1   TITLE: Horizon scan of conservation issues for inland waters in

2   Canada.

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25

26 ## ABSTRACT

27 Horizon scanning is a systematic approach increasingly used to explore emerging trends,

28 issues, opportunities, and threats in conservation. We present the results from one such

29 exercise aimed at identifying emerging issues that could have important scientific, social,

30 technological, and managerial implications for the conservation of inland waters in

31 Canada, in the proximate future. We recognized six opportunities and nine challenges,

32 for which we have provide research implications and policy options, such that scientists,

33 policy makers, and the Canadian society as a whole could prepare for a potential growth

34 in each of the topic areas we identified. The issues spanned a broad range of topics from

35 recognizing the opportunities and challenges of community-enabled science and the need

36 to consider the legal rights of nature, to the likely increase of pharmaceuticals in

37 wastewater due to an aging population. These issues represent a first baseline that could

38 help decision makers identify and prioritize efforts, while simultaneously stimulate new

39 research avenues. We hope our horizon scan will pave the way for similar exercises

40 related to the conservation of biodiversity in Canada.

INTRODUCTION

Rivers, lakes, springs, and other inland waters[1] are often classified among the most threatened ecosystems on the planet (Dudgeon et al. 2006; Reid et al. 2018). For example, fewer than 40% of large rivers remain free flowing (CBD 2014) and approximately 80% of the world's human population has experienced high levels of threat to water security for the last decade (Vörösmarty et al. 2010; Abel et al. 2019). Vertebrate populations in fresh water environments have shown to be particularly threatened, with declines in their abundances as dramatic as 83% since 1970 (WWF 2018) and approximately one-third being listed as threatened under the IUCN Red List (Collen et al. 2014). While inland water issues are of top concern for conservation biologists, economists, and national security experts alike, current approaches for managing inland waters have often failed to slow or reverse the declines in freshwater biodiversity (Strayer and Dudgeon 2010). Foreseeing future and emerging threats to inland waters as well as opportunities for improved monitoring or management can allow practitioners to prioritize research, plan strategically, and facilitate enhancements of management and conservation efforts in a pre-emptive way (Reid et al. 2018). For the last decade, horizon scans have facilitated such efforts by systematically exploring emerging trends, issues, opportunities, threats, and events relevant to various topics in conservation. In particular, Sutherland et al. (2019) have annually published horizon scans in global conservation,

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[1] All surface waters contained within lands (FAO 2008).

60 touching upon subjects that range from microplastic pollution (Sutherland et al. 2011) to

61 the use of robots to target invasive species (Sutherland et al. 2017). Nonetheless,

62 emerging issues specifically related to inland waters have been addressed only loosely

63 and none specifically within the Canadian context.

64   Canada holds 20% of the world's fresh water and is home to more lakes than any

65 other country, approximately 2,400,000 (Figure 1a) (Messager et al. 2016). Although

66 Canada is a water-rich nation, there are a few key disconnects. For one, on a per capita

67 basis, Canadians use more water than most other nations, only second to the U.S.A.

68 (Hoekstra and Mekonnen, 2012; OECD 2016). Yet, the vast majority (92%) of Canadian

69 water resources renew only over longer times scales (e.g., only a small fraction of our

70 water is found in rivers and is replenished quickly whereas the water residence time of

71 lakes is much longer and renews over longer time scales; Sprague 2007). In addition,

72 there is a disparity between the distribution of fresh water in Canada and the distribution

73 of human populations, whereby the supply of water available to most Canadians is much

74 smaller than the national total because a substantial fraction of the renewable water flows

75 to the Arctic (Sprague 2007; Renzetti and Dupont 2017). Moreover, many changes in

76 Canadian inland waters are occurring in remote regions and disproportionately affect

77 Indigenous communities (Figure 1b) (Patrick 2011). Finally, a recent synthesis of

78 Canadian watershed health (based on stream flow, quality, fish and invertebrate

79 abundances) and stressors (e.g.,pollution, water use, fragmentation, invasive species

80 and climate change) has highlighted the heterogeneity of data quality and availability for

5

81 large regions of the country (WWF 2017). Therefore, Canada would benefit from

82 proactive management and readiness to deal with future threats to its inland waters as

83 well as opportunities to improve conservation efforts. Horizon scanning allows us to

84 identify issues that are emerging and whose impact is currently unknown, in the hope of

85 motivating the data collection required to inform policy and research decisions in the

86 future. Here we report the results of a horizon-scan exercise that sought to identify issues

87 and opportunities related to governance/management, technology, and society that might

88 have an effect on the conservation of inland waters, and the biodiversity therein, in

89 Canada within the next 5-10 years.

90

MATERIALS AND METHODS

92 Our horizon scan followed the methodological framework described in Sutherland et al.

93 (2011). In the current exercise, representatives of the *Groupe de recherche*

94 *Interuniversitaire en Limnologie* at McGill University invited 30 researchers with expertise

95 in a wide range of topics related to fresh and/or inland waters to participate in a two-day

96 workshop in Montreal in January 2019. The invitees were selected to maximize

97 representation of expertise, gender and backgrounds (in terms of where participants

98 originated from): 17 agreed to participate. Prior to the workshop, participants submitted

99 up to three issues (positive or negative in nature) that they considered will become

100 important in the conservation of inland waters in Canada in the next 5-10 years, along

6

101   with a description (200-300 words) and a relevant bibliography. These contributions were

102   subsequently collated and consolidated to avoid repetition. The resulting 33 distinct

103   issues were returned to the participants for evaluation and ranking. Each participant

104   anonymously ranked all issues by taking into consideration their novelty (i.e., noting

105   whether the issue was already widely recognized such as climate change), its potential

106   impact, and its likelihood of occurrence. The median scores for these rankings were used

107   as a starting point for discussions during the workshop. Workshop participants broke out

108   into groups to discuss proposed issues and to consider any new issue that arose during

109   the discussions. All participants then scored each issue individually and anonymously.

110   Low scores identified issues that are already well known in Canada, unlikely to be

111   important, and/or unlikely to occur, whereas high scores denoted issues that could have

112   a strong impact and are least mainstream issues in Canada. The submitted scores were

113   converted to ranks and the median rank for each issue was calculated. Through this

114   procedure, the group identified 15 emerging issues and opportunities that are likely to

115   have substantial implications for the conservation of inland waters in Canada. Importantly,

116   we refer to inland waters as all continental waters that may be on the surface or

117   underground. We specifically did not restrict our discussions to fresh waters, as many

118   inland waters in Canada can be quite salty. Given that the expertise of the participants of

119   the workshop was mainly related to research, NL and RP provided input on the

120   manuscript, and refined the policy implications of the 15 issues previously identified.

121

122   We acknowledge that the set of issues identified here could have been influenced by the

123   composition of our group. However, it is worth noting that a recent review of decade's

124   worth of global horizon scanning efforts showed no association between the participants'

125   expertise and the emerging issues selected (Sutherland et al. 2019). Our group was

126   largely from the academic sphere spanning the fundamental-applied continuum, and

127   represented a population that was gender-balanced. Members originated from disparate

128   regions of Canada or international locations, and were from different career stages (i.e. 1

129   PhD student, 4 post-doctoral fellows, 2 science professionals, and 10 university

130   professors). One participant was an Indigenous scientist, and another was a government

131   employee. All issues were subjected to a democratic and confidential voting process,

132   which minimizes biases arising from any one individual (Sutherland et al. 2019). We

133   emphasize that our list of issues is not necessarily exhaustive but rather an important

134   subset, as identified by our participants.

135

136   As a secondary evaluation of the novelty of each of the issues identified we conducted a

137   search in Web of Science of the past five years' worth of manuscripts published in the

138   Canadian Journal of Fisheries and Aquatic Sciences. We searched for issue-specific

139   keywords in the topic or title field tags. All entries were then manually verified to

140   correspond to the target issue. We also quantified the relative frequency of the term

141   climate change (in terms of the relative proportion of articles where this term appears), as

142   a point of comparison for a timely issue that is already well studied.

143

ISSUES: FROM CHALLENGES TO OPPORTUNITIES

144

Chromite Mining in the Ring of Fire

145

146 The 'Ring of Fire' is a 5000 km^2 crescent-shaped chromite deposit (North America's

147 largest) in the Lowlands of Northern Ontario (Beukes et al. 2017). Chromite is needed for

148 producing stainless steel but is mined in few countries. The Ring of Fire is thus the

149 potential target of a massive development project, likely to proceed when the region's

150 infrastructure is modernized. The project will involve several underground mines and

151 possibly an open pit, both of which may cause water contamination through the release

152 of chromium-6 (hexavalent chromium). Chromium-6 is a priority substance in the

153 Canadian Environmental Protection Act because it is soluble, environmentally persistent,

154 and induces a broad suite of toxicological effects on fish and birds (Velma et al. 2009).

155 The Ring of Fire is in close proximity to the traditional territory of nine First Nations

156 communities (James Bay Treaty, 1905). The mineral deposits in the Ring of Fire lie

157 beneath a unique ecoregion that comprises the world's largest peatland and a global

158 breeding hotspot for waterfowl (Beukes et al. 2017).

159

160 **Research implications:**

161   1) Identify preventative and mitigative measures for chromium-6 and other

162   contaminants from mining activities.

9

163   2) Forecast potential downstream or legacy effects (e.g., bioaccumulation)

164   3) Determine the natural occurrence and spatiotemporal variability of chromium-6 in

165   soils, untreated chromite ore, and surface/groundwater, and identify areas of

166   ecological sensitivity.

167 **Policy options:**

168   1) Apply evidence-based decision-making processes regarding mining and ore

169   processing in the region (e.g., advantages of wet milling over dry in terms of

170   potential to generate chromium-6).

171   2) Include First Nations communities in the consultation process following

172   commitments made in the United Nations Declaration on the Rights of Indigenous

173   Peoples (UNDRIP) and the Calls to Action set forth by the Truth and Reconciliation

174   Commission of Canada (TRC 2015).

175   3) Provide rigorously-documented baseline studies to the public.

176

177 Consequences of dynamic winter conditions for aquatic life and its management

178 Winter in Canada is generally characterized by sub-zero temperatures, high snowfall, and

179 ice-covered waterbodies. However, such winters are becoming increasingly rare in face

180 of current rates of climate change in parts of southern Canada. Across such regions, the

181 previously long "deep freeze" is becoming a more dynamic season with episodic freeze-

182 thaw events and rapid fluctuations in temperature, along with shorter periods of ice cover

10

183 (Sharma et al. 2019). Winter is regarded as a strong selective force on aquatic life, yet

184 we know remarkably little about aquatic ecosystems during this season (Hampton et al.

185 2017). Some recent observations – such as extensive winter methane and CO_2 gas

186 production and release in lakes (Denfeld et al. 2018), under-ice nitrification contributing

187 to winter-kill events (Powers et al. 2017), and river ice dynamics altering the distribution

188 of fish (Brown et al. 2011) – reveal that winter effects are still largely unknown. This gap

189 in knowledge about how aquatic ecosystems function in winter, particularly when coupled

190 with dynamic conditions related to climate change, generates important uncertainty for

191 the management of inland waters in Canada.

192

193 **Research priorities:**

194   1) Quantify the variation in freeze-thaw events (frequency, intensity), and associated

195   impacts on aquatic life.

196   2) Harness the power of remote sensing and other tools like Earth Engine to interpret

197   freeze/thaw timing by fusing data from optical satellites and radar satellites (e.g.,

198   Canada's Radarsat and IceSat series).

199   3) Study how animal habitat use and behaviour differ in winter compared to other

200   seasons, and identify conditions and events (such as the development of frazil ice)

201   that may limit survival or reduce post-winter fitness of individuals.

202 **Policy options:**

203   1) Recommend construction windows to protect sensitive aquatic habitats, based on

204   knowledge of winter dynamics and changing climatic conditions.

205   2) Account for winter dynamics in aquatic management during other seasons (e.g.,

206   fish stocking, restoration, biomanipulation).

207   3) Include important winter refuges when considering the protection of critical habitats

208   for species at risk.

209

Considering effects of rapid global change requires integrating evolutionary adaptive capacity

210

211

212   Assessments of aquatic community responses to environmental stressors typically focus

213   on biodiversity at the species level, thereby overlooking a key component of biodiversity:

214   variation within species. Intraspecific variation can act as an evolutionary insurance policy

215   against rapid environmental change, as well as having significant effects on community

216   dynamics and ecosystem services (Schindler et al. 2015; Mimura et al. 2016). For

217   Canada to successfully manage and conserve its inland waters, standard environmental

218   impact assessments could be complemented by "evolutionary impact assessments"

219   (EvoIA). EvoIA entails the assessment of intraspecific variation and its potential for

220   enabling adaptive responses that maintain the long-term health of aquatic communities

221   and ecosystems (Laugen et al. 2014). EvoIA allows for more targeted and efficient use of

222   conservation resources as it identifies not only current contributions of evolution to

223 biodiversity and ecosystem function, but it can also predict how specific management

224 actions will enhance future contributions to the same services – that is "evosystem

225 services".

226

227 **Research priorities:**

228   1) Improve knowledge of within-species genetic differentiation to support the

229   identification of Designatable Units (DUs) used by COSWEIC

230   2) Develop field-ready genomic monitoring kits for rapid and easy assessment of

231   intraspecific diversity.

232 **Policy options:**

233   1) Consider management procedures that account for adaptive capacity of

234   populations (e.g., setting restrictions to avoid selective fishing/harvest, which

235   cause genetic bottlenecks).

236   2) Train practitioners to enhance competency with evolutionary principles and

237   methodology (e.g., through workshops or online training platforms).

238

239 Dynamics of state changes caused by multiple stressors

240 Most research and impact assessments have traditionally focused on how individuals,

241 populations, communities, and ecosystems respond to a single stressor, such as

242 temperature or turbidity or acidity. Yet these and many other stressors likely act

13

243   simultaneously in complex and often unpredictable ways (Folt et al. 1999). Despite

244   multiple stressors being the norm on the Canadian landscape, it is still not well understood

245   how multiple stressors interact to influence organisms, populations, communities, and

246   ecosystems (Ormerod et al. 2010). Multiple stressors have the potential to combine

247   additively, multiplicatively, or in other ways making it difficult for environmental managers

248   to predict responses (Jackson et al. 2016). It may also be possible for multiple stressors

249   to trigger regime shifts between alternative system states or alter tipping points (e.g.,

250   Leichenko et al. 2014) such that shifts are accelerated, delayed, or made more or less

251   abrupt (Piggott et al. 2015). Resource managers will face challenges in determining what

252   to do in the face of regime shifts given the complexity arising from multiple stressors.

253   Finally, multiple stressors have the potential to generate entirely new "non-analog" states

254   to which systems might shift – states that would not be observed even at high levels of a

255   single stressor.

256

257   **Research Priorities:**

258   1) Determine how multiple stressors influence the probability and nature of tipping

259   points that influence shifts between system states.

260   2) Define which combinations of particular stressors generate the strongest non-

261   additive and nonlinear effects on organisms, populations, communities, and

262   ecosystems.

263   **Policy options:**

264   1) Integrate multiple stressors in environmental risk assessments and

265   authorization/permitting decisions.

266   2) Integrate non-additive and non-linear effects of stressor combinations in

267   conservation management.

268

Expansion of land and water use in northern Canada

269

270 Since 1900, surface temperature in the Arctic (60-90 $^{\circ}$N) has been increasing at a rate

271 that is twice that of the global average (Overland et al. 2018). As such, northern areas

272 hold considerable potential for both an expansion of agriculture (Arsenault 2017) and

273 hydroelectric development (Canadian Hydropower Association 2009), amongst other

274 climatic and development-related pressures. Although northern agricultural expansion

275 could be a positive step towards northern food security and assist in feeding the growing

276 global population, important considerations include heightened water use pressures and

277 increased loading of agrochemicals to nearby water bodies. Also, the common perception

278 of hydropower as 'clean renewable energy', combined with increasing political pressure

279 to reduce greenhouse gas emissions, could provide impetus for hydroelectric power

280 development within vast areas of the Arctic (WWF 2017). Such development could

281 produce an array of impacts on northern First Nations and Indigenous communities, as

282 well as affect sensitive populations of invertebrates, fishes, and birds – as has been the

283 case for many existing hydropower projects in Canada and the US (Willacker et al. 2016),

284 and elsewhere in the world (Winemiller et al. 2016).

285

286 **Research priorities:**

287   1) Conduct life cycle assessment research to fully characterize current and potential

288   hydropower impacts in northern Canada.

289   2) Identify crops or strains that have the greatest local benefit while mitigate their

290   impacts on water resources.

291   3) Investigate the effects of agricultural expansion (northward) on land-water linkages

292   (e.g., fragmentation).

293 **Policy options:**

294   1) Develop northern-based farming and agricultural research institutes (e.g.,

295   Northern Farm Training Institute, NWT).

296   2) Develop a national-level plan for intensive land use projects in northern Canada.

297   3) Expand the National Hydrometric Program (Water Survey Canada) to provide

298   more extensive flow and water level data for northern systems.

299

Expectation for increased rigour and transparency in environmental decision making

302   The environmental assessment procedure in Canada has been under increased scrutiny

303 recently, and has launched this topic into the forefront of public policy discussions. Calls

304 for transparency in the use and sharing of data, and in the assessment of regional and

305 cumulative impacts are mounting (Westwood et al. 2019). Additionally, the need to

306 consider the impacts of such projects in the context of larger national goals (e.g.,

307 biodiversity targets, UN Sustainable Development Goals, and reduced carbon emissions)

308 has been consistently highlighted. The changes made in 2012 to the *Canadian*

309 *Environmental Assessment Act, Fisheries Act,* and *Navigable Waters Protection Act* (now

310 *Navigation Protection Act*), as well as the subsequent review and introduction of Bills C-

311 68 and C-69 have attempted to address such problems by putting an emphasis on

312 creating registries to improve public access to environmental information. The aim of

313 these changes is to encourage meaningful public participation in environmental decision-

314 making (Jacob et al. 2018). Putting evidence-based decision making into broader practice

315 will require additional capacity within natural resource management agencies (Cooke et

316 al. 2017), open data efforts, and regional assessments.

317

318 **Research priorities:**

319   1) Determine how data collected from strategic impact assessments can be

320   integrated into national databases, such that it is useful for conservation planning.

321   2) Conduct case studies to investigate the effects of legislative reforms on

322   transparency, accountability, and meaningful public involvement.

323 **Policy options:**

324   1) Provide open access to baseline and monitoring data, methodologies, and

325   metadata.

326   2) Include rigorous scientific methodologies in environmental decision making while

327   facilitating the implementation of Indigenous knowledge.

328   3) Make publicly available all documents used to inform government regulatory

329   impact analysis statements.

330

331 ## Geopolitical tensions over water access and trade

332 Under current climate change and human population growth, access to clean fresh water

333 is a major global concern (World Economic Forum, 2018). Stress on water resources will

334 arise from direct consumption, and indirectly through the consumption of commodities

335 that require substantial quantities of water for their production. Current analysis of national

336 water footprints from around the world have placed Canada as the second largest user

337 of fresh water, only second to the U.S.A. (OECD 2016). Serious water issues are already

338 apparent within Canada, ranging from hundreds of boil-water advisories to the

339   fragmentation of water management across multiple levels of government (Mitchell 2017).

340   Growing global trade networks could further strain access to clean water in Canada,

341   whether nations are geographical neighbours or not. Some recent examples that could

342   spark geopolitical tensions over water include Wisconsin's approval for the diverting of 28

343   million liters of water per day from Lake Michigan to the Mississippi River watershed to

344   support local industry (https://dnr.wi.gov/topic/WaterUse/Racine/). Although in 2013 the

345   Parliament of Canada approved a law prohibiting bulk water exports, some water policy

346   experts argue that considerable uncertainty remains over the strength of the protection

347   afforded by Canadian laws, particularly as new trade deals are negotiated (Rivera 2015;

348   Barlow 2016). Moreover, it is expected that under climate change and with increased

349   global environmental degradation, markets will become highly unstable, and over 200

350   million environmental refugees will seek asylum in Canada by 2050 (Murray 2010). In that

351   context, preserving water security on a global scale can be a lynchpin to an equitable,

352   prosperous and sustainable future, and it is clearly in Canada' interest to contribute to

353   that outcome.

354

355   **Research priorities:**

356   1) Improve understanding of how climate change will influence water demand for

357   agriculture and other intensive practices.

358   2) Identify Canadian waterbodies most likely to be affected by shifting water demands

359   and evaluate scenarios to determine which conservation strategies will be most

360   effective.

361 **Policy options:**

362   1) Determine the most effective policy levers to protect water quality and quantity,

363   while also encouraging a reduced national water footprint

364   2) Engage in stakeholder activities to promote participatory process in water-related

365   issues.

366   3) Explore options for Canada to contribute more fulsomely to the resolution of water

367   issues in other countries.

368

369 ## Increased loading of pharmaceuticals in wastewater

370 Pharmaceuticals are emerging environmental contaminants that are increasingly used in

371 human and veterinary medicine. Today, almost 70% of all Canadian citizens 65 years

372 and older take five or more drugs (CIHI 2018) and by 2031 it is expected that one in four

373 Canadians will be over 65 (Statistics Canada). Many drugs are not efficiently eliminated

374 by sewage treatment plants and are directly discharged into wastewater, finding their way

375 into inland waters (Koné et al. 2013). Despite the relatively low concentrations reported

376 in effluents of sewage treatment plants, several classes of drugs are expected to pose

377 high environmental risks including analgesics (e.g., salicylic acid, naproxen, and

20

378   ibuprofen), antibiotics (e.g., sulphamethoxazole and ciprofloxacin), antidepressants (e.g.,

379   fluoxetine), and hormone disrupters (Koné et al. 2013). The effects of such compounds

380   on aquatic organisms is often evaluated using acute toxicity assays. However, a major

381   concern is that their chronic toxicity and their subtle effects are not understood (Fent et

382   al. 2006). Although many pharmaceuticals are considered of low risk for lower-trophic-

383   level taxa, the potential remains for food-web-mediated effects on primary consumers

384   (Hamilton et al. 2016). Potential mitigation options include the development of advanced

385   treatment technologies of municipal wastewaters, source reductions, and proper

386   ecotoxicological testing of new generation drugs.

387

388   **Research priorities:**

389   1) Determine the safety limits for drugs and drug combinations in the environment.

390   2) Determine the impacts of key drugs, with an emphasis on sublethal and chronic

391   thresholds in individuals, populations and communities.

392   3) Develop advanced wastewater treatment techniques/options across different

393   scales, from communities to cities.

394   **Policy options:**

395   1) Development of efficient treatment and mitigation approaches.

396   2) Reduce improper disposal or collection of unused pharmaceuticals.

397   3) Increase monitoring of pharmaceuticals in effluents.

398

Increased risk of petroleum spills arising from new pipelines

400 With growing oil production in Canada, there is increasing demand for transport of crude

401 oil through pipelines to major refineries and terminals across North America. While most

402 research on threats posed by oil spills has focused primarily on high-profile events in

403 coastal marine environments, risks to inland aquatic ecosystems such as the Great

404 Lakes have been largely overlooked (IJC 2018). Nonetheless, existing and planned oil

405 transport infrastructure poses important threats of ecologically-significant spills in

406 sensitive fish habitats and species-rich environments such as estuaries, rivers, bays, and

407 wetlands (IJC 2018). Crude oil spills can impact all levels of an aquatic food web, and

408 their effects on benthic invertebrates can persist beyond 25 years (Bertrand and Hare,

409 2017). Moreover, laboratory experiments have revealed negative short-term and latent

410 impacts on growth and development of several fish species, including the economically-

411 and culturally-important salmonids (Alderman et al. 2018). However, the scope,

412 magnitude, and persistence of the effects of crude oil on freshwater biota, the recovery

413 capacities of aquatic habitats, and the behaviour and fate of oil products in freshwater

414 systems remain poorly understood.

415

416 **Research priorities:**

417   1. Develop technologies and test models for rapid and accurate detection of spills

418   (especially slow leaks that may go unnoticed for some time).

419   2. Understand the ecological effects of spills during different seasons (e.g., spring

420   runoff versus frozen winters) to inform possible seasonal limits on oil transport.

421   **Policy options**:

422   1. Consider sensitive aquatic habitats when planning pipeline routing and

423   configurations (e.g., salmon bearing streams and spawning/incubation/rearing

424   seasons).

425   2. Ensure that the standards of response planning for inland spills meet those upheld

426   for marine environments.

427   3. Incorporate modern safety standards and monitoring protocols into authorizations

428   for the construction and operation of pipelines to minimize the risk of spills.

429

430   Increasing pressure for Canada to enshrine constitutional rights to a healthy

431   environment and the rights of nature

432   Health Canada has estimated that, each year, over 14,000 premature deaths in Canada

433   are the result of air pollution, toxic chemicals, and other environmental risk factors (Health

434   Canada 2017). International comparisons have shown that Canadian environmental laws

435   and policies are lagging behind other industrialized countries (Boyd 2015). For example,

436   when a person or company obtains a legal right to land or water in Canada, these private

437   rights often trump public rights regarding that water or land. As a result, the public often

438   has little recourse for the negative impacts that the private use inflicts on the wider

439   community. Many communities and environmental organizations are seeking innovative

440   institutional arrangements that can address the environmental degradation of inland

441   waters and improve our stewardship of ecosystem health (Curran 2015). As a result, more

442   than 100 nations around the world now recognize constitutional environmental rights and

443   responsibilities. Several provinces have forms of enforceable environmental rights and

444   150 Canadian municipalities have passed declarations recognizing their residents' right

445   to live in a healthy environment. Pressure is now increasing for the federal government

446   to legislate similar rights and to include protection provisions in the Canadian constitution.

447

448   **Research priorities:**

449   1) Establish quantitative, objective definitions for terms such as "healthy" and "harm"

450   as they relate to inland waters so they can be applied in legal and policy

451   frameworks.

452   2) Develop and track standardized-nation-wide testing of key health indicators for

453   inland waters

454   **Policy options:**

455   1) Expand and unify municipal and provincial declarations of environment rights to all

456   jurisdictions.

457   2) Determine what constitutes ecological harm from a legal perspective.

458   3) Apply the emerging approach "legal personality" to provide water systems with

459   legal standing and enforceable rights.

460

461 Invasions by novel pathogens will challenge biosecurity and conservation

462 Invasive pathogens are being recorded with greater frequency in ecosystems worldwide

463 (Fisher et al 2012). Current rates of climate change, nutrient pollution, and global

464 transport of organisms are creating conditions in Canada that are conducive to the spread

465 and proliferation of pathogens that threaten endemic freshwater biodiversity and fisheries

466 (Schmeller et al. 2018). Many pathogens can go undetected before producing die-offs,

467 or can remain an unrecognized cause of mortality (Adams et al. 2018). Immense numbers

468 of undescribed taxa of bacteria, protozoa, oomycetes, and fungi are potentially

469 transported between disparate regions and can undergo rapid evolutionary changes that

470 affect their virulence or host repertoire in Canada (Hoberg & Brooks 2015; Robin et al.

471 2017). One such important emerging threat to Canadian freshwater biodiversity is

472 *Batrachochytrium salamandrivorans*, the chytrid fungus responsible for recent

473 catastrophic declines in wild salamanders in Europe after being introduced through the

474 pet trade (Martel et al. 2014). Although we recognize that Canada has recently restricted

475 the import of salamanders to limit the introduction of *B. salamandrivorans* into Canada

476 (https://www.cbsa-asfc.gc.ca/publications/cn-ad/cn17-17-eng.html), continued vigilance

477 is needed. The limited ability to detect emerging invasive pathogens will impede

478 conservation efforts to prevent or promptly contain and manage outbreaks across the

479 Canadian landscape.

480

481 **Research priorities:**

482   1) Determine how global stressors promote the emergence and virulence of novel

483   pathogens, and whether synergistic interactions are at play.

484 **Policy options:**

485   1) Reassess existing regulations concerning inspection of travellers and goods at

486   ports of entry to maximize detection of new pathogens.

487   2) Exercise vigilance towards illegal importations of amphibians (e.g., Government of

488   Canada 2017) and aquatic organisms in general using current mechanisms (e.g.,

489   the Aquatic Invasive Species Regulations SOR/2015-121 under the Fisheries Act).

490

491 New satellite and remote sensing technologies can transform our understanding

492 of aquatic ecosystems and their dynamics.

493 Recent advances in satellite and remote sensing technologies have set the stage for

494 transforming aquatic ecosystem research and monitoring. In particular, several new

495 satellites (launched since 2013) improve our ability to estimate lake properties. For

496 example, Landsat-8 provides a greater depth of possible measurement values within

497 images, and thus improve the signal-to-noise ratio (Roy et al. 2014). More recently,

498 Sentinel-2a and -2b have enhanced the frequency of imaging a given point on Earth's

499   surface, when data are combined across satellites (Pahlevan et al. 2017). A second major

500   area of advancement is the development of Google Earth Engine (Gorelick et al. 2016),

501   which enables users to access and manipulate the full suite of satellite images remotely,

502   greatly minimizing data storage and processing demands. Google Earth Engine has

503   already allowed for planetary-scale assessments of global surface water distribution at

504   fine resolution across multiple decades (Pekel et al. 2016), and it holds considerable

505   promise for creating new time series of lake characteristics at regional, continental, and

506   planetary scales.

507

508   **Research priorities:**

509   1) Seek out effective ways to expand remote sensing training into high school and

510   early undergraduate levels.

511   2) Develop remote sensing hardware and software to identify sensitive aquatic

512   habitats, such as groundwater upwelling zones, salmon redds, and winter thermal

513   refugia.

514   3) Improve multi-scale (reach, watershed, ecoregion) assessments of aquatic habitat

515   condition and stressors by incorporating new information available from emerging

516   remote sensing technologies.

517   **Policy options:**

518   1) Incorporate systematic remote sensing into government monitoring programs at

519   all levels (federal, provincial, territorial, municipal, Indigenous).

27

520   2) Develop planning methodologies that incorporate remotely-sensed data and

521   inform the prioritization of conservation and restoration actions.

522

523   ## Opportunities and challenges from technology-enabled community science

524   Over 85% of Canadians own a smartphone (CRTC 2019); which translates into

525   approximately 31.7 million potential sampling platforms distributed across the country.

526   Smartphones generate opportunities for community-based science and could help to fill

527   important data gaps on aquatic ecosystems that exist for most Canadian watersheds

528   (WWF 2017). Relying on engaged communities will be critical as monitoring resources

529   are sparse, and resource management agencies are unable to provide complete

530   coverage of the country – especially in the vast and difficult-to-access northern regions.

531   Moreover, the increase in accuracy and the development of novel sensors in

532   smartphones, in synergy with technological advances (e.g., computer vision), will enable

533   important improvements in the data quality of community-based science (Kosmala et al.

534   2016), while facilitating the validation and geo-localization of entries. Beyond data

535   acquisition, however, including schools and communities directly in the scientific process

536   provides excellent opportunities to educate and engage the public. Existing successful

537   programs, such as iFish (http://www.ifishalberta.com/; Papenfuss et al. 2015) and Water

538   Rangers (https://waterrangers.ca/en/) provide valuable models that could be further

539   developed.

28

540

Research priorities:

1) Develop robust processes for curation and validation of community-generated aquatic data.

2) Explore best practices for passive versus active engagement of community members.

3) Study how to incentivize the broader population and keep community scientists engaged.

Policy options:

1) Further engage Northerners as technological stewards with formal funding opportunities.

2) Incorporate instantaneous public reporting into early detection and rapid response procedures for aquatic invasive species.

3) Explore options for linking with "Big Data" initiatives of commercial data providers, such as Google and Amazon, to increase the development and distribution of third-party applications and decision support tools.

556

Opportunities from national data integration

The landscape of nation-wide ecological data collection and curation is changing through the collaborative efforts among academic research networks, government scientists, and

560   NGO partners. Large research networks focused on inland waters are paving the way to

561   a new scale of ecological inference, mainly by integrating spatial, temporal, historical, and

562   "dark" (collected but unused: Heidorn 2008) ecological data. This integration will naturally

563   involve partnerships and multi-sector research co-design, stimulating in this way a long-

564   term vision for data sharing and management while increasing data accessibility to

565   researchers, stakeholders, and policy makers. With systematic and continuous nation-

566   wide sampling, ecological variability across inland waters will be better understood

567   (Soranno et al. 2015), and gaps between fundamental ecological research and its

568   application by managers will be greatly narrowed (Cadotte et al. 2017). Current examples

569   that provide a model for scaling up include the NSERC Canadian LakePulse Network in

570   Canada (Huot et al. 2019) and the National Lakes Assessment Program in the USA.

571   Programs such as these will be instrumental in ensuring that Canada meets its

572   commitments under the 2030 Agenda and the implementation of the associated UN

573   Sustainable Development Goals.

574

575   **Research priorities:**

576   1) Develop best approaches for extrapolating from monitored to non-monitored inland

577   waters.

578   2) Improve forecasting of responses to environmental stressors such as invasive

579   species, climate change, or pollution through large scale surveys.

580   **Policy options:**

581   1) Support the development and management of large, comparative datasets that

582   will facilitate evidenced-based decision making.

583   2) Promote data sharing, trust and rights across sectors.

584   3) Establish open and long-term nation-wide monitoring databases.

585

586   ## Whole community monitoring opportunities arising from environmental DNA

587   The application of environmental DNA (eDNA) metabarcoding to biomonitoring of aquatic

588   systems has remarkable potential. Although techniques are still developing (Goldberg et

589   al. 2016; Pawloski et al. 2018; Cristescu & Hebert 2018), there are tremendous

590   opportunities for the use and development of eDNA surveys in Canada, as a complement

591   or supplement to conventional, time- and resource-intensive sampling. Scaled up, eDNA

592   metabarcoding has the potential to transform the frequency and range at which aquatic

593   communities are monitored, generating an unprecedented amount of biodiversity data.

594   Additionally, because of the relatively simple field equipment required, it is feasible to

595   sample eDNA across very large spatial scales and at high temporal frequencies. There

596   remain several challenges, such as high rates of false-positives and false-negatives

597   (Cristescu & Hebert 2018). However, with the establishment of coordinated efforts to

598   standardize methods for metazoan community detection, the approach could soon be

599   ready for widespread adoption and routine use in biodiversity assessments (Rees et al.

600   2014). The scale of data generation will foster collaborations with bioinformaticians, while

601 taxonomists will be crucial for building and improving reference databases. These

602 techniques have the potential to allow conservation practitioners to better inform policies

603 related to invasive species spread, climate-related range shifts, and seasonal signals,

604 amongst other critical conservation challenges.

605

606 **Research priorities:**

607   1) Develop more comprehensive genetic libraries of aquatic species, with a focus on

608   building localized and well validated species libraries.

609   2) Address high incidences of false positives and false negatives, and deal with the

610   complications arising from DNA decay, DNA advection, and primer bias.

611   3) Explore the use of environmental RNA (eRNA) as a means to examine the living

612   biodiversity in an ecosystem (i.e. tracking species relative abundances through

613   space and time).

614 **Policy options:**

615   1) Consider the systematic use of eDNA in routine monitoring for the early detection

616   of invasive species or climate-induced range shifts.

617   2) Manage fisheries and ecosystem heath based on detailed understanding of

618   community composition and dynamics.

DISCUSSION

619

620 Inland waters constitute an extremely valuable natural resource, in economic, cultural,

621 aesthetic, scientific, and educational terms. Fresh water has been identified by Canadians

622 as their most important natural resource for 10 years running (RBC Blue Water Project

623 2017). As stewards of one fifth of the planet's inland waters, Canadians also bear a large

624 international responsibility.

625

626 Despite the importance of inland waters, monitored populations of freshwater vertebrates

627 have experienced marked declines since the 1970s, relative to terrestrial and marine

628 ecosystems (WWF 2018). Forecasting future conservation issues concerning inland

629 waters can identify important gaps in our knowledge, identify new tools and help

630 proactively manage these ecosystems through informed policy (Sutherland et al. 2007).

631 Moreover, while efforts have been made to identify and highlight threats to global

632 freshwater biodiversity (e.g., Reid et al. 2018), or broadly considered Canadian

633 conservation issues (Boxall et al. 2012), these earlier studies have been not focused on

634 Canadian aquatic systems, despite the vast freshwater resources within the region. The

635 impetus for our horizon scanning exercise was to address this gap and herein we have

636 identified 15 issues (for a summary see Table 1). Our list of issues comprises a carefully

637 derived subset of both challenges and opportunities that we assess as un-recognized or

638 under-appreciated, and that require immediate attention to effectively prepare for the near

33

639   future. Some of the issues we have listed are not unknown and have been addressed in

640   other countries, yet they are relatively new in the Canadian context. Indeed, based on our

641   search in Web of Science, we found that many issues have been addressed infrequently.

642   For example, with the exception of changing winter dynamics, none of the issues have

643   been addressed in more than 10 articles published in CJFAS in the last 5 years, compared

644   to climate change that has been the subject of 126 publications (Figure 2).

645

646   We identified potential socio-political conflicts that could pose significant threats to the

647   management of Canada's water resources. Examples include debates among national

648   and international stakeholders on access to and extraction of water, increased risk of oil

649   spills arising from the development of new pipelines, and tensions over chromite mining

650   in Northern Ontario. However, we also identified opportunities to improve the

651   management of Canada's water resources in the face of rapid geopolitical and

652   environmental changes. For example, community science (often referred to as citizen

653   science) can play an important role in filling data gaps related to watersheds and aquatic

654   ecosystems – including in the northern regions of the country. Similarly, the integration of

655   ecological data at the national scale can stimulate a long-term collaborative vision in data

656   sharing and water management, and can allow for an increase in data accessibility to

657   researchers, stakeholders, and policy makers. National-scale monitoring programs for

658   inland waters are essential to achieve commitments under the 2030 Agenda for

659 Sustainable Development and its 17 Sustainable Development Goals (Dickens et al.

660 2019; Huot et al. 2019).

661

662 A recurrent issue during our discussions was the influence of climate change on many of

663 the emerging issues we have identified; its ramifying effects are still unclear and will

664 almost certainly vary across the country (e.g., Sharma et al. 2019). In this context, it

665 should not be surprising that we identified an expansion of land and water use in the north

666 as an emerging issue. In light of climate change and warming temperatures in northern

667 regions, integrating evolutionary adaptive capacity into environmental impact

668 assessments, while making these more transparent, will allow for more targeted and

669 efficient use of resources in conservation practices in an increasingly unpredictable future.

670

671 The emerging issues we have identified certainly reflect, in part, the interests and

672 knowledge of the participants engaged in the exercise, which in our case was comprised

673 mainly of academics. In future efforts, we envisage engaging with a group with broader

674 range of professions and backgrounds, with greater representation of Indigenous

675 peoples, NGOs, and government employees– so that more perspectives are represented.

676 Nevertheless, our group did identify a wide range of issues that are only loosely related

677 to academic and pure research questions. We see this publication as a first step to

678 engage the broader Canadian community to address the future of conservation of inland

679 waters in Canada.

35

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958 # Figures

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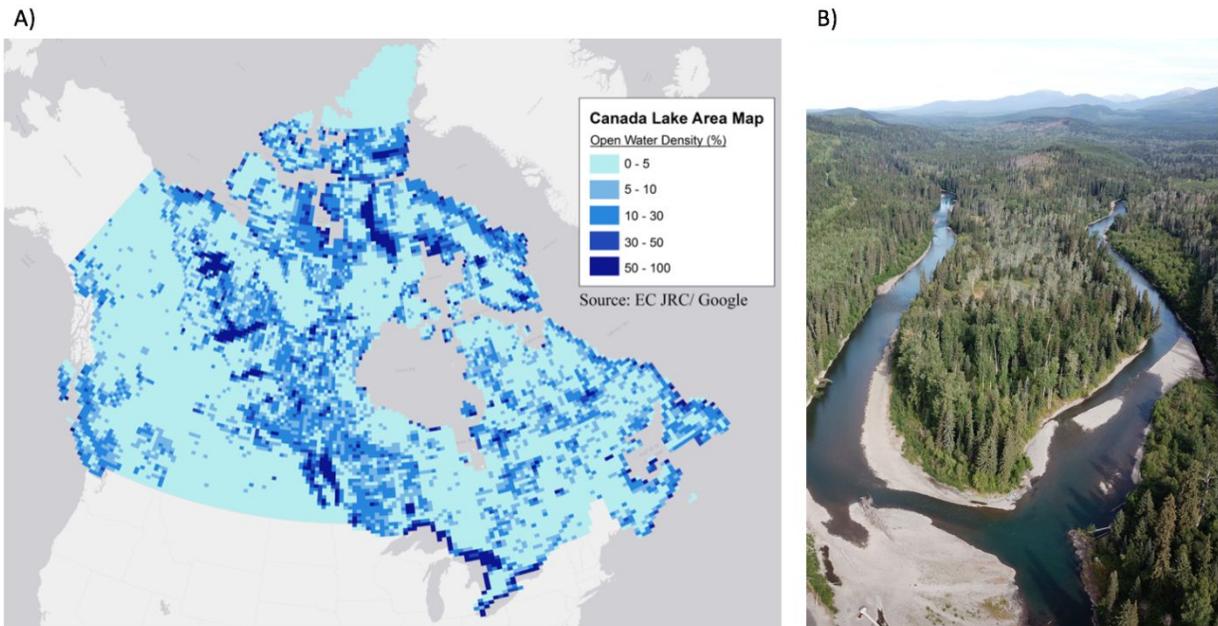
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961 Figure 1. Canada is home to 20% of the world's freshwater and over 2,400,000 lakes.

962 Nonetheless, extreme events and reductions in water levels have been recently

963 documented even in remote locations or in areas with few human settlements. A)

964 Proportion of permanent open fresh water across Canada within each 1:50,000 sheet of

965 the National Topographic System. Water presence was estimated from multiple Landsat

966 30-m resolution images by the European Commission's Joint Research Centre and

967 summarized in Google Earth Engine. B) Extreme droughts (levels 3 and 4) were reported

968 in 2018 for the Skeena-Nass river system in northern B.C., preventing salmon from

969 reaching upstream fall spawning sites.

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Percentage of all manuscripts published in CJFAS over the last 5 years
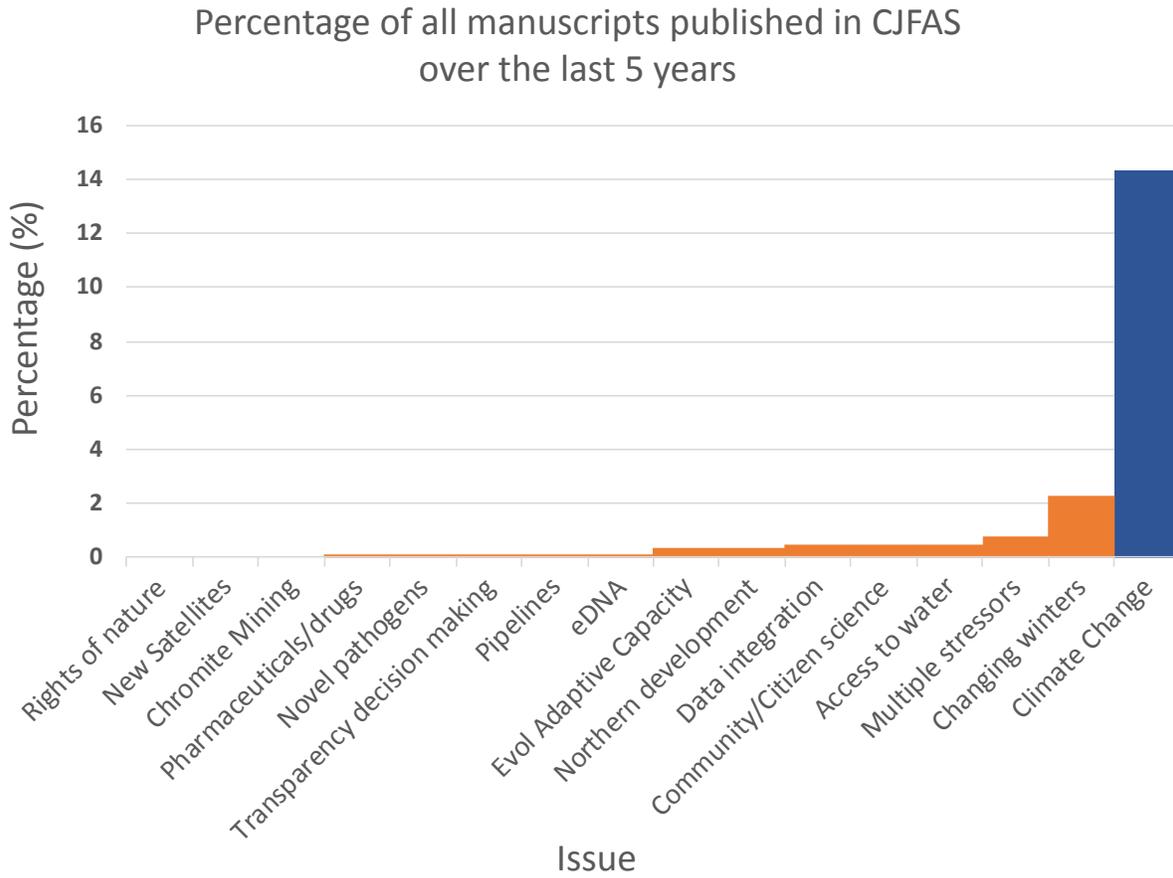
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973 Figure 2. Literature scan for all publications in CJFAS over the last 5 years that address

974 the 15 issues identified in the horizon scan. Labels on the x axis represent the keywords

975 used to search for each issue. Climate change was used as a control issue for novelty as

976 it is widely known and has received significant attention.

977

ISSUE	RESEARCH PRIORITY	POLICY OPTION
CHROMITE MINING IN THE RING OF FIRE	1. Identify preventative and mitigative measures for chromium-6 and other contaminants from mining activities. 2. Forecast potential downstream or legacy effects (e.g.,bioaccumulation). 3. Determine the natural occurrence and spatiotemporal variability of chromium-6 in soils, untreated chromite ore, and surface/groundwater, and identify areas of ecological sensitivity.	1. Apply evidence-based decision-making processes regarding mining and ore processing in the region (e.g., advantages of wet milling over dry in terms of potential to generate chromium-6). 2. Include First Nations communities in the consultation process following commitments made in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and the Calls to Action set forth by the Truth and Reconciliation Commission of Canada (TRC 2015). 3. Provide rigorously-documented baseline studies to the public.

CONSEQUENCES OF DYNAMIC WINTER CONDITIONS FOR AQUATIC LIFE AND ITS MANAGEMENT	1. Quantify the variation in freeze-thaw events (frequency, intensity), and associated impacts on aquatic life. 2. Harness the power of remote sensing and other tools like Earth Engine to interpret freeze/thaw timing by fusing data from optical satellites and radar satellites (e.g., Canada's Radarsat and IceSat series). 3. Study how animal habitat use and behaviour differ in winter compared to other seasons, and identify conditions and events (such as the development of frazil ice) that may limit survival or reduce post-winter fitness of individuals.	1. Recommend construction windows to protect sensitive aquatic habitats, based on knowledge of winter dynamics and changing climatic conditions. 2. Account for winter dynamics in aquatic management during other seasons (e.g., fish stocking, restoration, biomanipulation). 3. Include important winter refuges when considering the protection of critical habitats for species at risk.
CONSIDERING EFFECTS OF RAPID GLOBAL CHANGE REQUIRES INTEGRATING EVOLUTIONARY ADAPTIVE CAPACITY	1. Improve knowledge of within-species genetic differentiation to support the identification of Designatable Units (DUs) used by COSWEIC. 2. Develop field-ready genomic monitoring kits for rapid and easy assessment of intraspecific diversity.	1. Consider management procedures that account for adaptive capacity of populations (e.g., setting restrictions to avoid selective fishing/harvest, which cause genetic bottlenecks). 2. Train practitioners to enhance competency with evolutionary principles and methodology (e.g., through workshops or online training platforms).

DYNAMICS OF STATE CHANGES CAUSED BY MULTIPLE STRESSORS	1. Determine how multiple stressors influence the probability and nature of tipping points that influence shifts between system states. 2. Define which combinations of particular stressors generate the strongest non-additive and nonlinear effects on organisms, populations, communities, and ecosystems.	1. Integrate multiple stressors in environmental risk assessments and authorization/permitting decisions. 2. Integrate non-additive and non-linear effects of stressor combinations in conservation management.
EXPANSION OF LAND AND WATER USE IN NORTHERN CANADA	1. Conduct life cycle assessment research to fully characterize current and potential hydropower impacts in northern Canada. 2. Identify crops or strains that have the greatest local benefit while mitigate their impacts on water resources. 3. Investigate the effects of agricultural expansion (northward) on land-water linkages (e.g., fragmentation).	1. Develop northern-based farming and agricultural research institutes (e.g., Northern Farm Training Institute, NWT). 2. Develop a national-level plan for intensive land use projects in northern Canada. 3. Expand the National Hydrometric Program (Water Survey Canada) to provide more extensive flow and water level data for northern systems.
EXPECTATION FOR INCREASED RIGOUR AND TRANSPARENCY IN ENVIRONMENTAL DECISION MAKING	1. Determine how data collected from strategic impact assessments can be integrated into national databases, such that it is useful for conservation planning. 2. Conduct case studies to investigate the effects of legislative reforms on transparency, accountability, and meaningful public involvement.	1. Provide open access to baseline and monitoring data, methodologies, and metadata. 2. Include rigorous scientific methodologies in environmental decision making while facilitating the implementation of Indigenous knowledge. 3. Make publicly available all documents used to inform government regulatory impact analysis statements.

GEOPOLITICAL TENSIONS OVER WATER ACCESS AND TRADE	1. Improve understanding of how climate change will influence water demand for agriculture and other intensive practices. 2. Identify Canadian waterbodies most likely to be affected by shifting water demands and evaluate scenarios to determine which conservation strategies will be most effective.	1. Determine the most effective policy levers to protect water quality and quantity, while also encouraging a reduced national water footprint. 2. Engage in stakeholder activities to promote participatory process in water-related issues. 3. Explore options for Canada to contribute more fulsomely to the resolution of water issues in other countries.
INCREASED LOADING OF PHARMACEUTICALS IN WASTEWATER	1. Determine the safety limits for drugs in the environment. 2. Determine the impacts of key drugs, with an emphasis on sublethal and chronic thresholds in individuals, populations and communities. 3. Develop advanced wastewater treatment techniques/options across different scales, from communities to cities.	1. Development of efficient treatment and mitigation approaches. 2. Reduce improper disposal or collection of unused pharmaceuticals. 3. Increase monitoring of pharmaceuticals in effluents.
INCREASED RISK OF PETROLEUM SPILLS ARISING FROM NEW PIPELINES	1. Develop technologies and test models for rapid and accurate detection of spills (especially slow leaks that may go unnoticed for some time). 2. Understand the ecological effects of spills during different seasons (e.g., spring runoff versus frozen winters) to inform possible seasonal limits on oil transport.	1. Consider sensitive aquatic habitats when planning pipeline routing and configurations (e.g., salmon bearing streams and spawning/incubation/rearing seasons). 2. Ensure that the standards of response planning for inland spills meet those upheld for marine environments. 3. Incorporate modern safety standards and monitoring protocols into authorizations for

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		the construction and operation of pipelines to minimize the risk of spills.
INCREASING PRESSURE FOR CANADA TO ENSHRINE CONSTITUTIONAL RIGHTS TO A HEALTHY ENVIRONMENT AND THE RIGHTS OF NATURE	1. Establish quantitative, objective definitions for terms such as "healthy" and "harm" as they relate to inland waters so they can be applied in legal and policy frameworks. 2. Develop and track standardized-nation-wide testing of key health indicators for inland waters.	1. Expand and unify municipal and provincial declarations of environment rights to all jurisdictions. 2. Determine what constitutes ecological harm from a legal perspective. 3. Apply the emerging approach "legal personality" to provide water systems with legal standing and enforceable rights.
INVASIONS BY NOVEL PATHOGENS WILL CHALLENGE BIOSECURITY AND CONSERVATION	1. Determine how global stressors promote the emergence and virulence of novel pathogens, and whether synergistic interactions are at play.	1. Reassess existing regulations concerning inspection of travellers and goods at ports of entry to maximize detection of new pathogens. 2. Exercise vigilance towards illegal importations of amphibians (e.g., Government of Canada 2017) and aquatic organisms in general using current mechanisms (e.g., the Aquatic Invasive Species Regulations SOR/2015-121 under the Fisheries Act).

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NEW SATELLITE AND REMOTE SENSING TECHNOLOGIES CAN TRANSFORM OUR UNDERSTANDING OF AQUATIC ECOSYSTEMS AND THEIR DYNAMICS.

1. Seek out effective ways to expand remote sensing training into high school and early undergraduate levels.

2. Develop remote sensing hardware and software to identify sensitive aquatic habitats, such as groundwater upwelling zones, salmon redds, and winter thermal refugia.

3. Improve multi-scale (reach, watershed, ecoregion) assessments of aquatic habitat condition and stressors by incorporating new information available from emerging remote sensing technologies.

1. Incorporate systematic remote sensing into government monitoring programs at all levels (federal, provincial, territorial, municipal, Indigenous).

2. Develop planning methodologies that incorporate remotely sensed data and inform the prioritization of conservation and restoration actions.

OPPORTUNITIES AND CHALLENGES FROM TECHNOLOGY-ENABLED COMMUNITY SCIENCE	1. Develop robust processes for curation and validation of community-generated aquatic data. 2. Explore best practices for passive versus active engagement of community members. 3. Study how to incentivize the broader population and keep community scientists engaged.	1. Further engage Northerners as technological stewards with formal funding opportunities. 2. Incorporate instantaneous public reporting into early detection and rapid response procedures for aquatic invasive species. 3. Explore options for linking with "Big Data" initiatives of commercial data providers, such as Google and Amazon, to increase the development and distribution of third-party applications and decision support tools.
OPPORTUNITIES FROM NATIONAL DATA INTEGRATION	1. Develop best approaches for extrapolating from monitored to non-monitored inland waters. 2. Improve forecasting of responses to environmental stressors such as invasive species, climate change, or pollution through large scale surveys.	1. Support the development and management of large, comparative datasets that will facilitate evidenced-based decision making. 2. Promote data sharing, trust and rights across sectors. 3. Establish open and long-term nation-wide monitoring databases.

| WHOLE COMMUNITY MONITORING OPPORTUNITIES ARISING FROM ENVIRONMENTAL DNA | 1. Develop more comprehensive genetic libraries of aquatic species, with a focus on building localized and well validated species libraries.

2. Address high incidences of false-positives and false-negatives, and deal with the complications arising from DNA decay, DNA advection, and primer bias.

3. Explore the use of environmental RNA (eRNA) as a means to examine the living biodiversity in an ecosystem (i.e. tracking species relative abundances through space and time). | 1. Consider the systematic use of eDNA in routine monitoring for the early detection of invasive species or climate-induced range shifts.

2. Manage fisheries and ecosystem heath based on detailed understanding of community composition and dynamics. |

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979 Table 1. Tabular summary of the 15 issues identified with their corresponding Research Priorities and Policy Options. Issues

980 are presented in alphabetical order.

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