

THE OCEAN AND HUMAN HEALTH AS A META-DISCIPLINE: OPPORTUNITY FOR ATLANTIC CANADA

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ABSTRACT

The one global ocean is receiving unprecedented attention recently, due to numerous factors such as the ocean's role in climate change and the burgeoning blue economy. However, even though the ocean allows life on this planet, very little attention has been given to the complex relationship between the ocean and human health (OHH). USA and Europe have for a number of years focused funding on OHH as a meta-discipline (i.e., a discipline that includes the ideas and perspectives of a number of other disciplines), but Canada until now has not. This article examines the advancement of OHH and argues that Atlantic Canada could and should lead a Canadian meta-disciplinary program on the ocean and human health.

Keywords: global ocean, human health, meta-discipline

INTRODUCTION

Covering 72% of Earth, this single connected vast body of water known as the global ocean allows us to live on this planet. It accounts for 97% of the water, contains at least 96% of Earth's living space, and generates approximately 50% of the atmosphere's oxygen. It has cushioned the blow of climate change by absorbing close to a third of all anthropogenic carbon emissions and >90% of the heat added to the global system (IPCC 2014); it also influences our weather and provides food for billions of people. The ocean and its resources define a part of our common heritage which is a critical part of many cultures (Ocean Atlas 2017).

Of late, the ocean is receiving unprecedented attention, presumably fueled by at least two factors: 1) increasing acceptance of climate change as the greatest existing threat to humanity, coupled with the recognition (finally) that the ocean is both a driver and recipient of climate change impacts (IOC-UNESCO 2022);

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and 2) skyrocketing interest in the ocean's potential to generate income, or the 'blue' economy, whether sustainable or not (Watson-Wright 2022, McCauley 2022). The burgeoning interest in the blue economy is in turn being stimulated by several elements. The value of marine activities globally was assessed by OECD at 2.5% of global GDP, or about 1.5 trillion US dollars, with estimates that the ocean economy will double by 2030 to \$3 trillion USD for 5% global GDP (OECD 2016). Shipping by sea moves 90% of all goods in the world, while more than 40% of the human population lives in the coastal zone (UN Ocean Conference 2017), with projections that this number will reach 75% within this decade (UNESCO 2022). Fisheries provide more than 3.3 billion people with an estimated 20% of their average per capita intake of animal protein, and fisheries and aquaculture provide employment for more than 60 million people worldwide. Of course, the ocean supports many industries, not only fisheries and aquaculture, but also shipping, oil and gas, marine and coastal tourism (including cruise ships), submarine cables and pipelines, dredging, ports, offshore renewable energy beyond wind, such as waves and tidal, mining, pharmaceuticals, and more (IOC-UNESCO *et al.* 2011). All this activity means the ocean is facing threats from numerous stressors – globally, regionally, and locally (IOC-UNESCO 2022) (Fig 1).

THE OCEAN AND HUMAN HEALTH (OHH)

As the world's human population has increased to more than 7.8 billion today (US Census 2022), concerns about the range and intensity of threats to human health and well-being, arising in and from the ocean, have grown. Numerous studies have identified various issues such as marine pollution, overfishing, hypoxic dead areas, harmful algal blooms, coastal flooding and an increased frequency and intensity of extreme storms related to climate, among others, as serious dangers to the health of the global ocean, and consequently to humans (see Fleming *et al.* 2019). As outlined by Wells (2018), the list of stressors is long, creating a plethora of 'wicked' problems in the quest to find workable solutions for ocean protection. In addition, we understand little of the combined effects of those stressors beyond accepting that the collective impact often exceeds the sum of individual stressors (IOC-UNESCO 2022).

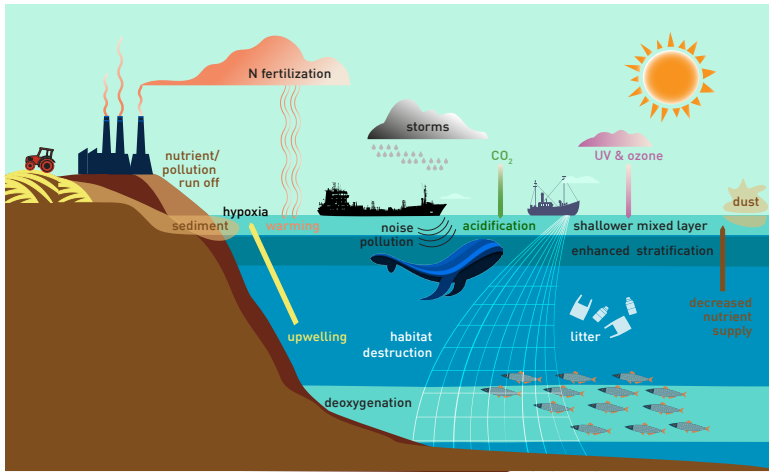


Fig 1 Illustrative examples of global (warming, acidification), regional (ozone, litter, atmospheric pollutants) and local (sedimentation, pollution and nutrient runoff) stressors, all of which can affect marine life (after IOC-UNESCO, 2022; adapted from Boyd *et al.*, 2018)

The ocean and coasts affect everyone, even those who do not live close to the sea (NOAA 2021). Despite this fact, the ocean and the many goods and services it provides have not traditionally been linked to human health. The health of the ocean itself has for many years and in many countries been assessed using the Ocean Health Index (OHI), which is a framework for rating ocean health based on the sustainable provisioning of benefits and services people expect from a healthy ocean (Halpern *et al.* 2020, Ocean Health Index 2022). However, the complex relationship between a healthy ocean and human health needs to be studied in a dedicated and holistic fashion (Borja *et al.* 2020, Bowen *et al.* 2014, Fleming *et al.* 2019, WHO 2019).

Peter Neill of the World Ocean Observatory perhaps articulated it best in saying that “the story of how human health and ocean health are related is not one easily told” (Neill 2017). In fact, the ocean and coastal seas are ‘like a double-edged sword’ when it comes to influences on human health (EMB 2013). Fleming *et al.* (2019) illustrated the complexities of these influences (Fig 2), and underlined that the many interactions attributed to increasing numbers of humans living on or near the coasts combine in complex and multifaceted ways with the effects of climate change (Fleming and Laws 2006).

In terms of risks to human health, stressors include but are not necessarily limited to: agricultural and sewage fecal waste runoff leading to nutrient enhancement; sea-level rise; tsunamis; storm surges; ocean acidification and warming which impact marine species upon which humans depend for nutrition; contaminants including chemicals, medical and veterinary pharmaceuticals; radionuclides; biotoxins from harmful algal blooms; sound and light pollution; climate change and extreme weather; increased UV-radiation; hypoxia; habitat disturbance (e.g. from commercial marine activities); microbial runoff, and others (EMB 2013). Depledge (2018) reminds us of our connections to the sea and that even though over 2.5 billion people live within 100 km of the coastline, we often fail to grasp the very real risks of the ocean to our health and well-being.

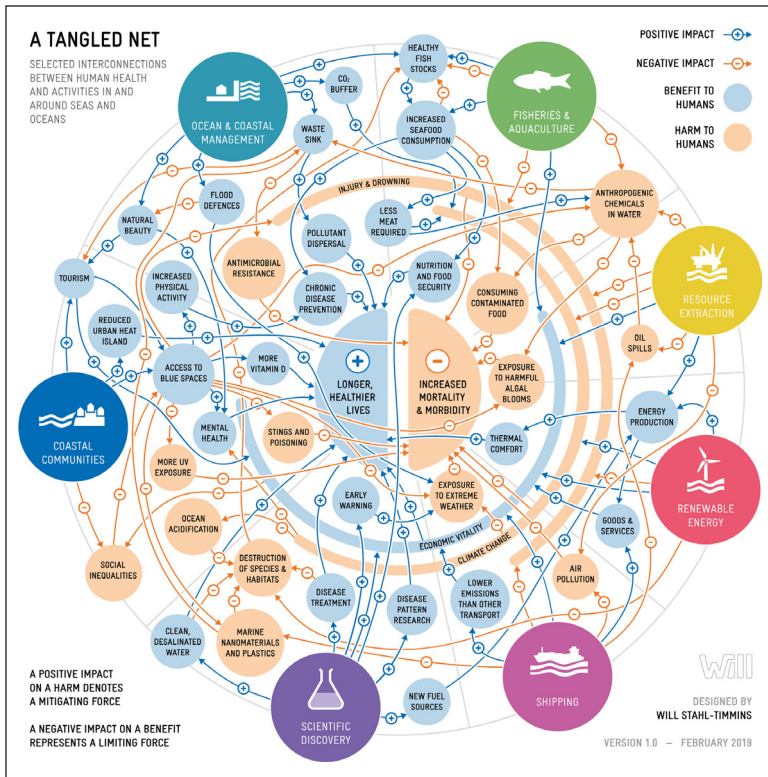


Fig 2 Tangled net of ocean-human health interactions (after Fleming *et al.*, 2019) (link to Ocean Viewer found at <https://besjournals.onlinelibrary.wiley.com/doi/full/10.1002/pan3.10038>).

Importantly, people in coastal communities, Indigenous populations and inhabitants in the high Arctic will bear the most serious of the ocean risks. As stated by Sexton (2020), “the very survival of these vulnerable populations depends on the health of the seas”.

Yet the ocean also offers innumerable benefits to human health including ‘non-market’ services related to provisioning (e.g., food), regulating (e.g., climate), and culture (e.g., recreational) (Mapping Ocean Wealth 2022, Ganter *et al.* 2021, WHOI 2021). In addition to transportation and tourism, the ocean provides sustenance in the form of animal protein, nutrition in the form of vitamins, and jobs and income for many (Ganter *et al.* 2021). Creatures from the ocean have been used by scientists for many years to study diseases in humans (National Academies of Science 1999), with some serving as an early warning system or “sentinel species” for the health of the ocean and humans (Fleming and Laws 2006). An example of the latter is the long running Gulf of Maine Gulfwatch wherein blue mussels have been and continue to be monitored for the presence of chemical contaminants since 1991 (Gulfwatch 2022). Evidence is also increasing which emphasizes the role of the ocean in enhancing human physical health, as well as for providing for both mental and spiritual wellbeing, an effect described as the ‘Blue Gym’ (Depledge and Bird 2009, Nichols 2014, White *et al.* 2016). Interest in the blue gym effect has greatly increased in the past two years due to COVID-induced confinement and the resultant impacts on mental health. As well, pharmaceuticals derived from marine organisms are enhancing treatments for a wide variety of diseases such as cancer and HIV (Kijjoo & Sawangwong 2004, NOAA Ocean Exploration 2021, NOAA 2022), with recent heightened optimism that the ocean will provide new drugs for the fight against COVID-19 (Tagliatalata-Scafati 2021) or the next pandemic (Robinson 2022).

COUNTRIES STUDYING OHH

The USA was the first to recognize the important relationship between the ocean and human health and its priority as a research topic as early as the 1970s. The publication by the National Research Council entitled ‘*From Monsoons to Microbes: Understanding the Ocean’s Role in Human Health*’ (1999) played a seminal role in advancing the topic and in having the ocean and human health

recognized as a meta-discipline, i.e., a discipline that includes the ideas and perspectives of a number of other disciplines (Sandifer *et al.* 2013). The establishment of NOAA's Ocean and Human Health Initiative in 2003, creation of a national network of seven OHH centres of excellence the following year, and other events including the passage of the Oceans and Human Health Act (NOAA 2012) led to the firm embodiment of linkages between the ocean and human health in American ocean policy (EMB 2013). Indeed, the USA continues to dominate the ocean and human health research arena with 49.3% of research articles from 1990 to 2017 relating to US populations (Short *et al.* 2021).

The EU took a page from the USA with the publication of the European Marine Board's 2013 position paper 19, '*Linking Oceans and Human Health: A Strategic Priority for Europe*' (EMB 2013). The main recommendation of this paper was to develop and support a consolidated European ocean and human health research programme to improve understanding of the potential public health benefits from marine and coastal ecosystems, to lower the burden of marine-related human disease, and to prevent serious new threats to public health. Subsequently, the Horizon 2020 program funded the SOPHIE project (Seas, Oceans and Public Health in Europe) from 2017 to 2020. Part of the project involved elaboration of a strategic research agenda (SRA) which focused on the three areas of: sustainable seafood and healthy people; blue spaces, tourism, and well-being; and marine biodiversity, biotechnology, and medicine. The SRA outlined policy needs, relevant research requirements, public and stakeholder attitudes, and capacity and training necessities (H2020 SOPHIE Consortium 2020). SOPHIE also published a policy brief that presented six recommendations, including promoting and supporting the development of a 'Health in All Policies' (HiAP) approach in marine and maritime initiatives (McMeel *et al.* 2019). Fleming *et al.* (2021), in the context of the UN Decade of Ocean Science for Sustainable Development, have since called for the development of an OHH action plan involving a multitude of different types of actors (from citizens to researchers to large international groups to policy makers) and offered thirty-five possible first steps to help kick start such a plan.

CANADA AND THE OCEAN

Canada has long considered itself a Maritime nation. Beginning with Confederation, it defined itself as a fishing and shipping nation, and its Fisheries Act of 1868 remains one of Canada's strongest pieces of federal environmental legislation. With by far the world's longest coastline – 243,042 km (Canada Yearbook 2011) which is four times longer than next nearest country (Indonesia) – Canada's ocean estate covers a surface area of approximately 7.1 million square kilometers or 70% of its land mass (Fisheries and Oceans Canada 2018). And while the great majority (90%) of the population is concentrated within 160 km of the US border, as of 2016, 14.5% of Canada's population or 4.8 million people lived within 10 km of the west, east, and north coasts, with an additional 4% living within 100 km (Ganter *et al.* 2021).

Canada has also been an acknowledged leader in global ocean issues and events. It was Canada who at the Rio Earth Summit of 1992 suggested celebrating a World Ocean Day, and who via UNESCO proposed the International Year of the Ocean, or YOTO, which was hosted by Portugal in 1998. In addition, Canada became the first country to pass an Oceans Act (in 1997) followed by an Ocean Strategy and Ocean Action Plan. More recently, among other things, Canada introduced the Charlevoix Blueprint (2018) along with the Ocean Plastics Charter (2018) during its presidency of the G7, is leading the Ocean Observations Action Group of the Commonwealth Blue Charter, is a member of the High Level Panel for a Sustainable Ocean Economy (2022) and co-hosted with Kenya and Japan the first global Sustainable Blue Economy conference in Nairobi in 2018.

Activities dependent on the ocean contribute substantially to Canadian provincial, regional, and national economies. Ocean-related industries in 2018 employed about 298,333 Canadians and contributed more than \$36.1 billion of GDP in 2018, or 1.6% (Ganter *et al.* 2021), which, while substantial, is well below the aforementioned global 2.5% (OECD, 2016). The marine sectors involved include not only fisheries and seafood processing, but aquaculture, shipbuilding, marine transportation, port activities, marine science and technology (including biotechnology), tourism, offshore energy, and a wide range of service industries that support these activities. Not surprisingly,

Canada has most recently embarked upon the development of its own Blue Economy Strategy (Fisheries and Oceans Canada 2022).

CANADA AND OHH

Despite its leadership on ocean issues, Canada has been largely absent in focusing integrated attention on the topic of the ocean and human health. Inspection Services of Fisheries and Oceans Canada (DFO)(now part of Canadian Food Inspection Agency) and Health Canada were long involved in the investigation of human illness related to ingestion of microbially- or biotoxin-contaminated seafood (see, for example, Todd *et al.* 1993, Watson-Wright *et al.* 1992), and one relatively modest program, Coasts Under Stress (2000-2005), looked at long- and short-term impacts of socio-environmental restructuring on the health of people, their communities, and the environment (Coasts Under Stress 2022). However, apart from these narrowly based activities, little else has happened. In fact, according to Short *et al.* (2021), between 1990 and 2017, only 5.5% of papers on OHH arose from Canada, but this was in comparison to only three other countries (USA, Australia, New Zealand) plus Europe. Recently, Kenny *et al.* (2020) have offered a very considered, thoughtful and well-researched perspective on the topic of the ocean and human health in this country, pointing out that ‘no dedicated OHH initiatives exist in Canada’ even though individual Canadian scientists have helped in establishing OHH as a meta-discipline. They call for a holistic climate-sensitive agenda for research, education, training, policy, and practice on OHH in Canada (Kenny *et al.* 2020).

WHAT ABOUT ATLANTIC CANADA?

The ocean plays a far more central role in Atlantic Canada than in the rest of the country. The majority of Atlantic Canada’s population lives in or near coastal communities where ocean-related activities make up 6, 10, 14 and 40% of GDP respectively in New Brunswick (NB), Prince Edward Island (PEI), Nova Scotia (NS) and Newfoundland and Labrador (NL) (Mills, 2021), much greater than Canada’s 1.6% and larger for each Atlantic province than for British Columbia (BC) (4.2%) (Ganter *et al.* 2021). In fact, 75% of Canada’s ocean

economy takes place in Atlantic Canada, along with two thirds of the jobs in fishing and aquaculture, 67% of defense jobs, and all the economy and jobs in offshore oil and gas (Ganter *et al.* 2021). Regarding ocean technology alone, the clusters of ocean technology companies in Atlantic Canada are considerable compared to the rest of Canada. The Atlantic Provinces represent roughly 6.5% of the population but nearly 60% of the Ocean Enterprise businesses. Compared to British Columbia, the Atlantic Provinces have roughly 5.5 times more companies per capita (COVE 2020). Thus, the ocean is very much top of mind to Atlantic Canadians – it is disproportionately important to us.

Our health matters a great deal too, but the Atlantic Provinces do not fare well as a region compared to the rest of Canada. According to a 2015 health status report by the Conference Board of Canada, Nova Scotia, PEI and New Brunswick received A's for self-reported health and self-reported mental health, but their overall health marks are dramatically different with PEI receiving a B, New Brunswick a C, and Nova Scotia a D. Newfoundland and Labrador ranked last among the provinces – only the territories fared worse (Conference Board of Canada 2015).

Given Canada's renewed interest in the ocean as well as the global population's focus on human health, now seems to be the time for a targeted Canadian meta-disciplinary research effort on the ocean and human health, and Atlantic Canada certainly seems to have the wherewithal to lead such an initiative. We have the largest concentration of ocean research institutes in the country, with active participation by Indigenous communities growing each year. Medical schools exist already in NS (Dalhousie University), NB (Dalhousie Medicine at UNB; Centre de formation médicale du Nouveau-Brunswick at Université du Moncton), and NL (Memorial University) and with the recently announced partnership between UPEI and Memorial University, will also be in PEI by 2024. Faculties of health and health sciences are prominent in many universities in all 4 provinces as are schools of environmental science. As stated above, Atlantic Canada hosts many ocean industry leaders as well as large initiatives such as the Ocean Supercluster, the Centre for Ocean Ventures and Entrepreneurship (COVE), the Ocean Frontier Institute, the recently announced PEI Bioscience Manufacturing Incubator, and others. And we have already begun

to examine the Ocean Health Index approach in the Bay of Fundy (Kidd 2016) which could and should be expanded to look more at human health measures.

CONCLUSION

That ‘Canada is back’ regarding ocean leadership is a welcome occurrence here and around the world. And given its geography, talent, processes and current political will, Canada in general and Atlantic Canada in particular have a golden opportunity to again make our mark on ocean issues, especially that of the ocean and human health. A meta-disciplinary program on OHH seems like a perfect candidate for the Tri-Council New Frontiers in Research Fund whose Transformation stream “...provides large-scale support for Canada to build strength and leadership in interdisciplinary and transformative research” (New Frontiers in Research Fund 2022). In fact, although still reasonably narrow, a good start has already been made with the funding of the Memorial University-led project, *Repurposing Marine By-Products or Raw Materials for the Development and Production of Functional Foods and Bioactives to Improve Human Health and Coastal Community Sustainability*.

As stated by Fleming *et al.* (2019) “...the current and future state of the Global Ocean will in large part determine the current and future sustainability, health and well-being of all humans on Earth.” Atlantic Canada has what it takes to lead a broad Canadian meta-disciplinary initiative on OHH to help ensure that sustainability. Will we rise to the challenge?

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