PROCEEDINGS OF THE NATIONAL WORKSHOP AIS: MOVING FORWARD January 14-15, 2020, Ottawa

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ABSTRACT

Tita, G., Foster, S. and Sardelis, S. (eds.) 2021. Proceedings of the National Workshop *AIS: Moving Forward* – January 14-15, 2020, Ottawa. Can. Manuscr. Rep. Fish. Aquat. Sci. 3228: vi + 19 p.

Following guidance from the 2004 *Canadian Action Plan to Address the Threat of Aquatic Invasive Species* (AIS), the Government of Canada is committed to protecting Canada's freshwater and marine ecosystems from the negative impacts of AIS. On Tuesday, January 14 and Wednesday, January 15 2020, scientists and managers from various federal departments and agencies met to discuss a revitalized path forward for addressing the threat of AIS in Canada. The objective of the workshop was to determine how Fisheries and Oceans Canada's Ecosystems and Oceans Science (EOS) sector can fill gaps in AIS knowledge to better deliver science products, and increase the effectiveness and efficiency of science in supporting decision and policy-making processes. Workshop participants from all departments and agencies presented overviews of their respective organizations' AIS activities to date, as well as their science needs. In addition, EOS provided in-depth regional summaries of AIS expertise, capacities, and undertakings. Finally, a summary of an internal gap analysis of EOS' AIS knowledge and research activities was presented. To synthesize the information presented into action, participants were engaged in breakout groups with the intention of identifying tangible steps for EOS to take moving forward. Discussions focused on the need for standardized and strategic priority setting between science and AIS management programs and the development of a governance structure for EOS AIS science activities. The workshop culminated in EOS staff developing a preliminary work plan for 2020/2021.

RÉSUMÉ

Tita, G., Foster, S. and Sardelis, S. (eds.) 2021. Proceedings of the National Workshop *AIS: Moving Forward* – January 14-15, 2020, Ottawa. Can. Manuscr. Rep. Fish. Aquat. Sci. 3228: vi + 19 p.

En suivant les conseils du Plan d'action canadien de lutte contre les espèces aquatiques envahissantes (EAE) de 2004, le gouvernement du Canada s'est engagé à protéger les écosystèmes d'eau douce et marins du Canada contre les impacts négatifs des EAE. Le mardi 14 janvier et le mercredi 15 janvier 2020, des scientifiques et des gestionnaires des ministères et agences fédéraux se sont réunis pour discuter d'une nouvelle voie pour lutter contre la menace des EAE au Canada. L'objectif de l'atelier visait à déterminer comment le secteur des Sciences des écosystèmes et des océans (SEO) de Pêches et Océans Canada peut combler les lacunes dans les connaissances sur les EAE afin de fournir des produits scientifiques améliorés et accroître l'efficacité et l'efficience des processus de prise de décision et d'élaboration des politiques. Les participants de chaque organisation ont présenté un aperçu de leurs activités sur les EAE à ce jour, ainsi que leurs besoins scientifiques. Le secteur SEO a fourni des résumés régionaux détaillés de l’expertise sur les EAE, des capacités et des activités en cours. Enfin, un résumé d’une analyse des lacunes dans les activités sur les EAE du secteur SEO a été présenté. Afin de synthétiser l’information présentée, les participants ont pris part à des sessions en petits groupes pour identifier des mesures concrètes que le secteur SEO pourrait mettre de l’avant, en se concentrant sur la nécessité d’établir des priorités normalisées et stratégiques entre les programmes de gestion et des sciences de même que l’élaboration d’une structure de gouvernance. L’atelier s’est terminé avec l’élaboration d’un plan de travail préliminaire pour 2020/2021 par le personnel du secteur SEO.

GLOSSARY

ACP: Asian Carp Program

AIS: Aquatic Invasive Species

ABWEZ: Alternative Ballast Water Exchange Zone

BIO: Bedford Institute of Oceanography

BWMS: Ballast Water Management System

CAISN: Canadian Aquatic Invasive Species Network

CEARA: Centre of Expertise for Aquatic Risk Assessment

CESD: Commissioner of the Environment and Sustainable Development

CFB: Canadian Forces Base

CMIST: Canadian Marine Invasive Screening Tool

CNMCAA: Canadian National Marine Conservation Areas Act

CoRE: Conservation and Restoration Program

CSAS: Canadian Science Advisory Secretariat

DFO: Department of Fisheries and Oceans Canada

DND: Department of National Defence

EOS: Ecosystems and Oceans Science Sector

FTE: Full-Time Employee

grAIS: Gulf Region Aquatic Invasive Species Database

GRDI: Genomics Research and Development Initiative

ICS: Incident Command System

IMO: International Maritime Organization

NAISC: National Aquatic Invasive Species Committee

NCP: National Core Program

NETE: Naval Engineering Test Establishment

NSERC: Natural Sciences and Engineering Research Council

O&M: Operations and Maintenance

OPP: Oceans Protection Plan

PBS: Pacific Biological Station

PCA: Parks Canada Agency

RCN: Royal Canadian Navy

SLCP: Sea Lamprey Control Program

TC: Transport Canada

1 CONTEXT

Fisheries and Oceans Canada (DFO) is committed to protecting Canada's freshwater and marine ecosystems from the negative impacts of aquatic invasive species (AIS). Under Budget 2005, DFO was funded to initiate the implementation of *An Invasive Alien Species Strategy for Canada* endorsed by federal, provincial, and territorial governments. This included scientific activities to support risk analysis through the development of methods to prevent, detect, monitor, control, and mitigate impacts of AIS, risk assessment, support for regulatory policy development, and funding for the Sea Lamprey Control Program (SLCP). Funding was renewed in 2010 on an ongoing basis.

In 2015, the *AIS Regulations* came into force, enabling the federal, provincial, and territorial governments to take action to prevent the introduction and spread of AIS, including management and control activities. Subsequently, under Budget 2017, the AIS National Core Program (NCP) was established under the Aquatic Ecosystems sector as the first ever national management initiative for, and DFO's new lead on, AIS. The AIS NCP's mission is to implement the *AIS Regulations* in Canadian waters, to act on sound scientific and other advice, and to report nationally on AIS activities according to four international AIS pillars: 1) prevention, 2) early detection, 3) response, and 4) control and management. DFO also received supplementary funding for the SLCP and the Asian Carp Program (ACP). With the establishment of the AIS NCP as DFO's AIS management lead comes an opportunity to refocus the Ecosystems and Oceans Science (EOS) sector's AIS science activities and responsibilities.

A number of other programs within DFO, such as aquaculture and species at risk, and other federal departments, such as Transport Canada, are involved in the management of AIS. As such, additional resources are often shared or leveraged across programs or departments to address the threat of AIS.

The *AIS: Moving Forward* national workshop was held on January 14-15, 2020. The meeting was focused on exploring how DFO's EOS sector's activities contribute towards a greater understanding of AIS trends and risks, as well as how they inform management, policy, and regulatory direction. This document provides an overview of the presentations and discussions at the meeting. The authorship of this document was a collaborative effort across all presenters and participants.

2 OBJECTIVES

The objectives of the workshop were to:

- Present the current status of DFO's Ecosystems and Oceans Science (EOS) sector's AIS activities, main achievements, and gaps.
- Identify actions that will allow EOS to:
    - Address existing gaps in AIS knowledge to better deliver science products (i.e., research, monitoring, and risk analyses).
    - Increase effectiveness and efficiency for supporting decision and policy-making processes of clients and partners.

3 DAY 1: STATE OF GOVERNMENT OF CANADA'S AIS ACTIVITIES

3.1 DFO OVERVIEW

3.1.1 Ecosystems and Oceans Science Sector

DFO has received annual Operations and Maintenance (O&M) funding for AIS activities since 2005/2006 dedicated to: (a) the Sea Lamprey Control Program, (b) science and technology, (c) priority biological risk assessment, (d) socio-economic risk assessment, (e) outreach, regulatory, and policy development, and (f) administrative overhead. In particular, science and technology funds are used to support AIS research, monitoring, and coordination. Funding for Full-Time Employees (FTEs) is not included in this envelope. Instead, FTEs are allocated nationally and regionally from other existing programs and/or on part-time or seasonal basis through O&M funding. The Ecosystems and Oceans Science sector also receives external funds from other programs within DFO (e.g., Great Lakes Action Plan) and federal government departments (e.g., Transport Canada) to undertake dedicated AIS research and other scientific activities to meet management needs.

From 2005 to 2014, DFO operated the Centre of Expertise for Aquatic Risk Assessment (CEARA) to develop national standards for, and provide guidance on, scientifically defensible biological risk assessment. CEARA was instrumental in establishing national guidelines for evaluating the risk to biodiversity of introducing aquatic non-indigenous organisms into a new environment[1], completing risk assessments and biological synopses on a number of species and pathways, establishing a framework to identify priority pathways and species for funding purposes, and developing the *Canadian Rapid Response Framework for AIS*[2].

From 2006 to 2016, the Canadian Aquatic Invasive Species Network (CAISN) (with the support of the Natural Sciences and Engineering Research Council of Canada (NSERC)) brought together academia, government, non-governmental organizations, and industry to advance invasion science and technology. CAISN explored topics related to vectors and pathways, factors affecting establishment success, risk modelling, early detection, rapid response, AIS as part of multiple stressors, and reducing uncertainty and prediction in management[3]. CAISN greatly facilitated the establishment of long-lasting scientific collaborations between DFO AIS scientists and academia.

To fulfill commitments made in the Ministerial Mandate Letter, Budget 2016 provided funds to EOS for 4 FTEs for freshwater science (including AIS activities among others) in the Great Lakes (2), St. Lawrence River (1), and Lake Winnipeg (1) basins, as well as additional funds for the SLCP and ACP. In addition, other DFO or science programs, such as species at risk and aquaculture, contribute funding towards AIS science activities where overlap occurs.

To date, EOS's activities have focused on studying the ecological impacts of AIS and their risk of invasion (including the development of screening and detailed-level risk assessment tools, such as the Canadian Marine Invasive Screening Tool [CMIST]), early detection (including novel methods, such as environmental DNA [eDNA]), and monitoring established populations for

[1] DFO (2009). Proceedings of the workshop to finalize National Guidelines for Assessing the Biological Risk of Aquatic Invasive Species (AIS) to Canada; June 3-5, 2008. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2009/006. https://waves-vagues.dfo-mpo.gc.ca/Library/337722.pdf

[2] Locke A., N.E. Mandrak, T.W. Therriault (2011). A Canadian Rapid Response Framework for Aquatic Invasive Species. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/114. vi + 30 p. https://waves-vagues.dfo-mpo.gc.ca/Library/342726.pdf

[3] CAISN (2018). Canadian Aquatic Invasive Species Network. https://www.nserc-crsng.gc.ca/Business-Entreprise/How-Comment/Networks-Reseaux/CAISN-CAISN_eng.asp

range expansion, particularly in high-risk habitats (e.g., ports, marinas, aquaculture sites). Biological risk assessments were led by CEARA until 2013, and were thereafter led by regional science leads and national staff according to available departmental resources and requests for science advice received from clients. EOS is also involved in international working groups and networks of experts, strengthening Canada's international engagement in addressing the threat of AIS.

3.1.2 Aquatic Ecosystem Sector: AIS National Core Program

The AIS NCP was established in 2017 as Canada's first ever national management program for AIS. The AIS NCP's mission is to implement the *AIS Regulations* and act on scientific and other advice according to the four international AIS pillars (prevention, early detection, response, and control), and to report on AIS, including the SLCP and ACP. The AIS NCP develops AIS regulatory processes and tools and collaborates with partners to manage AIS, including provincial and territorial governments and other federal departments through the National Aquatic Invasive Species Committee (NAISC). The AIS NCP's recent activities include outreach and education initiatives (e.g., tutorial videos, "Don't Let it Loose" messaging with NAISC), early detection and response activities in collaboration with EOS and Parks Canada, and fulfilling the commitments made in response to the Commissioner of the Environment and Sustainable Development (CESD)'s audit on AIS (2019).

The AIS NCP needs support from EOS on screening and detailed-level biological risk assessments for species and pathways, evidence-based advice on program management and prioritization, and regulatory support advice (e.g., species listing). Risk assessment results will help align resources for early detection programs in geographic areas of high AIS risk. Priority science topics identified for 2020-2021 include: (1) science advice on Clean, Drain, Dry, and Decontamination protocols and treatments, (2) science advice on trapping to control European Green Crab, (3) an updated national detailed-level risk assessment of dreissenid mussels, and (4) a screening-level risk assessment of non-native crayfish species. Science advice on aquatic invasive plants is also required in the medium-term. Long-term, research will be needed to better understand the effects of anthropogenic activity in bridging AIS biogeographic barriers, as well as the potential impacts of AIS on species at risk.

Other science needs include:

i. Support the development of a national AIS database, as recommended by the CESD Audit on AIS;
ii. Input on the threats and risks of invasive species, including plants, on freshwater habitats;
iii. Assess the efficacy of deleterious substances as mitigation tools for AIS;
iv. Consider climate change effects on AIS risks;
v. Collaborate on the development of AIS response plans; and
vi. Establish an inter-sector AIS governance structure to: (1) guide resource use, (2) frame AIS early detection, response, and control activities, (3) develop a National AIS Science Strategy, and (4) determine other science-related needs at a national level through facilitated discussions with the regions.

3.2 OTHER FEDERAL DEPARTMENTS

3.2.1 Transport Canada

Transport Canada (TC) has the authority to make regulations for the control and management of risks associated with the release of non-indigenous organism from vessels transiting or operating in Canadian waters. TC recognizes that ballast water and hull biofouling are both important vectors for AIS introduction and spread. DFO's EOS provides TC with extensive scientific support on topics related to ballast water regulations, including environmental risk, BWMS equipment performance, operational feasibility, input on cost-benefit analyses, and alignment with other international commitments. Continued support is needed, particularly for BWMS equipment performance and low-risk vessel regulatory exemptions.

Canada does not have regulations for the control and management of ship biofouling. TC recently sought DFO science advice to help shape national guidelines, policies, and regulations, as well as Canada's position on biofouling at the International Maritimes Organization. The science advice should be completed by March 2022.

3.2.2 Department of National Defence

The Department of National Defence (DND)'s Naval Engineering Test Establishment (NETE) operates a Biofouling Focus Group (BFG). This includes a monitoring program at the Canadian Forces Base (CFB) Halifax and CFB Esquimalt using collector plates coated with different antifouling substances that the navy applies to its vessels or is interested in trying. The program is conducted in collaboration with DFO's Bedford Institute of Oceanography (BIO) and Pacific Biological Station (PBS).

Another area of collaboration with DFO is the development of a biofouling-specific version of CMIST for use on naval ship deployments. This will help pre-assess the exposure risk of the Royal Canadian Navy (RCN) during their operations abroad, and to assess the source and sink risks of ports via species distribution modelling. The aim is to provide a list of species of high concern that DND may monitor for, as well as route planning support to mitigate species transfers between ports.

The nature of RCN operations requires fast turnaround times for detections of AIS. Future areas of potential work include the development of methods for rapidly (e.g., a few days) and accurately identifying species that foul hulls, visual tools for assessing ship biofouling, and eDNA tools with quick turnaround times that provide actionable assessments of fouling species. Facial recognition algorithms could be utilized, along with autonomous underwater vessels.

3.2.3 Parks Canada Agency

Regionally, AIS is a growing concern and increasing priority for the Parks Canada Agency (PCA), and research and monitoring continue to be the backbone of their early detection. National Parks are affected by high traffic and external visitors, putting them at higher risk (likelihood) of invasion. They protect important waterways, including some provincial headwaters, that would suffer severe consequences if AIS are introduced. Priorities for research and monitoring are determined locally (site-specific). A number of PCA sites have active management projects to combat AIS, mostly funded through the Conservation and Restoration Program (CoRE) as 5-year projects, many of which involve research often related to species at

risk. Other AIS-related activities are funded through species at risk funding and partnerships. For instance, a project on Round Goby, Asian carps, and modelling locks and dams to inform species at risk management in the Rideau Canal waterway had been funded through the Natural Sciences and Engineering Research Council of Canada (NSERC).

Science needs and gaps include: (1) assessing the effectiveness of control methods (e.g., Clean, Drain, Dry; trade-offs; wildfire program), (2) performing pathway analyses (e.g., recreational watercraft, visitors), (3) evaluating future climate scenarios on species shift (e.g., in Ontario waterways), (4) cross-jurisdictional work on species of concern (e.g., European Green Crab, *Phragmites*), (5) developing knowledge and technical capacity for emerging and priority AIS, (6) developing evidence-based rapid response and control or eradication mechanism for specific species (e.g., regulatory listing, permits to control Chain Pickerel and European Green Crab in the Atlantic, Brook Trout in Mountain Parks), and (7) advancing eDNA as a tool for management (e.g., in Banff). PCA sees DFO's role as overseeing a national AIS strategy, large scale approaches, protocol development, and identifying emerging issues, while PCA could focus on outreach and education, as well as onsite monitoring and mitigation.

3.3 DFO REGIONAL AIS SCIENCE ACTIVITIES OVER THE LAST 2 TO 3 YEARS

3.3.1 Overview

DFO conducts AIS activities nationally and across DFO's 6 geographic regions: Pacific, Central and Arctic, Quebec, Gulf, Maritimes, and Newfoundland and Labrador. Funding to support AIS activities comes from a variety of sources, including dedicated AIS funding for operational activities (e.g., science-led monitoring). The following is a summary of regional AIS science activities as of January 2020, including areas of expertise, current research, monitoring, and emerging issues, with a focus on recent work.

3.3.2 Pacific Region

Areas of Expertise	• Risk assessment of marine and freshwater species and vectors, and tool development • Research and impact studies of priority species (European Green Crab, tunicates) and pathways • Monitoring marine AIS
Research	• Application of CMIST to DND vessels for biofouling • Assessment of biogeographic barriers to dispersal and bridging pathways/vectors • Environmental niche modelling to determine the potential distribution of marine AIS • eDNA suitability for early detection of Green Crab • Power washing effectiveness to control spread of AIS associated with shellfish farming movements • Connectivity between AIS hotspots and marine protected areas in BC, especially via vessel traffic • Potential impacts of Green Crab on eelgrass habitats in BC in collaboration with Parks Canada
Monitoring	• Intertidal surveys to track the spread of AIS in BC (mostly molluscs) • Subtidal AIS plate surveys for early detection of new AIS and tracking the spread of existing tunicates and bryozoans along the Pacific coast • Identification of Green Crab monitoring sites in the Salish Sea in support of the Bilateral Action Plan • Green Crab trapping surveys in BC for early detection in new locations and spread/population dynamics in invaded locations • Logistical support for other AIS-related work, such as eDNA • AIS distribution information provided to numerous clients and collaborators
Other AIS Activities	• National risk assessment of aquarium, live food, and water garden organisms in trade • Screening-level risk assessment (CMIST) applied to Pacific Fisheries Regulation Schedule VIII • Development of AIS-based collaboration and outreach/advice to port authorities, First Nations, academia, provincial government, shellfish industry, and various DFO Sectors and other government departments
Emerging Issues	• Freshwater AIS in BC, especially introduction of dreissenid mussels via recreational boating, and other plants, fishes, and invertebrates from live food trade • AIS imported via online sales (e-commerce) • AIS impacts on salmon and species at risk • Vessel-mediated AIS introductions (e.g., biofouling of international and domestic commercial and recreational vessels, especially with pipelines) • Climate change effects, including risk posed by AIS in south of BC • Control options • Need for increased capacity to meet increased demands in a vast coastal zone
Other Strategic Considerations	• Building, leveraging, and extending AIS-related collaboration internationally and domestically, including informing management and policy • Led Chapter 25 on Marine Invasive Species for UN's World Ocean Assessment 2 • Better distinction between AIS activities post vs pre-border for species, vectors, and pathways • Contribution to articulation of regional roles and responsibilities for freshwater AIS

3.3.3 Central and Arctic Region

Areas of Expertise	• Ship-mediated pathways (ballast water, biofouling, recreational boating) and management efficacy • Bait fish • Modelling species distribution • Risk assessment • Sea Lamprey control, non-target species impacts, and connectivity/barriers
Research	• Ballast water: sampling, management, tools for compliance testing, reporting database • Ballast water, biofouling, and Black Carp risk assessments • Connectivity and barriers to control/manage Sea Lamprey and native fish • SLCP control impacts on non-target species
Monitoring	• Ballast water monitoring: assessing effectiveness of treatment systems and tools for measuring compliance • Round Goby: Small-scale long-term monitoring of population patterns after invasion
Other AIS Activities	• Impact of dreissenid mussels on native mussel species at risk • Development of eDNA tools for dreissenid mussels monitoring
Emerging Issues	• Biofouling: review of International Maritime Organization guidelines • Climate change and increased Arctic shipping traffic effects on potential invasions • Detection and distribution of AIS in the Great Lakes • Connectivity effects of fish passages
Other Strategic Considerations	• International Maritime Organization involvement and guidance • International Council for Exploration of the Sea • UN Decade for Ocean Science • Great Lakes Water Quality Agreement and Canada-Ontario Agreement • Convention on Great Lakes Fisheries and Joint Strategic Plan • Binational invasive mussels experimental control

3.3.4 Central and Arctic Region

Areas of Expertise	• Arctic coastal ecology and biodiversity • Indigenous community-based monitoring • Genomic monitoring tool development • Ballast water and biofouling research • Physiological thresholds • Ecological niche modelling • Risk assessment
Research	• Baseline characterization of native and non-native species composition, environmental conditions, and associations of Arctic coastal communities in areas of high shipping • Development and testing of monitoring tools (e.g., eDNA) in Arctic environments • Ecological niche modelling under current and future climate scenarios • Ecological risk assessments for species and vectors • Physiological thresholds and adaptive capacity of native and invasive species pairs • Biofouling risks with in-transit changes in salinity and temperature • Risks associated with domestic ballast management in vessels transiting to Arctic waters
Monitoring	• Community-based monitoring for early detection of AIS in coastal ecosystems on high-risk areas • Testing and use of genomic tools (e.g. eDNA) • Ballast water baseline data collection for updating shipping vector risk assessments and inform selection of species for screening-level risk assessment • Training of northern staff
Other AIS Activities	• Apply screening-level risk assessment tools to rank risk for introduction in Arctic marine waters • Risk assessment of alternative ballast water exchange zones (ABWEZ) and marine refuges in the Arctic • 3 science responses related to Baffinland's Mary River Project • Informal enforcement advice on compliance of risk assessment tool for AIS, vectors, and pathways • Input to Government of Canada's Genomics Research and Development Initiative (GRDI) prioritization on applications of genomic methods to address biological threats
Emerging Issues	• Climate change effects (e.g., sea ice loss and habitat suitability for alien species) • Growing maritime shipping impact on National Marine Conservation Area • Efficacy of ballast water treatment systems in cold temperatures (compliance testing needed) • characterization and risk assessment of biofouling threat • Monitoring for actual and potential high-risk invaders • Potential introduction of Zebra Mussel to western Arctic through overland transport and threat to largest freshwater fishery in the Arctic (Great Slave Lake); need for updated risk assessment
Other Strategic Considerations	• Building, leveraging, and contributing to AIS-related science internationally • Government focus on Indigenous involvement, especially youth, in planning future science activities in the Arctic • Oceans Protection Plan (OPP): extend coastal baselines/monitoring, capacity building, outreach

3.3.5 Quebec Region

Areas of Expertise	• Risk assessment • AIS monitoring in marine and freshwater ecosystems • Research on AIS biology, ecology, and impacts, vectors, ballast water treatment, standardized tools and methods for monitoring, species distribution modelling, and AIS mitigation methods (e.g., aquaculture transfers and antifouling paint)
Research	• Risks of recreational boating as vector of introduction and in-transit survival and post-arrival performance of biofouling AIS • Sediment and propagule release estimates during ballast water discharge • AIS acclimation capacity and realistic variability of tolerance (e.g., Common Periwinkle) • Collaborate on and support AIS risk analyses in the Arctic • Species specific studies on spread, invasion dynamics, and modelling for Coffin Box Bryozoan and Tench

Monitoring	• Marine:
	  ○ Early detection in targeted at-risk habitats through biofouling collectors supported with eDNA
	  ○ European Green Crab monitoring since 2005
	  ○ Comparison of detection methods (e.g., collectors, diving, plankton, eDNA)
	  ○ Rapid assessments following detection of new species and action plan development
	• Freshwater:
	  ○ Hotspots targeting
	  ○ Zooplankton monitoring since 2018
	  ○ eDNA monitoring of Chinese Mitten Crab since 2019

Other AIS Activities	• Development of rapid detection methods (e.g., eDNA) for marine and freshwater monitoring and research • Support for Asian carps detection • Outreach activities to raise AIS awareness
Emerging Issues	• Biofouling research and risk assessments to prevent new introductions and support regulations development • Ballast water • Inclusion of climate change effects in risk assessments, model species spatial distribution, and experimentally assesses species physiological adaptations to climate change • eDNA research on standardized methods • Risk assessments on AIS introduction due to climate and maritime traffic in the Arctic • Freshwater threat of AIS introduction in St. Lawrence River system (e.g. Asian carps, Rusty Crayfish, Eurasian Water Milfoil)
Other Strategic Considerations	• Various international commitments • Reflect on global change scenarios: update predictions, define “invasive” in the context of global change, emerging synergies

3.3.6 Gulf Region

Areas of Expertise	• Taxonomic expertise • Mitigation methods for ascidians related to aquaculture (chemical and physical treatment) • International networking (e.g., Northeast Aquatic Nuisance Species Panel)

Research	• Minimal since 2015
	• Proposed AIS early detection project on eDNA methods
	• Mostly collaboration with other regions on large scale projects:
	  ○ Risk pathway analysis for Vase Tunicate
	  ○ Genomic divergence of Green Crab in Northwest Atlantic
	  ○ Early detection of *Diplosoma* in eastern Canada

Monitoring	• European Green Crab, biofouling, and offshore bio-collectors • Rapid assessment surveys for ascidians, bryozoans, and crustaceans • Monitoring database development for Gulf Region (grAIS), basis for posting AIS biofouling monitoring data on DFO open data platforms • eDNA sampling/analysis in coastal areas of concern
Other AIS Activities	• Responded to 159 requests in 2019 for science advice, including from Introductions and Transfers Committees in New Brunswick, Nova Scotia, and P.E.I. • Identification of unknown specimens and response to general AIS inquiries via the DFO Science Gulf Region AIS reporting telephone line and email address • Liaison with stakeholders (e.g., academia, shellfish associations, community groups, NGOs) on AIS-related files • Provide AIS scientific advice to Introductions and Transfers Committees in New Brunswick, Nova Scotia, and Prince Edward Island, AIS provincial steering committees, and steering committees for Canadian Science Advisory Secretariat processes
Emerging Issues	• Risk assessments of Green Crab spread due to introduction and transfer of mollusks, and impact of non-indigenous shellfish introductions on Gulf coastal ecosystems • Efficacy of mitigation methods for minimizing risk of Green Crab secondary introduction via introduction and transfer movement • Clarification of DFO Science's role in freshwater • Uncertainty on freshwater AIS introduction and need to identify vectors of introduction and mitigation methods • Testing and validating innovative early detection methods (e.g., eDNA)
Other Strategic Considerations	• Leveraging CSAS process to formalize clients' Science-based questions • Need for better structuring roles and responsibilities (including archiving information) for AIS rapid response • Seek new and maintain international AIS networking

3.3.7 Maritimes Region

Areas of Expertise	• Monitoring established and yet-to-establish marine AIS • Risk assessment, rapid response, and delineation of marine species • Ecosystem modelling AIS response to environmental variability and climate projections • Experimental field and laboratory studies • Populations structure studies (genomics and environmental responses) • Nearshore environmental monitoring of marine ecosystems • Data management and sharing

Research	• Application of CMIST screening-level risk assessment to DND vessels for biofouling
	• Particle track modelling to assess natural biogeographic barriers to dispersal of non-indigenous species and anthropogenic pathways/vectors that compromise these barriers
	• Environmental niche modelling to estimate distribution of marine AIS under present day conditions, in response to inter-annual environmental variability, and under future climate projections (e.g., 50 – 100 years)
	• eDNA suitability for early detection of AIS
	• Connectivity between AIS hot spots and marine protected areas in B.C., especially via vessel traffic
	• Environmental monitoring and prediction, including:
	  ○ Physiological environmental tolerance
	  ○ Species distribution modelling
	  ○ Environmental variability and climate change projections
	  ○ Hotspot analysis (i.e., history of invasion)
	  ○ Vectors for dispersal (i.e., natural vs. anthropogenic connectivity)

Monitoring	• Marine AIS (presence/absence, relative abundance, range expansion) and very-nearshore environmental monitoring • Assessing fouling on collectors designed to mimic biofouling on naval vessels (funded by DND) • Early detection, rapid assessments, and rapid response • Control and management of established AIS • Ecological observations (e.g., overwintering effects, species interactions and impacts on native species, especially tunicates)
Other AIS Activities	• Screening-level and detailed-level risk assessment • Outreach and communication with a variety of stakeholders • eDNA research on standardized methods
Emerging Issues	• Ship-mediated pathways • Climate change and biogeographic shifts • Identification of high risk species • Prevention of future AIS to sensitive habitats via science-based evidence and effective control strategies • Need for a national governance structure to support AIS prioritization and coordination
Other Strategic Considerations	• AIS program governance at the national level is identified as a main factor to improve in order to be more effective in monitoring, research, and risk assessment, particularly in terms of coordinated and integrated funding across disciplines, programs, and DFO regions. A model of program governance as the CEARA is evoked.

3.3.8 Newfoundland and Labrador Region

Areas of Expertise	• AIS invasion dynamics and impacts and mitigation research, particularly for tunicates and European Green Crab • Surveys of biofouling on vessels and gear in harbours and marinas • Marine environmental parameter surveys • Development of best practices for pathways and vectors • Rapid response and invasion and mitigation assessment
Research	• Risk-based pathway analysis to prevent the spread of Vase Tunicate • Interactions between European Green Crab and lobster population through acoustic tracking in Fortune Bay • Invasive tunicate impact on eelgrass • Graduate student projects: (1) biofouling treatment effectiveness for aquaculture, (2) global climate change on Green Crab, (3) Green Crab mitigation dynamics, and (4) Green Crab overwintering dynamics

Monitoring	• Early detection and prevention:
	  ○ High priority multispecies surveys for coastal invasion assessments, including environmental parameters surveys and vector analysis
	  ○ SCUBA surveys on Oyster Thief presence in Notre-Dame Bay
	  ○ Southern Labrador marina AIS SCUBA survey and follow-up
	  ○ Northern Labrador harbour surveys and follow-up
	  ○ eDNA sampling to develop NL AIS specific library
	• Control and management:
	  ○ Assessing and evaluating mitigation of Vase Tunicate) in Placentia Bay
	  ○ Assessing and evaluating (independent trapping) effectiveness of Green Crab mitigation in Placentia Bay
	• Rapid response survey for Green Crab in St. Mary's Bay

Other AIS Activities	• Scientific authority and response from science to stakeholders, industry, and public • Outreach and communication activities with partners • Co-chair Newfoundland and Labrador AIS Advisory Committee
Emerging Issues	• Biofouling: prevention of primary introduction and spread • Control and mitigation of Green Crab, specific threshold levels for control and risk assessment are needed • Development of best practices and guidance regarding pathways of spread
Other Strategic Considerations	• Various international commitments

3.4 SUMMARY OF EOS AIS GAP ANALYSIS

EOS presented the results of an internal gap analysis conducted in Fall 2019 in preparation for the *AIS: Moving Forward* workshop. The findings were discussed by all meeting participants.

3.4.1 Scope

The objectives of the gap analysis were to:

i. Review EOS's AIS activities, including research, risk analyses, and monitoring, that have been completed since the allocation of dedicated resources for AIS in 2005.

ii. Identify DFO's science knowledge gaps in Canadian fresh and marine waters.

iii. Identify EOS's capacity gaps to meet the needs of its clients.

The ACP and SLCP were beyond the scope of the gap analysis, as they were transferred to Aquatic Ecosystems sector in April 2017 and April 2019, respectively. However, science activities that support those programs were considered. Further, due to time and resources constraints, the gap analysis is not an exhaustive overview of DFO's AIS science activities. It is instead a high-level overview with the intention of informing the discussions at the *AIS: Moving Forward* workshop.

3.4.2 Methodology

The gap analysis focused on three main areas of science activity: monitoring, research, and risk assessment. Two surveys were conducted and included input from regional AIS science leads, respectively focusing on quantifiable resources available to support AIS work (e.g., funding availability, funding sources, partnerships) and qualitative expert advice on gaps. A review of the AIS-related publications by DFO scientists was also conducted to provide an overview of the topics covered, particularly in terms of focal species, areas, and pathways.

3.4.3 Accomplishments

From 2005 to 2019, DFO produced more than 450 AIS-related publications (56% primary publications, 26% CSAS reports, 15% technical reports, 3% other). This included 70 publications related to detailed-level risk assessments, 9 on screening-level risk assessments, and 26 on other types of science advice. Twenty-four detailed-level biological risk assessments have been conducted on species and 10 on pathways. Twenty other science advice reports have been produced on a variety of AIS-related topics.

Overall, 76% of research projects and 86% of monitoring activity focused on species, while 24% and 10% respectively focused on vectors and pathways; 3% of projects included both. European Green Crab was the most studied species (22% of research, 29% of monitoring), while the most studied taxa was tunicates[4] (42% of research and 33% of monitoring). Seventeen percent of research focused on fish species and 2% were on dreissenid mussels. All taxa herein were identified as priorities through risk assessment. The majority of AIS work

[4] Species included Vase Tunicate, Clubbed Tunicate, Carpet Sea Squirt, Compound Sea Squirt, European Sea Squirt, and various botryllid species.

conducted in the Great Lakes Basin has focused heavily on Asian carps and Sea Lamprey through the Asian Carp Program and Sea Lamprey Control Program, respectively.

Since 2005, 62% of research projects focused on commercial shipping vectors (ballast water and biofouling), 12% on recreational boating, 19% on infrastructure movement, equipment, and aquaculture, and 8% on unauthorized introductions and use of live bait.

3.4.4 Gaps

Suggestions discussed by workshop participants to address existing knowledge and operational gaps included focusing future EOS efforts on:

- Assessing species' risk and updating past risk assessments.
- Developing tools and approaches to prevent introduction, eradicate, and/or control high-risk species.
- Assessing and prioritizing all marine and freshwater pathways and vectors, integrating climate change effects, biogeographical shifts, and impact of anthropogenic activities
- Identifying hotspots and vulnerable areas through predictive modelling.
- Developing monitoring tools for vast and remote areas, high-risk pathways and vectors.
- Improving data collection, analysis, maintenance, and development of baselines.
- Establishing a governance structure to (i) set national and regional priorities to address management needs while respecting existing limited capacity, (ii) delineate EOS's roles and responsibilities, and (iii) improve integration of biological and socio-economic considerations.

3.4.5 Conclusion

DFO has been productive over time in generating relevant knowledge to inform decision-making. However, knowledge and operational gaps exist and capacity to address them is limited. Current full-time employees (researchers, biologists) that work on AIS issues are allocated from other existing programs or as needed by temporary hiring through O&M funding. This limits the retention of expertise and highly qualified personnel to address knowledge gaps.

A clear governance structure for AIS science is needed in order to facilitate priority setting, develop short to medium-term work plans, and align science with management needs at national and regional levels. Opportunities for funding and other support and alignment of work between and among regions should be at the center of future discussions within EOS.

4 DAY 2: MOVING FORWARD

4.1 BREAKOUT GROUPS

Three themes were identified prior to the workshop to be discussed by dedicated break out groups. Each participant was given the opportunity to engage on all three themes. The following summaries of each discussion were agreed upon by the participants.

4.1.1 Theme 1: identifying priorities for science activities and matching needs with capacity

What approaches should EOS consider to prioritize limited resources for AIS science (e.g., focus on species, hot spots, pathways, or a combination)? What should EOS's short (1-2 year) and long-term (5 year) AIS priorities be?

Approaches to establish science priorities:

- Articulate EOS's roles and responsibilities (e.g., providing advice or guidance, conducting research) in relation to other DFO sectors, other departments and agencies, and external partners.
- Consider priorities through the lens of the four pillars of AIS management to gain a better understanding of how science information is used in decision-making and integrated into regulations and legislation.
- Compare needs of internal clients (e.g., introductions and transfers committees) with those of external clients (e.g., Transport Canada, Parks Canada, DND) and other key stakeholders (e.g., provincial and territorial governments).
- Adopt a risk-based approach to prioritize work on pathway, vector, and species-specific biological risk assessments, leveraging the use of existing tools (e.g., CMIST) and developing national baseline information on AIS
- Develop tools, frameworks, and guidance for national and regional priority setting of AIS science activities

Other actionable items for EOS:

- Update the AIS risk framework from 2011
- Create linkages with other initiatives (e.g., Marine Spatial Planning, OPP initiatives, Fish and Fish Habitat Protection Program)
- Regularly share best practices with stakeholders, industry, and clients (e.g., at annual meetings)
- Incorporating foresight into prioritization (e.g., emerging issues and threats)

4.1.2 Theme 2: What risk assessments are priorities and how will work plans be determined?

What species or pathways should be prioritized for new or updated screening or detailed-level risk assessment? What elements should be consider in prioritization?

Drivers of prioritization:

- *AIS Regulations*
- The 4 pillars (prevention, early detection, response, and control)
- International commitments
- Client needs and requests
- Client application of risk assessments
- Emerging threats

Actionable items:

- Be proactive! Hold periodic prioritization workshops (e.g., every 3-4 years) including external experts and considering socio-economic perspectives

- Conduct horizon scanning
- Set priorities at both regional and national scales
- Hire and train FTEs to conduct risk assessments, particularly for freshwater where expertise is lacking
- Develop agreements with academia to leverage resources
- Improve coordination, expertise and resource sharing between regions
- Conduct a national review of all pathways and vectors
- Fill gaps in knowledge around climate change effects
- Revisit the 2011 guidelines for risk assessment; review and standardize all risk assessment models and update older risk assessments
- Improve information sharing with clients regarding the risk assessment process and interpretation of results

Prioritization approaches:

- Consider and weigh ecosystem and socioeconomic impacts, and probability of arrival
- Apply objective quantitative and qualitative scoring criteria to prioritization processes
- Establish a national steering committee for prioritization

4.1.3 Theme 3: Governance: How can science work more effectively?

How can EOS and the AIS National Core Program work together to achieve better communication, collaboration, and coordination across the regions?

Actionable items:

- Regular national and regional face-to-face meetings between EOS and clients, with supplementary involvement from external experts, provincial and territorial governments, and other national and international stakeholders as needed
    - Clarify mandates, roles, and responsibilities within DFO and with other federal partners
    - Discuss short and long-term priorities, as well as paths forward to address them
    - Measure progress through action plans
    - Provide new staff with opportunities to engage with more experienced staff to increase knowledge base
    - Leverage existing platforms for coordination and efficiency (e.g., National Aquatic Invasive Species Committee [NAISC], international working groups)
- Long-term planning, indeterminate FTEs, and A-based funding for EOS
    - Develop a 5-year AIS science strategy with a clear national vision and indicators to maintain stable priorities and inform the AIS National Core Program
        - Incorporate room for flexibility
        - Inform with an analysis of governance structures for AIS science from other countries
- Regularly report to senior management on AIS needs to develop an ecosystem approach for science, leveraging monitoring, sample collection, and research from other programs within EOS
- Develop a national data platform as a mechanism for sharing and tracking work

5 CONCLUSION

Ecosystems and Oceans Science will continue to work diligently to address the threat of AIS across Canada by advancing core science knowledge of species and pathways, as well as meeting the needs of management programs within the capacity of existing resources.

To facilitate proactive management of AIS threats, short and long-term prioritization of science activities through a national governance structure will be necessary moving forward. The governance structure will require a clear vision for improved national and regional coordination and collaboration, informed by the principles of the *Canadian Action Plan to Address the Threat of AIS* (2004). Finally, roles and responsibilities should be delineated between EOS and the AIS National Core Program, such as monitoring population trends and early detection surveillance, to ensure that all essential action is accounted for to protect Canada's aquatic resources.

APPENDIX 1: AGENDA

Day 1: Tuesday, January 14, 2020

State of AIS Activities and Gaps		
9:00	DG Opening Remarks	Rowena Orok
9:30	Agenda and Process Review	Facilitator: Giles Olivier
9:45	Overview of DFO's AIS Activities • Ecosystem and Oceans Science Sector • Aquatic Ecosystem's AIS National Core Program	Sophie Foster Olivier Marois
10:30	Break	
10:45	Partners/Clients Needs • Transport Canada • Department of National Defence • Parks Canada Agency • AIS National Core Program	Colin Heinen, Jeffrey Johnson Adam Valenta Heather Mariash Susan Roe
12:00	Lunch	
13:15	DFO Science Regional Activities • Pacific • C&A • Quebec • Gulf • Maritimes • Newfoundland and Labrador	Thomas Therriault Sarah Bailey, Kimberly Howland Nathalie Simard Marc Ouellette Claudio DiBacco Cynthia McKenzie
15:00	Break	
15:15	AIS Science Gap Analysis	Marina Wright
16:45	Wrap-up	Facilitator

Day 2: Wednesday, January 15, 2020

Moving Forward			
8:30	Re-cap and Reflection on Day 1		Facilitator
Breakout Discussions			
9:00	Block 1		
	Theme 1 Chair: Guglielmo Tita	*Theme 2* Chair: Rowena Orok	*Theme 3* Chair: Olivier Marois
9:45	Block 2		
	Theme 1 Chair: Guglielmo Tita	*Theme 2* Chair: Rowena Orok	*Theme 3* Chair: Olivier Marois
10:30	Break		
10:45	Block 3		
	Theme 1 Chair: Guglielmo Tita	*Theme 2* Chair: Rowena Orok	*Theme 3* Chair: Olivier Marois
11:30	Outcomes of Breakout Group Discussions		Chairs
12:15	Lunch		
13:15	Wrap-up of Breakout Discussions • AIS National Core Program Perspective • DFO Science Perspective • Converging Needs and Coordinated Roles/Responsibilities		Facilitator
15:00	Break		
15:15	Plenary: *Moving Forward* with Actionable Priorities		Facilitator
16:30	Wrap-up		Facilitator

APPENDIX 2: LIST OF PARTICIPANTS

Participants	Region	Title	Email
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