Application - New Frontiers in Research Fund - NordForsk-led Joint Initiative - 2024

Application ID:	NFRFJ-2024-00088	**Administering Organization:**	McGill University
Applicant:	Roy, Denis	**Funding Opportunity:**	New Frontiers in Research Fund - NordForsk-led Joint Initiative
Title:	CASTAF: Climate Change Adaptation Strategies for Arctic Fisheries		

Application Details

Application title
CASTAF: Climate Change Adaptation Strategies for Arctic Fisheries

Language of the application
English

Does your proposal involve Indigenous research as defined by SSHRC?
Yes

International Call Details

Primary Application ID
195338

Primary Application - Lead applicant
J. Rasmus Nielsen

Proposed role of Canadian participants in the proposed project
Understanding how climate change will impact the availability of Arctic marine living resources is a worldwide concern (i.e., NordForsk call). A warming Arctic will change harvested species' production, distribution, and availability, which will have important ecological, economic, and cultural consequences for northern communities, countries, and international relations. CASTAF: Climate Change Adaptation Strategies for Arctic Fisheries project (#195338), aims to use broad-scale ecosystem modeling to predict the impacts of Arctic warming on northern-based fisheries in 3 large Arctic marine regions (Barents Sea, Icelandic Sea, and Baffin Bay). CASTAF plans to use the Atlantis modeling framework, which requires 3 types of data inputs: physical processes, biological processes supporting exploited resources, and the cultural/economic use of those resources. Based on this, CASTAF can formulate and offer adaptive management strategies to maintain marine living resources' sustainability under different Arctic warming scenarios. However, because Arctic marine resources are less extensively exploited in Canada than in other Arctic countries, there is also a shortage of primary biological data available as inputs into broader-scale ecological models, such as Atlantis. FISHSENS, an integrated part of the CASTAF project, will build the much-needed fundamental ecological data on the living resources that are, and are likely to become, important targets of marine harvesting in Arctic Canada. FISHSENS: Building Ecological Knowledge to Assess the Sensitivity of Canadian Marine Fishes to Atlantification, has Northern co-PIs, and will work closely with northern communities to co-produce genomic, chemical tracer, and movement ecology data for a list of key Arctic marine species supporting productive ecosystems in the Eastern Canadian Arctic. These data will be used to better understand the trophic interactions, population dynamics, and behaviours of key marine species, which are the very data needed as critical inputs into the large region-wide Atlantis models. Thus, results of the FISHSENS project will feed directly into the Atlantis model being developed for the Eastern Canadian Arctic and the Baffin Bay ecosystems. Together, the CASTAF and FISHSENS projects pair European expertise on broad-scale marine ecosystem modeling with Canadian ecologists, economists, and northern resource managers to better understand and safeguard Arctic marine-based fisheries for the future.

List of Participants

Participant	Primary Affiliation
Roy, Denis - Nominated Principal Investigator Assistant Professor McGill University, Natural Resource Sciences Canada	Assistant Professor McGill University , Natural Resource Sciences Canada
Martin, Zoya - Co-Principal Investigator Director of Fisheries and Sealing Government of Nunavut, Economic Development and Transportation Canada	Director of Fisheries and Sealing Government of Nunavut , Economic Development and Transportation Canada
Hussey, Nigel - Co-Principal Investigator Associate Professor University of Windsor, Integrative Biology Canada	Associate Professor University of Windsor , Integrative Biology Canada
Parlee, Brenda - Co-Principal Investigator Professor, Bieler Research Chair in Northern Climate Change and Sustainability McGill University, Department of Natural Resource Sciences Canada	Professor University of Alberta , Resource Economics and Environmental Sociology Canada
McKinney, Melissa - Co-Principal Investigator Associate Professor McGill University, Natural Resource Sciences Canada	Associate Professor McGill University , Natural Resource Sciences Canada
MUKHOPADHYAY, KAKALI - Co-Applicant Associate Professor -Tenured McGill University, Department of Agricultural Economics Canada	Associate Professor -Tenured McGill University , Department of Agricultural Economics Canada
Beiko, Robert - Co-Applicant Professor Dalhousie University, Computer Science Canada	Professor Dalhousie University , Computer Science Canada

Collaborators

Name	Position	Department and Organization

No information to display

Socioeconomic Objectives

Primary	Code	Group
✔	RDS10805	Fisheries (including aquaculture and wild caught)
	RDS10104	Climate and climate change
	RDS10201	Environmentally sustainable human activities
	RDS10205	Control and care of the environment
	RDS11003	Tourism

Fields of Research

Primary	Code	Division / Group / Class / Subclass (Field)
✔	RDF1051001	Natural sciences / Earth and related environmental sciences / Natural environment sciences / **Indigenous peoples environmental knowledge**
✔	RDF1060401	Natural sciences / Biological sciences / Ecological applications / **Ecological impacts of climate change**
✔	RDF1060603	Natural sciences / Biological sciences / Genetics / **Conservation genetics**
	RDF1020899	Natural sciences / Computer and information sciences / Bioinformatics / **Bioinformatics, n.e.c.**
	RDF5020111	Social sciences / Economics and business administration / Economics / **Environment and natural resources economics**

Keywords

Arctic warming
Fish genomics
Ecological tracers
Atlantis modeling framework
Indigenous Knowledge
Knowledge co-production
Telemetry
Arctic fish sensitivity to climate change
Economic valuation
Resource availability

Summary of Proposal

The world is warming, and Arctic marine ecosystems are doing so at four times the global average. This is leading to sub-Arctic species encroachment into Arctic marine areas, creating no-analog ecosystems with unpredictable outcomes. Already at the edge of their thermal tolerances, many native species must either shift their distributions or be replaced by sub-Arctic competitors. Such ecosystem changes will impact Inuit communities, which value marine species for food, culture, and local economies. Integrated ecosystem modeling approaches can predict the impacts of warming conditions on species distribution and availability, informing adaptive management strategies. Yet, for many marine fishes in the Canadian Arctic, knowledge of their population number, size, connectivity, and trophic relationships is insufficient to use as input into ecosystem-based modeling, as proposed by our NordForsk partners (CASTAF project). As an integrated part of CASTAF, FISHSENS will fill this gap by engaging in knowledge co-production with Nunavummiut communities combining western science and Inuit knowledge to produce basic ecological knowledge on key Arctic marine fishes. This combined knowledge will feed into five deliverables: (1) identification of community-based priority fish species on which to focus data development, (2) assessment of Arctic marine fishes' sensitivity to warming conditions through a sensitivity analysis framework, (3) co-generation of useful fish monitoring tools for Nunavut stakeholders, (4) an economic and cultural valuation of key marine fishes to Nunavummiut, and finally (5) integration of this knowledge into the modeling framework proposed by CASTAF to predict ecosystem-level changes and their consequences for the Eastern Canadian Arctic. The northern co-PI is pivotal to FISHSENS by liaising with stakeholders and Indigenous knowledge holders and providing management/monitoring advice for the region. We know of no other large-scale initiative, in Canada or abroad, using such multidisciplinary techniques to safeguard Arctic marine biodiversity and to enable sustainable development of northern communities affected by climate change.

Proposed Budget

Direct Costs Year 1 $800,000	**Indirect Costs Year 1** $200,000	**Year 1 Total** $1,000,000
Direct Costs Year 2 $800,000	**Indirect Costs Year 2** $200,000	**Year 2 Total** $1,000,000
Direct Costs Year 3 $800,000	**Indirect Costs Year 3** $200,000	**Year 3 Total** $1,000,000
Direct Costs Year 4 $800,000	**Indirect Costs Year 4** $200,000	**Year 4 Total** $1,000,000
Total Direct Costs $3,200,000	**Total Indirect Costs** $800,000	**Total** $4,000,000

Suggested Reviewers

Name	Position	Department and Organization	Areas of Expertise
Barluenga, Marta	Tenured Scientist and head of research department	Biodiversidad y Biología Evolutiva, Museo Nacional de Ciencias Naturales	Expertise in ecology and evolution, Biodiversity of fishes
Genner, Martin	Professor	School of Biological Sciences, University of Bristol	Historical phylogeography in fish, Influence of climate change and fishing on marine fish assemblages, Conservation genetics of marine species
Pearce, Tristan	Associate Professor	Department of Geography, University of Northern British Columbia	Geography, Cumulative impacts of environmental changes, Knowledge uptake by stakeholders, Community outreach
Somers, Daryl	President	Independent, Somers Consulting	Reviewer on large scale genomics projects, Genomics methods and project design, genomic/genetic application to agriculture and natural resources, breeding programs, International project mangement

Reviewer Exclusions

Name	Department and Organization

No information to display

Equity, diversity and inclusion in research design (EDI-RD)

Indicate whether EDI in research design (EDI-RD) are appropriate considerations for the project, and whether they have been integrated into the proposed research. A rationale must be provided in cases where a research team believes no aspect of their research may benefit from an analysis to take into consideration sex, gender or other identity factors. These fields must be completed before your application can be submitted.
Yes

Have EDI in research design (EDI-RD) considerations been integrated into the proposed research?
Yes

Equity, diversity and inclusion in research practice (EDI-RP)

Analysis of Context

Explain your team's specific challenges in relation to EDI-RP.

Women, Indigenous Peoples, racialized minorities, persons with disabilities, and LGBTQA+ communities continue to be underrepresented among university faculty in Science, Technology, Engineering and Mathematics (STEM), including within the PI's Department of Natural Resource Sciences. By way of example, while the general population comprises 51% women and 36% racialized/ethnic minorities, the percentages are 27% and 11%, respectively, of assistant professors in fisheries sciences in the United States (academic.oup.com/bioscience/article/66/7/584/2463185). In the Canadian context, First Nations, Métis, and Inuit remain underrepresented in academic departments and government agencies pertinent to the conservation and management of natural resources, yet these resources are often within the lands or unceded territories of Canada's Indigenous Peoples. Our project team is well aware that students in our natural resource-based programs value learning about traditional ecological knowledges and approaches, and yet there are few Indigenous faculty, who would be best positioned to teach in these areas.

There are concerted efforts at our department, faculty, and university levels to improve representation. Our university has put in place multiple Indigenous initiatives, as well as an Anti-Black Racism Plan, an Accessibility Strategy, and an overall EDI Strategic Plan. We also have a Faculty Committee on EDI, Anti-Black Racism, and Indigenous initiatives, while our department's strategic plan has led to the recruitment of a new chair whose research is focused on community-based initiatives in Canada's North. Such initiatives are crucial for reducing barriers at the university level, yet, many of the issues that lead to underrepresentation also exist at other educational stages. For example, Inuit are already underrepresented by the end of high school, with graduation rates of just 50% versus 84% for Canadians as a whole (https://www150.statcan.gc.ca/n1/ daily-quotidien/ 221130/ g-a004-eng.htm). This leaky pipeline across educational stages exacerbates EDI issues in recruitment at the university level, and thus addressing underrepresentation means that our team, field, and institution need to consider EDI strategies not just within but also beyond the university.

Team Composition and Recruitment Process

Identify the best practices applied.

We use EDI best practices in recruitment (recognize unconscious bias, target ads to solicit underrepresented applicants, shortlist candidates by equity bins) and do outreach at northern schools for longer-term improvement of EDI in recruitment.

Explain the relevance, approach and expected impacts of the best practices implemented, and how the impacts will be measured.

Relevance: Research approaches and outcomes benefit from promoting EDI in all aspects of research practice. Our team is committed to putting in place evidence-based practices that improve EDI during the recruitment stages of the project. We will further work towards improving EDI in recruitment beyond a single project, by going to schools and colleges in Nunavut to make contacts with students and exchange knowledges about the project and university research.

Approach: To attract diverse applicants, we will advertise available positions widely through mailing lists of specific society websites, minority society websites, PI websites, and social media. Nunavut Arctic College

(NAC) and Aurora Research Institute (ARI) Environmental Technology/Science Program Coordinators will also be sent ads by email with poster PDFs to print and display on campus and during career fairs. In the screening process, each applicant will be asked the same set of questions, which will include inquiries on their contributions and experience beyond traditional academic settings to more holistically evaluate candidates. Interview scores will be grouped into equivalency bins (i.e., excellent, very good, good, etc.), allowing us to offer the position to a member of an underrepresented group if there is more than one top candidate. To improve EDI in the long term, when we do fieldwork in Nunavut communities, we will ensure to include outreach activities (presentations, workshops, discussions) that engage local high school and college students. This will allow us to make connections with students potentially interested in studying natural resources at university, which is something that team members already do regularly as part of other projects in these regions.

Expected impact: We expect that such EDI approaches in the recruitment of our team will result in increased applicants from underrepresented groups and in the representation of those offered positions. Our team plans to track EDI information to evaluate progress over time. While the influence of outreach in schools in Nunavut is not likely to be observable during the project itself, we will keep records of our outreach activities, and obtain local feedback on them, with the aim of continued improvement to encourage greater participation of underrepresented groups in the long-term and to facilitate the incorporation of Inuit knowledge and values into project design, execution, and dissemination.

Training and Development Opportunities

Identify the best practices applied.

Highly qualified personnel (HQP) will be supported equitably in scholarship applications, conference presentations, training workshops, and networking. HQP will meet bi-weekly with their PIs and be supported to participate in regular group meetings.

Explain the relevance, approach and expected impacts of the best practices implemented, and how the impacts will be measured.

Relevance: It is essential to ensure that each HQP has the individualised support and training needed to succeed in their program, to secure a relevant position after graduation, and to make important contributions to their research field.

Approach: Newly hired HQP are provided with a letter of understanding detailing what to expect from the PI and department, and what is expected of them. HQP work with the PI to create an individual development plan, which continues to evolve over regular meetings discussing timelines, challenges, opportunities, and career paths. Each HQP will be supported to apply for scholarships and to attend and present at one major conference per year. The PI will connect HQP to broader research networks including Canadian team members and our international CASTAF partners in Denmark (and Greenland), Norway, and Iceland. University-based team members form an active group of Arctic biologists, largely residing in Natural Resource Sciences at McGill. Thus, HQP will be part of an enriched multidisciplinary department. Funding is allocated in the budget for HQP participation in field courses, short courses/workshops on data analysis, and science communication. HQP will be further supported in professional training via McGill SKILLSETS, with workshops in critical thinking, project management, ethical conduct, finances and funding, leadership, and EDI. As the project is guided by the values/needs of Indigenous stakeholders, we are committed to respectfully incorporating Inuit knowledges and values throughout its development and implementation. To do this, partners and HQP will receive training on how to engage with Indigenous communities and respect Indigenous knowledges through Indigenous research data frameworks courses available through McGill including “The First Nations Principles of OCAP®” and “The CARE principles”. Many of our HQPs will work alongside stakeholders to share progress and outcomes with Inuit communities via workshops at local schools, college campuses, and Hunters and Trappers Organisations (HTOs) and via digital platforms (websites).

Expected impacts: We anticipate the strategies we have outlined will result in high HQP retention and excellent career opportunities for underrepresented groups upon graduation. Although these career impacts are likely to materialise only after the project end date, we will, as we already do, keep in touch with graduates and track their professional trajectories.

Inclusion

Identify the best practices applied.
We will stay updated on EDI best practices and dedicate meeting time to discuss new approaches and their implementation in our network. We will work with co-management partners to include participating Inuit communities at all stages of the project.

Explain the relevance, approach and expected impacts of the best practices implemented, and how the impacts will be measured.
Relevance: Practicing inclusivity is essential to the well-being and success of HQP across backgrounds, as well as to meaningfully incorporating western scientific and Inuit knowledges together within our team and project.

Approach: Every team member will take EDI training offered through their institutions (e.g., “It takes all of us” – McGill EDI in research framework). To put this training into practice, during all group activities, our team will take action to ensure each participant has opportunities to participate and that their contributions are valued across backgrounds and knowledges. In addition, journal clubs will regularly include papers addressing EDI issues; in this way, the group develops knowledge about EDI issues and can also discuss strategies for implementing improvements within our team on an ongoing basis. We have found that this practice has fostered a greater sense of belonging in HQP and has allowed us to grow awareness of issues as they arise. This also allows us to develop the skills needed to take concrete steps towards positive changes. As the project is centered on knowledge co-production with Inuit communities and Inuit-led organisations, our team is also dedicated to taking the time to exchange ideas and knowledges at all stages from initial project planning to implementation to results dissemination. This means spending time in communities talking with the HTO Boards, developing and teaching activities for students at local schools, being on the land with local field assistants carrying out sampling, and sharing and getting feedback on project findings in an accessible way for community members – from elementary students to elders. We have the right team in place and the necessary support in the project budget to ensure these activities are successful.

Expected impacts: Our team expects that specific, evidence-based practices to improve inclusion will lead to high recruitment, retention, and career opportunities for trainees of diverse backgrounds and experiences. To measure this impact, we will monitor HQP recruitment and retention and keep in touch with HQPs post-graduation. To measure impacts in local communities, we will evaluate project feedback from local organisations with our northern partners.

Early Career Researchers (ECRs)

Provide a description of how ECRs will be included in the team and integrated in a meaningful way, including plans to support their leadership and development throughout the project.

The FISHSENS team is committed to providing tangible supports to early-career researchers (ECRs) involved in the project. We acknowledge how crucial these supports are to the professional development of ECRs and to recruiting and retaining ECRs, particularly from underrepresented groups, in academic positions in the long-term. In addition, evidence points to structured mentorship improving EDI and leading to higher success in research grants and a more positive view of the academic environment [1].

ECR researchers are integrated within the PI/Co-PI team on the project and will be supported by the diverse set of established researchers within Canada and internationally from Denmark, Iceland and Norway as part of the broader NordForsk project. ECRs will be supported in developing excellence in trainee supervision by ensuring that they share co-supervision of trainees with established researchers on the team. Being part of the large, international NordForsk team will also help ECRs in establishing strong research networks and in pursuing additional research and professional avenues and funding. ECRs will also work with northern co-partners, establishing connections in Canada's North, and learning how to foster these relationships and how to navigate community and territorial organizations and governance structures.

ECRs will also be provided with structured mentorship opportunities in our Department of Natural Resource Sciences and, more broadly, at McGill University. At the department level, our department assigns two suitable faculty members to mentor tenure-track faculty starting in the first semester that they arrive at the university and through to applying for and receiving tenure. We also have regular informal gatherings among tenure-track and recently-tenured faculty in our Faculty to support one another and to enhance collegiality across departments on our campus. At the university-level, ECRs are also provided with opportunities to access formalised mentorship through the established Provost's Faculty Mentorship Network. This network pairs mentors, who are recognized for their excellence in contributions as teachers and researchers, with pre-tenure faculty. A mentorship agreement is established and the pair meets for up to 30 hours per year to provide mentorship to the ECR on wide-ranging topics, including, but not limited to, trainee supervision, equity-concerns, work-life balance, and reappointment and tenure processes.

1- van der Weijden et al 2015 How do young tenured professors benefit from a mentor? Effects on management, motivation and performance. High Educ 69, 275–287. https://doi.org/10.1007/s10734-014-9774-5

Certifications, Licenses and Permits

Certification Requirements

Which of the following does the proposed research involve?

✔ Animals

Biohazards

Human subjects

Human pluripotent stem cells

None of the above

What level of physical containment is required?
My proposed research does not require physical containment

Is this a clinical trial?
No

Does your proposed research require an exemption from Health Canada?
No

Will any phase of the proposed research take place outdoors?
Yes

Impact Assessment

Will any phase of the proposed research take place on federal lands in Canada, other than lands under the administration and control of the Commissioner of Yukon, the Northwest Territories or Nunavut, as interpreted in section 2 of the Impact Assessment Act (IAA)?
No

Will any phase of the proposed research take place in a country other than Canada?
No

Will the grant permit a designated project (listed in the Physical Activities Regulations) to be carried out in whole or in part?
No

Will any phase of the proposed research activities depend on a designated project (listed in the Physical Activities Regulations) being led and carried out by an organization other than SSHRC?
No

Supporting Documents

Document Name	Stage	Status
Description of the potential outcomes of the project, including the benefits to Canada’s Arctic (maximum 1 page)	Application	Attached
Summary of the Canada-based portion of the project (maximum 4 pages)	Application	Attached
Letter of Support (maximum 4 pages)	Application	Attached
Budget justification (maximum 2 pages)	Application	Attached

Attachments

HIGH REWARD - NEW KNOWLEDGE ON SUSTAINABLE DEVELOPMENT OF THE ARCTIC

Social, cultural, and health impacts

Country foods are recognised as an integral part of Inuit social and cultural systems, and for reducing food insecurity in Canada's North[1]. While country foods are preferred to store-bought foods, barriers to access include lack of an active hunter as a household member, no snowmobile or boat, and high costs of gas and other supplies for fishing and hunting[2]. Such findings, along with recent declines in country food use, have led to the recommendation that **a revitalisation of country food systems should improve food security**[3]. With climate-driven increases in Arctic Ocean productivity and invasion of Atlantic fishes, **increasing marine fish catches are projected in the Arctic**[4]. While many communities are highly reliant on the freshwater/anadromous Arctic char, Arctic marine fishes are considered an **underused resource**[5]. **FISHSENS will** provide the required information on new and existing species to communities **support the development of fisheries** and **strengthening monitoring in Nunavut by Nunavummiut** to ensure sustainability of the ecosystem and country food supply. FISHENS tools will enrich Nunavummiut awareness of species adaptation and increase the ability to manage these species leading to a more consistent supply of nutritious food to communities **benefitting Inuit socio-cultural systems**.

Scientific impacts

Traditional species assessments are labour and time-intensive and can be unreliable, with negative consequences for stock status[6]. Here, combined population genomics, chemical tracers, and electronic tracking will **rapidly and reliably assess population structure, abundance, connectivity, and food web interactions of important species**, with all findings synthesised to evaluate species-specific sensitivity to, and adaptive potential under, climate change[7]. The sensitivity analyses results will provide the ecological underpinning to direct management strategies and policies for Arctic regions facing intense climate change and are a prerequisite for **CASTAF modelling projections for ecosystems and fisheries in Nunavut**. Findings will allow managers to target sensitive species and populations for the development of adaptive, sustainable harvest strategies under expected changes.

Technological impacts

FISHSENS will develop next-generation tools to monitor and manage Canada's Arctic fishes, revitalizing Canada's reputation as a global leader in fisheries management. FISHSENS will develop fish GBS panels with co-management partners to address Nunavummiut priorities, allowing for **simplified, precise, and relevant genomics-based monitoring**. Panels produced in partnership with Illumina Canada will also benefit other Arctic nations (United States, Denmark, Norway, Sweden, Finland, and Iceland) in developing their own monitoring capacity, thus placing Canada at the forefront of Arctic fish biodiversity research. The proposed GBS panel will **enable circumpolar signatories to meet their obligations** to develop ecological knowledge of Arctic marine fishes under the **Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean** and across the circumpolar Arctic.

Economic impacts

Sustainable ecosystem management requires an understanding of how different management strategies impact the provisioning and cultural services provided by marine fishes. The System of Environmental-Economic Accounts for Arctic fisheries will be the first of its kind in the Canadian Arctic; the biophysical Ecosystem Extent Accounts, Ecosystem Service Accounts, and Biodiversity Asset Account will provide a biophysical and monetary flow of the biodiversity. Currently, the average annual catch of Arctic fish is ~189,000 t valued at $560 million USD ($710 million CAD), while the subsistence fishery catch is 1,903 t[8]. A 10% increase in harvest in 3–5 years after the project would increase fisheries output by 56 million USD ($71M CAD)/year and subsistence harvest by 190 t. Given the high price of food in the North, this increased subsistence harvest alone would greatly benefit food security. **Increased employment opportunities and income from subsistence and commercial fisheries activities** will further support purchasing supplies to obtain country foods. As Canada works towards reconciliation with Indigenous communities, outcomes from FISHSENS will be critical to promoting sustainable exploitation of underused marine resources. These strategies related to country foods are of utmost importance, as these foods underpin Inuit culture, nutrition, and identity.

[1]Egeland 2010 International Polar Year Inuit Health Survey: Health in Transition and Resiliency. 51 p. [2]Searles 2016 *Food Foodways* **24**:194. [3]Herrmann et al 2020 *Curr Opin Clin Nutr* **23**:59. [4]Cheung et al 2016 *Ecol Model* **325**:57. [5]Zeller et al 2011 *Polar Biol* **34**:955. [6]Dolan et al 2005 *EcoHealth* **2**:195. [7]Foden et al 2019 *WIREs Climate Change* **10**:e551. [8]Tai et al 2019 *Mar Policy* **108**:103637.

INTRODUCTION

Marine fisheries are vital to Inuit well-being, providing economic, cultural, and food security benefits[1,2]. Yet, communities across Inuit Nunangat are concerned about the continued availability of these resources under rapid Arctic warming and about the increasing global interest in Arctic fisheries[3]. As Arctic marine fishes are also the **most data-deficient** vertebrate group[4], there is large data gap in the ecological indicators required for Inuit organizations to monitor fisheries sustainability[5]. Monitoring tools have traditionally relied on Western science (WS) with little incorporation of Inuit knowledge (IK); yet, multiple knowledge systems allow more holistic evaluations of species' status and promote inclusion and empowerment of Indigenous stakeholders[5]. Thus, **co-development of ecological, cultural, and economic knowledges** of Arctic marine fishes is urgently **needed to predict the impacts of climate change** and to **support sustainable fisheries development**.

Integrated ecosystem modelling approaches can predict species distributions, their interactions, and available biomass under warming conditions, which can inform adaptive management strategies, as **proposed for three Arctic regions by our NordForsk partners (CASTAF)**. But first, **to populate such models in the Eastern Canadian Arctic (ECA)** (Baffin Bay-Davis Strait) region of Inuit Nunangat, the **large knowledge gaps on key ECA marine fishes will be filled by the joint NFRF project, FISHSENS**. FISHSENS will establish community priorities for management (Activity 1), which will inform development of crucial ecological knowledge (Activity 2) and co-development of relevant monitoring tools (Activity 3), and feed into an economic and cultural valuation of marine fishes to Nunavummiut (Activity 4). **Co-produced ecological and economic knowledges will be integrated into the modeling framework proposed by CASTAF** (Activity 5) to predict ecosystem-level changes and their consequences for ECA fisheries. We know of no other large-scale initiative, in Canada or abroad, intending to use such multidisciplinary techniques to safeguard northern marine biodiversity **to support sustainable natural resources for Arctic communities** affected by a warming world.

BIOGRAPHICAL INFORMATION AND PROJECT MANAGEMENT

FISHSENS integrates cross-disciplinary expertise to complete the Activities: WS and IK knowledge co-development (Parlee: Activity 1.1, 3.1, 3.4), population genomics (Roy: Activity 2.1, 2.4, 3.2, 3.3), ecological tracers (McKinney: Activity 2.2, 2.4), animal telemetry (Hussey: Activity 2.3, 2.4), bioinformatics and data visualisation (Beiko: Activity 3.2-3.4), ecological economics (Mukhopadhyay: Activity 4), and Arctic fisheries co-management and Inuit strategies, policies, and priorities (Martin: Activity 1.1, 3.1, 3.4, Director of the Nunavut Fisheries and Sealing Division – *the Inuit organisation responsible for marine fish resources in Nunavut*). This team leverages longstanding collaborations with regional stakeholders and co-managers (>30 joint publications) to ensure rapid initiation of the project and partner integration throughout. The FISHSENS executive committee (Roy, Hussey, Martin, and CASTAF lead Nielsen) will ensure integration within CASTAF. The steering committee (Roy, Martin, McKinney, Hussey, Parlee, Beiko, Mukhopadhyay) will oversee FISHSENS timelines, budgets, and deliverables. Activity leads (see Budget Justification) will be responsible for progress and reporting.

RESEARCH PLAN

<u>Activity 1 SETTING</u> **1.1 Co-development of priority species aligned with FISHSENS and Government of Nunavut needs.** Our recent work used existing ecological, economic, and cultural knowledge to draft a priority list of species for Arctic marine fish conservation[6]. This synthesis independently prioritised several species for which co-PIs have active research programs and many samples in hand. Thus, FISHSENS can begin immediately, demonstrating project feasibility. To strengthen the list, an initial consultation meeting (C1) will be held (*Fig 1*). Subsequently, co-PIs Martin and Parlee will meet with communities involved (see Letters of Support) to 1) ensure local concerns and values are reflected in the species selection and 2) carry out IK surveys of knowledge holders on these species' populations, feeding, and movements to incorporate in a climate change sensitivity assessment (Activity 2.4). To facilitate knowledge exchange, pictures, videos, and short text in Inuktitut of listed species will be made available. Community inputs will be supplemented, as needed, by data from the Nunavut Fisheries Strategy and National Inuit Health Survey. Community tours will further dialogue on the direction of project activities including economic valuation of listed species, additional sampling requirements, and developing stakeholder-accessible monitoring tools. Following this, the

[1]Snook et al 2022 *Mar Policy* **140**:105071. [2] Kenny 2019 in *Predicting Future Oceans* pp. 249-263.[3]Galappaththi et al 2019 *J Environ Manage* **250**:109534. [4]Coad & Reist 2017 *Marine fishes of Arctic Canada*. 632 p. [5]Kourantidou et al 2020 *Arctic Sci* **6**:279. [6]Sanchez-Schacht et al 2024 *Submitted*.

priority species list milestone (M1) will be achieved (*Fig 1*), and a manuscript will be produced (Deliverable D1): *Braiding a list of priority Arctic marine fish species using ecological, economic, and cultural perspectives*. Additional sampling will then be completed (M2), setting the stage for the rest of the project.

Figure 1. *FISHSENS Timeline of workplan*

			Year1				Year2				Year3				Year4			
	Activity	**Description**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
1	**Setting**																	
1.1	Stakeholder consultation	Co-production of target species list	C1	M1	D1	M2												
2	**Ecology**																	
2.1	Genomics	Whole genome sequecing (wgs)								M3								
		Low coverage wgs												M4				D2a
2.2	Trophic ecology	Ecological tracers analyses												M5				D2b
2.3	Tracking	Tracking data collection and analyses												M6				D2c
2.4	Arctic fish sensitivity	Combining ecological data																D2d
3	**Monitoring**																	
3.1	Stakeholder consultation	Co-production of monitoring tools													C2			
3.2	Genotype by sequencing	Co-developed, species-specific													M7			
3.3	Bioinformatics Hub	Co-developed and maintained													M8			D3a
3.4	Training resources and stakeholder consultation	Co-produced for northern coPI/stakeholders																D3b C3
4	**Economics**																	
4.1	Broad-economic valuation	Co-developed system of econ-valuation										M9			D4			
5	**CASTAF Integration**																	
5.1	FISHSENS -> CASTAF	Western Arctic Atlantis/Nemo models												M10			D5	

Consultation (C), Milestones (M), and Deliverables (D)

Activity 2 ECOLOGY **2.1 Genomics.** There is a need for transformative new data on the basic ecological features of Arctic marine fishes for accurate assessments of the impacts of fishing and climate change on their short- and long-term survival[7,8].Traditional catch-based abundance and distribution assessments of a species biocomplexity (population numbers, connectivity, effective sizes (*Ne*) and adaptive potential (amount of standing genetic variation, assessed as expected heterozygosity (*He*)) can take years. Genomics techniques, however, can develop species-specific, high-resolution biocomplexity data efficiently and cost-effectively in just a single study[9]. Here, we will develop the genomic tools and databases to assess the biocomplexity of ECA marine fishes. First, genomes will be developed for target species lacking one currently (i.e., ~ 6 species) using whole genome sequencing (WGS)[10]. Completed genomes will be submitted to the NCBI repository (M3) (*Fig 1*). With genomes, we will then identify genome-wide markers using low-coverage whole genome sequencing[11]. Biocomplexity will be assessed with bioinformatics pipelines[12], and genomic resilience[13] under changing environments will be determined from identified genomic markers (M4). Population genomics will be completed for 8-10 species, leading to a set of papers (D2a). Importantly, identified species-specific markers will feed into Activity 3 to develop co-produced genomics-based monitoring tools to provide near real-time data to inform adaptive management strategies. **2.2 Trophic ecology.** With the arrival of new species, novel competition interactions may occur, while other interactions may disappear[14]. This leads to no-analog communities and ecosystems with unpredictable outcomes[15]. To understand such outcomes, new data on the basic ecology of Arctic marine fishes must also consider impacts of altered species interactions[16]. To evaluate how Arctic marine fish foraging ecology is modified in response to species' northward redistributions and possible extirpations, the feeding niche (feeding position/role in the ecosystem) size, and extent of feeding niche overlap among species, will be assessed. Here, we will use bulk stable isotopes and fatty acid composition, along with compound-specific amino acid and fatty acid isotopes, as indicators of trophic roles (M5) (*Fig 1*). Species-specific feeding niche size and overlap among species within and among regions will be determined via Stable Isotope Bayesian Ellipses in R (SIBER) and nicheROVER. Produced data and analyses will form the basis of a set of manuscripts (D2b) and will feed directly into the Arctic fish sensitivity analyses to climate-driven changes in resource use and overlap. **Activity 2.3 Tracking.** In ectothermic fish, movement is fundamental for foraging, reproduction and dispersal, but dictated by temperature[17]. Quantifying core movement metrics such as home ranges (i.e., activity space), residency, migration corridors, and connectivity among populations, along with the degree of inter- and intra-individual levels of variation, provides fundamental knowledge to direct management and conservation[18]. When combined with environmental features, movement metrics can provide the basis for predicting how

[7]Zeller et al 2011 *Polar Biol* **34**:955. [8]Frainer et al 2017 *Proc Natl Acad Sci USA* **114**:12202. [9]Colella et al 2020 *TREE* **35**:149. [10]Yasodha et al 2018 *DNA Res* **25**:409. [11] Therkildsen & Palumbi 2017 *Mol Ecol Res* **17**:194. [12]Beausoleil et al 2023 *Evolution* **77**:2533. [13]Tigano et al 2024 *Evol Appl* **17**:e13602. [14]Fossheim et al 2015 *Nature Clim Change* **5**:673. [15]Williams et al 2007 *Proc Natl Acad Sc. USA* **104**:5738. [16]Yurkowski et al 2017 *Biol Lett* **13**:20170433. [17]Dingle 2014 *Migration: The biology of life on the move*. 2nd Ed. [18]Brooks et al 2019 *CJFAS* **76**:1238.

changing conditions shape a species overall 'state' in terms of fitness, health, and resilience to ecosystem modifications. Here, standardised movement metrics will be generated for target species via electronic tracking. The scale of data required will be leveraged from >10 yrs of ongoing tracking data (co-PI Hussey, lead of the Arctic Ocean Tracking Network), as well as piggybacking off in-kind telemetry infrastructure already in Nunavut to address data gaps (speaking to project feasibility). Movement metrics will include kernel utilisation distributions (to quantify activity space (i.e., 50 and 95%), various residency indices, net displacement (at daily, weekly and monthly time scales) and habitat suitability models. Standardised movement metrics in prioritised species will form the basis of several manuscripts (D2c) and feed into the sensitivity analysis (D2d) and the modelling framework of CASTAF. **2.4 Assessing Arctic fish sensitivity to climate change.** Population, feeding, and movement knowledge from IK surveys (Activity 1) and WS (Activity 2.1-2.3) will be used as parameters in estimating each species' sensitivity to climate change via modifying an established framework[19] to include IK. This framework has been applied to other highly mobile Arctic species and relies on comparing key traits, including home range, habitat selectivity, dispersal ability, trophic niche breadth, and adaptive potential (or, standing genetic diversity) [19,20]. Each species will be assigned a score (high, lower, low, unknown) on each trait and the overall sensitivity will be summed[19]. Trait scores will indicate (1) which species are most vulnerable, (2) why they are vulnerable (specific traits), and (3) where they are vulnerable (portion of range). The assessment will be shared with knowledge holders and co-PI Martin for feedback and interpretation, with results forming the basis for an important manuscript (D2d). **Activity 3 MONITORING.** **3.1 User consultation.** Stakeholder-mediated knowledge development and scientific monitoring tools produced via shared decision-making improve subsequent adoption by stakeholders[21]. Evidence derived from such tools is also more likely to be incorporated in policy decisions related to subsequent resource use and management[21]. This activity will unite co-PIs and stakeholders in exchanging relevant knowledges toward developing easy-to-use genomics-based target species monitoring tools. Ecological findings from WS will be presented and the northern co-PI and stakeholders will present IK monitoring and management approaches. Subsequently, causal loop diagrams[22] weighing the costs and benefits of developing genomics-based monitoring will be generated. Participant diagrams will be compared, identifying consensus and contrasts, with contrasting viewpoints resolved using collaborative solutions. Priorities for the development of monitoring tools and supporting bioinformatics will be set (C2). **3.2 Genotype by sequencing (GBS).** This activity will leverage FISHSENS genomics data to create monitoring tools for northern co-PI/stakeholders. Using GBS methods, we will select ~250 high-resolution markers from the full set identified, first by filtering paralogs, then by performing feature selection using machine-learning to identify combinations that differentiate populations. Combinations will be developed into genotyping pools, selected in consultation with all partners. Selected markers will be used to track biocomplexity parameters (Activity 2.1). Using Illumina's AMPLIseq technology, genotyping pools will be developed for each species with the ability to subsequently genotype hundreds of individuals per species using existing infrastructure at McGill (MiSeq sequencer). These data will be openly accessible to northern partners via the bioinformatics hub (Activity 3.3) and provide near real-time insights for species adaptive management (M7). **3.3 Bioinformatics hub.** FISHSENS will produce extensive data that needs to be stored, analysed, used to produce monitoring tools, and fed into CASTAF's modeling framework. To manage this data effectively, we will co-produce a decentralised, sustainable bioinformatics hub, with input from the northern co-PI and stakeholders. The hub will provide users ready access to data, workflows, analysis scripts, training resources, and visualisation tools, all designed to support repeatable and comparable analyses. Hub designers will work with the northern co-PI and stakeholders to ensure long-term data management and accessibility. At the hub's core will be a *Discord server* for training, support, and project discussions, linking resources such as Google® Drives, GitHub for metadata and workflows, and NCBI BioProjects for genomic/ecological data. A MySQL database and spreadsheets will track project and external datasets, with URLs for easy data access. The hub will also house co-developed training modules to help solidify monitoring tool adoption (M8). Once developed, this hub will be easy to maintain and adaptable beyond the life of the grant (D3a). **3.4 Training resources and consultation.** Training workshops will be conducted, including hands-on sessions, online videos, and step-by-step guides for managers and stakeholders, who will

[19]Foden et al 2019 *WIREs Climate Change* **10**:e551. [20]Foden et al 2013 *PLoS ONE* **8**:e65427. [21]Nutt 2002 *Why decisions fail: Avoiding the blunders and traps that lead to debacles*. 353 p. [22]Inam et al 2015 *J Environ Manage* **152**:251.

learn GBS data analyses and applications to management priorities (C3). Because training resources will be co-produced, their use will be relatively intuitive and made available in relevant formats (e.g., Inuktitut), with feedback from users informing iterative improvements. Produced training materials will be available as long as monitoring resources are deemed useful by stakeholders (D3b). The distributed approach of the bioinformatics hub ensures sustainability for training post project completion.

Activity 4 ECONOMICS 4.1 Broad economic valuation. Ecological-economic assessments require tools measuring the integration of economic activities with ecosystem services. The economic impact of climate change on Nunavut fisheries will be assessed by developing the Canadian Regional Input Output (RIO) model using regional Supply-Use Tables (Statistics Canada). The UN's System of Environmental-Economic Accounts for Agriculture, Forestry and Fisheries (SEEA-AFF)[23] will be used for physical and value assessment of stock and flow of fisheries and the environmental cost will be factored into the estimation of 'Green GDP'. Provisioning services to optimise dietary patterns of northern communities will also be studied, considering deviations of nutritional intake from Health Canada Dietary Reference Intakes, Canada Food Guide, and Healthy Eating Indices. The economic value and environmental impacts of growing tourism in the region will also be assessed using revealed preference methods applied through stakeholder surveys and Provincial and Territorial Tourism Satellite Accounts (PTTSA). The RIO model and the SEAA-AFF framework will provide a broad net-economic-environmental analysis of climate change impacts on Nunavut fisheries (M9, D4).

Activity 5 CASTAF INTEGRATION 5.1 Integration into CASTAF project. The Atlantis Holistic End-to-End Marine Ecosystem Model is a spatially explicit ecosystem modeling framework linking climate variables to hydrodynamics[24,25]. If hydrodynamic impacts on key functional species within an ecosystem are known, Atlantis can predict how climate shifts will impact marine species and fisheries. CASTAF will apply this framework to three large Arctic ecoregions, including the ECA using the developed IK and WS knowledges from FISHSENS. The produced findings will be vetted and processed as input parameters for the Atlantis ECA (M10) by Research Scientist and Atlantis expert Bossier at McGill (D5).

EQUITY, DIVERSITY, AND INCLUSION IN RESEARCH DESIGN (EDI-RD)

From planning through to dissemination, EDI considerations will be foundational and **aligned with SSHRC Guidelines for Merit Review of Indigenous Research**. The project **relies on IK** synthesised by Nunavut organisations to inform on priority fishes and the climate change sensitivity assessment, such that social, cultural, and economic values and needs of Inuit drive study design, knowledge development and synthesis. Recruitment practices will include concrete actions aiming to **increase recruitment of Inuit HQP** (see EDI-RP). Field **research will be performed with Inuit fishers and fisheries**, and the **findings will be reviewed and interpreted by Inuit** IK holders before wider dissemination. Deliverables, including genetic resources and the bioinformatics hub, will be co-designed with Inuit organisations to ensure useability and accessibility for all stakeholders and support adoption of monitoring tools **towards Inuit-led fisheries management and conservation**. The project budget provides funding to compensate IK holders and harvesters in these activities to ensure success.

RESEARCH DATA MANAGEMENT

FISHSENS will adhere to data management best practices, following the Findable, Accessible, Interoperable, Reusable (FAIR) Principles, First Nations principles of Ownership, Control, Access, and Possession (OCAP), and Free, Prior & Informed Consent (PFIC). **Documentation:** Notebooks will record procedures and sample data, also transcribed into Excel files. Field and lab operations will follow documented SOPs. Data will be compiled using standard folder structures and naming conventions (e.g., ISO 8601 formatted dates). Genomics and tracking data will be <10 TB; other data, <100 GB. **Storage/backup:** Recommended strategies will be used: 2 copies on 2 computers and 1 on the cloud. Notebooks will be stored in-house, with copies providing additional access. **Data preservation/ sharing:** Data will be deposited to freely-accessible repositories (ncbi.nlm.nih.gov; polardata.ca) with links given in open-access journal articles. **Resources/responsibilities:** For each activity, activity leads will be responsible for data management, with DMP training that includes Indigenous research data frameworks. **Ethical/legal compliance:** Communities/co-partners will be consulted regularly, and plans revised, to ensure acceptability, accessibility, and data sovereignty. Communities will decide and agree on disaggregated IK data use and sharing and will retain ownership and access in perpetuity.

[23] UN 2020 https://seea.un.org/content/system-environmental-economic-accounting-agriculture-forestry-and-fisheries. [24]Audzijonyte et al 2019 *Methods Ecol Evol* **10**:1814. [25]Fulton et al 2011 *Fish Fish* **12:**171.

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Nattivak Hunters & Trappers Association

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November 21st, 2024

Dear Drs. Roy and Hussey:

We are writing to indicate that the community of Qikiqtarjuaq Hunter's and Trapper's Organisation (HTO) strongly supports your projects "*FISHSENS: Building ecological knowledge to assess the sensitivity of Canadian marine fishes to Atlantification*". This project is part of an international collaboration with several Nordic nations that aims to better understand and prepare for the likely ecosystem level changes to Arctic marine environments considering Arctic warming trends as a result of climate change. This project responds well to the 2024 NordForsk-led International Joint Initiative on Sustainable Development of the Arctic.

The community of Qikiqtarjuaq's HTO believe that the results of the proposed research will substantially improve knowledge and monitoring capabilities for multiple data deficient marine fish species in the region, which is urgently needed to adaptively manage and conserve them. This is especially important considering the expected impacts of continuing warming in Arctic regions, which are warming in places at four times the global average.

Qikiqtarjuaq's HTO would be happy to be involved in project consultation and community engagement in the project, including fish sampling, as well as providing our thoughts and input on genomics and bioinformatics tool design and its use to ensure long-term monitoring of key fish species. The Qikiqtarjuaq HTO also supports the development of the environmental economic valuation of key fish species in the Arctic, so that a better appreciation of their socio-economic importance can be gained to assist regional management and improved socio-economic growth.

We look forward to working with you on this timely project and see great value in this endeavour.

Sincerely,

Jeelie Tassiutik

P.O. Box 10 Qikiqtarjuaq, Nunavut X0A 0B0
Telephone: (867) 927-8836 Fax: (867) 927-8525 E-mail: nattivak@baffinhto.ca

Nunavut Fisheries Association

November 21st, 2024

Dr. Denis Roy and Dr. Nigel Hussey
McGill University – Department of Natural Resources Science
University of Windsor – Department of Integrative Biology

Dear Drs. Roy and Hussey:

The Nunavut Fisheries Association (NFA) is pleased to write in support of "*FISHSENS: Building ecological knowledge to assess the sensitivity of Canadian marine fishes to Atlantification.*"

This project is part of an international collaboration with several Nordic nations that aims to better understand and prepare for the likely ecosystem level changes to Arctic marine environments considering Arctic warming trends as a result of climate change. This project responds well to the 2024 NordForsk-led International Joint Initiative on Sustainable Development of the Arctic.

NFA in the industry trade association representing 4 indigenous-owned fishing companies operating in Nunavut, particularly in the offshore. Greenland halibut is main targeted species, being the largest groundfish fishery in eastern Canada. Members also conduct significant fisheries for northern shrimp (*pandalus borealis* and *jordani*). NFA works in the areas of public policy, stakeholder and media relations, research and fisheries sustainability.

The proposed research is of great interest and importance to the industry, as it contributes to improve knowledge and monitoring capabilities for multiple data deficient marine fish species in our region. Better and adaptive management and conservation is of course essential. This is especially important considering the expected impacts of continuing warming in Arctic regions, which are warming in places at four times the global average.

NFA and its members are pleased to provide support for this project. We look forward to greater involvement in all its stages and notably in the operations phase, such as fish sampling, as well as providing our thoughts and input on genomics and bioinformatics tool design and its use to ensure long-term monitoring of key fish species. We also support the development of the environmental economic valuation of key fish species in the Arctic, so that a better appreciation of their socio-economic importance can be gained to assist regional management and improved socio-economic growth. This is a crucial element of the project.

We look forward to working with you on this timely project and see great value in this endeavour.

Sincerely,

Derek Butler
Executive Director

General

All FISHSENS-NFRF partners costs are combined into a single per year budget shown in **Table 1**. The total budget is $3.2M CAD with an additional 20% ($800K CAD) in indirect costs. The budget is split by co-PI, each leading one or more activities, as detailed below. Funding to lead consultations and Inuit stakeholders' contributions are included under **Knowledge co-production**.

CASTAF integration (McGill)

Funds, administered through McGill, are requested to support early-career research (ECR) scientist Bossier (~$82K/yr, including benefits/taxes/inflation), with expertise on the Atlantis and Nemo ecosystem models, to oversee the integration between CASTAF (Nordforsk partner project) and FISHSENS (**Table 1**).

Table 1. *FISHSENS budget outlining costs per Activity/co*-PI

Activity	2025 (1/2)	2026 (1)	2027 (1)	2028 (1)	2029 (1/2)	SUMS
CASTAF Integration						
Research Scientist	40921	82250	82250	82250	40921	328592
Genomics (McGill)	Genomes, low coverage whole genome sequencing, and GBS genotyping)					
HQP support	51875	103750	103750	103750	51875	415000
Consummables/analyses	42286	84164	84164	84164	42286	337064
Mobility/travel	3125	6250	6250	6250	3125	25000
Dissemination/outreach	1375	2750	2750	2750	1375	11000
subtotal	**98661**	**196914**	**196914**	**196914**	**98661**	**788064**
Ecological Tracers (McGill)	Bulk and compound specific stable isotope and fatty acid analyses					
HQP support	12766	25532	25532	25532	12766	102128
Consummables/analyses	38813	77625	77625	77625	38813	310500
Mobility/travel	1406	2813	2813	2813	1406	11250
Dissemination/outreach	0	0	0	0	0	0
subtotal	**52985**	**105970**	**105970**	**105970**	**52985**	**423878**
Tracking (UWindsor)	Electronic tracking and movement of fish using acoustic tags					
HQP support	51875	95000	95000	95000	51875	388750
Consummables/analyses	8250	16500	16500	16500	8250	66000
Mobility/travel	3655	7313	7313	7313	3655	29249
Dissemination/outreach	2000	4000	4000	4000	2000	16000
subtotal	**62500**	**125000**	**125000**	**125000**	**62500**	**500000**
Bioinformatics hub (Dalhousie)	Development of bioinformatics support for data and genomic monitoring					
HQP support	47750	95500	95500	95500	47750	382000
Consummables/analyses	0	0	0	0	0	0
Mobility/travel	1750	3500	3500	3500	1750	14000
Dissemination/outreach	500	1000	1000	1000	500	4000
subtotal	**50000**	**100000**	**100000**	**100000**	**50000**	**400000**
Knowledge co-production (McGill)	Co-production of focal species list, genomic monitoring tools, and tool adoption					
HQP support	17500	35000	35000	35000	17500	140000
Consummables/analyses	0	0	0	0	0	0
Mobility/travel	0	0	0	0	0	0
Dissemination/outreach	19905	39810	39810	39810	19905	159240
Stakeholder engagement	10000	20000	20000	20000	10000	80000
subtotal	**47405**	**94810**	**94810**	**94810**	**47405**	**379240**
Economics (McGill)	Economic valuation of focal fish species					
HQP support	44653	89306	89306	89306	44653	357224
Consummables/analyses	1125	2250	2250	2250	1125	9000
Mobility/travel	1250	2500	2500	2500	1250	10000
Dissemination/outreach	500	1000	1000	1000	500	4000
subtotal	**47528**	**95056**	**95056**	**95056**	**47528**	**380224**
Grand Total	**400000**	**800000**	**800000**	**800000**	**400000**	**3200000**

Genomics (McGill - Roy)

HQP support. Requested funds for genomics include funding for highly qualified personnel (HQP) with 1 post-doctoral fellow (PD), and one PhD student (PhD) hired at the rate of $70K/year and $33.8K/year, respectively. McGill graduate students are topped up $5-7K/year by Graduate Entry Awards (GEA) making PD and PhD salaries commensurate with current NSERC rates. *Consumable/analyses.* Work will process 8-10 species from 6 regions with sample sizes of 10-20 individuals/region/species for a total *n* ~1000. For species without an annotated genome (~6), whole genomes will be sequenced using long-read technology at $7.7K/species, totalling ~46K, or $11.5K/yr. Samples will also be processed for low coverage whole genome sequencing at $222/ sample for a total of ~$222K, or $30.5K/yr. Markers identified as informative will be used to develop genotype-by-sequencing panels for target species for genomic monitoring costing ~$81.7K overall, or ~$20.4K/yr. Total consumable costs for genomics is ~$84.1K/yr (Table 1). *Mobility/travel.* Funds of $5K/yr are requested to present genomics data at conferences and for HQP to attend FISHSENS workshops (supplemented with NSTP travel funds). *Dissemination/outreach.* Finally, $2.75K is requested for publishing in open-access journals (e.g., Arctic Science) and for costs of translating materials into Inuktitut for stakeholders). The total genomics budget is ~$196K/yr (Table 1).

Ecological Tracers (McGill - McKinney)

HQP support. The ecological tracers budget includes time equivalent 1/3 lab technician salary (including benefits/taxes/ inflation) at $25.5K/yr. *Consumable/analyses.* The bulk of the costs arerelated to consumables with fatty acid (FA) and stable isotopes (SI) at $80 and $28 a sample, respectively, or $80K and $28K for ~1000 samples. A subset of 250 samples will be analysed for compound-specific stable isotopes at $50 (FA C) and $200 (amino acid C and N) per sample. Total consumables sum to ~$310K, or $77.6K/yr. *Mobility/travel.* While funds for travel and workshop participation are included at $2.8K/yr, no dissemination funds are requested as the data will be incorporated in other works (genomics papers/sensitivity analyses/Atlantis model - CASTAF). The total funds requested for ecological tracers' is ~$106K/yr (Table 1).

Tracking (UWindsor - Hussey)
FISHSENS project feasibility relies on the in-kind contributions provided by co-PI Hussey's northern research program through *ArcticNet* and the *Arctic Ocean Tracking Network*. This infrastructure includes telemetry arrays ($1.7M) already in place in key sampling areas (e.g., Clyde River, Scott Inlet, Pangnirtung, and Qikiqtarjuaq). This research has also tagged many species likely to top the priority species list such as Greenland halibut and Arctic cod, among others. Contributions also include ship time ($2.7M) and logistics, which may be leveraged to collect additional required samples. Importantly, while confirming the list of priority species is important, many fish samples from key communities supporting FISHSENS (see Letters of Support) have already been collected, helping FISHSENS begin data generation quickly (e.g., genomics). Moreover, extremely important community connections already exist with key co-PIs (Parlee, Martin, Hussey) and FISHSENS funding will further foster these with new data co-generation and exchanges. *HQP support.* Funds are requested to support 1 PD at $70K/yr and 1 PhD at $25K/yr, with additional funds for the PhD (~$15K/yr) contributed from other scholarships. HQP funds requested are thus ~$95K/yr. *Consumable/analyses.* Consumable funds of $16.5K/yr for the purchase of additional tracking tags (~$400/tag) are also requested. *Mobility/travel.* Travel and mobility funds are requested to participate in FISHSENS/CASTAF meetings and workshops (~$7.3K/yr). *Dissemination/outreach.* Funds are requested for sharing results through publications/presentations and community outreach (~$4K/yr). In all, telemetry tracking fund requests total $500K, or $125K/yr.

Bioinformatics hub and machine learning marker selection (Dalhousie - Beiko)
HQP support. The bulk of requested funds for the bioinformatics hub and training resources are for salaries supporting a developer ($65K/yr including benefits/taxes/inflation) and a PhD student at $30.5K/yr. As with McGill, graduate students at Dalhousie are topped up $5-7K/yr by GEAs. *Mobility/travel.* Funds in the amount of $3.5K/yr are requested for participation in key FISHSENS workshops, but travel will also be supplemented using other funds (e.g., NSTP). *Dissemination/ outreach.* Funds are also requested to make the training resources accessible in Inuktitut and to advertise its use ($1K/yr). The total bioinformatics budget sums at $400K, or $100K/yr (Table 1).

Knowledge co-production (McGill - Parlee, Government of Nunavut - Martin)
HQP support. Requested fund for the knowledge co-production includes HQP salary for 1 PhD working with co-PI - Parlee and northern co-PI (Martin – Government of Nunavut – GoN) to engage community stakeholders in knowledge sharing and discussions and to complete community surveys (see Letters of Support). *Dissemination/outreach.* No consumables or travel/mobility funds are requested specifically, but ~ $40K/yr are requested for dissemination and outreach to plan critical FISHSENS workshops in quarters 1 (Q1) of year 1, Q1 of year 4, and Q4 of year 4. These funds will also support the collection of IK through surveys and site visits. Regular interactions with Martin (northern co-PI) and special requested fund ($20K/yr) to compensate Inuit knowledge holders and field assistants for participation in FISHSENS workshops, meetings and knowledge exchange. Knowledge co-production budget sums to ~$380K, or ~$95K/yr (Table 1).

Economics (McGill - Mukhopadhyay)
HQP support. Funds supporting the economic valuation are mostly to support HQP on the project in the form of 1 PD (~$64K/yr including benefits/taxes/inflation), 1 PhD at $35K/year (expected to be topped up by GEA), and 1 MSc student at $30K/yr for 2 years. Rates are commensurate with McGill rates and/or current NSERC rates. The salary request sums to ~$357K, or ~$89K/yr. *Consumable/analyses.* Consumables include new laptop computers for northern travel and data collection ($3K), economic data repository subscriptions ($4K) and miscellaneous supplies ($2K) for a total of $9K, or $2.3K/yr. *Mobility/travel.* Funds are requested to attend FISHSENS and other meetings ($2.5K/yr) supplemented with others for travel to the north (e.g., NSTP). *Dissemination/outreach.* Funds for knowledge transfer and dissemination to defer publication costs and interaction with northern stakeholders are also included ($1K/yr). The total requested funds for the economic valuation activity are ~$380K, or ~$95K/yr (Table 1).