not feasible
6.5		Probably not feasible
7		Probably not feasible
7.5		Definitely not feasible
8		Definitely not feasible

* Feasibility was assigned a score between 1 and 8 because it is the sum of affordability and achievability, whereas priority was assigned a score between 1 to 4 as in the survey Likert scale (Table 1).

3.4.1 HIGHEST-RANKED RESEARCH PRIORITIES

Twelve research priorities were identified as the highest ranked research priorities according to the scoring in the rubric outlined in Table 9 and are summarized in Table 10 below. Only first order priorities (priority score of 1 on Table 9) were considered highest ranked, and they are ordered based on feasibility scores and shortest timeframe. The table is sorted in descending order. The bottom three highest ranked research priorities (in descending order: FM-9, CC-1 and SN-4) are all deemed achievable in the medium (2-7 years) to long-term (8 years or longer) and may be unachievable by the end of the Ocean Decade (2030). However, these were kept in the list of highly ranked research priorities due to their ranking as “first order” priorities, and as preparatory work to address these research priorities may be undertaken during the Ocean Decade.

Table 10: Highest ranked research priorities, including the point of agreement (the score from table 9 is listed in brackets) and consensus for priority, feasibility, and timeframe.

Research priority			Priority	Feasibility	Timeframe
SN-6	Conduct a comprehensive risk assessment for changing shipping	*PA*	First order priority (1)	Probably feasible (3)	Medium-term

	activities across Canada (enabling national, regional, and sub-regional level evaluations)	*C*	High	High	Medium
FM-6	Produce a comprehensive set of flood inundation and flood risk maps related to storm surge and sea level rise for all coastal areas across Canada (national, regional, and localized)	*PA*	First order priority (1)	Probably feasible (3)	Medium-term
		C	High	High	Medium
SN-11	Monitor and model the release of ship-based contaminants, emissions, and pollutants in Canadian ocean regions	*PA*	First order priority (1)	Probably feasible (3.5)	Medium-term
		C	High	Medium to high	High
GP-6	Evaluate readiness for responding to major ocean-based pollution events from anthropogenic sources that stem from within and also outside of Canada	*PA*	First order priority (1)	Neutral (4)	Short to medium-term
		C	High	High	High
SN-10	Evaluate the environmental, economic, social, and cultural implications of increased shipping in Arctic waters	*PA*	First order priority (1)	Neutral (4)	Medium-term
		C	High	High	Medium
FM-7	Examine the potential impacts of marine hazards on Indigenous and coastal communities including those dependent on marine resources for their livelihoods and well-being	*PA*	First order priority (1)	Neutral (4)	Medium-term
		C	High	High	Medium
TI-4	Evaluate the potential for and risks of ‘green fuel’ technologies (i.e., hydrogen, wind, solar)	*PA*	First order priority (1)	Neutral (4)	Medium-term
		C	High	High	Low

CC-4	Evaluate the level of climate readiness and what climate change adaptations are needed to ensure safe and sustainable coastal community infrastructure	*PA*	First order priority (1)	Neutral (4)	Short to medium-term
		C	High	Medium to high	Medium
SN-3	Identify and monitor significant marine areas (ecological, biological, and cultural) and consider voluntary shipping measures in these areas, such as speed reductions, no anchor areas, and others	*PA*	First order priority (1)	Neutral (4.5)	Medium-term
		C	High	Medium to high	Medium
FM-9	Engage in comprehensive habitat mapping and risk assessments for vulnerable and economically important marine species	*PA*	First order priority (1)	Neutral (4)	Medium to long-term
		C	High	High	Medium
CC-1	Enhance mapping and baseline information on coastal regions to enable monitoring of climate change (and human use) impacts	*PA*	First order priority (1)	Neutral (4)	Medium to long-term
		C	High	Medium	High
SN-4	Enhance bathymetric charting and modern digital charting in all regions but especially in northern latitudes	*PA*	First order priority (1)	Probably not feasible (5.5)	Medium to long-term
		C	High	Medium to high	High

Five highly ranked research priorities were from the Shipping and Safe Navigation theme, three were from the Fisheries, Marine Economies & Well-being theme, two from the Climate Change: Impacts, Risks and Adaptation theme, and one each from the Governance, Policy, and Planning and Technology and Innovation themes. None of the highest-ranked research priorities stemmed from the Weather, Water, Ice and Ocean Conditions theme.

The top three highest ranked research priorities (in descending order: SN-6, FM-6 and SN-11) were all first order priorities and were “probably feasible”. They all pertained to monitoring, assessing, and mapping risks and impacts from shipping, natural disasters, and pollution for coastal communities and marine ecosystems. They also demonstrated

relatively high consensus, with a minimum of two evaluation criteria labelled as having “high” consensus, and the other labelled as “medium” consensus. These three research priorities were all believed to be achievable in the “medium-term”, i.e. within the Ocean Decade (Table 10).

3.5 CONSIDERATION OF DIVERGENCE IN OPINION IN RESEARCH PRIORITIES

It is unlikely that full agreement will be reached on any research priority, but it is important to consider consensus and dissent to properly evaluate the responses provided by survey participants. The final ranking of the full suite of research priorities considered the degree of consensus among respondents, which was generally very high for highly ranked research priorities, having a minimum of two of the criteria for each research priority demonstrating “high” consensus (Table 10). This finding suggests that *Delphi Round 3* respondents generally agreed on which research priorities were the most important and what should be the focus of the Ocean Decade. Consensus was lower among medium and low ranked research priorities (Appendix B).

Figures 13 through 18 show the range of similarities and differences for the priority and feasibility evaluation criteria among the main *Delphi Round 3* respondent affiliations (i.e., university and federal government; see Figure 6). The response rate for other affiliations (i.e., NGO, industry, and other; see Figure 6) was too low (less than 2 respondents) to be used to evaluate consensus. The point of agreement demonstrates the average score of an affiliation group for both priority and feasibility (see Table 9 in Section 3.4 for scoring rubric).

In general, there are strong similarities on the point of agreement within the two groups (i.e., federal government employees tend to agree with federal government employees, academics tend to agree with academics). There are also strong similarities on the point of agreement between university- and federal government-affiliated respondents, especially for Shipping and Safe Navigation (Figure 13), Weather, Water, Ice, and Ocean Conditions (Figure 16), Technology and Innovation (Figure 18), and for feasibility for Governance, Policy, and Planning (Figure 17). This finding suggests that, for the most part, university- and federal government-affiliated respondents agreed in their ranking of research priorities, regardless of their affiliation.

Generally, respondents from both affiliations agreed on what were priorities. There was only one major difference for GP8 (Conduct preliminary impact and opportunity assessments for deep sea mining in Canada's Oceans), where federal government employees said it was a research priority while academics said it was not (Figure 17). There was more dissent for feasibility, particularly for Fisheries, Marine Economies, and Well-Being, where academics said most research priorities in that group were definitely feasible, while federal government employees said feasibility was neutral (Figure 14).

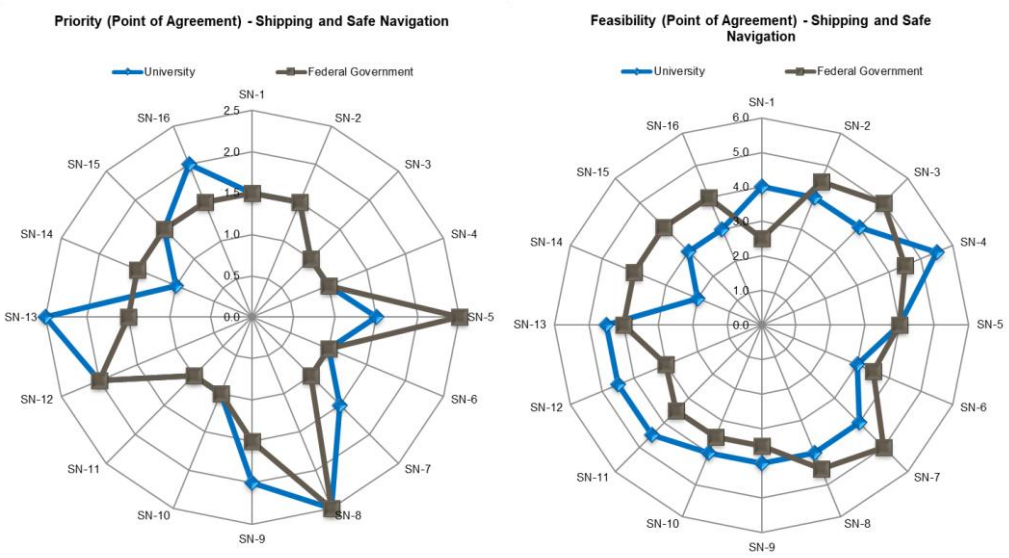


Figure 13: Point of agreement among respondents in the University (n=11) and Federal Government (n=15) affiliations on priority (left) and feasibility (right) of Shipping and Safe Navigation research priorities.

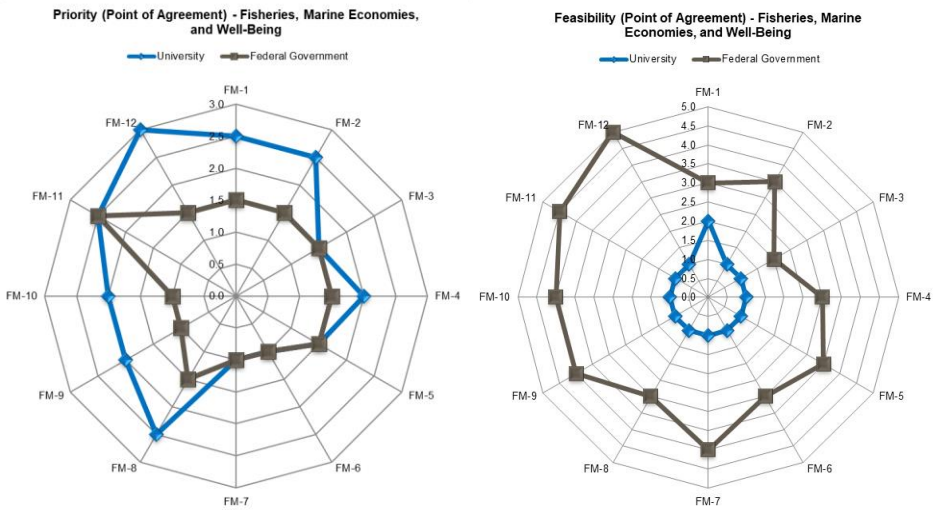


Figure 14: Point of agreement among respondents in the University (n=11) and Federal Government (n=15) affiliations on priority (left) and feasibility (right) of Fisheries, Marine Economies, and Well-Being research priorities.

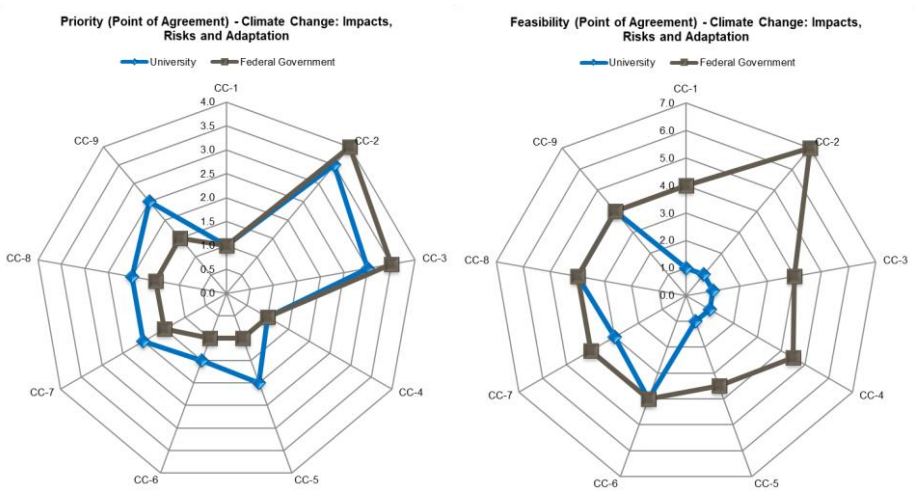


Figure 15: Point of agreement among respondents in the University (n=11) and Federal Government (n=15) affiliations on priority (left) and feasibility (right) of Climate Change; Impacts, Risks and Adaptation research priorities.

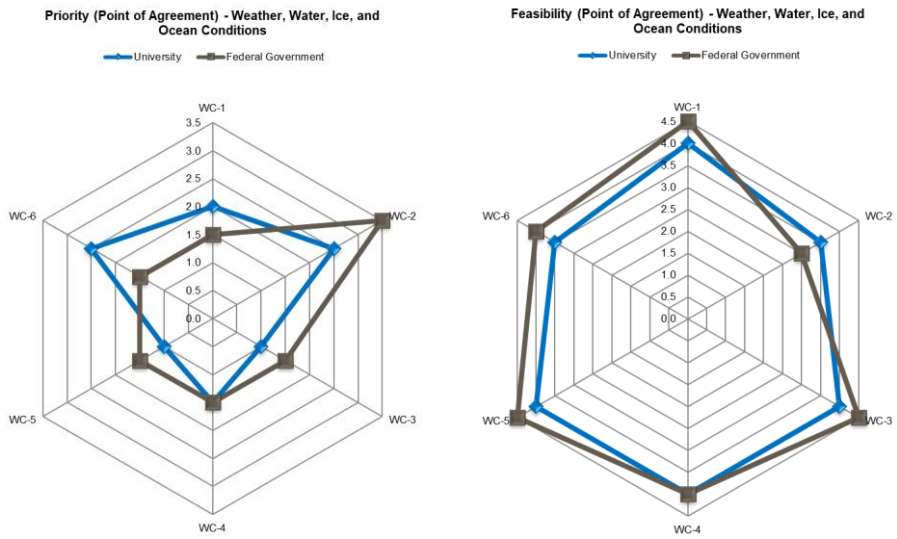


Figure 16: Point of agreement among respondents in the University (n=11) and Federal Government (n=15) affiliations on priority (left) and feasibility (right) of Weather, Water, Ice, and Ocean Conditions research priorities.

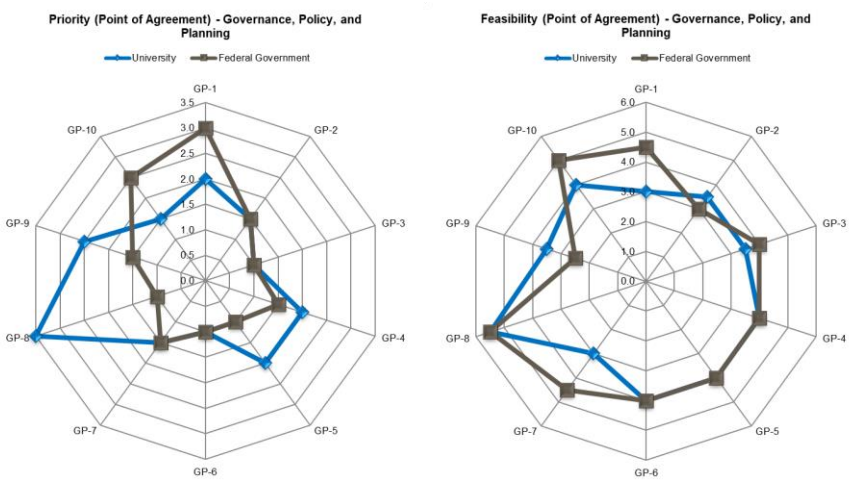


Figure 17: Point of agreement among respondents in the University (n=11) and Federal Government (n=15) affiliations on priority (left) and feasibility (right) of Governance, Policy, and Planning research priorities.

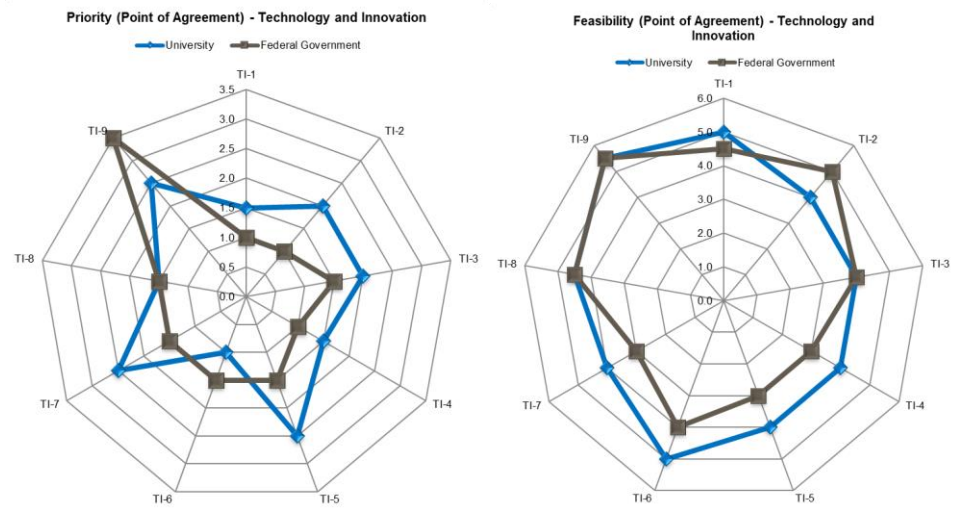


Figure 18: Point of agreement among respondents in the University (n=11) and Federal Government (n=15) affiliations on priority (left) and feasibility (right) of Technology and Innovation research priorities.

4.0 Conclusion

In this report, we established a vision and research priorities related to the Ocean Decade 'Safe Ocean' theme. We set a baseline for the state of affairs and what we want to accomplish so that we may evaluate our achievements throughout and at the end of the Decade. We inventoried over 600 projects, programs, and experts across Canada that can support Ocean Decade efforts within the Safe Oceans theme. We then engaged a suite of these experts, stakeholders, and rights holders in a two-part Policy Delphi survey, where we established a vision of a 'Safe Ocean' for Canada and sought to identify knowledge gaps and research priorities to achieving this vision. After analyses of survey responses, 12 research areas emerged as the most important and we suggest prioritizing these first within the Ocean Decade. These research priorities all fell under the themes of

Shipping and Safe Navigation, Fisheries, Marine Economies & Well-being, Climate Change: Impacts, Risks and Adaptation, Governance, Policy, and Planning, and Technology and Innovation.

The next step is to develop a Strategic Science Plan for the Safe Oceans Theme to support and monitor work in Canada on this topic during the Ocean Decade. This will incorporate the "vision" of what a safe ocean will look like by 2030 (Section 3.2) and consider all research priorities outlined in Section 3.3, with particular consideration for the highly ranked research priorities identified in this effort and outlined in Table 10. These will provide resources upon which the Government of Canada's 'Safe Ocean' vision can be operationalized and will provide the basis upon which goals and indicators can be established among the government, academic, NGO, and other sectors. Investigation and identification of specific indicators for each vision statement and research priority will be crucial for measuring and reporting progress, as well as for accountability.

5.0 References

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APPENDIX A - Methodology

Table A1: Survey respondents listed in alphabetical order with affiliations indicated, based on each respondent's preference. Delphi Round 3 respondents are indicated with *. An additional 34 respondents chose to remain anonymous.

Cathryn Abbott, Fisheries and Oceans Canada
Jeffrey Barrell, Fisheries and Oceans Canada*
Jennifer L. Boldt, Fisheries and Oceans Canada
Paul Blomerus, Clear Seas
Daniel Breton, Fisheries and Oceans Canada
Michel Breton, Fisheries and Oceans Canada
Norm Catto*
Omer Chouinard
Andrés Cisneros-Montemayor, Simon Fraser University
Colin Cooke*
Miguel Correia, University of British Columbia
Anna Crawford, University of Stirling*
Greg Crocker
Brian Dixon, University of Waterloo
Britt Dupuis
Brent Else, University of Calgary*
Susanne Emond
Eric Esclamadon, Garde Côtière Canadienne*
Peter Galbraith, Fisheries and Oceans Canada
Nathalie Gauthier, Fisheries and Oceans Canada
Yanick Gendreau, Pêches et Océans Canada*
Maxime Geoffroy, Memorial University
Blair Greenan, Fisheries and Oceans Canada
William Halliday, WCS Canada*

Dr. Larry Hildebrand, WMU-Sasakawa Global Ocean Institute, World Maritime University, Sweden
Ali Khelifa, Environment and Climate Change Canada*
Anders Knudby, University of Ottawa
John Krgovich
Paul D. Larson, University of Manitoba
Steven Lonsdale, Qikiqtani Inuit Association
Samantha McBeth
Chris Mckindsey
Humfrey Melling, Fisheries and Oceans Canada
Colleen Mercer Clarke, Canadian Society of Landscape Architects, International Federation of Landscape Architects
Chris Milley, NEXUS Coastal Resource Management/ Dalhousie University Marine Affairs Program
Ella Minicola, Ocean Networks Canada
Lorenzo Moro
Anna Naylor, SOI Foundation
Adrian Nicoll, Transport Canada
Ole Nielsen, Fisheries and Oceans Canada
Alice Ortmann*
Mia Otokiak, Ikaarvik Youth Mentor
Will Perrie, Fisheries and Oceans Canada
Danika van Proosdij
Vida Ramin, VP, Policy and Partnerships, Chamber of Shipping BC

Heather Reader, Memorial University of Newfoundland*
Rosemary Ricciardelli, Memorial University of Newfoundland
Olivier Riche*
Gabriela Sabau, Memorial University of Newfoundland
Elizabeth Sanli, Memorial University of Newfoundland*
Michael Scarratt, Fisheries and Oceans Canada
Jinyu Sheng, Dalhousie University

Matthew Surch, Canadian Coast Guard
Cedar Swan, Adventure Canada
Sebastian Weissenberger, département science et technologie, Université TÉLUQ
Peter G. Wells
Maxine Westhead
Hugh R. Williamson, International Ocean Institute*
Clara Jane Wood - Native Council of Prince Edward Island
Andrew J. Wright, Fisheries and Oceans Canada, Arctic Region

APPENDIX B – Additional Data

Table B1: Medium ranked (priority score of 1.5 on Table 9) research priorities, including the point of agreement (the score from table 9 is listed in brackets) and consensus for priority, feasibility, and timeframe. They are ordered based on feasibility (lowest score on Table 9).

Research priority			Priority	Feasibility	Timeframe
SN-1	Evaluate shipping patterns and changes in shipping activity in Canadian oceans including, distance travelled, incidents, accidents, speed, cargo type, passengers, crew, and other attributes	*PA*	First order to second order priority (1.5)	Probably feasible (2.5)	Short to medium term
		C	High	High	High
FM-3	Analyze existing and underused historic data stored at DFO to support fisheries management	*PA*	First order to second order priority (1.5)	Probably feasible (2.5)	Short to medium term
		C	Low	Medium to high	Medium
SN-14	Evaluate the implications of the upcoming Heavy Fuel Oil Ban in Arctic waters	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Short to medium term
		C	Low	Medium	Low
FM-4	Quantify the role of Canada's marine-based economies (nationally and regionally)	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Short to medium term
		C	Medium	High	Medium
FM-5	Quantify the risks and opportunities associated with Arctic cruise tourism in Canada's north	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Short to medium term
		C	Medium	High	Medium
FM-8	Evaluate how Canadian marine species contribute to food security locally, regionally, nationally, and globally	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Short to medium term
		C	None	Medium	Low

CC-5	Establish better and higher resolution models (coupled to atmospheric drivers) of ocean conditions to support more accurate climate change projections and decision making	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Medium term
		C	Medium	Medium	High
CC-7	Evaluate and identify options for improving climate-resilient (i.e., adaptation for extreme events and climate change risks) marine supply chains across Canada	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Short to medium term
		C	Low	Low to medium	Low
GP-1	Evaluate Canada's readiness for autonomous shipping (i.e., policies, mitigation measures, etc.)	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Short to medium term
		C	None	None	None
GP-2	Analyze how different levels of government and knowledge systems (i.e., science, Indigenous knowledge, others) can most effectively work together to support safe oceans	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Short to medium term
		C	Low	Low to medium	Low
GP-4	Evaluate the role and levels of training among mariners and what human factors contribute to marine industry error, incidents, and accidents	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Short to medium term
		C	None	Medium	Low
GP-5	Examine engineering and planning solutions for port reception facilities to adequately and efficiently (limit ship wait times) deal with wastes and waste streams (regionally specific waste characterization and	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Short to medium term
		C	Low	None to low	None

	management capacity)				
GP-9	Identify the factors affecting human survival time in the ocean, particularly for extended survival situations in the Arctic	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Short to medium term
		C	None	None	None
TI-5	Evaluate the potential for and risks of using small nuclear reactors (SMRs) to power ships and/or port infrastructure	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Medium to long term
		C	None	None to low	None
TI-6	Explore innovations in spill response in the ocean and in ice-infested marine waters (e.g., bioremediation, automation / uncrewed equipment, etc.)	*PA*	First order to second order priority (1.5)	Probably feasible (3.0)	Medium term
		C	Low	None to low	Medium
SN-15	Evaluate the implications of LNG use among vessels in Canadian waters	*PA*	First order to second order priority (1.5)	Probably feasible (3.5)	Short to medium term
		C	Low	Medium to high	None
WC-1	Evaluate current and future ice-hazards for marine industries (spatial extent and size), particularly given changes to sea-ice extents and glacier calving dynamics	*PA*	First order to second order priority (1.5)	Probably feasible (3.5)	Medium term
		C	Medium	Low to medium	Medium
WC-3	Increase number of real-time tide (water level) gauges to support monitoring, adaptation, and decision making	*PA*	First order to second order priority (1.5)	Probably feasible (3.5)	Short to medium term
		C	Low	Medium to high	Medium
GP-3	Identify best practices for marine protected areas design and	*PA*	First order to second order priority (1.5)	Probably feasible (3.5)	Short to medium term

	governance (which consider how Indigenous peoples use the ocean)	*C*	Medium	Low to medium	Low
SN-9	Observe and model ship-source underwater noise risk for different marine mammal species and by region and identify targeted risk mitigation options	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Medium term
		C	High	High	Medium
FM-1	Evaluate the plausibility of zero-waste fisheries	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Medium to long term
		C	None	None to low	Medium
FM-10	Evaluate how ocean-based green energy production activities (e.g., hydrogen, wind, solar, tidal, etc.) affect marine species and ecosystems	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Medium term
		C	Medium	Medium to high	Medium
CC-6	Enhance understanding of the climate change impacts on sea ice (concentration, mobility, thickness, etc.)	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Medium term
		C	Medium	High	Medium
CC-9	Evaluate the potential carbon sequestration potential of Canada's ocean regions	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Medium to long term
		C	Low	Low to medium	Medium
WC-4	Establish new systems for the management and integration of weather, water, ice, and climate data (big data, sharing data, etc.)	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Medium term
		C	Medium	Medium	Medium
WC-5	Improve and enhance near-time forecasting – hours/days	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Short to medium term
		C	Low	None to low	None

GP-7	Identify and evaluate ocean-based security threats to Canada	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Short to medium term
		C	None	None	None
GP-10	Evaluate the best approaches for the decarbonization of ships	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Short to medium term
		C	Low	Low	None
TI-1	Enhance and optimize geospatial technology (satellites, drones etc.), synoptic tools, Artificial Intelligence (AI) to enhance monitoring and forecasting	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Medium term
		C	High	Medium to high	Medium
TI-3	Establish new techniques (algorithms, scripts, web-scraping, AI, machine learning) for more efficiently analyzing automatic information system (AIS) spatial shipping data (i.e., big data)	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Medium term
		C	Medium	Low to medium	Medium
TI-7	Evaluate the utility and benefits of drones/autonomous surface vessels for search and rescue at sea, safer navigation, and other in-situ decision making	*PA*	First order to second order priority (1.5)	Neutral (4.0)	Short to medium term
		C	Low	Low	Low
SN-2	Analyze small vessel patterns (non-mandatory AIS vessels) in Canadian oceans to better understand small vessel activity patterns	*PA*	First order to second order priority (1.5)	Neutral (4.5)	Medium term
		C	High	Medium to high	Medium
SN-7	Establish real-time communication of marine mammal locations with ship operators - especially during migration, calving, and Indigenous hunting seasons	*PA*	First order to second order priority (1.5)	Neutral (4.5)	Medium term
		C	Medium	Low to medium	High

CC-8	Track changes in marine mammal movements and migration patterns and evaluate stressors and pressures related to climate change and human activity changes (i.e., shipping, mining, other)	*PA*	First order to second order priority (1.5)	Neutral (5.0)	Medium to long term
		C	Medium	Medium to high	Low
GP-8	Conduct preliminary impact and opportunity assessments for deep sea mining in Canada's Oceans	*PA*	First order to second order priority (1.5)	Neutral (5.0)	Short to medium term
		C	None	Low	None
TI-8	Establish techniques for detecting ships that turn off AIS transponders (dark ships)	*PA*	First order to second order priority (1.5)	Neutral (5.0)	Short to medium term
		C	None	Low	None

Table B2: Low ranked (priority score of 2 or greater on Table 9) research priorities, including the point of agreement (the score from table 9 is listed in brackets) and consensus for priority, feasibility, and timeframe.

Research priority			Priority	Feasibility	Timeframe
SN-12	Evaluate the impact of shipping emissions on human health in high traffic areas (i.e., Vancouver and Saint Lawrence)	*PA*	Second order priority (2)	Probably feasible (3.5)	Medium to long term
		C	Medium	Medium to high	Medium
SN-16	Establish linked climate change and socio-economic change models for projecting future maritime trade opportunities through the Northwest Passage	*PA*	Second order priority (2)	Neutral (4.0)	Medium to long term
		C	Medium	Medium to high	Medium
TI-2	Improve predictive models and enable finer spatial scales of structure and function of the ocean for	*PA*	Second order priority (2)	Neutral (5.0)	Medium to long term
		C	High	Low	Medium

	greater applicability to decision-making				
CC-3	Identify people's perception of the levels of risk to various ocean-based economic sectors from extreme ocean events and ocean related climate changes	*PA*	Second order to third order priority (2.5)	Probably feasible (3.0)	Short to medium term
		C	Low	Medium	None
WC-2	Evaluate the question "does better forecasting of weather, water, ice, and climate translate to increased marine safety"	*PA*	Second order to third order priority (2.5)	Probably feasible (3.0)	Short to medium term
		C	None	High	Medium
SN-5	Set up a system that enables crowd sourcing and sharing of bathymetric data using ships of opportunity and social networks	*PA*	Second order to third order priority (2.5)	Probably feasible (3.5)	Medium to long term
		C	Low	Medium	Medium
FM-2	Study the feasibility of cultivating food-grade seaweed through responsible aquaculture	*PA*	Second order to third order priority (2.5)	Probably feasible (3.5)	Medium to long term
		C	Low	Medium	Low
FM-11	Evaluate the role and impact of technology developments (i.e., autonomous vessels, fuel systems, etc.) on pilotage in Canada	*PA*	Second order to third order priority (2.5)	Probably feasible (3.5)	Short to medium term
		C	Low	Low to medium	None
WC-6	Increase sampling and analysis of micro and nano plastics in Canada's oceans (origin, etc.)	*PA*	Second order to third order priority (2.5)	Probably feasible (3.5)	Medium to long term
		C	Low	Medium to high	Low

SN-8	Evaluate the effect of 'light pollution' from ships and ports on marine wildlife and marine ecosystems	*PA*	Second order to third order priority (2.5)	Neutral (4.0)	Medium to long term
		C	Low	Medium to high	Medium
SN-13	Measure the level of 'paint-based pollution' emerging from the ablation of hull paint off vessels (marine-going and icebreaking) in ocean sediments and evaluate potential ecosystem and health impacts	*PA*	Second order to third order priority (2.5)	Neutral (4.0)	Medium to long term
		C	Low	Medium to high	Medium
FM-12	Track emerging viruses in the marine environment that may have human health implications	*PA*	Second order to third order priority (2.5)	Neutral (5.0)	Medium to long term
		C	Low	Low to medium	None
CC-2	Evaluate the impact of transgressing individual planetary boundaries for Canada's marine economy	*PA*	Second order to third order priority (2.5)	Neutral (5.0)	Medium to long term
		C	None	None	None
TI-9	Evaluate the technological feasibility of marine autonomous surface ships	*PA*	Third order to no priority (3.5)	Neutral (5.0)	Medium to long term
		C	None	None	None