BRITISH COLUMBIA OCEAN ACIDIFICATION AND HYPOXIA ACTION PLAN

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

We acknowledge with respect and gratitude that this work was produced on, and concerns itself with the land, waters and living creatures across the unceded territories of the First Nations of Coastal British Columbia. We express our gratitude for their past and ongoing generations of care and stewardship.

MESSAGE FROM **GEORGE HEYMAN**

MINISTER OF ENVIRONMENT AND CLIMATE CHANGE STRATEGY

Climate change is having significant consequences for the web of marine life that sustains our coastal ecosystems and the communities that depend on them. Already, we have seen the impacts of a warmer, more acidic ocean in our province, and we expect these changes to become more acute in the years to come. It's why our government is taking action through the Ocean Acidification and Hypoxia Action Plan, an important part of our Climate Preparedness and Adaptation Strategy. By taking action now, we can explore new ideas that can reduce future impacts. By harnessing the knowledge of Indigenous Peoples, coastal communities, scientific experts and others, we can build a better, more resilient future and be better prepared for the changes ahead.

MESSAGE FROM **PAMELA ALEXIS**

MINISTER OF AGRICULTURE AND FOOD

Climate change is dramatically affecting B.C.'s ocean and watersheds and the B.C. government has been working collaboratively with Indigenous communities, the federal government and conservation organizations on this issue that is so important to our environment, history, economy, identity and way of life. This action plan provides us with insight on ocean acidification and hypoxia in British Columbia's coastal waters and helps us with long-term goals for addressing knowledge gaps and developing adaptation and mitigation strategies to support our fisheries and aquaculture sectors, including our valuable food-fish harvesters. I look forward to the continued work with our partners on this action plan and together, supporting our coastal communities and the food security they provide to British Columbians.

MESSAGE FROM **NATHAN CULLEN**

MINISTER OF WATER, LAND AND RESOURCE STEWARDSHIP (WLRS)

British Columbians care deeply about our rich coastal ecosystems. These marine environments support iconic species like wild salmon, a foundation of Indigenous culture and way of life and an integral part of the province's food security, ecosystems and economy. B.C.'s Ocean Acidification and Hypoxia Action Plan is critical to addressing the impacts of climate change on marine environments and the diverse species that rely on them. We continue to take actions to minimize impacts and benefit future generations, such as enhancing coastal observation and monitoring programs, protecting and restoring nearshore blue carbon sinks, and supporting innovation in the aquaculture industry. We're also developing the Province's first Coastal Marine Strategy to improve stewardship of marine areas, advance reconciliation with First Nations and foster community resilience in the face of increasing pressures on coastal environments. Building a strong, secure marine future requires shared approaches to caring for the land, waters and all the life that depends on healthy ecosystems.

MESSAGE FROM **CHIEF GORDON PLANES**

T'SOUKE FIRST NATION

I have witnessed the challenges that my neighbouring American Tribes are going through as a result of the changes to their waters and the resulting adverse effect on their livelihoods. As coastal First Nation peoples we depend on the ocean. We need to do our due diligence and to ask ourselves what is it that we can do to adapt or mitigate the effects of climate change? In order to preserve our culture, food security, marine resources, ocean habitat and species we need to look to new technology, new innovations.

Through this action plan my hope is that we can bring everyone along, to understand the science, to support and engage and learn from each other, to respect and incorporate Traditional Ecological Knowledge. To share a common goal to preserve and protect our marine resources.

MESSAGE FROM **RICHARD HARRY**

PRESIDENT, ABORIGINAL AQUACULTURE ASSOCIATION

I would like to thank the Advisory Committee for the work they have done to develop this comprehensive action plan. First Nation coastal communities rely on the ocean to sustain our way of life, culturally and economically. We recognize that ocean acidification and hypoxia pose a real risk to our coastal waters in BC and will impact our traditional way of life, fisheries and aquaculture.

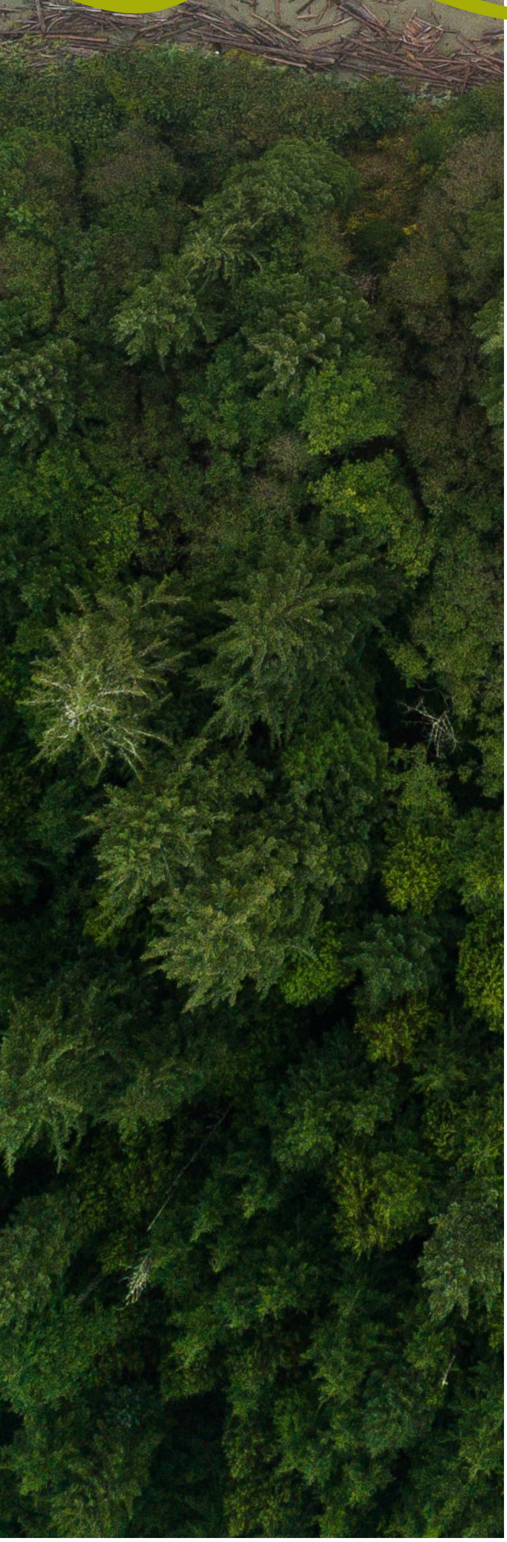
This action plan lays out a path forward. All levels of government need to work collaboratively and in this era of reconciliation need to recognize the unique role of First Nations in ensuring meaningful participation in the process.

MESSAGE FROM **JENNIFER WALKUS**

WUIKINUXV NATION COUNCIL

I appreciate that we are working towards having western science and traditional ecological knowledge (TEK) work together. Ocean acidification and hypoxia are consequences of climate change. They have the possibility of decimating ecosystems.

The holistic approach of First Nations and the siloed approach of western science have their strengths and weaknesses. We must learn to work together to best protect the resources that we all depend on. Government policy mandates require TEK without building in a mechanism to include it early enough in the process so that it can be used effectively. TEK comes from living within the systems 24 hours a day, 7 days a week, 365 days a year, over millennia - and is often not recorded in a way that western science is able to easily access. Partnerships where First Nations voices are sought early, and include their historical and current knowledge and observations, will help determine what critical questions should be asked. Ecosystems are not stable and decisions should not be made based solely on Western Science. This time of rapid change requires flexibility and cooperation from all parties. Inclusion in tables such as this is uplifting because it shows the commitment of all parties to work together.



This document is based upon

*The Scientific Assessment for the British Columbia Ocean Acidification and Hypoxia Action Plan ("BC OAH Scientific Assessment")**

Both documents were prepared for the Province of British Columbia Ministry of Agriculture and Food by the British Columbia Ocean Acidification and Hypoxia Action Plan Advisory Committee:

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* *Evans, W., I. Giménez, J. Christian, M. Hessing-Lewis, R. Dewey, H. Gurney-Smith, R. Martone, J. Turner, and M. Roth (2023), Scientific Assessment for the British Columbia Ocean Acidification and Hypoxia Action Plan, GUID: https://www2.gov.bc.ca/assets/download/01B9154F307E498B8EDAB95D948D86D1*

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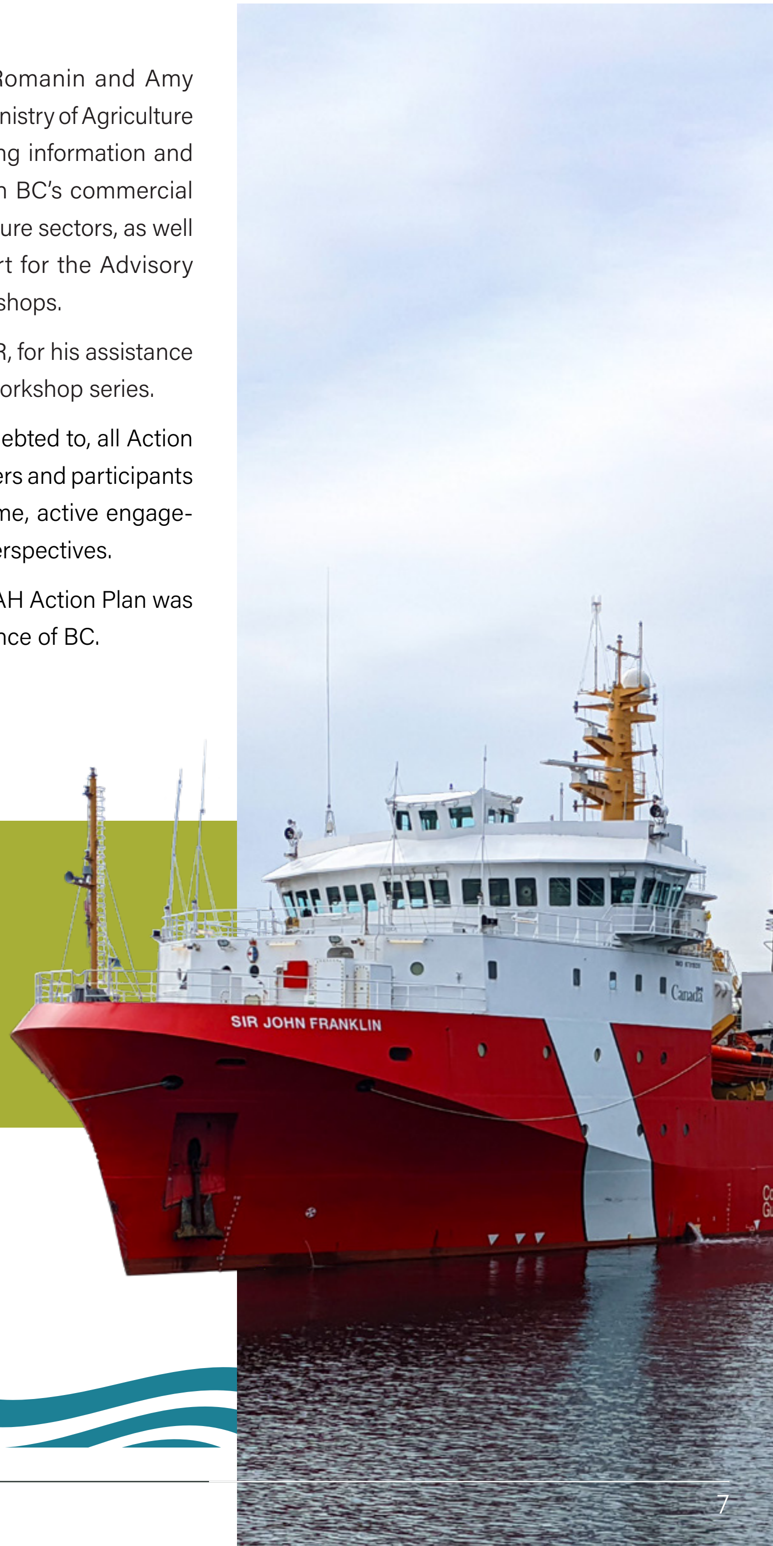

EXECUTIVE SUMMARY

The British Columbia Ocean Acidification and Hypoxia (OAH) Action Plan was developed in response to BC's *Preliminary Strategic Climate Risk Assessment* (2019) and compliments *BC's CleanBC Roadmap to 2030* (2021) and *Climate Preparedness and Adaptation Strategy: Actions for 2022-2025* (2022) as well as *BC's Coastal Marine Strategy* (in development). The *Risk Assessment* identified ocean acidification as a significant climate change risk. It is now apparent that OAH and ocean warming threaten the health of marine ecosystems impacting all marine species and the well-being of coastal communities, industries, and First Nations. While the OAH Action Plan addresses these issues through a fisheries and aquaculture lens, its scope is intended to reach beyond these sectors by considering BC coastal marine ecosystems, communities, industries, and economy.

> *It is now apparent that OAH and ocean warming threaten the health of marine ecosystems impacting all marine species and the well-being of coastal communities, industries, and First Nations.*

Fossil fuel emissions have increased atmospheric carbon dioxide (CO_2) by nearly 50% since the start of the industrial era. CO_2 traps heat in the atmosphere, leading to warming – 91% of which is transferred to the ocean's surface waters. Warmer surface waters hold less oxygen and are less dense, and this is contributing to the decline of oxygen within the interior of the global ocean. In addition, the ocean has absorbed ~26% of the $C0_2$ emitted to the atmosphere, and this has increased the average surface ocean acidity by 30% (*i.e.*, made it less basic) – a process called ocean acidification. Acidified seawater is more corrosive to shellfish. At the current rate of emissions, average surface ocean acidity is expected to increase by 100 - 150% over preindustrial levels by the year 2100.

Several oceanographic characteristics of BC's waters increase vulnerability to ocean acidification and hypoxia. For example, the oxygen content of the upper 3000 m of the Northeast Pacific Ocean has declined by 15% over the last 60 years, far exceeding the global average of 2%. Further, the average contemporary acidification level in BC nearshore waters is almost 40% higher than pre-industrial levels, exceeding the global average increase of 30%. At current emission levels, acidification in BC coastal waters over the next 15 years could be equal to almost 50% of the acidification that occurred over the previous 260 years. The "one-two punch" of ocean acidification and hypoxia serves as a multi-stressor that can greatly increase negative impacts on marine organisms and ecosystems.

Concerns over ocean acidification (OA) came to prominence following the oyster seed crisis that emerged in the Pacific Northwest in 2007. This was followed by reports of acidified waters in US and Canada, and formal recognition of OA by the UN Intergovernmental Panel on Climate Change (IPCC) in their 2009 Assessment Report. BC first began inquiries into OA and its impacts though the Ministry of Agriculture's 2017 Ocean Acidification Shellfish Industry Seed Supply (OASISS) project that supported instrumentation for monitoring and the initial development of a breeding program to establish strains of Pacific oysters adapted to changing local climate conditions. However, it wasn't until 2019 and the publication of the *Risk Assessment* that OA was recognized as a major threat to BC.

The BC seafood industry now recognizes that OAH could significantly disrupt its contribution to BC's food security and ocean economy, which contributes an estimated $1.5 B to the provincial GDP and supports 14,631 jobs, mostly in coastal communities. OAH will be particularly challenging for the economies and social fabric of BC's coastal communities, including Indigenous coastal communities where ~90% of dietary protein is derived from seafood. Given the effect that OAH could have on the province's economy and its people, it is essential that BC anticipate impacts from OAH on marine health, aquaculture and fisheries, food security, and coastal community economies – and act on them.

To support the development of the BC OAH Action Plan, an Advisory Committee was formed that convened a series of four

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virtual workshops between November 2021 and March 2022:

1. State of the Science on Ocean Acidification and Hypoxia Research in British Columbia
2. BC Seafood Harvester and Producer Perspectives on OAH
3. BC Coastal Communities' Perspectives on OAH
4. Policy and Governance Considerations for BC's OAH Action Plan

Overall, 172 individuals representing 88 groups and institutions attended the workshops. Through active dialogue, information gaps were identified, as well as actions to strengthen BC's ability to adapt and mitigate OAH. The BC OAH Action Plan identified 5 goals, 15 objectives, and 62 actions, that, taken collectively, aim to enhance understanding and awareness and build resilience through increased collaboration and include measures to enhance mitigation and adaptation to OAH.

GOAL 1 - BUILD AND STRENGTHEN COLLABORATIONS RELATED TO OAH SCIENCE & ENGAGEMENT

Collaboration is a critical aspect of the BC OAH Action Plan. A task force (multi-disciplinary, multi-agency) appointed by the Province of British Columbia will enable stronger collaboration and engagement, define metrics of success, and track progress made in carrying out the BC OAH Action Plan.

GOAL 2 - INCREASE AWARENESS AND UNDERSTANDING OF OAH

Awareness and understanding of OAH must be elevated among the public decision makers and resource managers to support communities and industries potentially impacted by OAH. This includes building relationships with coastal communities, cataloging concerns, and BC-specific OAH messaging and information needs.

GOAL 3 – ADVANCE SCIENTIFIC UNDERSTANDING OF OAH

Scientific advancements must be made to increase the understanding of OAH in BC. Central to this is coordination among research entities, including bridging Traditional Ecological Knowledge and western science in ways to better define shifts in biodiversity and species range for characterizing impacts from OAH. BC lacks OAH forecasting capacity and is missing biological and chemical measurements in many regions. Supporting scientific understanding of OAH in BC directly aligns with the *Climate Preparedness and Adaptation Strategy: Actions for 2022-2025*.

GOAL 4 - EVALUATE INTERACTIONS BETWEEN MARINE CARBON DIOXIDE REMOVAL APPROACHES AND OAH

Proposed marine CO^2 removal approaches remain exploratory, largely untested, and could present risks for the welfare of coastal ecosystems and communities. Significant research must be undertaken to evaluate the efficacy, potential remediation benefits, and permanence of these approaches in addition to the risks some strategies may pose to intensify OAH.

GOAL 5 - ENHANCE MITIGATION, ADAPTION AND RESILIENCE TO OAH

Important actions must be taken to increase mitigation and adaptive capacity to current and future manifestations of OAH to BC's aquaculture and fisheries sectors. Recommended actions are in addition to deep and rapid reductions in fossil fuel emissions. OAH presents challenges that span all levels of government thus a coordinated inter-governmental approach is needed.

Internationally, the United Nations recognized OA as one of ten targets for Sustainable Development Goal (SGD) 14, *"Life Below Water"*; specifically (14.3): *"Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels"*. The UN proclaimed 2021-2030 as the Decade of Ocean Science for Sustainable Development. The BC OAH Action Plan is consistent with SDG 14.3 OA target and has been endorsed by the UN as an Ocean Decade Project.

From provincial to global scales, coordination and collaboration to address the existential threat of OAH to coastal environments and societies is our best path forward. The BC OAH Action Plan Advisory Committee envisions that the implementation of the BC OAH Action Plan will span five years. Successful implementation of the BC OAH Action Plan would establish a sustained and coordinated focus on OAH, with investment into strengthening the understanding of OAH, including adaptation and mitigation approaches, that sets BC on the path toward enhanced resiliency. With the publication of the BC OAH Action Plan, BC has established itself as a leader in Canada as the first province to produce an action plan to help address ocean acidification and hypoxia.

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ABOUT THIS REPORT

At the request of the Climate Action Secretariat of the BC Ministry of Environment and Climate Change Strategy, the BC Ministry of Agriculture and Food developed the British Columbia Ocean Acidification and Hypoxia Action Plan (BC OAH Action Plan) to address commitments in the *CleanBC Roadmap to 2030* and the *Climate Preparedness and Adaptation Draft Strategy and Phase I Actions for 2021-2022* publications[1]. While the BC *Preliminary Strategic Climate Risk Assessment*[2] report identified ocean acidification as a significant risk from climate change for BC, it is now apparent that ocean acidification, hypoxia, and ocean warming threaten the health of marine ecosystems impacting shellfish, salmon, and other marine species, along with the well-being of coastal communities, industries and First Nations that depend on them. The BC OAH Action Plan therefore addresses impacts of changing ocean conditions due to ocean acidification and hypoxia and their interaction with other marine stressors. While the plan addresses these issues through a fisheries and aquaculture lens, its scope is intended to reach beyond these sectors to become the first step in the development of a living document that considers BC coastal marine ecosystems, communities, industry, and economy.

Key actions addressed in the *CleanBC Roadmap to 2030* include:

- Supporting Green House Gas (GHG) efficient practices
- Exploring the potential for seaweed aquaculture to sequester carbon
- Negative Emission Technologies (in the coastal marine environment)

An action addressed from the *Climate Preparedness and Adaptation Draft Strategies Phase I Actions 2021-2022* include:

- Assess climate risks and vulnerabilities to BC fisheries and aquaculture

The OAH Action Plan also meets several commitments of the Pacific Coast Collaborative (PCC). As a founding member, the Province of BC is a signatory to the Pacific Coast Climate Leadership Action Plan (2016)[3] committing to: *Increase awareness, understanding, and action on ocean acidification and other climate-related changes in ocean conditions with actions to:*

1) In partnership with federal agencies (US and Canada) and key stakeholders, design and implement coordinated, effective West Coast ocean acidification monitoring and research.
2) Initiate the development of an international network of countries, states, provinces, and cities that will work together to address the threat of changing ocean conditions with a particular focus on ocean acidification.

As a founding member of the International Alliance to Combat Ocean Acidification (OA Alliance, OAA), BC is committed to *creating a unique OA Action Plan which outlines actionable responses to climate-ocean threats in its region and helps to leverage existing expertise, partners, and resources,* and advance the following goals:

REDUCE ATMOSPHERIC CARBON DIOXIDE EMISSIONS.

ADVANCE SCIENTIFIC UNDERSTANDING OF CLIMATE-OCEAN IMPACTS.

REDUCE LOCAL POLLUTION THAT EXACERBATE OCEAN ACIDIFICATION.

PROTECT THE ENVIRONMENT AND COASTAL COMMUNITIES FROM CLIMATE-OCEAN IMPACTS.

EXPAND PUBLIC AWARENESS.

SUSTAIN INTERNATIONAL AND MULTI-GOVERNMENTAL SUPPORT FOR ADDRESSING THIS GLOBAL PROBLEM.

In addition to addressing key goals and commitments to the province's *CleanBC Roadmap to 2030* and the *Climate Preparedness and Adaptation Strategy, Draft Strategy and Phase 1 Actions for 2021-2022*, and our PCC and OAA partners, this Plan forms an important component of the BC Coastal Marine Strategy and will support the Canadian Blue Economy Strategy[4]. The recommendations provided in this plan are developed from materials provided within the accompanying Scientific Assessment.

THE BIG PICTURE:
CLIMATE CHANGE, OCEAN ACIDIFICATION AND HYPOXIA IN BRITISH COLUMBIA

The changing ocean environment, as well as receding glaciers, increasing temperatures, and intensifying wildfires offer striking evidence of climate change impacts in BC. These challenges are the result of a common driver: *the release of human-generated carbon dioxide and other greenhouse gases into the atmosphere*. Since 2018, the Government of BC has taken a series of important steps to address carbon dioxide emissions and their impacts:

2018

- **Climate Change Accountability Act:** Amended Greenhouse Gas Reductions Target Act of 2007, setting new greenhouse gas emission reduction targets.
- **CleanBC Plan:** Established BC's roadmap to achieve emission targets of the Climate Change Accountability Act.
- **Managing Climate Change Risks - An Independent Audit:** BC Auditor General report highlighted that, to become a climate resilient province, BC will require actions that: 1) reduce greenhouse gas emissions (mitigation); 2) reduce the potential harms of climate change (adaptation).

2019

- **Preliminary Strategic Climate Risk Assessment for British Columbia:** Identified ocean acidification's potential impact on fisheries and aquaculture as an immediate high-risk threat and recommended further evaluation of its impacts.
- **Climate Change Accountability Act Amendment:** Added interim 2025 emission target and enhanced annual reporting requirements.
- **Climate Change Accountability Annual Report:** Highlighted ocean acidification as an important threat to be addressed within the *Climate Preparedness and Adaptation Strategy.*

2020

- **Climate Change Accountability Annual Report:** Highlighted ocean acidification as an important threat to be addressed within the *Climate Preparedness and Adaptation Strategy.*

2021

- **Roadmap to 2030:** Provided enhanced measures to ensure emission targets are met, including the potential use of negative emission technologies that remove carbon dioxide from the environment.
- **Climate Preparedness and Adaptation Strategy, Draft Strategy and Phase I Actions for 2021-2022.** Laid out actions needed to elevate the province to a state of greater resilience, including the development of an ocean acidification action plan.

2022

- **Climate Preparedness and Adaptation Strategy, Actions for 2022-2025.** Update to the Draft Strategies and Phase I Action. Identified "Responding to Ocean Acidification" as a priority initiative.

A BRIEF HISTORY OF
OAH ACTION ON THE WEST COAST

Concerns over ocean acidification came to prominence in the late 2000s (see Figure 1). There was notable attention paid to potential impacts of ocean acidification due to the oyster seed crisis that first emerged in Pacific Northwest in 2007[5], the first report of acidified seawater on the U.S. west coast in 2008[6], the first mention of ocean acidification in the Fisheries and Oceans Canada (DFO) State of the Pacific Ocean Report for 2007[7], and recognition of ocean acidification within the UN Intergovernmental Panel on Climate Change (IPCC) Assessment Report in 2009[8].

In the U.S., the state of Washington released the first OA Action Plan in 2012 to address ocean acidification in response to concerns from the shellfish industry and the *Washington State Blue Ribbon Panel Report on Ocean Acidification – Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response*[9]. The report not only coalesced information and mobilized action in Washington State but triggered other states and regions to establish similar plans of inquiry and action. Recognized as a global problem, the first Global Ocean Acidification Observing Network (GOA-ON) workshop took place in Seattle, WA in 2012 to define the goals and requirements of a global ocean acidification observing network that would support policy and decision-makers[10]. These efforts expanded regionally and topically to include hypoxia with a number of reports between 2015 and 2016 including: *The West Coast Ocean Acidification and Hypoxia Science Panel Major Findings, Recommendations, and Actions*, *Ocean Acidification and Hypoxia Monitoring Network: Tracking Impacts of Changing Ocean Chemistry to Inform Decisions*[11], and *Multiple Stressor Considerations: Ocean acidification in a deoxygenating ocean and a warming climate*[12]. Building on West Coast regional efforts, the International Alliance to Combat Ocean Acidification (OA Alliance, OAA) was launched in 2016 to help other jurisdictions (including BC) develop similarly styled OAH action plans.

> *"From provincial to global scales, coordination and collaboration to address the existential threat of OAH to coastal environments and societies is our best path forward."*

Actions in Canada accelerated in 2015 with workshops on the Atlantic and Pacific Coasts to discuss emerging ocean climate stressors including ocean acidification and the aquaculture industry[13]. In BC, provincial support to help the aquaculture industry track and adjust to ocean acidification conditions first came in 2017 in the form of the Ocean Acidification Shellfish Industry Seed Supply (OASISS) and the Baynes Sound Environmental Intelligence Collaborative (BaSEIC) projects that both supported instrumentation for monitoring and the initial development of a breeding program to establish strains of Pacific Oysters adapted to changing local climate conditions. BC recognized ocean acidification as a major threat in 2019 with the *Preliminary Strategic Climate Risk Assessment for British Columbia*. Through these efforts, BC has established itself as a leader in Canada, both through this innovative report and as the first province to produce an action plan to help address ocean acidification and hypoxia.

The United Nations has emphasized the importance of multi-scale action to address ocean acidification by undertaking a series of important actions. In 2016, the General Assembly established a reduction of ocean acidification as one of ten targets for Sustainable Development Goal (SGD) 14. The following year, the UN proclaimed 2021-2030 as the Decade of Ocean Science for Sustainable Development (the "Ocean Decade"); the GOA-ON subsequently established the Ocean Acidification Research for Sustainability (OARS) Program, which aims to increase the understanding of ocean chemistry changes and their impacts on marine life worldwide. To further support multi-scale action, the UN endorsed the OA Alliance initiatives to support development of OAH Action plans around the world. The BC OAH Action Plan is consistent with these international initiatives and has been endorsed by the UN as Ocean Decade Action Project under the the OARS Program.

From provincial to global scales, coordination and collaboration to address the existential threat of OAH to coastal environments and societies is our best path forward. BC's OAH Action Plan strives to embody this spirit and serve as a model, along with earlier action plans, for jurisdictions to join this collective vision.

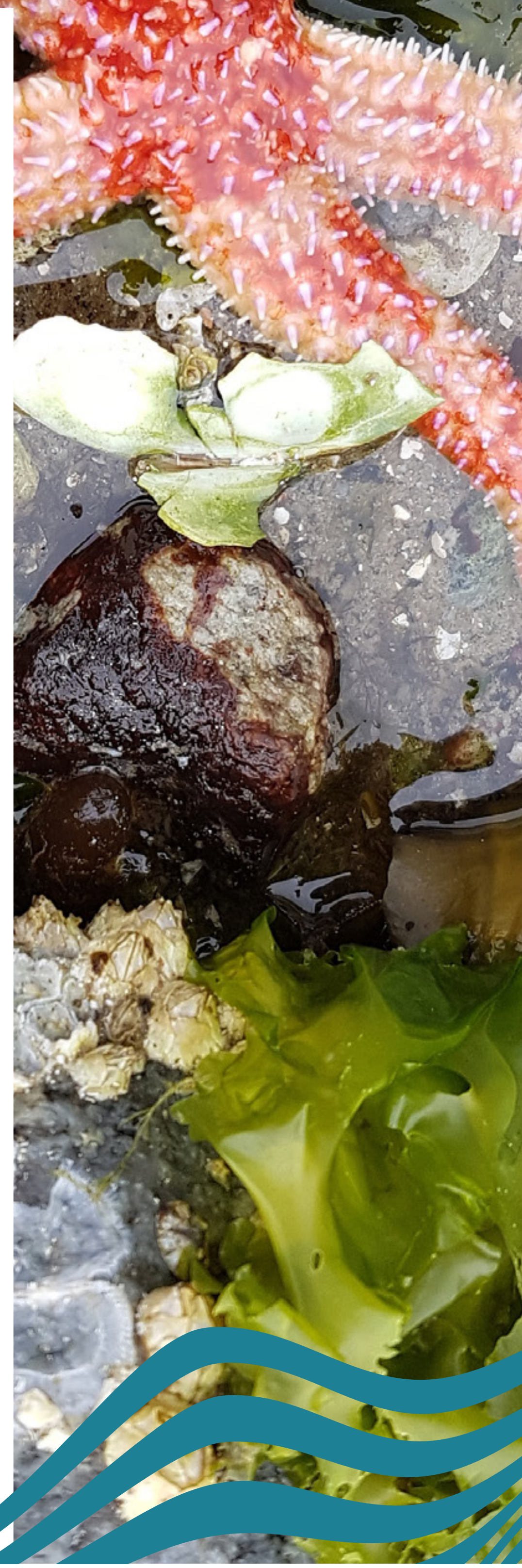
FIGURE 1. Timeline of Canadian and USocean acidification and hypoxia reports and actions.

UN DECADE OF OCEAN SCIENCE FOR SUSTAINABLE DEVELOPMENT

Proclaimed in 2017 by the United Nations General Assembly, the UN Decade of Ocean Science for Sustainable Development (2021-2030) ('the Ocean Decade') seeks to stimulate ocean science and knowledge generation to reverse the decline of the state of the ocean system and catalyse new opportunities for sustainable development of this massive marine ecosystem. The vision of the Ocean Decade is 'the science we need for the ocean we want.' The Ocean Decade provides a convening framework for scientists and stakeholders from diverse sectors to develop the scientific knowledge and the partnerships needed to accelerate and harness advances in ocean science to achieve a better understanding of the ocean system, and deliver science-based solutions to achieve the 2030 Agenda. The UN General Assembly mandated UNESCO's Intergovernmental Oceanographic Commission (IOC) to coordinate the preparations and implementation of the Decade. The BC OAH Action Plan has been officially endorsed as an Ocean Decade Project under the Ocean Acidification Research for Sustainability (OARS) Program.

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

BC'S AQUACULTURE AND FISHERIES SECTORS



As presented in this report, ocean acidification and hypoxia (OAH), individually and combined, have adverse effects on both marine organisms and marine ecosystems. OAH therefore poses a significant threat to BC's aquaculture and wild capture fisheries, as well as coastal ecosystems and communities.

The BC shellfish aquaculture industry is working to build capacity for increased resilience to climate change across local hatchery operations. Based upon discussions with industry, they are increasingly formulating adaptation strategies to manage the harmful effects of OAH to highly susceptible larval and juvenile shellfish, following many practices developed in Washington and Oregon[5]. Such strategies include buffering hatchery rearing water and selective breeding programs to develop shellfish farm stocks that show greater tolerance to OAH. Similarly, the BC salmon farming sector is increasingly employing the use of a variety of adaptive farming practices such as oxygenation systems, deeper pens, and innovative feeding practices to manage changing and unpredictable water conditions that may be influenced by OAH.

Less is known about the current and future impacts from OAH on commercial fisheries. However, laboratory and field studies on impacts to invertebrates, and invertebrate larvae, suggest there is potential for far reaching effects to food webs and ecosystems[15,16]. Further, changing water conditions, and in particular ocean warming, has the potential to bring southern species into BC waters as well as send BC species to cooler more northerly waters – thereby disrupting species distribution and diversity[16].

Given the potential impacts on aquaculture, the BC seafood industry (which includes aquaculture, wild capture fishing, shellfish and marine plant harvesting and seafood processing) now recognizes that OAH could significantly disrupt its contribution to BC's food security and ocean economy. In 2020 BC harvested 272,000 tonnes of seafood (Figure 2) with a wholesale value of $1.62 billion[17] (see Figures 3 & 4). The seafood sector contributes an estimated $1.5 billion to the provincial GDP[18] and provides employment for 14,631[19]. This economic activity and employment, which occurs primarily in coastal communities, generates an estimated $850 million in labour income and $815 million in tax revenue.

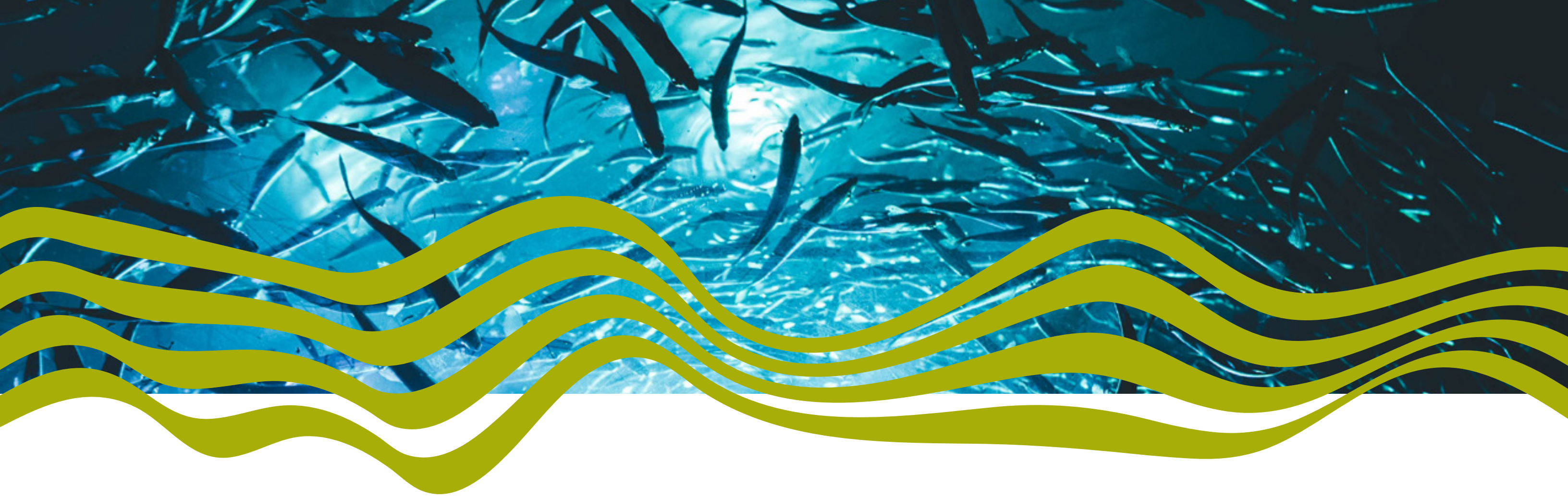
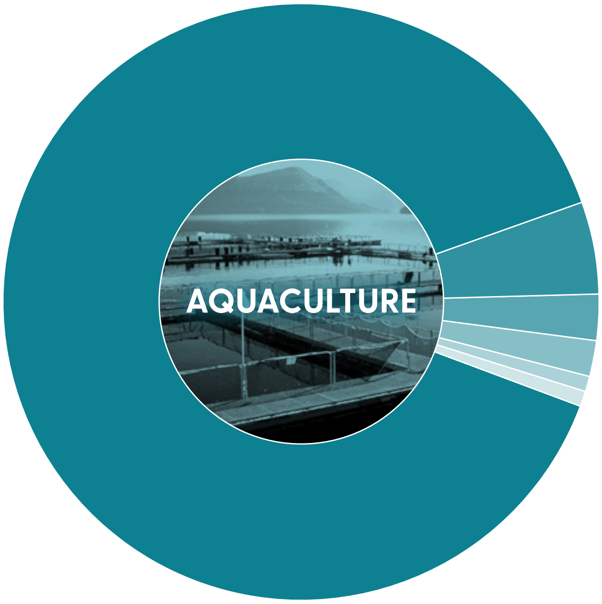
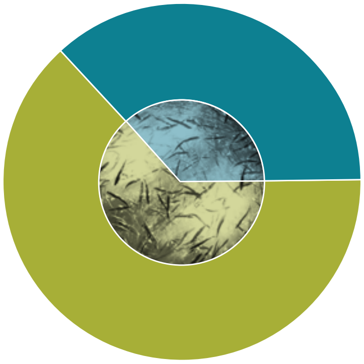


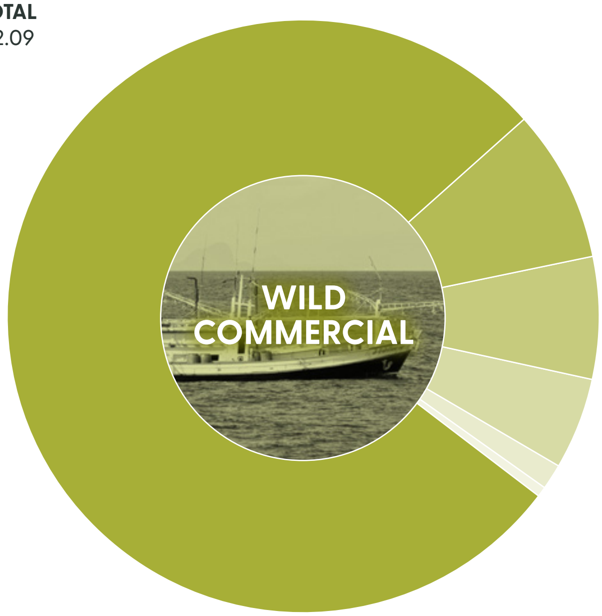
FIGURE 2. Landed volumes for aquaculture and wild commercial fisheries in BC. (Source: BC Stats).

2020 LANDED VOLUMES IN B.C.

(,000 TONNES)







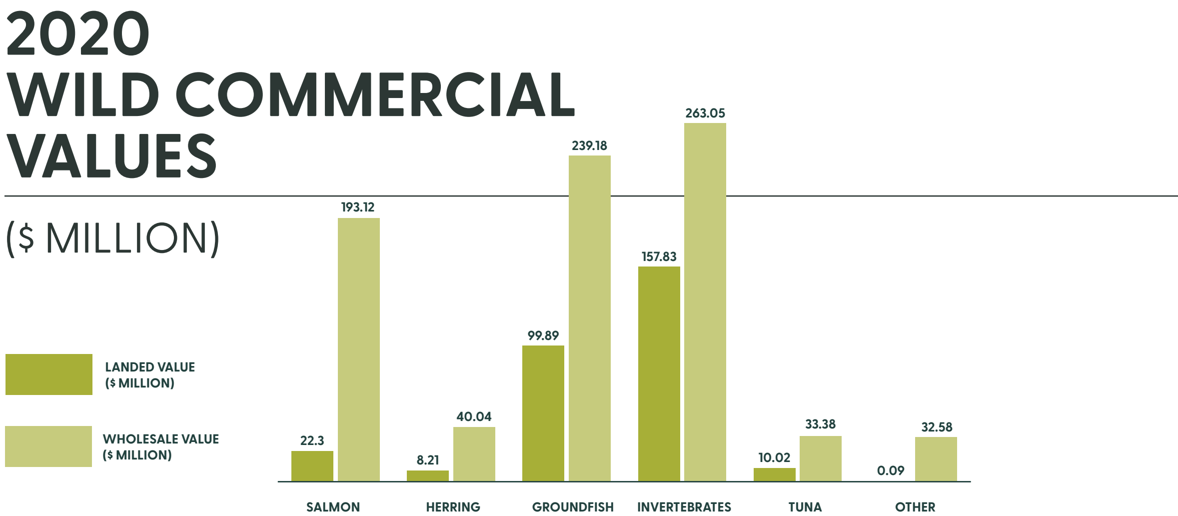


FIGURE 4. Landed and wholesale value of wild commercial fisheries in BC.

According to the ***Preliminary Strategic Climate Risk Assessment for British Columbia***, direct and indirect economic consequences of ocean acidification to the fish and shellfish industry could exceed $100 million; the cost to the government, including lost revenue as well as programs to help the shellfish industry cope with ocean acidification, could be up to $375 million.

OAH will be particularly challenging for the economies and social/cultural fabric of BC's coastal First Nations. With strong ties to coastal waters, First Nations have been participating in fisheries and shellfish aquaculture since time immemorial[20]. Today, First Nations are significant participants in BC commercial fisheries (primarily in the fishing fleet), the processing sector, and more recently the aquaculture sector. For example, on the North and Central Coast, First Nation participation in seafood processing, commercial fishing, aquaculture, and the operation of fish hatcheries generated an estimated annual revenue of $150 million – and employed 1,700 in seafood processing, 140 in aquaculture and hatcheries, and 811 Fisher Registration Card Holders in 2008[21]. On the South Coast, First Nations involvement in salmon aquaculture generates $83 million in direct, indirect, and induced economic activity, $47.8 million in GDP and $36.6 million in salaries for 707 jobs[22]. Overall, approximately one third of all commercial fishing and processing jobs are held by Indigenous persons. A 2018 survey of First Nation's leaders in the southwest coast region found that fisheries, aquaculture, and value-added seafood were commonly ranked as the strongest economic sectors[22].

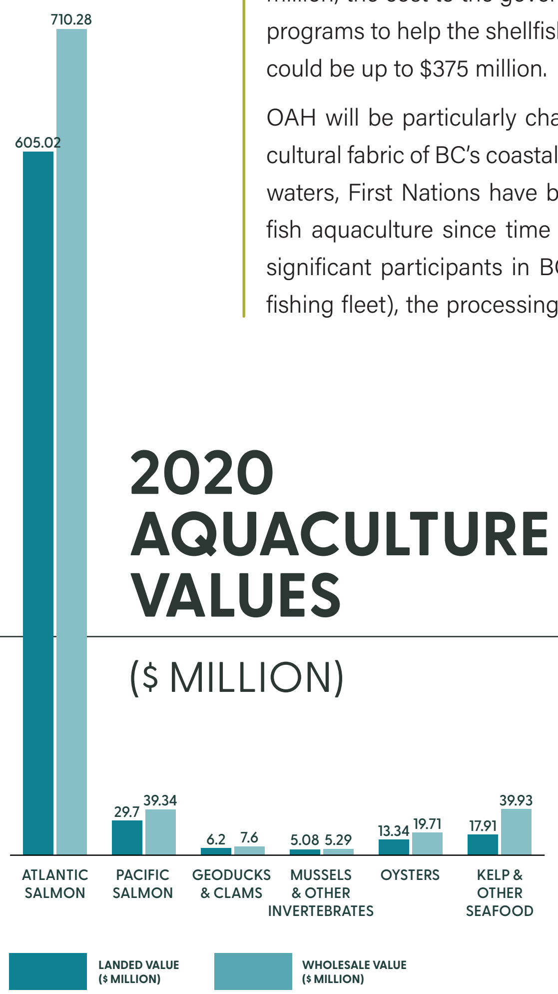
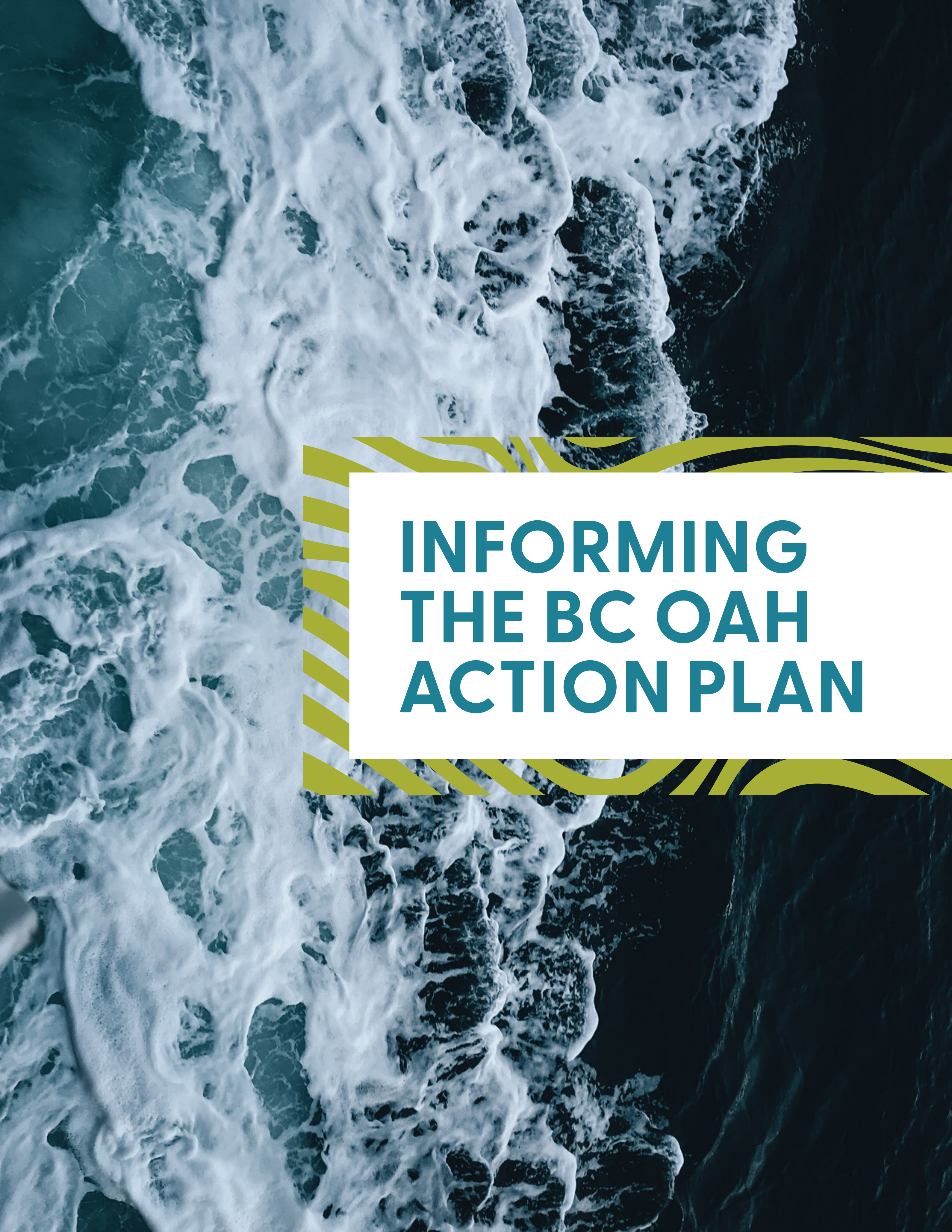


FIGURE 3. Landed and wholesale value of aquaculture production in BC.

OAH impacts that reduce the capacity to access traditional harvests will also be acutely felt by BC coastal First Nations. With ~90% of dietary protein derived from seafood in Indigenous coastal communities[23], access to traditional foods is important for Indigenous food security, health and nutrition, and cultural connections to key traditional food species.

Given the ramifications that OAH could have on the province's economy and its people, it is essential that BC anticipate the effects of OAH on marine health, aquaculture, food security[24,25], and coastal community economies – and develop actions that mitigate or reduce their impact.



INFORMING THE BC OAH ACTION PLAN

To support the development of the BC OAH Action Plan, a series of four virtual workshops were convened between November 2021 and March 2022 to: (1) produce a synthesis of the current state of knowledge regarding OAH in BC; and (2) engage external perspectives to provide input on recommended actions to address knowledge and capacity gaps. The topics of the workshops were:

1. State of the Science on Ocean Acidification and Hypoxia Research in British Columbia
2. BC Seafood Harvester and Producer Perspectives on OAH
3. BC Coastal Communities' Perspectives on OAH
4. Policy and Governance Considerations for BC's OAH Action Plan

Each workshop included invited speakers with relevant subject matter expertise, presented background knowledge of OAH research in BC, facilitated dialogue and exchange on the topic among participants, and provided opportunities for feedback on draft recommendations. Through this process, gaps in information exchange, collaboration, scientific understanding, and BC's ability to adapt and mitigate OAH manifestations were identified. These gaps were then used to refine the recommendations developed through the workshop series. Further details from the workshops can be found within the accompanying Scientific Assessment.

→

BC OAH ACTION PLAN - WORKSHOP SUMMARY

1 — *STATE OF THE SCIENCE*

NOV 2-4, 2021

Environmental scan of the current knowledge gaps related to patterns, trajectories, and impacts of OAH along the BC coastal margin.

92 participants

36 institutions/groups represented

2 — *HARVESTER & PRODUCER PERSPECTIVES*

JAN 27-28, 2022

Review key themes and recommendations developed during Workshop 1 and provide and opportunity for BC's commercial harvesters, food-fish harvesters, and aquaculture producers to share their views and perspectives.

86 participants

51 institutions/groups represented

3 — *COASTAL COMMUNITIES PERSPECTIVES*

FEB 15-16, 2022

Review the key themes and recommendations from Workshops 1 & 2 and provide an opportunity for BC/s coastal community members to share their views and perspectives on potential impacts of OAH and approaches for adaptation and mitigation.

To present the draft recommendations for the BC OAH Action Plan to participants for further refinement.

44 participants

26 institutions/groups represented

4 — *POLICY & GOVERNANCE CONSIDERATIONS*

MARCH 22, 2022

Engage with provincial, federal, local, and First Nation policy makers in the development of the BC OAH Action Plan by reviewing the key themes and recommendations from Workshop 1, 2, & 3 and provide attendees with the opportunity to share their views, perspectives, and insights.

20 participants

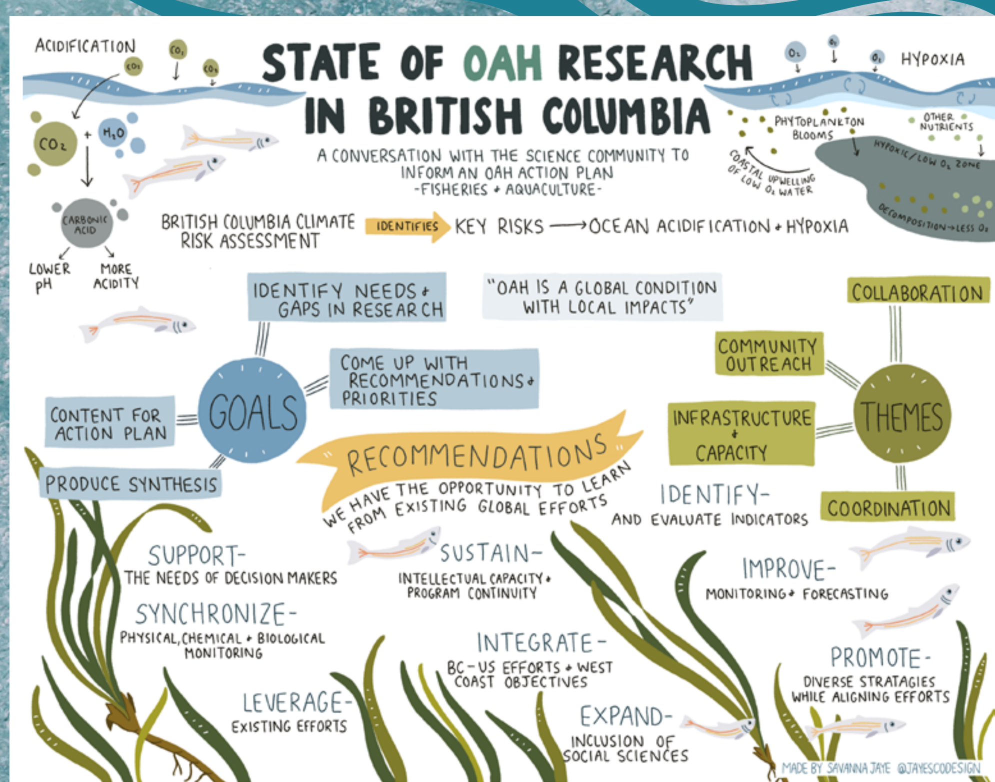
12 institutions/groups represented

242
TOTAL # OF PARTICIPANTS

172
TOTAL # OF UNIQUE PARTICIPANTS

125
TOTAL # OF INSTITUTIONS / GROUPS REPRESENTED

88
TOTAL # OF UNIQUE INSTITUTIONS / GROUPS REPRESENTED



RECOMMENDATIONS FOR BC'S OAH ACTION PLAN

The accompanying BC OAH Scientific Assessment *was created based on input from the workshop series; the assessment details key information that formed the recommendations presented in this report. The BC OAH Action Plan identified 5 goals that, taken collectively, aim to: (1) enhance understanding and awareness of ocean acidification and hypoxia; and (2) build stronger resilience with approaches to increase collaboration and measures to enhance mitigation and adaptation. Each goal contains one or more objectives, and each objective contains one or more actions that will be needed to successfully reach the goal. In total, 62 actions were identified across 15 objectives and 5 goals.*

→

GOAL 1

BUILD AND STRENGTHEN COLLABORATIONS RELATED TO OAH SCIENCE AND ENGAGEMENT

Enhancing collaborations is a critical aspect of the BC OAH Action Plan. A Task Force appointed by the Province of British Columbia will enable stronger collaboration and engagement, define metrics of success, and track the progress made in carrying out the BC OAH Action Plan recommended actions over the coming years.

OBJECTIVE 1

Establish a Task Force to implement the BC OAH Action Plan

ACTION 1

Appoint a multi-disciplinary, multi-agency provincial OAH Task Force

ACTION 2

Establish a communication platform to highlight funding opportunities, link to national and international networks, and share knowledge between research, education, industry, First Nations, and coastal communities

ACTION 3

Develop a directory identifying expertise and capacity needs for the research community, First Nations, seafood industry partners, and coastal communities

OBJECTIVE 2

Grow and sustain Northwest Pacific collaborations

ACTION 1

Organize an annual workshop for industry, research, and community groups working on and concerned about OAH

ACTION 2

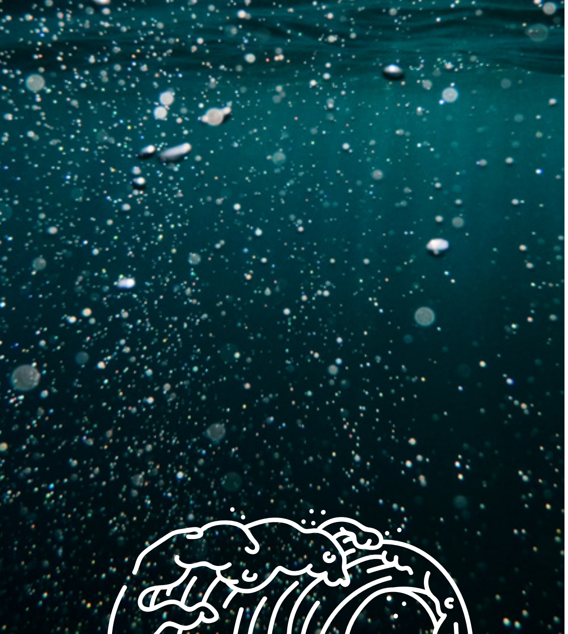
Identify new citizen science and industry partners, data contributors, and collaborators

ACTION 3

Identify engagement opportunities with existing regional meetings and workshops

ACTION 4

Collaborate with Indigenous communities to identify funding for data collection (including traditional ecological knowledge), information exchange, and stewardship decisions



GOAL 2

INCREASE AWARENESS AND UNDERSTANDING OF OAH

To ensure BC's efforts are successful, awareness and understanding of OAH must be elevated among the public – as well as among decision makers from the highest levels of government to stakeholders and resource managers making day-to-day operational and management decisions. Greater awareness and understanding will lead to decision making that best supports communities and industries potentially impacted by OAH. The process of increasing awareness and understanding includes connecting to and building relationships with coastal communities, and cataloging concerns or management information needs from these communities related to OAH. Since positive messaging can help inspire engagement, the identification and promotion of positive steps forward is also important[*].

OBJECTIVE 1

Establish BC-specific OAH messaging and information needs

ACTION 1
Develop speaker series for regional districts and coastal communities to increase awareness about OAH and assess information needs

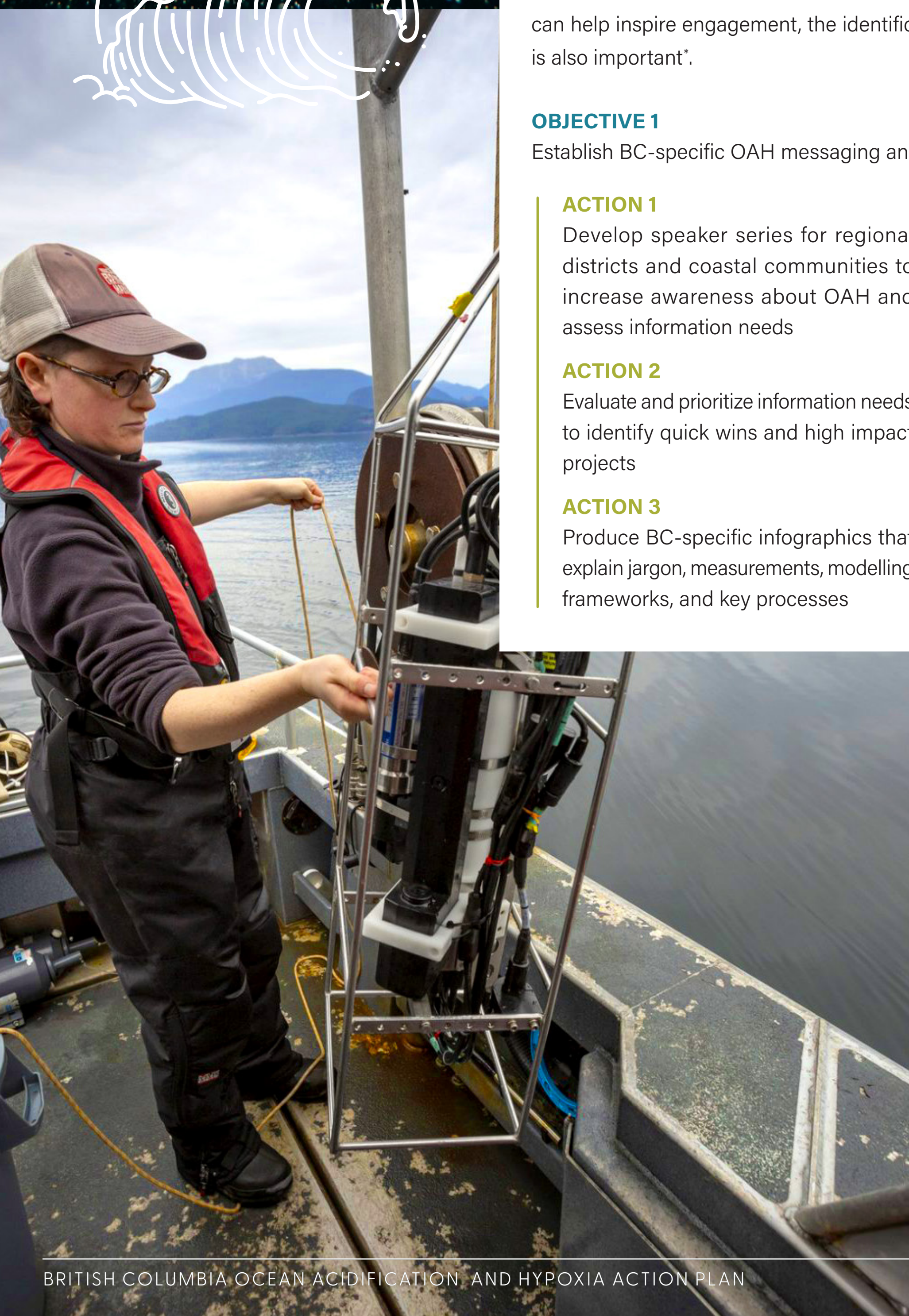
ACTION 2
Evaluate and prioritize information needs to identify quick wins and high impact projects

ACTION 3
Produce BC-specific infographics that explain jargon, measurements, modelling frameworks, and key processes

ACTION 4
Develop BC-specific species impact graphics

ACTION 5
Develop communications to highlight and promote progress on implementation

ACTION 6
Develop OAH modules for BC schools



* *Some existing programs, such as the Master of Disaster: Youth emergency preparedness classroom program (https://www2.gov.bc.ca/gov/content/safety/emergency-management/education-programs-toolkits/master-of-disaster), can be utilized to build OAH messaging into the BC school system.*

GOAL 3

ADVANCE SCIENTIFIC UNDERSTANDING OF OAH

A number of key scientific advancements must be made to increase the understanding of OAH in BC. Central to this is coordination among research entities such that rapid and holistic information can be generated to better predict local trajectories of OAH and specific impacts. Bridging Traditional Ecological Knowledge and western science in ways to better define shifts in biodiversity and species range will be critical for characterizing the breadth of biological impacts from OAH, as well as for setting priorities for evaluating species where impacts are unknown. BC lacks model forecast capacity on management-relevant time scales (i.e., months to seasons) – and is missing biological and chemical measurements in many regions. Supporting the advancement of scientific understanding of OAH in BC is directly in line with facilitating a more resilient future for BC as outlined by the *Climate Preparedness and Adaptation Strategy: Actions for 2022-2025*.

OBJECTIVE 1

Facilitate regional coordination

ACTION 1
Advocate for a multi-agency funding approach for observing, evaluation of biological and socioeconomic impacts, and modelling

ACTION 2
Update OAH inventory, including model metadata and experimental facilities, and evaluate gaps and opportunities

ACTION 3
Provide capacity for seafood producers, harvesters, and coastal communities to contribute knowledge and data

ACTION 4
Develop pathways to bridge western science and Traditional Ecological Knowledge to expand understanding of OAH impacts

OBJECTIVE 2

Enhance understanding of biological impacts

ACTION 1
Identify priority species with input from stakeholders and First Nations

ACTION 2
Use OAH inventory gap analysis to enhance biological observations

ACTION 3
Develop best practices for assessing biological impacts

ACTION 4
Determine cumulative effects between OAH and other stressors

ACTION 5
Identify OAH thresholds from species responses

ACTION 6
Assess how impacts on individual species alter marine food webs

ACTION 7
Enhance biological and chemical benthic sampling

ACTION 8
Enhance capacities within, and collaborations between, experimental research facilities

ACTION 9
Conduct vulnerability assessments for fisheries, aquaculture, and cultural resources

OBJECTIVE 3

Enhance observing efforts

ACTION 1
Enhance measurements on existing platforms

ACTION 2
Establish high-precision indicator sites and a distributed array of lower precision sites

ACTION 3
Expand sub-surface, nearshore, and river observing

ACTION 4
Establish a framework for engaging early career researcher and other interested groups

ACTION 5
Collate and synthesize historical observations

ACTION 6
Map OAH hot spots and compare with the distribution of fisheries and conservation efforts

OBJECTIVE 4

Enhance regional modelling

ACTION 1
Address capacity issues for model downscaling

ACTION 2
Develop seasonal and short-term forecast capacity

ACTION 3
Organize a workshop to identify modeling issues and priorities and evaluate approaches to addressing gaps

ACTION 4
Establish priorities for modeling species impacts

OBJECTIVE 5

Enhance OAH data display and dissemination within Canadian Integrated Ocean Observing System (CIOOS) Pacific

ACTION 1
Utilize CIOOS Pacific to host the BC OAH Inventory as a living document

ACTION 2
Expand applications that integrate datasets to provide accessible knowledge for decision-makers

ACTION 3
Develop link between CIOOS and international repositories

GOAL 4

EVALUATE INTERACTIONS BETWEEN MARINE CARBON DIOXIDE REMOVAL APPROACHES AND OAH

BC's *Roadmap to 2030* and the recent Intergovernmental Panel on Climate Change Assessment Report[26] highlight the need to enhance atmospheric carbon dioxide removal, in addition to deep and rapid reductions in fossil fuel emissions, to reach climate targets. Proposed marine carbon dioxide removal approaches remain exploratory, largely untested, and could present a myriad of potential risks for the welfare of coastal ecosystems and communities. Significant research must be undertaken to evaluate the efficacy, potential remediation benefits, and permanence of these approaches in addition to the risks some strategies may pose that worsen the effects of OAH.

OBJECTIVE 1

Inventory and protect existing blue carbon ecosystems

ACTION 1
Link existing efforts to inventory coastal ecosystem services and pathways to restoring or preventing loss of blue carbon habitats

ACTION 2
Increase coordination with the Pacific Coast Collaborative's Climate Resilience Working Group and other transboundary initiatives

ACTION 3
Establish linkages between the OAH research community and blue carbon programs and projects

ACTION 4
Develop and standardize methodology for determining sequestration, storage time, and carbon origin

OBJECTIVE 2

Develop a scientific assessment of marine carbon dioxide removal approaches for BC

ACTION 1
Support scientific and socio-cultural evaluations of marine carbon dioxide removal approaches, building on national and international efforts targeting this research

ACTION 2
Determine OAH impacts within, and downstream of, marine carbon dioxide removal pilot studies and natural analogues

ACTION 3
Characterize time and space variation of atmospheric carbon dioxide uptake in BC coastal ocean

ACTION 4
Increase coordination with international partners on marine carbon dioxide removal across the Northeast Pacific

OBJECTIVE 3

Assess the social and economic costs and benefits from natural climate solutions

ACTION 1
Develop a cost-benefit analysis for natural climate solutions

ACTION 2
Assess carbon market feasibility, and linkages to provincial carbon credit programs, for existing and future blue carbon projects

ACTION 3
Evaluate if < 100-yr sequestration timescales for carbon credit allocation are beneficial for transition planning

GOAL 5

ENHANCE MITIGATION, ADAPTATION, AND RESILIENCE TO OAH

Important actions can be taken to mitigate adverse marine carbonate chemistry conditions, increase adaptive capacity, and build stronger resilience to current and future manifestations of OAH. The below recommended actions are in addition to deep and rapid reductions in fossil fuel emissions – and should be considered "short-range" recommendations. OAH presents challenges that span Provincial, Federal, and First Nations Government jurisdictions. A coordinated inter-governmental approach is therefore needed to develop long-range solutions for BC.

OBJECTIVE 1

Develop frameworks to modernize fisheries and aquaculture production

ACTION 1
Review and make recommendations on regulatory constraints that inhibit stakeholders and communities from adapting in a timely manner

ACTION 2
Establish a funding program for regional pilot projects to develop and evaluate adaptation strategies

ACTION 3
Support efforts to incorporate Traditional Ecological Knowledge into fisheries and aquaculture management

ACTION 4
Support efforts to modernize data outputs from fisheries and aquaculture

ACTION 5
Support efforts to determine the baseline carbon footprint of the fisheries and aquaculture sectors

OBJECTIVE 2

Enhance support for the development of adaptation strategies for aquaculture and commercial fisheries production

ACTION 1
Support the development of selective breeding initiatives

ACTION 2
Investigate restorative aquaculture as an ocean acidification mitigation tactic

ACTION 3
Evaluate and promote best practices for ocean acidification mitigation

ACTION 4
Evaluate mitigation strategies for a variety of spatial scales

OBJECTIVE 3

Evaluate the influence of co-stressors and emerging climate-related threats on OAH

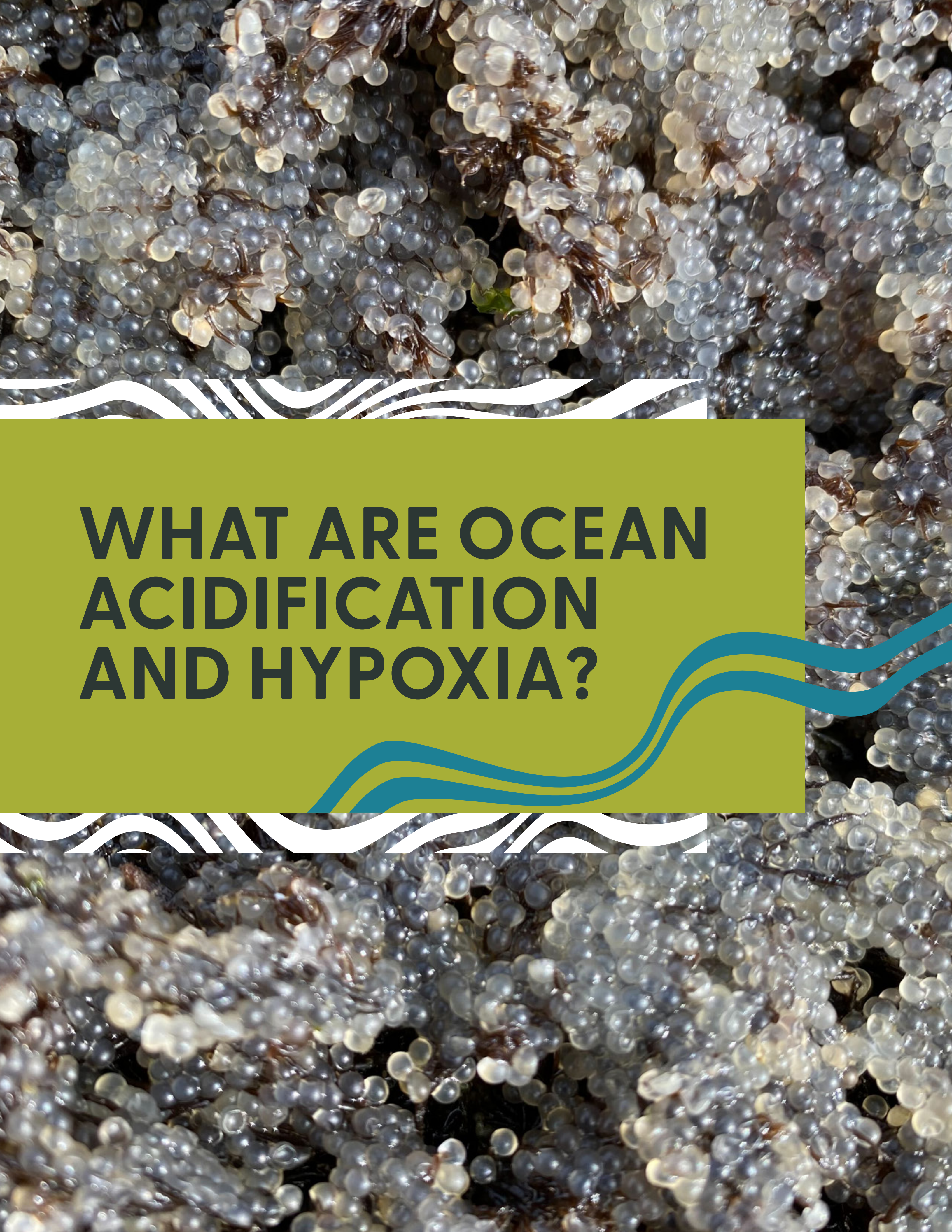
ACTION 1
Investigate the linkages between harmful algal blooms, forest fires, heat domes, floods, and OAH

ACTION 2
Identify and mitigate point sources of pollution and terrestrial runoff that act as co-stressors

OBJECTIVE 4

Maintain a provincial focus on OAH

ACTION 1
Include OAH reporting in British Columbia's Climate Change Accountability Reports



WHAT ARE OCEAN ACIDIFICATION AND HYPOXIA?

THE EARTH'S CARBON CYCLE

Carbon is the foundation of life on earth. All living organisms require it to form complex molecules like proteins and DNA. While most of the Earth's carbon is stored in sedimentary rocks, the ocean is the largest carbon reservoir that can exchange with the atmosphere on humanly meaningful time scales. In the atmosphere, carbon is present primarily as carbon dioxide gas. The atmosphere continuously exchanges this carbon dioxide with the ocean. Due to the high solubility of carbon dioxide in seawater, the oceans store ~50 times more carbon than the atmosphere or the terrestrial biosphere.

PHOTOSYNTHESIS AND REMINERALIZATION

In the ocean, inorganic carbon is used by phytoplankton, marine plants and macroalgae for their growth, creating organic matter and releasing oxygen via the process of photosynthesis.

> ***"Due to the high solubility of carbon dioxide in seawater, the oceans store ~50x more carbon than the atmosphere or the terrestrial biosphere."***

PHOTOSYNTHESIS ⟷ **REMINERALIZATION**

$$106CO_2 + 16NO_3^- + 1H_3PO_4 + 122H_2O \leftrightarrow (CH_2O)_{106}(NH_3)_{16}H_3PO_4 + 138O_2$$

Carbon dioxide + Inorganic Nutrients + Water ⟷ **Organic Matter + Oxygen**

Equation 1. The relationship between photosynthesis and remineralization

Phytoplankton are the foundation of the aquatic food web. When zooplankton and small fish that graze on phytoplankton are eaten by larger organisms, their carbon is passed up the food chain in the form of organic matter.

Carbon stored as organic matter is returned to seawater when marine organisms die. Through the process of remineralization, the decaying organic matter is broken down by microorganisms to produce carbon dioxide and inorganic nutrients and consume oxygen. When this process occurs near the ocean's surface waters, the carbon dioxide released by remineralization can exchange with the atmosphere. However, if remineralization occurs at great depths, for example below 1000 m, the carbon dioxide produced during remineralization will remain at these great ocean depths for centuries[27]. Carbon storage in the deep ocean is one approach being evaluated to help reach internationally agreed upon climate targets[28].

OCEAN ACIDIFICATION

Over millions of years, the carbon of prehistoric organisms became buried deeper and deeper in the earth where heat and pressure transformed it into coal, natural gas, and oil. When these 'fossil fuels' are extracted and burned, this prehistoric carbon is released into the atmosphere – primarily as carbon dioxide. **Due largely to fossil fuel emissions, atmospheric carbon dioxide has increased by nearly 50% since the beginning of the industrial era[29].**

Increases in atmospheric carbon dioxide lead to increased levels of dissolved carbon dioxide in the ocean (the ocean currently absorbs ~26% of the carbon dioxide released into the atmosphere). **The increased level of dissolved carbon dioxide is leading to changes in ocean chemistry[30]**. As shown in Equation 2, atmospheric carbon dioxide (CO_2) dissolves in seawater to form carbonic acid (H_2CO_3). Carbonic acid then breaks down, losing hydrogen ions (H^+) in two steps to form bicarbonate ions (HCO_3^-) and carbonate (CO_3^{2-}) ions.

$$CO_{2(atmosphere)} \leftrightarrow CO_{2(aqueous)} + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2H^+ + CO_3^{2-}$$

Aq. Carbon Dioxide + Water | **Carbonic Acid** | **Hydrogen ion + Bicarbonate** | **2 Hydrogen ions + Carbonate**

Equation 2. Carbonate Chemistry of the Ocean[31]

Increased carbon dioxide in the ocean leads to increased concentrations of hydrogen ions: this is known as *ocean acidification*. The level of acidification in seawater is determined by measuring its pH – where pH is a logarithmic measure of the hydrogen ion concentration*. According to the pH scale, a neutral solution has a pH of 7.0; solutions with pH values less than 7.0 are 'acidic' – while those with pH values greater than 7.0 are 'basic.'

Over the last 250 years, the average upper-ocean pH has decreased by ~0.1 units, from approximately 8.2 to 8.1. Because pH is expressed on a logarithmic scale, this small change in pH **corresponds to a ~30% increase in the average acidity of the surface ocean**. At the current rate of human-generated carbon dioxide emissions, the average acidity of the global surface ocean is expected to increase by 100 - 150% over preindustrial levels by the end of this century[32].

> ***The increased level of dissolved carbon dioxide is leading to changes in ocean chemistry.***

* *See BC OAH Scientific Assessment on how the marine carbonate system is measured.*

HYPOXIA

The most important process delivering oxygen into the ocean interior is exchange with the atmosphere. Since 1960, the average oxygen content within the ocean has decreased by ~2%[33]. Like ocean acidification, this decrease is driven by human-generated carbon dioxide emissions. Carbon dioxide and other greenhouse gases trap heat in the atmosphere. Approximately 91% of the human-generated heat trapped by these gases is subsequently absorbed by the ocean's surface waters[34]. Warmer surface seawater holds less oxygen than colder seawater, and this contributes to the declining ocean oxygen content.

Warmer surface waters are also less dense, and therefore lighter, than the colder, heavier waters below. As the difference in density increases between these layers of the water column, the natural exchange of oxygenated surface seawater with the ocean interior becomes more difficult – and also contributes to the global oxygen decline.

Even small decreases in the amount of oxygen dissolved in seawater can significantly impact marine organisms. When oxygen concentrations decrease to levels that harm most macrofauna such as fish (<2 mg oxygen/litre), conditions are referred to as *hypoxic*.

In coastal areas, compounding factors like runoff containing nutrients from human activities (e.g. agriculture, wastewater) can increase the potential for hypoxia. The excess nutrients stimulate the growth of phytoplankton and marine algae. When this excess organic matter sinks from the surface ocean, it is remineralized and oxygen is consumed faster than it can be replenished. Moreover, carbon dioxide is also released – contributing to further acidification. This one-two punch of hypoxic and acidified conditions serves as a multi-stressor that can greatly increase negative impacts on ecosystems (see Figure 5 for overview of coastal processes affecting OAH).

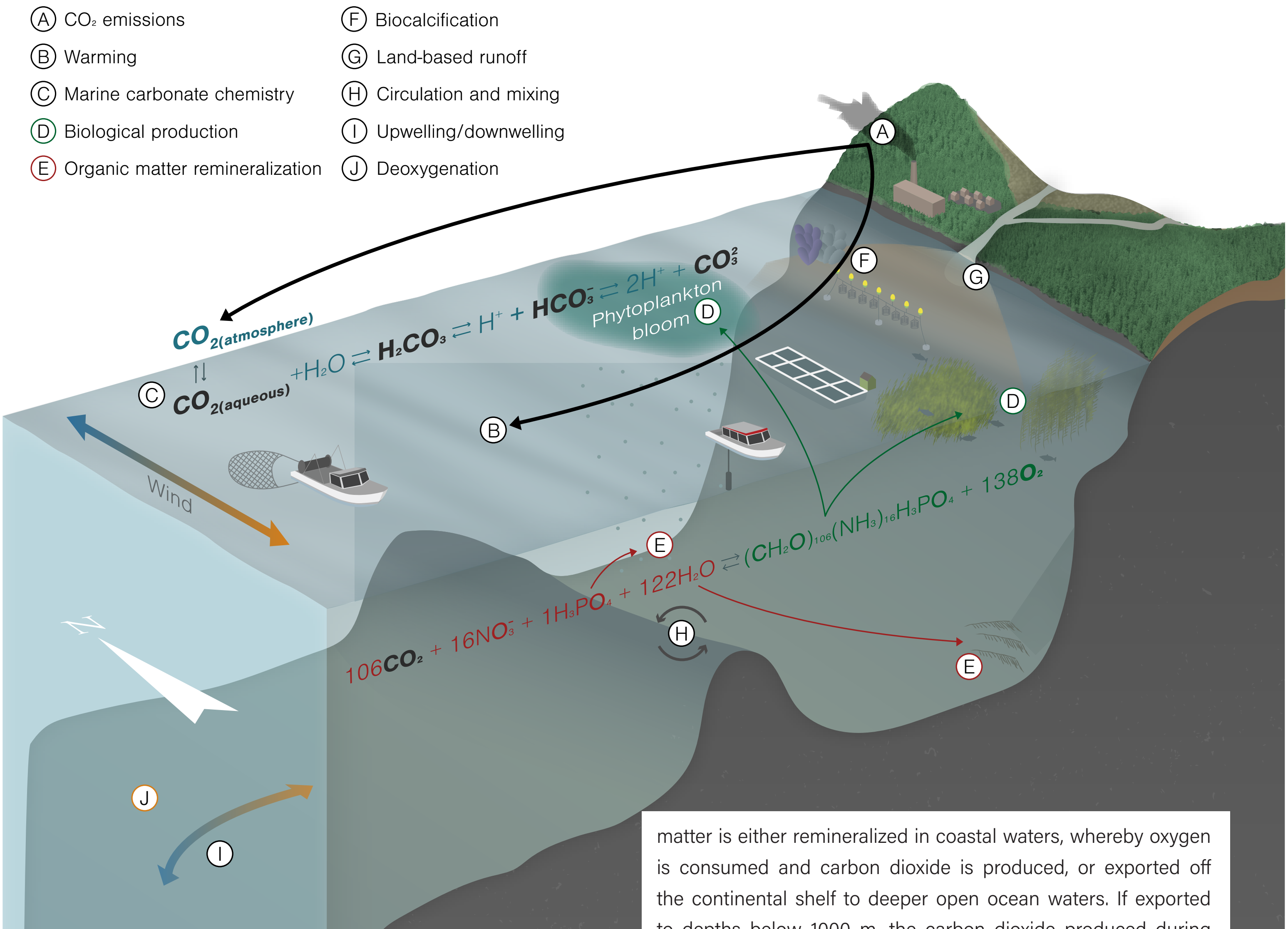
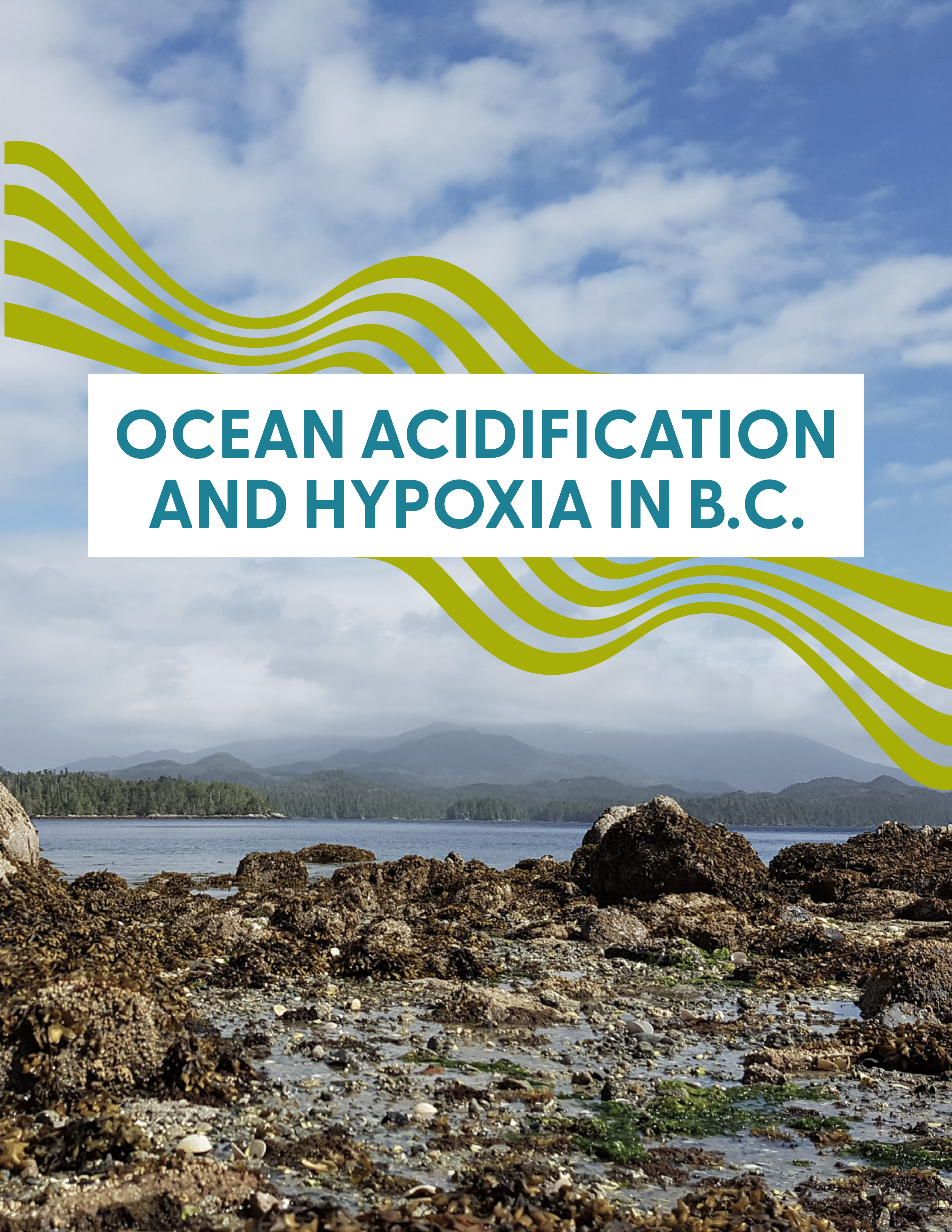


Figure 5: Overview of major processes driving variability in the marine carbonate system and oxygen concentration of coastal waters in British Columbia. Human-generated carbon dioxide emissions (A) results in ocean warming (B) and acidification through its impact on marine carbonate chemistry (C). These changes are occurring against a backdrop of natural processes that alter the ocean's marine carbonate system and oxygen levels, including: biological production (D), organic matter remineralization (E), biocalcification (F), land-based runoff (G), circulation and mixing (H), and wind-driven upwelling and downwelling (I). Southward (northward) winds along the British Columbia coast during summer (winter) drive upwelling (downwelling). Seasonal upwelling brings subsurface open ocean water onto the continental shelf (*i.e.*, waters around the continent with depths shallower than about 200 m). The upwelled water is rich in nutrients and enhances the growth of phytoplankton that support productive marine food webs. The production of organic matter by phytoplankton and marine vegetation acts to remove carbon dioxide from seawater as well as produce oxygen. This organic matter is either remineralized in coastal waters, whereby oxygen is consumed and carbon dioxide is produced, or exported off the continental shelf to deeper open ocean waters. If exported to depths below 1000 m, the carbon dioxide produced during remineralization can be removed from contact with the atmosphere (*i.e.*, sequestered) for > 200 years. Ocean warming alters the rate of organic matter remineralization, the vertical layering of the water column (*i.e.*, stratification), and the solubility of gases (***e.g.***, carbon dioxide and oxygen) in seawater. This combination of factors is leading to ocean deoxygenation (J). When low-oxygen water is carried onto the continental shelf by wind-driven upwelling, oxygen concentration can be further reduced by organic matter remineralization, leading to hypoxia that is harmful for many marine organisms. Land-based runoff can also supply nutrients that promote phytoplankton growth, as well as dilute seawater alkalinity*. Biocalcification** also reduces alkalinity, and both reductions in alkalinity and increases in carbon dioxide lead to more weakly-buffered seawater conditions that would exhibit faster rates of change in response to human-generated carbon dioxide uptake. Image created by Mark Garrison/Hakai Institute.

** See glossary in BC OAH Scientific Assessment.*

*** See glossary in BC OAH Scientific Assessment.*

OCEAN ACIDIFICATION AND HYPOXIA IN B.C.



BC IS PRE-CONDITIONED TO BE VULNERABLE

Ocean acidification is a global phenomenon, but several oceanographic characteristics of BC's offshore waters increase vulnerability to ocean acidification and hypoxia:

- The interior Northeast Pacific (at depths below 200 m) is old in terms of the length of time since last contact with the atmosphere. As a result, extensive remineralization of organic matter has occurred; the water is therefore naturally very low in oxygen and high in carbon dioxide. Summer wind patterns drive this low oxygen / high carbon dioxide deep water onto the continental shelf and to the surface from BC to California.

- This low oxygen / high carbon dioxide deep water also supplies nutrients that fuel phytoplankton growth which supports productive ecosystems and fisheries. However, **this deep water also now carries an increasing load of human-generated carbon dioxide acquired from its last contact with the atmosphere[6]**. As a result, this deep low oxygen / high carbon dioxide water is becoming more corrosive to calcifying organisms including oysters, clams, scallops, mussels, crabs, abalone, and pteropods[6,9].

CHANGES IN THE OFFSHORE AND CONTINENTAL SHELF WATERS

Trends are evident in offshore and continental shelf waters, including:

- **A 15% reduction in oxygen in the upper 3000 m of the Northeast Pacific Ocean over the last 60 years**[35]. This reduction far exceeds the global average open ocean decline of 2%[33]. Associated with this decline, the oxygen minimum zone of the Northeast Pacific Ocean is expanding by ~3 m/yr[35].

- **Measurements of carbonate chemistry in offshore surface water show long-term trends that reflect the uptake of human-generated atmospheric carbon dioxide (Figure 6)[36]**. The water that is corrosive to carbonate minerals used in shell formation is rising to shallower depths by 1-2 m/yr since the 1980s[35]. These trends are less than expected given the level of human-generated carbon dioxide uptake – and thereby illustrate that long time-series measurements are essential to capture interactions between ocean processes and human-generated carbon dioxide uptake.

- In addition to the overall OAH trend, conditions over the BC continental shelf show significant but poorly understood variations over a broad range of spatial and temporal scales due to interactions with the topography, currents, and winds.

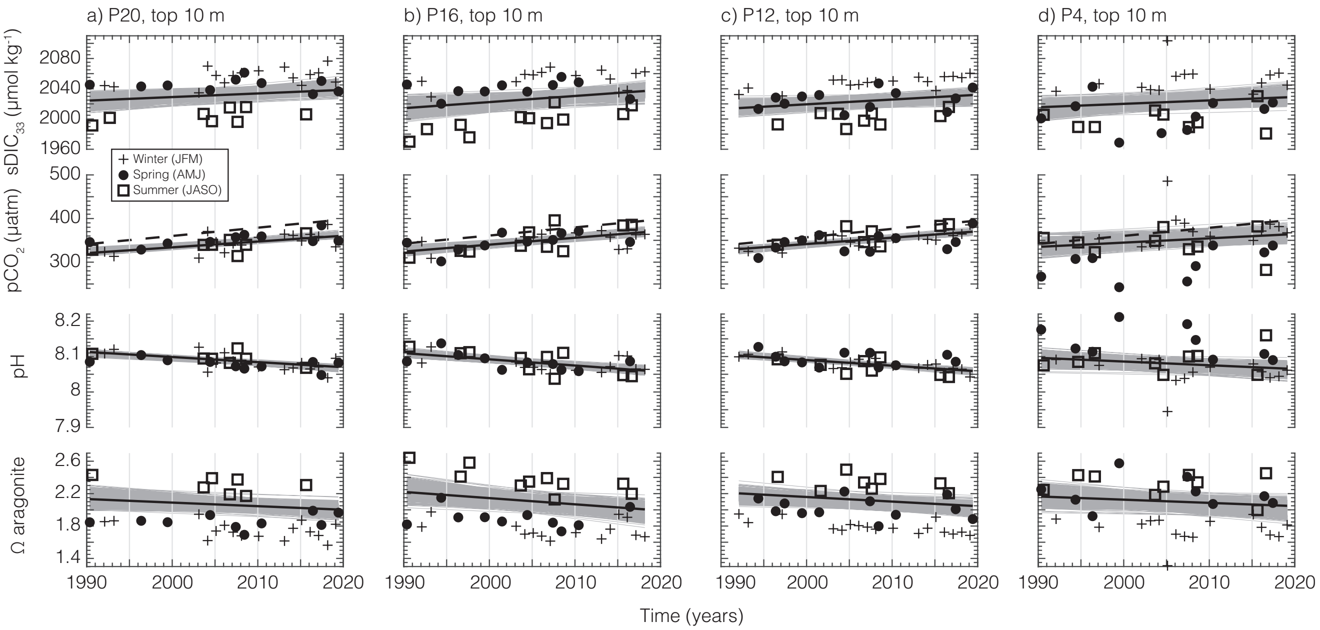


FIGURE 6. Time series of surface (upper 10 m) $sDIC_{33}$ (µmol/kg; dissolved inorganic carbon (DIC) normalized to a salinity of 33), pCO_2, pH, and aragonite saturation state at four stations along Line P from offshore (P20) to the continental shelf (P4). Figure from Franco et al.[36]. See BC OAH Scientific Assessment for additional information about Line P and ocean chemistry measurements in the Northeast Pacific.

HEIGHTENED VULNERABILITY IN NEARSHORE WATERS

Nearshore waters along the BC coast span areas of high and varying freshwater input, locations where exchange with the open Northeast Pacific is restricted, and areas of persistent and strong tidal mixing. These environmental conditions help to shape OAH trends in BC coastal waters.

> ***If the current level of emissions continues, the level of acidification occurring over the next 15 years could be equal to almost 50% of the acidification that occurred over the previous 260 years.***

- **The rate of acidification in BC's coastal waters is estimated to be proceeding at a rate that exceeds the global average**[37]. While the degree of acidification varies regionally and seasonally, the average contemporary acidification level in BC nearshore waters is almost 40% higher than pre-industrial levels – and thus exceeds the global average increase of 30%. If the current level of emissions continues, the level of acidification occurring over the next 15 years could be equal to almost 50% of the acidification that occurred over the previous 260 years[37].
- **The Strait of Georgia has a naturally high carbon content relative to the open Northeast Pacific that enhances the region's vulnerability to ocean acidification**[38]. In combination with other factors, the high carbon content leads to a reduction in carbonate availability for biocalcification processes over most of the water column[38,39]. Coastal areas and fjords on the periphery of the Salish Sea[40] – including within Baynes Sound and Okeover Inlet[41] – also show a high sensitivity to ocean acidification.
- At least three of BC's prominent mainland fjords (Rivers Inlet, Knight Inlet, and Bute Inlet) have shown **significant decreases in oxygen and increases in temperature and salinity**[42].

MODELLING OCEAN ACIDIFICATION AND HYPOXIA IN BC WATERS

Models provide a range of useful information that is not available from observations alone. For example, models:

- "Fill in the gaps" in space and time. Models are the best available means of extrapolating observational data to three-dimensional fields in a dynamically consistent way.
- Provide a means of creating projections of potential future climates.
- Make forecasts of conditions on time scales of up to a few years. Canada maintains several operational forecast systems for the physical ocean, but operational forecasting of ocean chemistry is still in an early stage of development.

A variety of numerical ocean models have been developed to examine ocean acidification and hypoxia on the BC continental margin. As is described in greater detail within the Scientific Assessment, a major gap in BC's modeling capacity is for predictions on resource management relevant timescales (seasonal to multi-year).

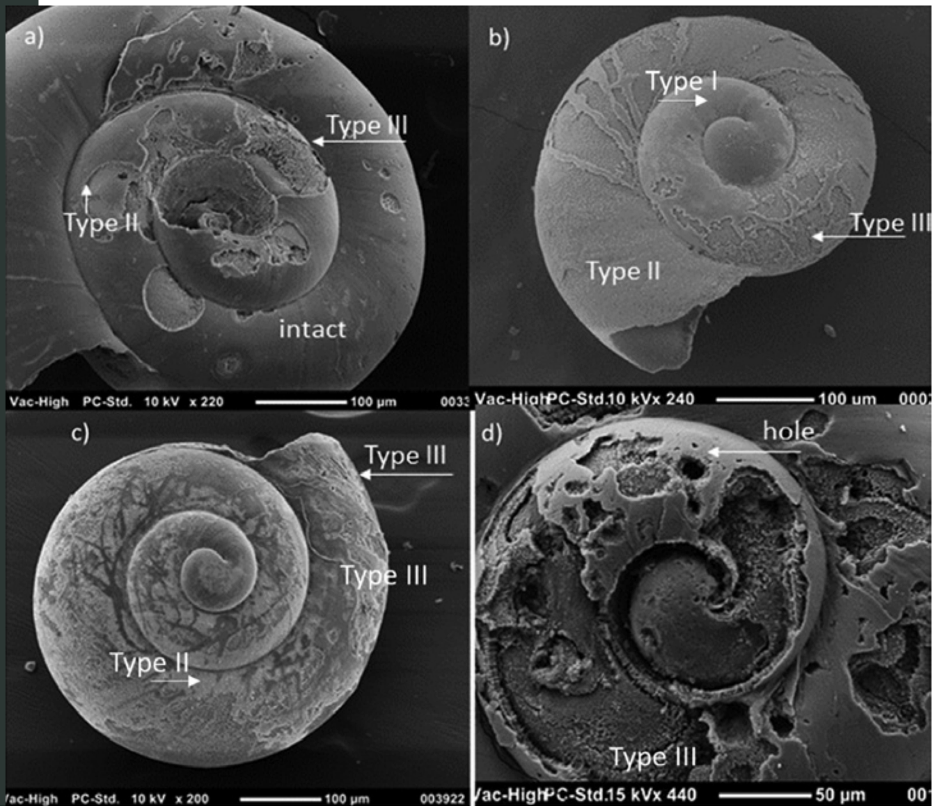


FIGURE 7. Evidence of pteropod shell dissolution in Puget Sound[43].

BIOLOGICAL IMPACTS OF OAH IN BC

Impacts of Ocean Acidification

Ocean acidification can have direct and indirect effects on species and ecosystems, with economic and cultural impacts on human populations. The below infographic summarizes the biological impacts of ocean acidification on important marine species found in BC.

Summary of biological impacts of ocean acidification on important marine species found in British Columbia. Species are classified as having negative responses to a biological process if adverse responses have been observed in at least one life-stage (even if other life-stages are not highly sensitive). When multiple laboratory results show contradictory results within a single life-stage, the overall effect is characterized as mixed. The ecological, economic, and cultural importance of BC species affected by OAH was considered through a combination of qualitative and quantitative methods. Trophic level was determined using qualitative descriptors of trophic role within food webs and quantitative classification following Haigh[44]. Some species play key roles within the ecosystem including serving as important food links across trophic levels (e.g. dominant zooplankton groups such as copepods and krill species), acting as ecosystem engineers by providing and modifying structural habitat and ecosystem dynamics (e.g. oyster or clam beds), or by acting as foundational species by dominating and modulating an ecosystem and its diversity (e.g. mussels on rocky intertidal shores). The economic importance of non-commercial species was estimated based on their role in supporting higher trophic levels commercial fisheries (e.g. krill and copepods) or emerging industries (e.g. kelp farming); however, we acknowledge that this approach underestimates potential indirect commercial value for some species. For commercial species, the 2018-2020 wholesale landing value was used and grouped under three categories: Low: <$5 ; Medium: $5-$20; High: >$25 (in CAD millions). Assigning cultural value to species is contingent on consultation with First Nations, coastal communities, and diverse groups of stakeholders. The descriptors provided here are our best estimates to date. Readers are directed to the Scientific Assessment for detailed information on the biological impacts of ocean acidification.

Impacts of Hypoxia

As summarized in the following infographic, hypoxia also has direct and indirect effects on BC species and ecosystems, together with economic and cultural impacts on human populations.

Summary of biological impacts of hypoxia on important marine species found in British Columbia. This infographic follows the same approach as the biological impacts from ocean acidification infographic, and readers should examine the Scientific Assessment for further details.

		OCEAN ACIDIFICATION IMPACTS					ECOLOGICAL AND HUMAN DIMENSIONS IMPORTANCE			
		SURVIVAL	GROWTH	CALCIFICATION	REPRODUCTION	BEHAVIOR	TROPHIC LEVEL[1] / ECOLOGICAL ROLE[2]	ECONOMICAL[3]	CULTURAL	STUDIES ON BC POPULATIONS?
PRIMARY PRODUCERS	PHYTOPLANKTON	NE	▲	NA	NE	NA	P.PRODUCER (1.0)	NA	NA	N
	MACROALGAE	NE	MIXED	▼	MIXED	NA	P.PRODUCER (1.0)	MEDIUM	HIGH	N
	SEAGRASSES	NE	MIXED	NA	▲	NA	P.PRODUCER (1.0) / HABITAT	MEDIUM	HIGH	N
	GIANT KELP	NE	MIXED	NA	MIXED	NA	P.PRODUCER (1.0) / HABITAT	HIGH	HIGH	N
	BULL KELP	NE	MIXED	NA	U	NA	P.PRODUCER (1.0) / HABITAT	HIGH	HIGH	N
PELAGIC	KRILL	▼	MIXED	NA	U	U	GRAZER (2.1) / KEY FOOD LINK	HIGH	HIGH	Y
	COPEPODS	MIXED	MIXED	NA	U	U	GRAZER (2.0) / KEY FOOD LINK	MEDIUM	LOW	N
	PTEROPODS	▼	MIXED	▼	U	MIXED	GRAZER (2.0) / FOOD LINK	LOW	LOW	N
BETHNIC INVERTEBRATES	RED SEA URCHIN	▼	▼	U	▼	U	KEY GRAZER (2.7) / ENGINEER	MEDIUM	HIGH	ONGOING
	GREEN SEA URCHIN	MIXED	▼	U	MIXED	▼	KEY GRAZER (2.7) / ENGINEER	LOW	HIGH	ONGOING
	PURPLE SEA URCHIN	MIXED	▼	MIXED	MIXED	NE	KEY GRAZER (2.7) / ENGINEER	LOW	HIGH	ONGOING
	NORTHERN ABALONE	▼	▼	▼	U	U	GRAZER (2.2-2.7)	LOW	HIGH	Y
	BAY MUSSEL	▼	▼	▼	MIXED	U	FILTER F. (2.2) / FOUNDATION & ENGINEER	LOW	MEDIUM	ONGOING
	CALIFORNIA MUSSEL	▼	▼	▼	MIXED	U	FILTER F. (2.2) / FOUNDATION & ENGINEER	LOW	LOW	ONGOING
	MEDITERRANEAN MUSSEL	▼	▼	▼	MIXED	U	FILTER F. (2.2) / FOUNDATION & ENGINEER	LOW	LOW	ONGOING
	BLUE MUSSEL	▼	▼	▼	MIXED	U	FILTER F. (2.2) / FOUNDATION & ENGINEER	LOW	LOW	ONGOING
	PACIFIC OYSTER	▼	▼	▼	MIXED	U	FILTER FEEDER (2.2) / ENGINEER	HIGH	HIGH	ONGOING
	OLYMPIC OYSTER	▼	▼	▼	MIXED	▼	FILTER FEEDER (2.2) / ENGINEER	LOW	HIGH	N
	PACIFIC GEODUCK	U	▼	▼	U	U	FILTER FEEDER (2.2) / ENGINEER	HIGH	HIGH	N
	MANILA CLAM	▼	▼	▼	▼	▼	FILTER FEEDER (2.2) / ENGINEER	MEDIUM	HIGH	N
	DUNGENESS CRAB	▼	▼	▼	MIXED	NE	PREDATOR (2.8)	HIGH	HIGH	N
	TANNER CRAB	▼	▼	▼	▼	U	PREDATOR (2.8)	HIGH	HIGH	N
	PINK SHRIMP	U	▼	NE	U	U	PREDATOR (3.0)	MEDIUM	HIGH	N
	NORTHERN SHRIMP	▼	▼	NE	U	U	PREDATOR (3.0)	MEDIUM	HIGH	N
FISH	PINK SALMON	MIXED	MIXED	NA	U	U	PREDATOR(3.9)	MEDIUM	HIGH	ONGOING
	COHO SALMON	U	U	NA	U	▼	PREDATOR(4.3)	HIGH	HIGH	N
	CHINOOK SALMON	NE	NE	NA	U	U	PREDATOR(4.2)	MEDIUM	HIGH	ONGOING
	CHUM SALMON	MIXED	MIXED	NA	U	U	PREDATOR(3.8)	MEDIUM	HIGH	ONGOING
	PACIFIC HERRING	MIXED	MIXED	NA	U	U	PREDATOR(3.3)	HIGH	HIGH	ONGOING
	PACIFIC COD	▼	▼	NA	U	U	PREDATOR(3.7)	LOW	MEDIUM	N
	WALLEYE POLLOCK	▼	▼	NA	U	U	PREDATOR(3.5)	MEDIUM	MEDIUM	N
	NORTHERN ROCK SOLE	NE	MIXED	NA		U	PREDATOR(3.4)	MEDIUM	MEDIUM	N
	ATLANTIC SALMON	MIXED	MIXED	NA	U	U	NON-MIGRATORY FARMED	HIGH	LOW	N
OTHERS	COLD-WATER CORALS	U	MIXED	MIXED	U	NA	FILTER FEEDER / HABITAT	HIGH	HIGH	N
	GLASS SPONGES	U	▼	NA	U	NA	FILTER FEEDER / HABITAT	MEDIUM?	HIGH	Y

LEGEND

▲ INCREASED　**MIXED**: MIXED RESULTS　**NE**: NO EFFECT

▼ DECREASED　**U**: UNKNOWN　**NA**: NOT APPLY

[1]TROPHIC LEVEL VALUES ADAPTED HAIGH ET AL. 2015

[2]FOUNDATION SPECIES. DOMATES AN ECOSYSTEM, DETERMINES DIVERSITY AND MODULATES ECOSYSTEM DYNAMICS; ECOSYSTEM ENGINEERS: ALTER THE PHYSICAL STATE OF LIVING AND NON-LIVING MATERIALS AND MODULATES ECOSYSTEM DYNAMICS

[3]IN ITALICS, QUALITATIVE ASSESSMENT OF POTENTIAL BENEFITS INCLUDING SUPPORT TO GREATER TROPHIC LEVELS. OTHER ASSESSMENTS BASED ON BC SEAFOOD PRODUCTINO, 2018 - 2020 DATASET WHOLESALE VALUE ($ MILLION) . LOW: <5 ; MEDIUM: 5-20; HIGH: >25

GAPS

IMPORTANT BC SPECIES WHOSE RESPONSES TO OAH HAVE NOT BEEN STUDIED:

- SOCKEYE SALMON
- SPOT PRAWN
- PACIFIC HAKE
- PACIFIC HALIBUT
- SABLEFISH
- EULACHON
- SOUTHERN ROCK SOLE
- PACIFIC ROCKFISH
- LINGCOD
- STEELHEAD
- MACKEREL
- SEA CUCUMBER(S)
- ROCK CRAB
- ROCK SCALLOP
- COLD-WATER CORALS
- GELATINOUS ZOOPLANKTON
- ECHINODERMS
- ELASMOBRANCHS

MANY SPECIES OF:

- PHYTOPLANKTON
- ZOOPLANKTON
- MACROALGAE

IMPORTANT KNOWLEDGE GAPS AFFECTING ALL BC SPECIES:

- RESPONSES TO VARIABLE OA
- MULTISTRESSOR (HYPOXIA, HEATWAVES) INTERACTIONS
- BC POPULATION-SPECIFIC RESPONSES
- ECOSYSTEM/MULTI-TROPHIC EFFECTS

		HYPOXIA IMPACTS					ECOLOGICAL AND HUMAN DIMENSIONS IMPORTANCE			
		SURVIVAL	GROWTH	PHYSIOLOGY	REPRODUCTION	BEHAVIOR	TROPHIC LEVEL[1] / ECOLOGICAL ROLE[2]	ECONOMICAL[3]	CULTURAL	STUDIES ON BC POPULATIONS?
PRIMARY PRODUCERS	PHYTOPLANKTON	MIXED	MIXED	MIXED	MIXED	NA	P.PRODUCER (1.0)	NA	NA	N
	MACROALGAE	NE	MIXED	MIXED	U	NA	P.PRODUCER (1.0)	MEDIUM	HIGH	N
	SEAGRASSES	MIXED	▼	▼	U	NA	P.PRODUCER (1.0) / HABITAT	MEDIUM	HIGH	N
	GIANT KELP	NE	MIXED	U	U	NA	P.PRODUCER (1.0) / HABITAT	HIGH	HIGH	N
	BULL KELP	NE	MIXED	U	U	NA	P.PRODUCER (1.0) / HABITAT	HIGH	HIGH	N
PELAGIC	KRILL	▼	NE	MIXED	▲	NE	GRAZER (2.1) / KEY FOOD LINK	HIGH	HIGH	Y
	COPEPODS	MIXED	U	U	U	▼	GRAZER (2.0) / KEY FOOD LINK	MEDIUM	LOW	N
	PTEROPODS	NE	U	▼	U	U	GRAZER (2.0) / FOOD LINK	LOW	LOW	N
BETHNIC INVERTEBRATES	RED SEA URCHIN	▼	U	▼	U	▼	KEY GRAZER (2.7) / ENGINEER	MEDIUM	HIGH	ONGOING
	GREEN SEA URCHIN	U	▼	▼	▼	▼	KEY GRAZER (2.7) / ENGINEER	LOW	HIGH	ONGOING
	PURPLE SEA URCHIN	MIXED	▼	▼	MIXED	▼	KEY GRAZER (2.7) / ENGINEER	LOW	HIGH	ONGOING
	NORTHERN ABALONE	U	U	U	U	U	GRAZER (2.2-2.7)	LOW	HIGH	N
	BAY MUSSEL	U	U	U	U	U	FILTER F. (2.2) / FOUNDATION & ENGINEER	LOW	MEDIUM	ONGOING
	CALIFORNIA MUSSEL	NE	NE	▼	U	U	FILTER F. (2.2) / FOUNDATION & ENGINEER	LOW	LOW	ONGOING
	MEDITERRANEAN MUSSEL	NE	NE	▼	U	MIXED	FILTER F. (2.2) / FOUNDATION & ENGINEER	LOW	LOW	ONGOING
	BLUE MUSSEL	▼	▼	▼	MIXED	▼	FILTER F. (2.2) / FOUNDATION & ENGINEER	LOW	LOW	ONGOING
	PACIFIC OYSTER	NE	U	▼	U	U	FILTER FEEDER (2.2) / ENGINEER	HIGH	HIGH	ONGOING
	OLYMPIC OYSTER	MIXED	▼	U	▼	U	FILTER FEEDER (2.2) / ENGINEER	LOW	HIGH	N
	PACIFIC GEODUCK	U	U	U	U	U	FILTER FEEDER (2.2) / ENGINEER	HIGH	HIGH	N
	MANILA CLAM	▼	▼	▼	U	▼	FILTER FEEDER (2.2) / ENGINEER	MEDIUM	HIGH	N
	DUNGENESS CRAB	▼	▼	MIXED	MIXED	NE	PREDATOR (2.8)	HIGH	HIGH	Y
	TANNER CRAB	U	U	U	U	U	PREDATOR (2.8)	HIGH	HIGH	N
	PINK SHRIMP	NE	U	U	U	MIXED	PREDATOR (3.0)	MEDIUM	HIGH	Y
	NORTHERN SHRIMP	NE	U	U	U	MIXED	PREDATOR (3.0)	MEDIUM	HIGH	N
FISH	SOCKEYE SALMON	▼	▼	▼	▼	▼	PREDATOR(3.9)	MEDIUM	HIGH	Y
	COHO SALMON	▼	▼	▼	▼	▼	PREDATOR(4.3)	HIGH	HIGH	Y
	CHINOOK SALMON	▼	▼	▼	▼	▼	PREDATOR(4.2)	MEDIUM	HIGH	Y
	CHUM SALMON	▼	U	U	▼	U	PREDATOR(3.8)	MEDIUM	HIGH	Y
	PACIFIC HERRING	NE	NE	U	NE	NE	PREDATOR(3.3)	HIGH	HIGH	N
	PACIFIC HAKE	NE	U	U	U	NE	PREDATOR(3.3)	HIGH	MEDIUM	Y
	ATLANTIC SALMON	▼	▼	▼	U	U	NON-MIGRATORY FARMED	HIGH	LOW	N

LEGEND

▲ INCREASED **MIXED**: MIXED RESULTS **NE**: NO EFFECT

▼ DECREASED **U**: UNKNOWN **NA**: NOT APPLY

[1]TROPHIC LEVEL VALUES ADAPTED HAIGH ET AL. 2015

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[3]IN ITALICS, QUALITATIVE ASSESSMENT OF POTENTIAL BENEFITS INCLUDING SUPPORT TO GREATER TROPHIC LEVELS. OTHER ASSESSMENTS BASED ON BC SEAFOOD PRODUCTINO, 2018 - 2020 DATASET WHOLESALE VALUE ($ MILLION). LOW: <5; MEDIUM: 5-20; HIGH: >25

GAPS

IMPORTANT BC SPECIES WHOSE RESPONSES TO OAH HAVE NOT BEEN STUDIED:

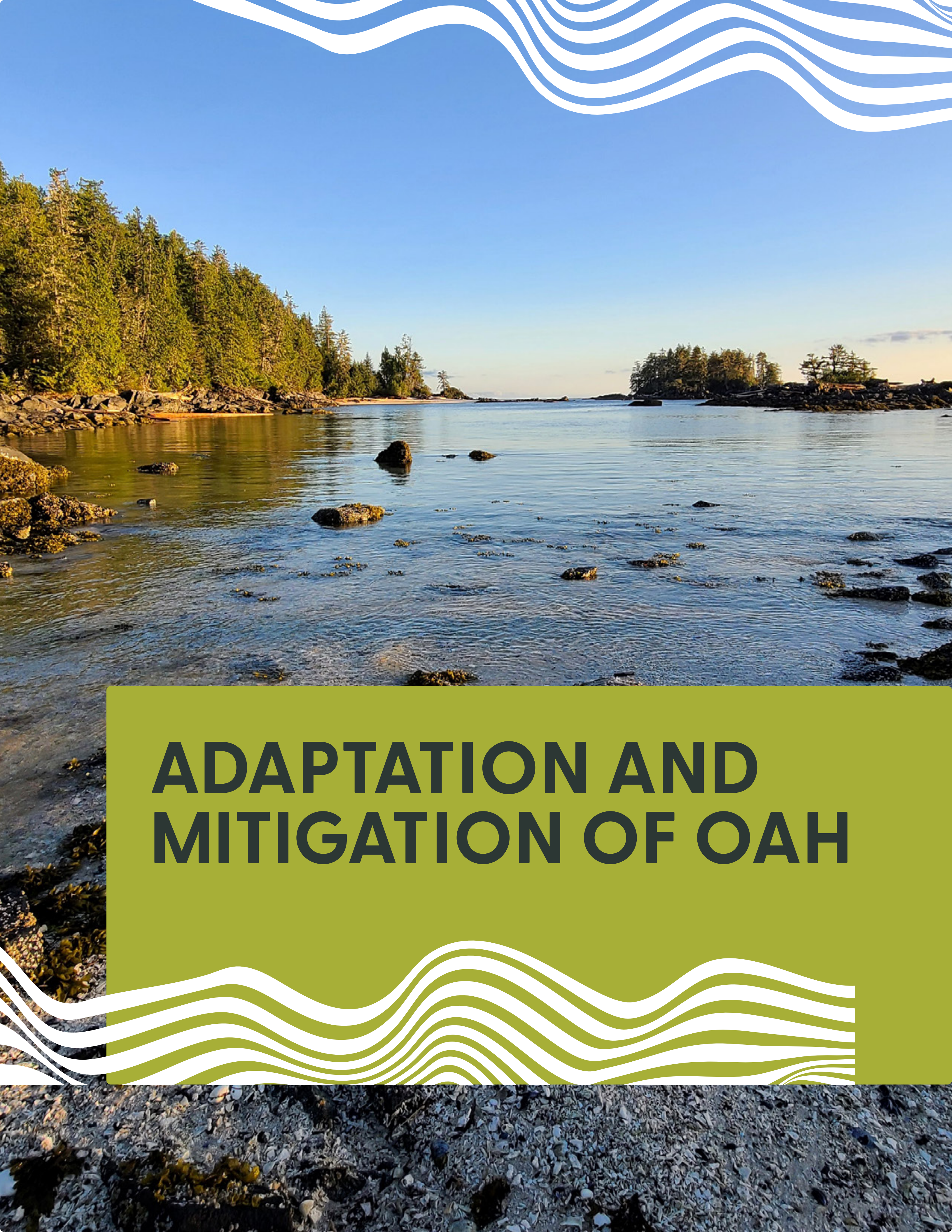
- PINK SALMON
- PACIFIC COD
- SPOT PRAWN
- PACIFIC HALIBUT
- SABLEFISH
- ULACHON
- WALLEYE POLLOCK NORTHER
- ROCK SOLE
- SOUTHERN ROCK SOLE PACIFIC
- ROCKFISH
- LINGCOD
- STEELHEAD
- MACKEREL
- SEA CUCUMBER(S)
- ROCK CRAB
- ROCK SCALLOP

MANY SPECIES OF:

- PHYTOPLANKTON
- ZOOPLANKTON
- MACROALGAE
- COLD-WATER CORALS
- GELATINOUS ZOOPLANKTON
- ECHINODERMS
- ELASMOBRANCHS

IMPORTANT KNOWLEDGE GAPS AFFECTING ALL BC SPECIES:

- RESPONSES TO PULSE
- HYPOXIA
- MULTI-STRESSOR (ACIDIFICATION, HEATWAVES) INTERACTIONS
- BC POPULATION-SPECIFIC RESPONSES
- ECOSYSTEM/MULTI-TROPHIC EFFECTS



ADAPTATION AND MITIGATION OF OAH

In addition to implementing deep and rapid reductions in fossil fuel emissions, various approaches may serve to address different aspects of the challenges created by OAH, including:

- Bridging western science and Traditional Ecological Knowledge to enhance ocean observing and understanding of OAH impacts and achieve better management of coastal resources.
- Frameworks to modernize fisheries and aquaculture sectors. Priority areas requiring consideration within these frameworks include:
  - Evaluate and update the regulatory process for aquaculture and commercial fisheries to adapt more quickly to changing ocean conditions.
  - Evaluate restorative aquaculture and best practices to mitigate OAH within aquaculture settings.
  - Support genetic research on aquaculture species. Such as the research conducted through Vancouver Island University's Selective Breeding Program that selects for individuals in a species that have a greater tolerance to anticipated future levels of OAH.
- Evaluation of interactions between OAH and other emerging climate-related threats e.g., the increasing frequency and intensity of atmospheric rivers or heat domes.
- Evaluation of proposed approaches for marine carbon dioxide removal in terms of their capacity to alter ocean chemistry in ways that impact OAH.

THE PATH FORWARD

The United Nations declared 2021-2030 as a Decade of Ocean Science for Sustainable Development (the "Ocean Decade") to ensure that ocean science can support the global community to achieve the 2030 Agenda for Sustainable Development. The 2030 Agenda for Sustainable Development[45] includes a global goal to address *"life below water"* (SDG 14); this goal targets a number of areas of degradation in the marine environment including ocean acidification (SDG 14.3). SDG 14.3 specifically calls to *"minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels".* **Through the development of this action plan, BC is taking a landmark step forward along this path as the first Canadian province to recommend actions needed to understand and minimize the impacts of OAH within the province's coastal waters.** Enacting these recommendations will take a coordinated approach that involves federal, provincial, First Nations and community-level engagement. BC's OAH Action Plan demonstrates how provincial leadership is thinking globally about the world-wide problem of increasing OAH by acting locally to enhance BC's resilience to these threats.

The BC OAH Action Plan Advisory Committee envisions that the implementation of the BC OAH Action Plan will span the coming 5 years and be orchestrated by a provincially-appointed OAH Task Force. The OAH Task Force should comprise key science experts as well as community and government leaders. The vision for the future involves:

- Strong coordination and collaboration between research groups, stakeholders and rightsholders, and BC's coastal communities.
- Enhanced ocean observing that has addressed the key gaps outlined in the Scientific Assessment.
- A clearer and more holistic understanding of the responses to OAH across species and ecosystems.
- Ability to predict ocean conditions over timescales important for resource managers and decision-makers.
- A clear BC-focused view of the implications of marine carbon dioxide removal on OAH manifestations as well as impacts on biodiversity and equitable deployment.

Achievement of these objectives will lead to a more resilient ocean environment that realizes the sustainability goals of the Ocean Decade for British Columbia.

METRICS OF SUCCESS

The Province of BC has recently released a *Climate Preparedness and Adaptation Strategy: Actions for 2022-2025* that defines the development of this action plan as one of a group of plans focused on "enhancing the resiliency of species and ecosystems through improved understanding of the impacts of climate change on key species, habitats and ecosystems" (Pathway 3). BC's growing focus and momentum for facing the challenges of OAH will drive the successful implementation of this plan. The success of the OAH action plan, in terms of how aspects of this plan are implemented, will be gauged by a provincially-appointed OAH Task Force and tracked through the Ocean Decade. Ideally, success would also be assessed through an open review and evaluation of the actions implemented and information gained over the coming years. BC's Climate Change Accountability Act provides an avenue for this review and evaluation through the comprehensive re-assessment of climate risks on a 5-year basis – as well as through the annual Climate Change Accountability Reports that should include metrics of OAH for BC.

Ultimately, successful implementation of the BC OAH Action Plan would establish **a sustained and coordinated focus on OAH, with investment into strengthening the understanding of OAH, including adaptation and mitigation approaches, that sets BC on the path toward enhanced resiliency.**

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