An ecosystem-based approach to sustainable resource management in the eastern Arctic: KEBABB (Knowledge and Ecosystem-Based Approach in Baffin Bay) 2019 sampling plan.

Monika Pućko, Christine Michel, Kevin Hedges, Zou Zou Kuzyk, Joannie Charette

Fisheries and Oceans Canada
Freshwater Institute
501 University Crescent
Winnipeg, MB R3T 2N6
Canada

2019

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 3185

Fisheries and Oceans Canada | Pêches et Océans Canada

Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 1426 - 1550 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 900 de cette série ont été publiés à titre de Manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme Manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de Rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de Rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

CANADIAN MANUSCRIPT REPORT

FISHERIES AND AQUATIC SCIENCES 3185

2019

AN ECOSYSTEM-BASED APPROACH TO SUSTAINABLE RESOURCE MANAGEMENT IN THE EASTERN ARCTIC: KEBABB (KNOWLEDGE AND ECOSYSTEM-BASED APPROACH IN BAFFIN BAY) 2019 SAMPLING PLAN.

by

Monika Pućko [1], Christine Michel [1], Kevin Hedges [1], Zou Zou Kuzyk [2], and Joannie Charette [1]

[1] FISHERIES AND OCEANS CANADA, FRESHWATER INSTITUTE, Winnipeg, Manitoba.

[2] UNIVERSITY OF MANITOBA, CENTRE FOR EARTH OBSERVATION SCIENCE, Winnipeg, Manitoba.

Cat. No. Fs97-4/3185E-PDF ISBN 978-0-660-32682-5 ISSN 1488-5387

Correct citation for this publication:

Pućko, M., Michel, C., Hedges, K., Kuzyk, Z. A., and Charette J. 2019. An ecosystem-based approach to sustainable management in the eastern Arctic: KEBABB (Knowledge and Ecosystem-Based Approach in Baffin Bay) 2019 sampling plan. Can. Manuscr. Rep. Fish. Aquat. Sci. 3185: vii + 12 p.

TABLE OF CONTENTS

Table of Contents…….iii

List of Tables……..iv

List of Figures……..…....v

Abstract……...vi

Résumé.……...…….....vii

1. Program participants……1

2. Relevance and scope of the program…….....…..……2

3. Scientific components of the program & sampling stations……..…….....3

4. Sampling schedule……..…….……8

5. Acknowledgements…….....12

6. References…...…...……..…….....12

List of Tables

Table 1. Oceanographic variables planned for Rosette operations during the KEBABB 2019 expedition.…….……..……..…...…….…….....10

Table 2. KEBABB 2019 zooplankton sampling schedule….……...11

List of Figures

Figure 1. NAFO (red) and Shrimp Fishing (green) areas in Eastern Canada along with overall KEBABB sampling area (yellow). (Figure modified from the DFO Integrated Fisheries Management Plan for Northern shrimp and striped shrimp – Shrimp fishing areas 0, 1, 4-7, the Eastern and Western Assessment Zones and North Atlantic Fisheries Organization (NAFO) Division 3M; http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/shrimp-crevette/shrimp-crevette-2018-002-eng.htm….....4

Figure 2. 2019 *Amundsen* leg 3 cruise track (green) with general KEBABB sampling area marked in orange (A), and locations of planned KEBABB 2019 sampling stations (B)……..……..….5

Abstract

Pućko, M., Michel, C., Hedges, K., Kuzyk, Z. A., and Charette J. 2019. An ecosystem-based approach to sustainable management in the eastern Arctic: KEBABB (Knowledge and Ecosystem-Based Approach in Baffin Bay) 2019 sampling plan. Can. Manuscr. Rep. Fish. Aquat. Sci. 3185: vii + 12 p.

Application of an ecosystem-based approach to fisheries management is a priority for Fisheries and Oceans Canada (DFO) and is an intrinsic part of the Department's mandated activities for the sustainable management of marine resources. Implementation of an ecosystem approach to fisheries management requires an understanding of the patterns and changes in abiotic and biotic factors that affect or are affected by harvested stocks. Baffin Bay hosts important Canadian fisheries for Greenland Halibut (*Reinhardtius hippoglossoides*) and Northern and Striped Shrimp (*Pandalus borealis* and *P. montagui*, respectively). Stock assessment surveys for these commercially harvested species are carried out routinely, but they often lack crucial environmental parameters, or have insufficient spatial resolution, to allow description of factors underlying inter- and intra- annual population dynamics. To address this important functional knowledge gap, DFO has established a new program, KEBABB (Knowledge and Ecosystem-Based Approach in Baffin Bay), as an important step towards the development and application of an ecosystem-based assessment approach to fisheries management in Baffin Bay. Here, we present the overarching vision and sampling plan for the first KEBABB field campaign (2019), to be carried out onboard the CCGS *Amundsen*, as a collaborative effort between DFO, Canadian universities, and Northern communities. We describe core components of the KEBABB program, along with detailed lists of biological, oceanographic and biogeochemical variables planned to be measured. Finally, we discuss how the planned components of KEBABB will contribute to establishing Baffin Bay fisheries as an example for sustainable and informed natural resource management.

Résumé

Pućko, M., Michel, C., Hedges, K., Kuzyk, Z. A., and Charette J. 2019. An ecosystem-based approach to sustainable management in the eastern Arctic: KEBABB (Knowledge and Ecosystem-Based Approach in Baffin Bay) 2019 sampling plan. Can. Manuscr. Rep. Fish. Aquat. Sci. 3185: vii + 12 p.

L'adoption d'une approche écosystémique à l'égard de la gestion des pêches est une priorité pour Pêches et Océans Canada (MPO) et fait partie intégrante des activités visées par le mandat du Ministère en ce qui a trait à la gestion durable des ressources marines. La mise en œuvre d'une approche écosystémique pour la gestion des pêches exige une compréhension des tendances et des changements liés aux facteurs biotiques et abiotiques qui ont une influence sur les stocks exploités ou qui sont influencés par ceux-ci. D'importantes pêches canadiennes au flétan noir (*Reinhardtius hippoglossoides*), à la crevette nordique et à la crevette rayée (*Pandalus borealis* et *P. montagui*, respectivement) sont pratiquées dans la baie de Baffin. Même si des évaluations des stocks de ces espèces exploitées commercialement sont effectuées régulièrement dans la région, des paramètres environnementaux essentiels manquent souvent pour décrire les dynamiques inter et intra-annuelles des populations. En raison de ce grand manque de connaissances fonctionnelles, le MPO a mis sur pied un nouveau programme, KEBABB (Knowledge and Ecosystem-Based Approach in Baffin Bay), qui est un élément crucial à l'établissement et à l'application d'une approche d'évaluation écosystémique pour la gestion des pêches dans la baie de Baffin. Nous présentons ici le plan d'échantillonnage de la première campagne de terrain de KEBABB (2019) qui sera menée à bord du NGCC *Amundsen* dans le cadre d'une collaboration entre le MPO, les universités canadiennes et les collectivités du Nord. Nous décrivons les principales composantes de KEBABB et présentons les listes détaillées des variables biologiques, océanographiques et biogéochimiques à mesurer. Enfin, nous discutons de la façon dont les composantes prévues de KEBABB contribueront à faire des activités de pêche menées dans la baie de Baffin un exemple de gestion durable et éclairée des ressources naturelles.

1. Program participants

Principal Investigator: Christine Michel, Senior Research Scientist, Fisheries and Oceans Canada

Co-leads:

Kevin Hedges, Research Scientist, Fisheries and Oceans Canada

Zou Zou Kuzyk, Assistant Professor, University of Manitoba

Collaborators:

Philippe Archambault, Professor, Laval University

Jean-Eric Tremblay, Professor, Laval University

Louis Fortier, Professor, Laval University

Coordinator: Monika Pućko, Biologist, Fisheries and Oceans Canada

Field participants:

Joannie Charette, Biologist, Fisheries and Oceans Canada; Field lead and safety representative

Jason Etuangat, Research Staff, Fisheries and Oceans Canada

Pascal Tremblay, Technician, Fisheries and Oceans Canada

Stephen Ciastek, Technician, University of Manitoba

Constance Duffaud, M.Sc. Student, Université du Québec à Rimouski

Devin Hammett, B.Sc. Student, University of Manitoba

Monica Sokolowski, B.Sc. Student, University of Windsor

2. Relevance and scope of the program

Application of an ecosystem-based approach to fisheries management is a priority for Fisheries and Oceans Canada (DFO) and is an intrinsic part of its mandated activities for the sustainable management of marine resources. Implementation of an ecosystem approach to fisheries management requires an understanding of the patterns and changes in abiotic and biotic factors that affect or are affected by harvested stocks. DFO conducts annual stock assessment surveys for Greenland Halibut (*Reinhardtius hippoglossoides*) and Northern and Striped Shrimp (*Pandalus borealis* and *P. montagui*, respectively) in the Eastern Canadian Arctic. These surveys provide data on targeted commercial species and the surrounding benthic fish and invertebrate community, but the collection of essential ancillary environmental data is limited to a trawl-mounted CTD (Conductivity, Temperature, Depth) and a few irregularly-sampled CTD cast stations which yield observations that are, at best, difficult to interpret. The CTD casts are considered a lower priority than fishing activities and are the first measurements cut when faced with rough weather or other time constraints. Thorough, standardized and defensible collection of data on physical, chemical and biological oceanographic conditions are needed for an ecosystem approach to fisheries management in Eastern Canadian Arctic fisheries. Collection of oceanographic data across fishing areas (i.e., NAFO Divisions and Shrimp Fishing Areas shown in Figure 1) is needed to interpret changes in stock abundances and distributions at a regional scale. Data collected in the Eastern Canadian Arctic can complement and be combined with similar data collected as part of the ongoing Atlantic Zone Monitoring Plan.

In 2019, DFO in partnership with Northern communities is establishing a new program, KEBABB (Knowledge and Ecosystem-Based Approach in Baffin Bay) as a crucial component for the development and application of an ecosystem-based assessment approach for fisheries management in Baffin Bay. The KEBABB program is also intended as one of the components of an overall Arctic marine ecosystem monitoring program, providing ecosystem-based science and monitoring for the productive region of Baffin Bay east of Baffin Island. Northern communities were involved at the planning stage of KEBABB as integral partners in the development of Integrated Fisheries Management Plans for Greenland Halibut and shrimps in the region. It is also planned to

have at least one Northern communities' representative involved in field sampling each year. The first field expedition for KEBABB will be carried out in summer 2019 onboard the CCGS *Amundsen*. The CCGS *Amundsen* offers state-of-the-art capability for oceanographic data collection, including chemical and biological oceanography, as well as for zooplankton and benthic studies, all essential components of the KEBABB program. At each station, we will use the CTD -Rosette system for a full suite of physical (e.g., CTD and PAR, photosynthetically active radiation) and biochemical measurements including water mass tracers (e.g., $\delta^{18}O$), acidification conditions, dissolved inorganic and organic matter (nutrients, organic carbon and nitrogen), and the abundance, biomass and composition of protist and microbial communities, pigmented biomass (Chlorophyll *a,* Chl *a*), particulate organic carbon and nitrogen, and phytoplankton species diversity. We will also carry out net tows for zooplankton species diversity, abundance and biomass. The benthos and benthic environment will be characterized with a box corer at key stations. Stable isotopes and fatty acid biomarkers will provide insights into trophic linkages from primary producers to zooplankton, benthos and fish species (fish samples will be collected in other studies).

3. Scientific components of the program & sampling stations

The 2019 KEBABB field program will take place from 15 August to 10 September, starting in Resolute Bay and ending upon the return of the ship in Quebec City. The proposed sampling plan includes a total of twenty-five (25) stations distributed along five (5) transects of five (5) stations each (Figure 2). The location and distribution of the sampling stations is strategically planned to inform DFO stock assessment surveys and fish distribution and habitat use studies. The five (5) transects each cover a coastal-offshore gradient and are distributed along a south-north axis. The number of stations, transects, and stations per transect determined make it possible for DFO to achieve a near-synoptic ecosystem-based survey, within ten (10) days of sampling. The **overall objective of KEBABB is to characterize the variability and trends in physical, chemical and biological oceanographic conditions and their influence on fisheries resources in western Baffin Bay.**

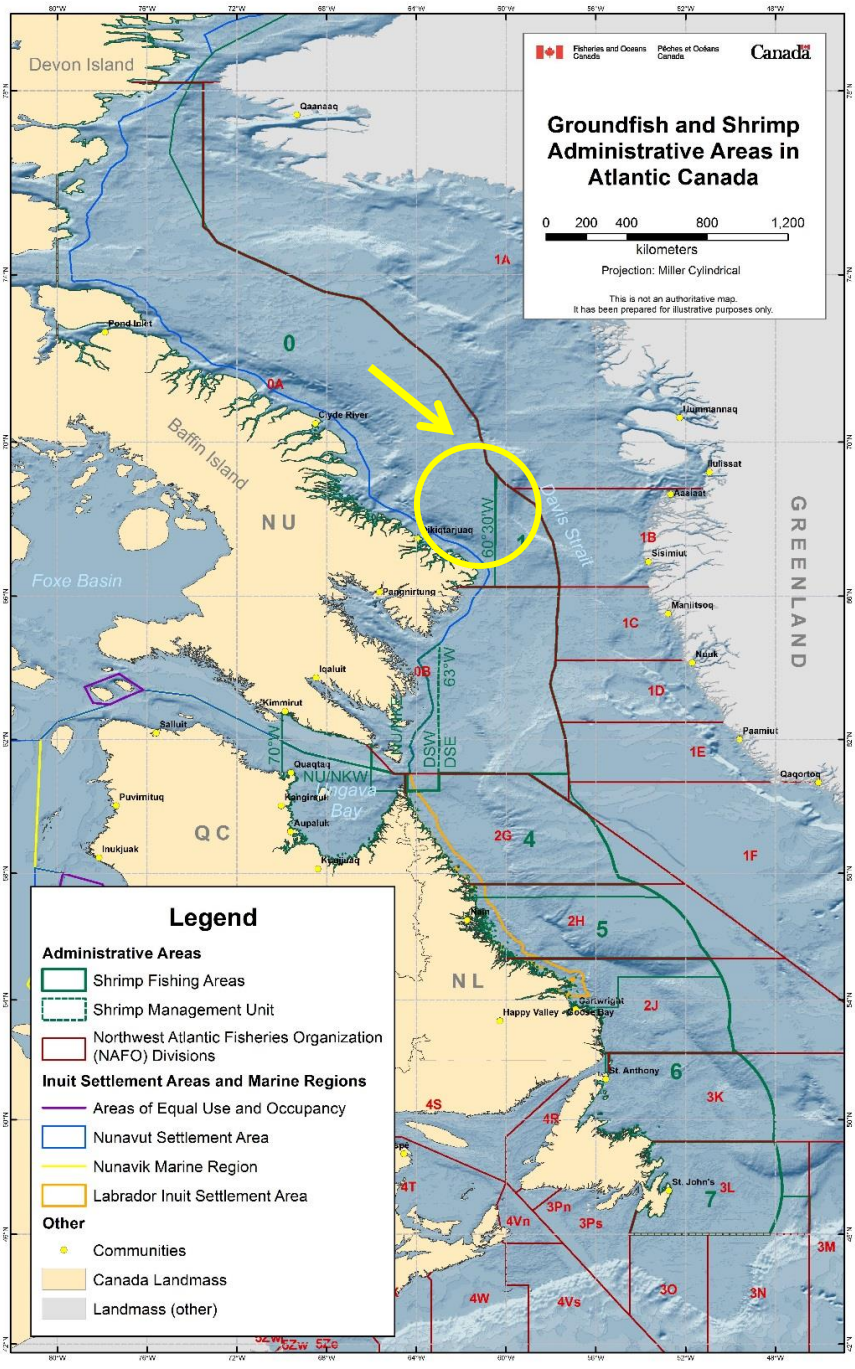

Figure 1. NAFO (red) and Shrimp Fishing (green) areas in Eastern Canada along with overall KEBABB sampling area (yellow). (Figure modified from the DFO Integrated Fisheries Management Plan for Northern shrimp and striped shrimp – Shrimp fishing areas 0, 1, 4-7, the Eastern and Western Assessment Zones and North Atlantic Fisheries Organization (NAFO) Division 3M; http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/shrimp-crevette/shrimp-crevette-2018-002-eng.htm

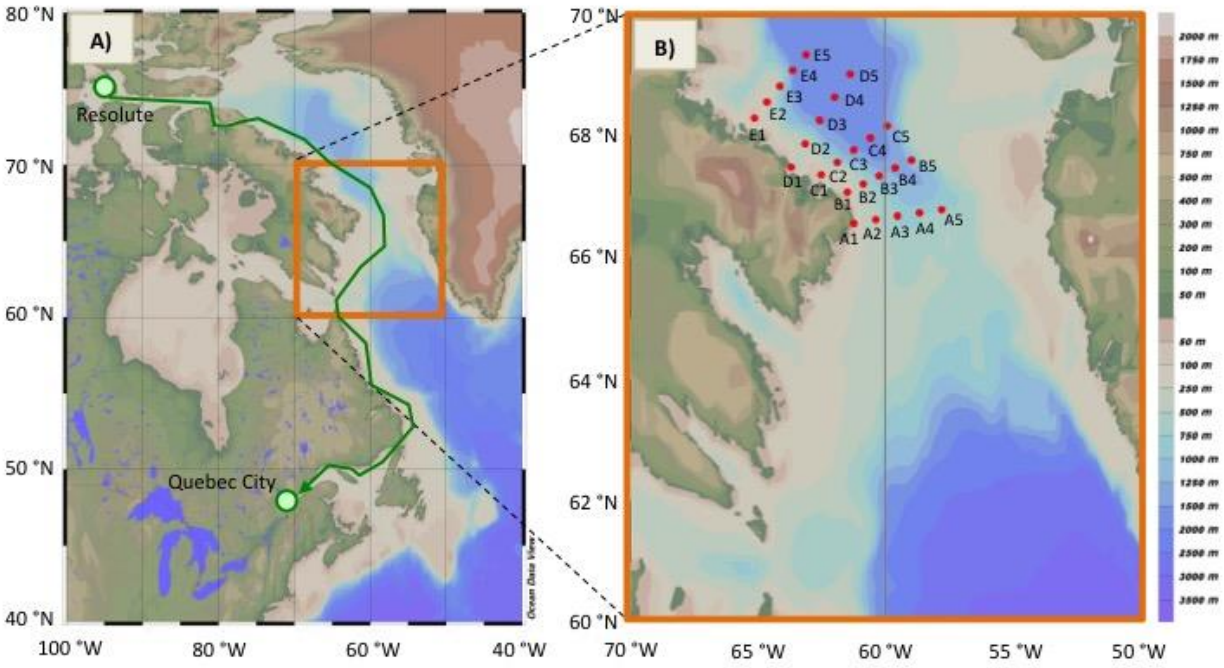

Figure 2. 2019 *Amundsen* leg 3 cruise track (green) with general KEBABB sampling area marked in orange (A), and locations of planned KEBABB 2019 sampling stations (B).

Towards this objective, the KEBABB program is divided into 5 main components:

A. Physical and chemical oceanographic conditions *(C. Michel/J.-E. Tremblay)*

Rationale: Understanding and mapping physical and chemical oceanographic conditions provides habitat context for fisheries resources, and helps explain and predict regional and year-to-year differences in harvested species abundance and composition. Water temperature, salinity, acidification conditions, as well as general mixing and circulation patterns can directly influence shrimp and fish species diversity, distribution, and abundance in the Canadian Arctic by deviating species optimum habitat conditions. Additionally, water mass distribution and mixing influence nutrients (Nut) and dissolved constituents concentrations, which in turn will affect marine productivity at the bottom of the food web, ultimately controlling food abundance for fisheries resources in the region.

Measurements: Vertical profiles and contour distribution of Temperature, Salinity (S), Oxygen isotope ratio ($\delta^{18}O$), Nutrients (nitrate, nitrite, phosphate, silicic acid), Dissolved organic carbon/nitrogen (DOC/DN), Dissolved inorganic carbon (DIC), and Total alkalinity (TA).

B. Abundance and composition of phytoplankton and microbial communities *(C. Michel)*

Rationale: Marine productivity and biodiversity at the base of the food web has major impact on the overall productivity of the region, and translates both directly and indirectly into fisheries resources abundance and diversity. Monitoring phytoplankton abundance and composition, microbial community structure, and particulate organic carbon and nitrogen distribution and trends are crucial to understand regional and temporal variability in food web patterns and fish stocks. Information on the abundance and composition of phytoplankton and microbial communities complement catch limit thresholds to fully explain past and help predict future fisheries population dynamics.

Measurements: Vertical profiles of Chlorophyll a (Chl *a*) concentration, contour distribution of Particulate organic carbon and nitrogen (POC and PON); abundance and size of phytoplankton and bacteria (flow cytometry (FA) techniques), phytoplankton species abundance and composition (inverted microscopy techniques), and abundance of bacteria (nucleic acid staining techniques, DAPI).

C. Abundance and composition of zooplankton (*K. Hedges/L. Fortier)*

Rationale: Zooplankton provides a crucial link between the primary producers and higher trophic levels including commercially harvested species in the Eastern Canadian Arctic. Abundance and diversity of zooplankton affects trophic energy

transfer in the food web, ultimately impacting fisheries resources. On the one hand, shrimp are omnivores that can feed on zooplankton, and zooplankton population dynamics can affect these species directly. On the other hand, Greenland Halibut are predators feeding on shrimp and smaller fishes such as Arctic Cod or Capelin, and thus are indirectly affected by zooplankton population structure and dynamics in the region.

Measurements: Abundance and diversity of zooplankton species.

D. Benthic communities and biogeochemistry *(Z. Kuzyk/P. Archambault)*

Rationale: The benthic ecosystem constitutes natural habitat for the Baffin Bay commercially harvested species of shrimp and Greenland Halibut, and as such can have crucial impact on these species' population health and abundance. Characterizing composition and biomass of benthic infauna and epibenthic communities and applying biogeochemical proxies to explore their diets can provide insights into regional and temporal variability in fisheries resources. Geochemical characterization of surficial (top 40 cm) sediments themselves provides insights into rates of organic matter deposition, remineralization, and preservation and variability in organic matter sources across space and time. Sediments also may contain an archive that records changes in marine productivity and biodiversity through recent decades.

Measurements: Abundance and diversity of benthic infauna and epibenthic species, biogeochemical proxies, geochronological tools (^{210}Pb and ^{137}Cs) and organic carbon and nitrogen content in sediments.

E. Ecosystem health and interactions *(C. Michel)*

Rationale: Ecosystem health is a broad term that generally comprises three main attributes: vigor (productivity), organization (species diversity and interactions),

and resilience (capacity to sustain productivity and diversity). Overall ecosystem health results from numerous cumulative impacts of human activities and natural variability. By complementing information gathered in other KEBABB components with food web interactions using biomarkers, marine toxin profiling, and climate change related predictions for the region, we aim at establishing baseline information for general ecosystem health considerations. Providing the KEBABB program becomes a long-term initiative, such baseline information can become a reference point for future assessments, supporting an effective ecosystem-based approach to fisheries resources management in the region.

Measurements: Food web interactions using Fatty acid (FA) and Stable isotope composition in phytoplankton, zooplankton (sorted), and benthic epifauna (sorted); marine algal toxin presence and potentially concentration (Domoic acid, Saxitoxins, and Lipophilic toxin groups) in benthic bivalves.

4. Sampling details

Sampling will be carried out around the clock with two 12-h shifts; the KEBABB team will work as outlined below:

Rosette: Joannie Charette/Constance Duffaud with help from J.-E. Tremblay's team

Zooplankton: Pascal Tremblay/Monica Sokolowski/Jason Etuangat with help from L. Fortier's team

Benthos: Stephen Ciastek/Devin Hammett with help from P. Archambault's team

Rosette sampling and processing details:

There will be one CTD/Rosette cast for KEBABB per station.

Rosette sampling details can be found in Table 1. Order of samples collection from the Rosette is as follows:

- DIC/TA
- Nutrients
- DOC/DN
- $\delta^{18}O$/salinity (can be done directly from Rosette or in the lab)
- Remaining water sample for the remainder of biological analyses

Samples will be processed according to established methods in biological oceanography (Parsons et al. 1984; Knap et al. 1996; Grasshoff et al. 1999).

Zooplankton sampling and processing details:

Nets will be operated by L. Fortier's team. Sampling details for nets is presented in Table 2.

Benthos sampling and processing details:

Box core/Agassiz trawl will be operated by Z. Kuzyk/P. Archambault's teams. There will be 1 box core per station to be shared between sediment collection and benthic infauna collection. KEBABB team has half a bench in the benthic lab for processing of samples.

P. Archambault's team will collect samples for epibenthic species diversity, abundance, and biomass and infauna diversity, abundance and biomass. They will also collect small sediment samples for pigment content (top 1 cm), organic carbon content (top 1 cm), and grain size (top 5 cm). Bivalve samples (sorted; 2-15g/sample) from the Agassiz trawl (3 stations/transect) from P. Archambault's team will be provided to KEBABB team for FA and marine toxin analyses. Z. Kuzyk's team will insert a thin-walled core tube under suction into their half of the undisturbed box core to obtain a push-core (20 cm – 45 cm in length) that will be sectioned immediately using an extruder. Cores will be sectioned into 1 cm sections for the top 10 cm, 2 cm sections for the 10-20 cm portion, and 5 cm sections thereafter to the bottom of the core. Physical features will be described (e.g., sediment color and texture, presence of drop stones, etc.) and sediment sections will be frozen for later geochemical analyses.

Table 1 Oceanographic variables planned for Rosette operations during the KEBABB 2019 expedition.

Depth [m]	DIC/ TA	Nut	DOC/ DON	$\delta^{18}O$	S	FC_{Bact}	FC_{Prot}	FC_{Vir}	$Cells_{Lug}$	$Cells_{Form}$	DAPI	Chl *a* tot	Chl *a* 5	POC/ PON*	FA	DNA
5	1x	2x	2x	1x	1x	2x	2x	2x			2x	2x	2x			
10		2x		1x	1x							2x	2x			
20	1x	2x	2x	1x	1x	2x	2x	2x				2x	2x			
30		2x		1x	1x							2x	2x			
Chl max	1x	2x	2x	1x	1x	2x	2x	2x	1x	1x	2x	2x	2x	2x	2x	2x
40	1x	2x	2x	1x	1x	2x	2x	2x				2x	2x			
50		2x		1x	1x							2x	2x			
60	1x	2x	2x	1x	1x	2x	2x	2x				2x	2x			
80	1x	2x	2x	1x	1x	2x	2x	2x				2x	2x			
100	3x	2x	2x	1x	1x	2x	2x	2x								
150		2x		1x	1x											
200	1x	2x	2x	1x	1x											
250		2x		1x	1x											
300	1x	2x		1x	1x											
500	1x	2x	2x	1x	1x											
750	1x	2x		1x	1x											
1000	1x	2x	2x	1x	1x											
bottom	1x	2x	2x	1x	1x											

1x: single measurement, 2x:duplicate samples; 3x – triplicate samples; *3x at 5 or more stations

Table 2 KEBABB 2019 zooplankton sampling schedule.

Analysis	Net	Frequency	Notes
Zooplankton taxonomy (entire water column)	Monster 200 µm	Each station	❖ In collaboration with Fortier's team (Laval University). ❖ One net (200 µm mesh size) is provided to KEBABB team at each station. Possibly 2 nets; one for FA/SI analysis. ❖ Important to note volume filtered through net for each tow.
Zooplankton taxonomy (stratified tows)	Hydrobios	3/transect	❖ In collaboration with Fortier's team (Laval University). ❖ On near-shore, middle- and most off-shore station from each transect. ❖ Typical strata: Three (3) strata with top 20 m, bottom 20 m, middle section between top and bottom 20 m. ❖ Important to note volume filtered through net for each tow.
Zooplankton species (FA and stable isotopes)	Tucker (oblique tow) 500 µm Monster 200 µm	Each station	❖ If feasible, sort out smaller (<500 µm) zooplankton species from the Monster net. As often as possible.

5. Acknowledgements

This work is supported by DFO Science funds. Special thanks go to our collaborators, Drs. Philippe Archambault, Jean-Éric Tremblay and Louis Fortier and their scientific teams, for their input into the KEBABB field program planning. We are also extremely grateful to Anissa Merzouk, Colline Gombault, Alexandre Forest, and other members of Amundsen Science for planning the CCGS *Amundsen* 2019 scientific expedition and for their extraordinary coordinating efforts.

6. References

Grasshoff, K., Kremling, K., and Ehrhardt, M. (Eds.) 1999. Methods of Seawater Analysis 3rd edition, Wiley.

Knap, A., Michaels, A., Close, A., Ducklow, H., and Dickson, A. 1996. Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements, JGOFS Report No. 19, Reprint of the IOC Manuals and Guides No. 29, UNESCO 1994.

Parsons, T.R., Maita, Y., and Lalli, C.M. 1984. A manual of Chemical and Biological Methods for Seawater Analysis. Pergamon Press, Toronto.