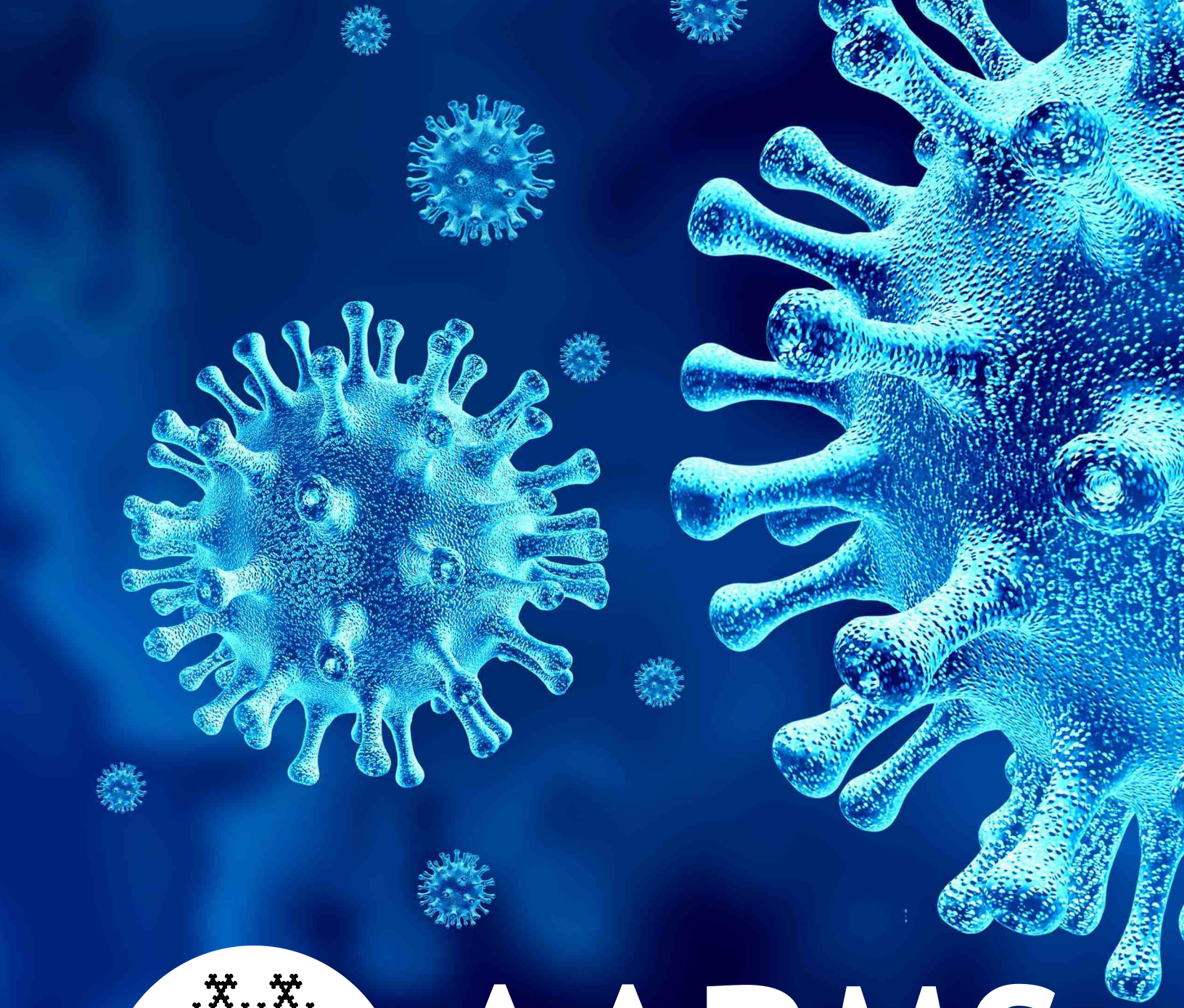


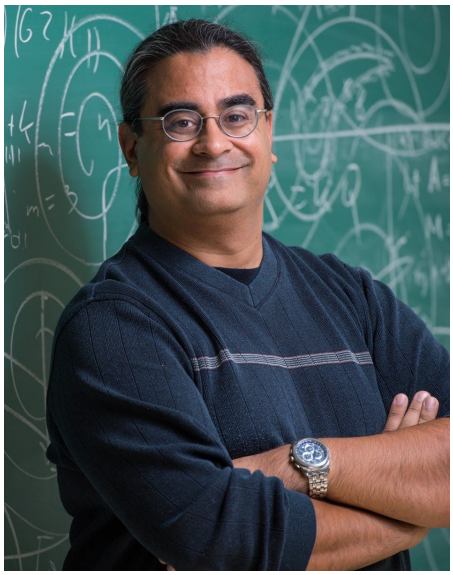
AARMS

Atlantic Association for Research in the Mathematical Sciences

2019 Annual Report

aarms.math.ca

1 Director's Message



2019 was a challenging year for AARMS. At the start, several funding arrangements with federal and provincial governments were either finished or on the verge of ending, and it was unclear if and when these agreements would be renewed. Uncertainty persisted throughout the year, induced the Executive committee to take an conservative financial approach to planning. However, I am pleased to report that in late 2019 and in early 2020, we received a number of positive funding decisions that have reinforced AARMS's financial foundation:

- We started 2019 with no commitment for funding from Nova Scotia. After extensive discussions, AARMS managed to secure brand new funding from Nova Scotia's Department of Early Education and Childhood Development (EECD), as well as a renewal from the Department of Labour and Advanced Education (LAE).
- We received further good news in early 2020 with renewed one-year funding from the Government of New Brunswick for the 2019-20 fiscal year.
- Finally, Memorial University's support for AARMS was renewed for the 2019-20 fiscal year in February 2020.

In addition, the federal government has at long last announced tentative plans for the next competition for institute funding. Our upcoming application to NSERC's new Discovery Institute Support (DIS) Program in late 2020 is a significant opportunity to secure stable revenue for the next five years. We are currently awaiting final details of the program before submitting a letter of intent in June.

On the research side, the most notable event from 2019 was the competition for new Collaborative Research Groups (CRGs). After an exhaustive selection process, the Executive committee decided to award CRGs to the following groups:

- Computational Aspects in Finance and Insurance (2019-2021)
  Administered by Kai Liu (UPEI)
- Groups, Rings, Lie and Hopf Algebras (2019-2021)
  Administered by Yorck Sommerhäuser (MUN)

The former is the first ever CRG to be headquartered at the University of Prince Edward Island. I am very much looking forward to seeing the outcomes that both groups will generate over the coming months. I would also like to congratulate the two recently completed CRGs—statistical

learning and spatial ecology, respectively—on their successful collaboration for the past two years.

The 18th AARMS Summer School in 2019 was held at UPEI and focussed on various topics from the theory of differential equations. Several students were able to attend this year's School under the Memorandum of Understanding between AARMS and the African Institute of Mathematical Sciences.

Two newer AARMS initiatives had their second incarnation in the summer of 2019. The first is the AARMS-Girl Guides outreach event "All SySTEMs Go". This year's camp saw over 500 girls aged 9-17 visit Dalhousie and St Mary's universities for a weekend of STEM based learning with a mathematical sciences flavour. The event featured a number of innovations and refinements from the first camp in 2018, including a popular evening "round robin" session for younger girls. Many thanks to the AARMS outreach coordinator Daniele Turchetti and AARMS Executive Committee member Dorette Pronk for the countless hours required to organize this large and complicated event. The "All SySTEMs Go" format is proving popular, with events partly modelled on the AARMS initiative being held at the University of Toronto and the University of Alberta in the Fall of 2019.

The other event held for the second time in 2019 was the AARMS Industrial Problem Solving Workshop (IPSW). This year's IPSW at UNB (Fredericton) was bigger than the inaugural event at Dalhousie in virtually every respect: the event was longer, attended by more students, and featured more problems. Presenters included a number of organizations interested in health data analytics such as the Government of New Brunswick and the New Brunswick Health Council. Next year's IPSW will be held at Acadia, and the 2020 IPSW will be held at MUN. I would like to highlight the crucial contribution of AARMS Executive committee member Richard Karsten (Acadia) in the organization of all the IPSWs to date. I must also thank the many sponsors of the event: the enthusiastic support we have received indicates that there is a significant demand for events of this type in the region.

Finally, like every other institute in the world, COVID-19 will play a huge role in shaping our 2020 activities. All of the AARMS-organized signature events for the summer have been cancelled, and many of the activities we have agreed to support will not happen. Conversely, the coronavirus pandemic has allowed us to forge new relationships with national and provincial funding bodies to support research in mathematical modelling. To this end, a consortium of Canada's mathematical sciences institutes have received funding from Canada's Institutes for Health Research (CIHR) for infectious disease research. AARMS has received further matching funding from the New Brunswick Health Research Foundation (NBHRF) to specifically support research in Atlantic Canada.

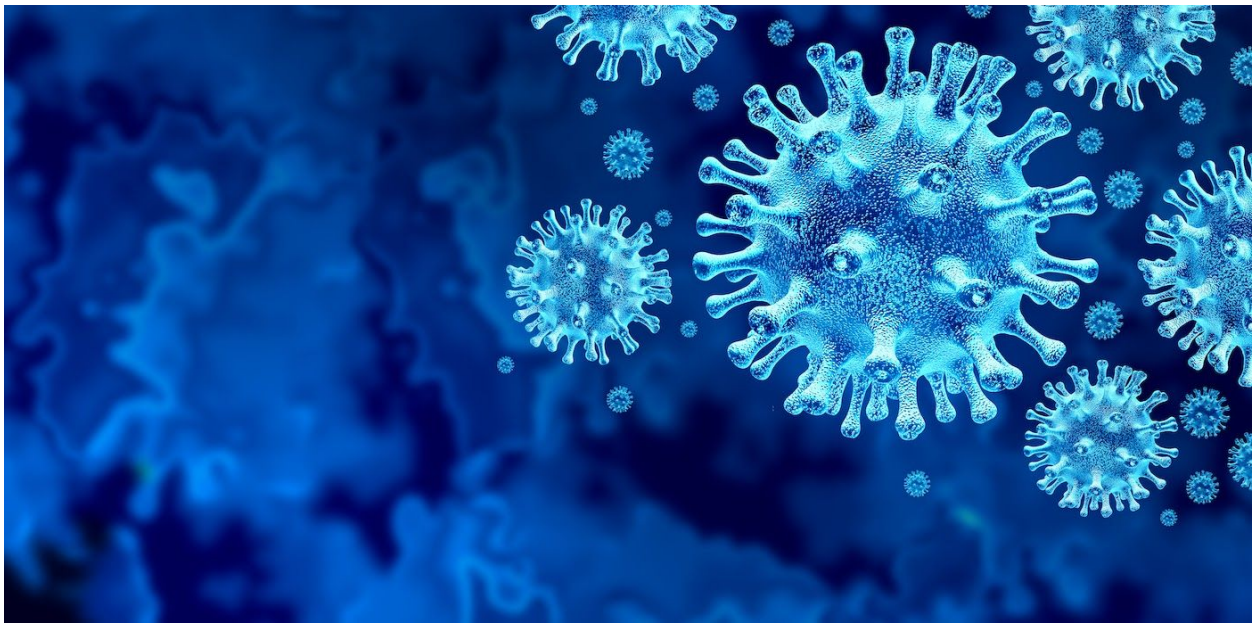
In conclusion, I would like to express my appreciation to the AARMS Executive, AARMS Board, AARMS Scientific Review Panel, and wider Atlantic mathematical sciences community for their sustained efforts in driving all of our programs and initiatives. AARMS is grateful for the continued support of a number of organizations, including the provinces of New Brunswick, Prince Edward

Island, and Nova Scotia; NSERC; and all of AARMS's member universities. Special recognition is due to David Langstroth for expert administrative efforts during challenging financial times. I would also like to thank PIMS, Fields, CRM and CANSSI for their ongoing and valued collaboration.

Sanjeev Seahra
AARMS Director
April 2020

2 Highlights

2.1 AARMS receives funding to combat COVID-19



The Canadian Institutes of Health Research (CIHR) has recently awarded a consortium of Canada's mathematical sciences Institutes $666,667 to fight the global coronavirus pandemic. The successful application to the Government of Canada's 2019 Novel Coronavirus (COVID-19) Rapid Research Funding call was led by the Fields Institute, and partner institutes include AARMS, CRM, and PIMS.

This federal funding has been supplemented by an additional $90,000 support for AARMS from the New Brunswick Health Research Foundation (NBHRF).

The research will mobilize a national network of infectious disease multi-scale modellers to assess the transmission risk of COVID-19 and project outbreak trajectories. This will enable them to evaluate public health interventions for outbreak prevention and control, while informing public health policymakers in the development of effective treatment strategies.

Two Atlantic Canadian mathematical scientists have joined the Canadian COVID-19 Math Modelling Task Force: James Watmough from the University of New Brunswick, and the Director of AARMS Sanjeev Seahra.

"The objective of the CIHR-funded project centres on control of the spread of the infection through and between communities," says Dr. Watmough. "Obvious short term objectives are

understanding the main means of spread and the effectiveness of various strategies, such as school closures and physical distancing, in reducing the peak demand on our health care system.

“We will also be modelling treatment of individuals, what we call in-host modelling, to understand the disease and how treatment works. The holy grail of this project would be to test proposed treatments on simulated people. This is still a long way off, but we can use modelling to get more information out of trials.”

“The main goal of this research is to help public health authorities make informed decisions about how to manage the COVID-19 outbreak,” says Dr. Seahra. “Governments will have to make many hard decisions about how to combat this virus, and we would like to help them in any way we can. We will also be learning as much as we can about this emergency to ensure we are better prepared for future pandemics in Atlantic Canada.”

Leah Carr, interim CEO of NBHRF, says “NBHRF is proud to support our New Brunswick researchers, Drs. Seahra and Watmough, in their significant contribution to this urgent issue.”

Other partner organizations are the Public Health Agency of Canada, the Vaccine and Infectious Disease Organization-International Vaccine Centre and the National Research Council.

More information:

- CBC news article
- CBC radio interview of James Watmough
- UNB news article
- Fields Institute news article

2.2 AARMS Industrial Problem Solving Workshop 2019

AARMS held its second ever Industrial Problem Solving Workshop (IPSW) from July 15-19, 2019 at the University of New Brunswick's Fredericton campus. This year's workshop was attended by 64 participants including nearly 40 students, 12 faculty mentors and problem presenters from industry. Participants came from all over the Atlantic region and other parts of Canada.

Three of the problems this year had a strong focus on health data analytics. For example: The New Brunswick Department of Health was looking for ways to automatically detect medicare billing errors, which could save the province millions of dollars a year. Healthcare Simulations Inc was trying to address the difficult problems of conducting health data research in a manner that maintains patient privacy by leveraging artificial intelligence to generate simulated data sets.

Another problem involved the accurate simulation of traffic in small cities are rural area. This was presented by the Black Arcs, who were making their second appearance

at an AARMS IPSW. The Institute of Biomedical Engineering from UNB challenged students devise a control system for prosthetic limbs that faithfully mirrors the user's intent.

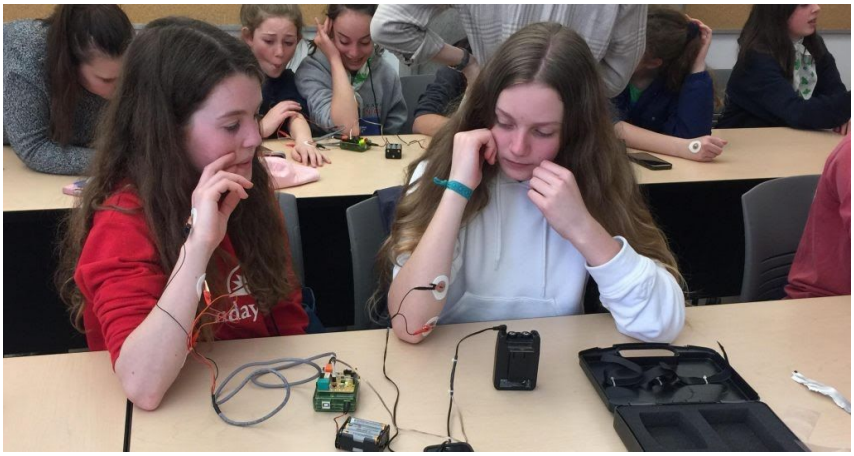
While students made excellent progress on all the problems, a couple of teams really stood out. One of these was the runner-up for the "Best Solution" competition. The problem was presented by The New Brunswick Health Council, and focussed on leveraging large scale survey data into a community sickness index that could be the basis of evidence-based allocation of health resources. Students managed to quantitatively identify the most important survey variables that predict general health, which is the most important step towards constructing a sickness index.

The winning problem was presented by Patriot One. Students were tasked with developing machine learning algorithms that automatically estimate crowd size from still images and video footage. The team, mentored by Moulay Akhloufi from Universite de Moncton and Nicholas Touikan from UNB, successfully developed code to count people from image sources where individual heads can be seen.

Like IPSW 2018, AARMS also hosted a mathematical sciences focussed academic-industrial connector during the IPSW called "Formulating Success". This event featured 28 flash presentations from researchers, companies, non-profits, and funding agencies on mathematical and statistical problems and projects. Both the connector event and IPSW as a whole have spawned numerous new collaborations between Atlantic Canadian mathematical sciences researchers and non-academic organizations.

AARMS would like to sincerely thank the many sponsors of the 2019 IPSW: the Atlantic Canada Opportunities Agency (ACOA), ACEnet, CANSSI, Mitacs, the New Brunswick Innovation Fund (NBIF), Springboard Atlantic, the UNB School of Graduate Studies, the Fields Institute, and PIMS. The support of these organizations was crucial to the success of this event.

2.3 All SySTEMs Go 2019: AARMS Girl Guides STEM Event



On May 11-12, 2019, AARMS hosted the second annual *All SySTEMs Go* event in collaboration with the Girl Guides of Nova Scotia. This year's event involved nearly 500 girls aged 9-17 and almost 200 adult volunteers from the Guiding community.

Over the course of the two days, each of the girls attended five one-hour mini-sessions. There were nearly 100 sessions offered in total delivered by more than 80 faculty, postdoctoral fellows, and students from Saint Mary's and Dalhousie universities. The workshops covered the entire spectrum of the STEM disciplines, including sessions on mathematics, physics, chemistry, biology, medicine, computer science, and engineering. Here is a sample of the session titles:

- How to use a slide rule
- Neuroscience with the human-human interface
- Engineering a space habitat
- Busting myths about girls and STEM

On Saturday evening, the older girls got a chance to ask a diverse group of women working in the STEM fields about their current jobs and their career paths. The panel consisted of a mathematician, an oceanographer working in the private sector, a physicist, a software developer, and a veterinarian.

The younger girls participated in a round robin event where they interacted in small groups with twenty female scientists and engineers. They learned about the medical science program at Dalhousie, the mathematics of robot planning, the formation of rocks and fossils, the breathing of the ocean, the mathematics of polyhedra and weaving, the fun of coding, and many other topics.

The AARMS-Girl Guides collaboration started in 2017 and is supported by the National Science and Engineering Research Council of Canada (NSERC) via the PromoScience program. A large number of outreach organizations helped organize workshop sessions, including Let's Talk Science, the Discovery Centre, Women in Technology and Science (WiTS), Women in Science and Engineering (WISE), Brilliant Labs, Supernova, and Engineers Nova Scotia.

The principal event organizers were Darlene Banks (Girl Guides of Nova Scotia), Dorette Pronk (Dalhousie University), and Daniele Turchetti (AARMS and Dalhousie University). The student assistants, Kieran Bhaskara, Sarah Li, Tammy Zhang played a crucial role in promptly solving any issues that arose and making sure that the whole weekend ran smoothly.

2.4 AARMS Summer School 2019

From June 17 to July 12, 2019, the School of Mathematical and Computational Sciences at the University of Prince Edward Island (UPEI), in collaboration with the Atlantic Association for Research in the Mathematical Sciences (AARMS), hosted the AARMS Summer School 2019. The AARMS Summer Schools are an annual event with a general focus on the mathematical sciences learning. Each year AARMS Summer School offers a different theme with this year's theme focused on Dynamical Systems, Differential Equations, and Special Functions. During this year's summer school, 30 students from around the world participated in the four graduate level courses offered.

In order to make the summer school more attainable for all students around the world, the AARMS Summer School 2019 paid the course tuition for all participating students, as well as the accommodation expenses for all traveling students.

During the four week period this summer, AARMS Summer School 2019 offered four graduate level courses taught by highly regarded mathematical scientists:

- **Rough Paths Theory**
  Dr. Laure Coutin from the Institut de Mathématiques de Toulouse, France
- **q-Series in Analysis and Combinatorics**
  Dr. Mourad Ismail from the University of Central Florida, USA.
- **Fractals: Using Iterated Function Systems to Construct, Explore, and Understand Fractals**
  Dr. Franklin Mendivil from Acadia University, Wolfville, Nova Scotia
- **The Mathematics and Science of Chaos**
  Dr. James Yorke from the University of Maryland, USA

The AARMS Summer School courses consisted of a daily schedule of lectures. All courses are certified to be graduate level courses by both SMCS and AARMS.

Upon successful completion of a course, each student was awarded a certificate of completion indicating their course grade for the students to take back to their home institutions if they wish to receive credit for the courses towards their degree.

The 2019 AARMS Summer School was sponsored by the Faculty of Science and School of Mathematical and Computational Sciences at UPEI. The organizing committee consisted of:

- **Dr. Shafiqul Islam (2019 Summer School Director)**
  Associate Professor
  School of Mathematical & Computational Sciences, UPEI
- **Dr. Alexander Alvarez**
  Assistant Professor
  School of Mathematical & Computational Sciences, UPEI
- **Dr. Shannon Fitzpatrick**
  Associate Dean (interim) & Professor
  School of Mathematical & Computational Sciences, UPEI
- **Dr. Nasser Saad**
  Professor
  School of Mathematical & Computational Sciences, UPEI

3 Report on Funding

3.1 Province of Nova Scotia

In 2019 we continued our discussions with the Province of Nova Scotia concerning funding going forwards and submitted proposals for their consideration. The Dept of Education and Early Childhood Development (EECD) has agreed to fund a selection of outreach programs in Nova Scotia in 2020 to the amount of $40,000 and the Department of Labour and Advanced Education (LAE) will provide support to AARMS for our core research activities in Nova Scotia to the amount of $30,000 per year.

3.2 Province of Newfoundland and Labrador

In 2019 our five-year project with the Research and Development Corporation of Newfoundland and Labrador (RDC) was concluded. RDC provided, over that time a proportion of the costs for salaries for postdoctoral fellowships, graduate students and summer students and for travel expenses related to AARMS CRGs, workshops etc.

3.3 Province of New Brunswick

Our five year funding agreement $50,000/year finished at the end of the 2018-2019 fiscal year. We learned in March 2020 that our funding from New Brunswick had been extended for the 2019-2020 fiscal year. The Minister of Department of Post Secondary Education, Training and Labour (PETL) appreciated AARMS's "[strong] work in addressing industry-identified challenges, in developing highly qualified personnel and in promoting science technology engineering and mathematics (STEM) among young women." PETL has indicated that it would like to review AARMS funding on a yearly basis moving forward.

3.4 Memorial University

Our five year funding agreement $30,000/year also came to an end in 2018. In February 2020, we came to an agreement with the Vice-President Research for $30,000 of funding for 2019-2020. AARMS would like to thank the MUN Dean of Science, Mark Abrahams, for his crucial assistance in bringing this about.

3.5 Note about financial statements

The financial statements presented at the end of this document represent AARMS financial status as of December 31, 2019. At that time, we had not yet heard from the New Brunswick government or Memorial University about funding for 2019-2020. Furthermore, the balance sheet assumed expenses for 2020 events that have been cancelled as a result of the COVID-19

emergency. The net result is that the reader should keep in mind that AARMS's financial situation has evolved significantly since the moment in time reflected by these statements.

4 Report on Activities

4.1 AARMS Collaborative Research Groups (CRGs) Program

4.1.1 Dynamical Systems and Spatial Models in Ecology

In September 2019 we received the second and final year report from the CRG **Dynamical Systems and Spatial Models in Ecology**, under the administration of Amy Hurford from Memorial University of Newfoundland. This group uses their expertise to address regionally vital issues such as the propagation of invasive green crabs throughout Atlantic Canada and the treatment of salmon lice in aquaculture. CRG funds have been spent on activities that have benefited AARMS member institutions MUN, UNB, Dalhousie and St. Francis-Xavier.

In the second year, CRG research focussed on the following 4 areas:

- **Green crab** Two manuscripts are in preparation describing the application of integrodifference equations to modelling green crab dynamics (Watmough et al. and Bekyzadeh and Watmough). Ali Bekyzadeh (UNB) presented green crab research at the Society for Mathematical Biology (SMB) meeting in July 2019 and the Canadian Society for Ecology and Evolution meeting (CSEE) in August 2019. In December 2018, Joey Smokey, a PhD candidate at MUN, visited UNB as part of collaborative green crab modelling research. Data for green crab invasions to Newfoundland were provided to Amy Hurford by the Department of Fisheries and Oceans St. John's. MUN-UNB collaborative research green crab research has stalled due to the withdrawl of Joey Smokey from his PhD program in July 2019. At the Canadian Society for Ecology and Evolution (CSEE) meeting, Amy Hurford made posters to advertise the CRG's ongoing activities related to green crab.

- **Sea lice** One manuscript describing the analysis of a delay differential equation model describing sea lice dynamics was published in 2019, in the Proceedings of the Royal Society London B journal (IF: 4.3; Hurford et al. 2019a). This was collaborative research involving CRG members Amy Hurford, Xiao-Qiang Zhao, and Xiunan Wang. This manuscript considered specific applications to aquaculture in Newfoundland, Nova Scotia, and New Brunswick, and combined rigorous mathematical analysis with efforts to motivate the relevance to aquaculture. This research was presented by Amy Hurford at the SMB and CSEE meetings. Beyond September 2019, Amy Hurford has recruited MSc student Jake Prosser to continue sea lice research and has meet with the Newfoundland Aquaculture and Industry Association to discuss data sharing and industry partnership.
- **Spatial models in ecology** With the exception of the sea lice manuscript (Hurford et al. 2019a), all other 10 published or in preparation manuscripts describe research that uses integrodifference equation or partial differential equation models in spatial ecology. Chunhua Ou was a co-organizer for the minisymposium at the SMB meeting 'Wave propagation in biological media'. Members of the CRG gave 6 talks at national or international conferences describing research in spatial ecology.
- **Delay differential equations** Four manuscripts describing delay differential equations applied to ecology were published by CRG members: Hurford et al. 2019a, Wu and Zhao 2019a, Mai et al. 2019b, and Mai et al. 2019c. Amy Hurford and Lin Wang organized a minisymposium at the SMB annual meeting 'Delay differential equation models in population biology'. Members of the CRG gave 6 talks at national or international conferences describing applications of delay differential equations to biology.

4.1.1.1 Members

- Eric Pedersen (DFO)
- James Watmough (UNB)
- Theodore Kolokolnikov (Dalhousie)
- Crawford Revie (UPEI)
- Gregor McEwan (UPEI)
- Garrett Otto (U of Ottawa)
- Xiaoying Wang (U of Ottawa)
- Mohammad El Smaily (UNB)
- Chunhua Ou (MUN)
- Xiaoqiang Zhao (MUN)
- Yuan Yuan (MUN)
- David Iron (Dalhousie)
- Olga Vasilyeva (MUN - Grenfell)
- Lin Wang (UNB)
- Myriam Barbeau (UNB)

4.1.1.2 Year 2 activities

AARMS CRG receptions

Two conferences occurred in eastern Canada during the summer of 2019 with relevance to CRG members: the Society for Mathematical Biology (SMB) meeting (July 21-26, Montreal); and the Canadian Society for Ecology and Evolution meeting (August 18-20, Fredericton). The CRG provided financial support to attend these meetings and encouraged CRG members to present their research at these meetings in place of an annual CRG meeting. To facilitate the networking, Amy Hurford organized AARMS CRG receptions at each of these meetings.

The CRG reception at SMB was attended by approximately 25 people including 11 CRG members (MUN: Ou, Hurford, Marino, Moran, Prosser, Wu, Li, Huang; UNB: Watmough, Wang, Bekyzadeh). The CRG reception at CSEE was attended by approximately 15 people including 6 CRG members (MUN:Hurford, Marino; UNB: Watmough, Barbeau, Bekyzadeh; Concordia: Pedersen)

Workshops

Hurford (MUN) and Watmough (UNB) organized a 1.5 hr workshop 'Agent-Based Models and the Mathematical Equations That Describe Them' on August 19 at the CSEE meeting in Fredericton. The workshop was attended by 35 participants (25 students and postdocs; 29 from Canada; 3 from USA; 1 from Norway and 2 from South Korea). The workshop materials are archived at https://github.com/jameswatmough/CSEE2019-AARMS-ABM-workshop. This activity was successful in making meaningful connections between the ecological and applied mathematics communities.

Agent-based models and the mathematical equations that describe them

The aim of this workshop was to clarify the relationship between some types of Agent Based Models (ABMs) and familiar equations from mathematical ecology. This was a hands-on workshop where participants would run and analyze computer code. Such mathematical approximations to ABMs are valuable because: (1) they reduce computational time to facilitate a more thorough model investigation; (2) eliminate some complexity from the model description to yield clearer results; and (3) reveal parallels with the existing mathematical ecology literature.

Minisymposia organized by CRG members

The CRG organized 3 minisymposia at the Society for Mathematical Biology meeting and 1 minisymposium at the CSEE meeting. These workshops aimed to give exposure to the research of CRG members and to invite speakers with research relevant to key CRG research areas.

- **Title:** Population dynamics in marine ecology
  Organizer: A. Hurford

Meeting: Society for Mathematical Biology
Participants: 1 CRG member (Marino); 2 graduate students (Marino, Harrington)
Description: The dynamics of marine populations in distinct regions are linked by dispersal and movement, and the analysis of these spatially-explicit population models provides insight into the design of marine protected areas. This minisymposium discussed next generation approaches, population models inspired by dynamic energy budget models, species interactions, behavior, and harvesting.

- **Title:** Delay differential equation models in population biology
  Organizers: A. Hurford and L. Wang (UNB and MUN)
  Meeting: Society for Mathematical Biology
  Participants: 2 CRG members (Wang; Li); 1 graduate student (Li)
  Description: Delay differential equation (DDE) models consider dependencies on the past states of a population and many biological processes involve such dependencies. DDEs offer a realistic framework for modeling populations and novel dynamics may arise due to the delay-related assumptions. This minisymposium considered distributed, periodic, and dispersal delays and the population dynamics that arise from these model assumptions.

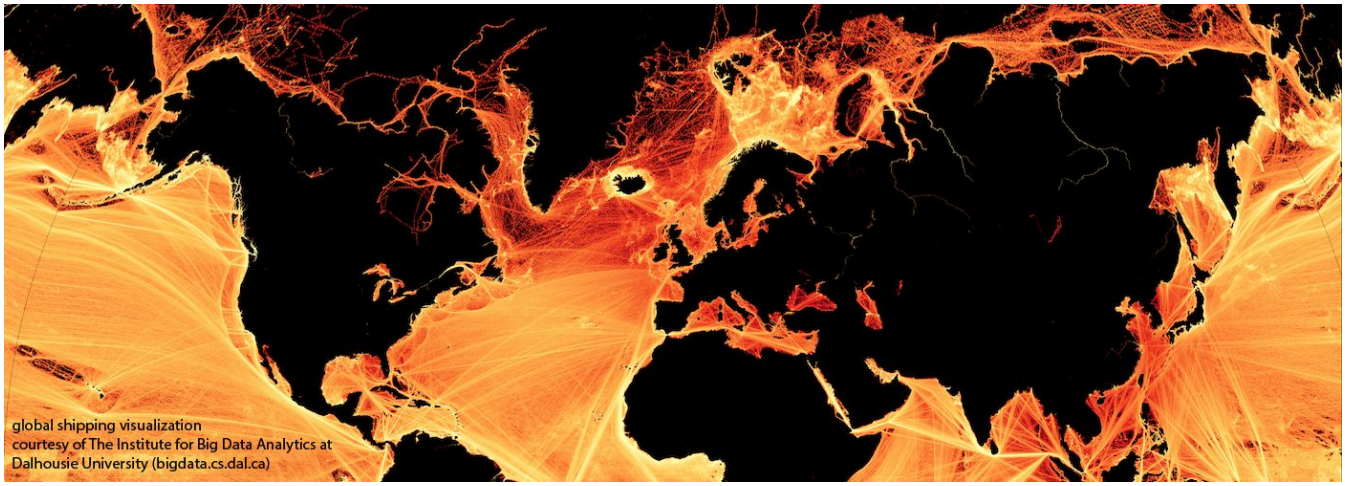
- **Title:** Wave propagation in biological media
  Organizers: M. Mei, C. Ou, Y. Wu
  Meeting: Society for Mathematical Biology
  Participants: 1 CRG member (C. Ou)
  Description: Since the pioneer work of Fisher and KPP, Wave Propagation in Biological Media has been widely studied in various mathematical models establishing the movement or invasion of species in heterogenous media or the spread of infectious disease among species. Recently, there have been tremendous advancements in the theory of traveling wavefronts itself, with considerable applications to competition or predation models in the biological field. The purpose of this session was to invite mathematical researchers with biological backgrounds to work together and contribute to the study of biological waves. It served as a platform to report new breakthroughs, exchange research ideas and extend academic networks. Speakers and talks were carefully selected to make the session attractive to a diverse audience. PhD students and post-doctoral fellows were encouraged to attend.

4.1.1.3 Publications

- **Hurford, A., X. Wang, & X. Zhao**. 2019a. Regional climate affects salmon lice stage structure, dynamics and management. Proceedings of the Royal Society London B 286: 20190428
- **Hurford, A.**, C. A. Cobbold, and P. K. Molnar. 2019b. Skewed temperature dependence affects range and abundance in a warming world. Proceedings of the Royal Society London B. 286.
- **R. Wu and X.-Q. Zhao**. 2019a. A Reaction-Diffusion Model of Vector-Borne Disease with Periodic Delays, Journal of Nonlinear Science, 29, 29-64.

- **R. Wu and X.-Q. Zhao**. 2019b. Spatial Invasion of a Birth Pulse Population with Nonlocal Dispersal, SIAM J. Appl. Math., 79, 1075-1097.
- Y. Liu, Z. Guo, M. **El Smaily and L. Wang**. 2019a. Biological invasion in a predator-prey model with a free boundary, Boundary Value Problems, 33.
- Y. Liu, Z. Guo, **L. Wang and M. El Smaily**. 2019b. A Leslie-Gower predator-prey model with a free boundary, DCDS-S, 12(2019), 2063--2084.
- A. Mai, G. Sun and **L. Wang.** 2019a. The impacts of dispersal on the competition outcome of multi-patch competition models, Math. Biosci. Eng., 16, 2697--2716.
- A. Mai, G. Sun and **L. Wang**. 2019b. Impacts of the dispersal delay on the stability of the coexistence equilibrium of a two-patch predator-prey model with random predator dispersal, Bull. Math. Biol., 81(5) 1337–1351, doi.org/10.1007/s11538-018-00568-8.
- A. Mai, G. Sun, F. Zhang and **L. Wang**. 2019c. The joint impacts of dispersal delay and dispersal patterns on the stability of predator-prey metacommunities, J. Theoret. Biol., 462(2019), 455--465.
- **Watmough, J., L. Wang, Ali Gharouni, M. Barbeau**. Larval versus adult dispersal: implications of two modes of dispersal on the spread rate of an invasion. (in preparation)
- **Ali Beykzadeh and James Watmough**. An explicit formula for a dispersal kernel in a patchy landscape https://www.biorxiv.org/content/10.1101/680256v1.abstract

4.1.2 Statistical Learning for Dependent Data



Statistical Learning for Dependent Data under the administration of Ying Zhang (Acadia) also submitted its final second-year report in 2019. This CRG involves ten faculty members from four Atlantic Universities, and aims to address emerging statistical learning and computing issues motivated by multidisciplinary collaborations related to big data.

4.1.2.1 Members

- Paul Cabilio (Acadia)
- Hugh Chipman (Acadia)
- Hong Gu (Dalhousie)
- Tariqul Hasan (UNB)
- Wenjiang Jiang (Yunnan Normal)
- Toby Kenney (Dalhousie)
- Renjun Ma (UNB)
- Jianan Peng (Acadia)
- Gary Sneddon (MSVU)
- Connie Stewart (UNB)
- Guohua Yan (UNB)
- Ying Zhang (Acadia)
- Henrik Stryhn (UPEI)
- Wenjiang Jiang (Yunnan Normal U., China)

4.1.2.2 Year 2 activities

CRG Workshop

"*Statistical analysis and machine learning with application in medicine, biology, environmental sciences*" was held at Dalhousie University May 9 and 10, 2019, aiming at local research exchanges, student training, and outreach activities for the further development of collaborative research and student placements.

Invited sessions organized in national/international conferences/meetings

We successfully co-organized four invited sessions that entertained eight invited presentations by our CRG members in the following.

- *New Developments in State-space Modeling Approaches for Ecology and Environmental Research* (Annual Meeting of Statistical Society of Canada, May 26-29, 2019, 2019, Calgary) organized by Ying Zhang to highlight the collaborative research activities in environmental science by our CRG members.
    - Integrating Population Dynamics Models and Population Abundance/Indices Data: A Hierarchical State-space Approach (Acadia, Hugh Chipman)
    - A State-space Model for Analyzing Multinomial Time Series Data with An Application to Air Pollution Related Emergency Room Visits (UNB Fredericton, Gouhua Yan)
    - Measuring Repeatability in the Diets of Grey Seals (UNB Saint John, Connie Stewart)
- *Rocky and Atlantic Collaborations in the Health Sciences* (Annual Meeting of Statistical Society of Canada, May 26-29, 2019, 2019, Calgary) co-organized by Henrik Stryhn (UPEI).

Renjun Ma (UNB) and Henrik Stryhn reported our CRG collaborative outcomes and challenges faced in statistical medical research in Atlantic.

- *Recent Developments in Statistical Methods for Skewed Data, Time Series, and Text Data* (The fourth International Chinese Statistical Association, Canada Chapter Symposium, August 9-11, 2019, Queen's University) organized by Ying Zhang. The session exchanged the research outcomes of our CRG members with researchers in the field.
    - Tweedie Mixed Models for Skewed Longitudinal Data (Renjun Ma)
    - On Consistency of Approaches to Ranking Problems (Tobias Kenney, Dalhousie)
- *Multivariate Data Exploratory and Modeling Methods* (The fourth International Chinese Statistical Association, Canada Chapter Symposium, August 9-11, 2019, Queen's University) organized by Renjun Ma,
    - Semiparametric Transformed PCA for Exploring Microbiome Data (Hong Gu, Dalhousie)
    - A New Procedure in Unequal Probability Sampling without Replacement (Wilson Lu, Acadia)
    - A Folded Model for Compositional Data Analysis (Connie Stewart)

Participation in the 2019 AARMS IPSW in UNB

Five of our CRG members participated in three IPSW teams as supervisors.

Joint HQP training

- Four HQP have participated in research conferences.
- Four HQP have participated in workshop presentation and organizing.
- Three research travel awards toward graduate students from UNB, Dalhousie, and Acadia
- Joint supervision of a research associate by Hong Gu and Ying Zhang
- Joint supervision of a Master student by Wilson Lu and Ying Zhang

New collaborative research network website for MSHSCC launched

http://mshscc.acadiau.ca/home.html

4.1.2.3 Publications

CRG faculty members indicated in bold; HQP flagged by *

- Tsagris, M. and **Stewart, C.** (2018). A Dirichlet regression model for compositional data with zeros. [Special Statistics Issue] *Lobachevskii Journal of Mathematics*, 39(3), 398-412.
- **Stewart, C.** and McCloskey, R. (2019). Learn to use the chi-square homogeneity test in Minitab with data from a 2015 health care observational study. London, United Kingdom: *SAGE Publications*, Ltd. doi: 10.4135/9781526488237
- McCloskey, R., **Stewart, C.** and Keeping-Burke, L. (2019). Predictors of Success in the NCLEX-RN® for Canadian Graduates. *Nursing Leadership,* 32(4), 30-45.

- Tsagris, M. and **Stewart, C.** (Accepted, 2019). A folded model for compositional data analysis. *Australian and New Zealand Journal of Statistics.*
- M. T. Pratola, **H. A. Chipman**, E. I. George & R. E. McCulloch (2019). Heteroscedastic BART via Multiplicative Regression Trees. *Journal of Computational and Graphical Statistics*, DOI: 10.1080/10618600.2019.1677243
- A. Corkum*, P. Cabilio and **Y. Zhang** (2019). Nonparametric confidence intervals for location in time series data. *Communications in Statistics - Simulation and Computation,* 48(5), 1292-1311
- Khurram Nadeem* and Entao Chen* and **Ying Zhang** (2018). *A Novel Hierarchical Multinomial Approach to Modelling Age-specific Harvest Data*. Quantitative Methods in Environmental and Climate Research (Editors: Michela Cameletti and Francesco Finazzi), 29-48, Springer.
- **Yan, G., Ma R. and Hasan, MT** (2019). A joint Poisson state-space modelling approach to analysis of binomial series with random cluster sizes. *International Journal of Biostatistics* Vol. 15, No 1(accepted).
- **Ma R., Yan, G. and Hasan, MT** (2018). Tweedie family of generalized linear models with distribution-free random effects for skewed longitudinal data. *Statistics in Medicine*, Vol. 37, No 24, 3519–3532.
- **Hasan, MT, Sneddon, G and Ma, R**. (2018). Simultaneously modelling clustered marginal counts and multinomial proportions with zero-inflation with application to analysis of osteoporotic fractures data. *Journal of the Royal Statistical Society*, *C*. Vol. 67, No 1, 185–200.
- Wei Chen, **Toby Kenney**, Joseph Bielawski and **Hong Gu** (2019). Testing adequacy for DNA substitution Models. *BMC Bioinformatics 2019* ***20****:349*. https://rdcu.be/bHn14
- Katherine A. Dunn, **Toby Kenney**, **Hong Gu** and Joseph P. Bielawski (2019). Improved inference of site-specific positive selection under a generalized parametric codon model when there are multinucleotide mutations and multiple nonsynonymous rates. BMC Evolutionary Biology, 201919:22 https://doi.org/10.1186/s12862-018-1326-7
- Chaoue Liu*, Benjamin Wright*, Emma Allen-Vercoe, **Hong Gu** and Robert Beiko (2018). Phylogenetic clustering of genes reveals shared evolutionary trajectories and putative gene functions. *Genome Biology and Evolution*, evy178, https://doi.org/10.1093/gbe/evy178
- Moamen Bydoun, Andra Sterea, Henry Liptay, Andrea Uzans, Weei-Yuan Huang, Gloria J. Rodrigues, Ian Weaver, **Hong Gu**, David M Waisman (2018). S100A10, a Novel Biomarker in Pancreatic Ductal Ade-nocarcinoma. *Molecular Oncology*. doi: 10.1002/1878-0261.12356.

4.1.3 New Collaborative Research Groups

In 2019 AARMS awarded funding two support two new Collaborative Research Groups, **Computational Aspects in Finance and Insurance**, administered by Kai Liu (UPEI); and **Groups, Rings, Lie and Hopf Algebras,** administered by Yorck Sommerhäuser (MUN). These new groups

started work in September, 2019 and reports of the first year of activities will be included in the AARMS Annual Report for 2020.

4.2 AARMS Postdoctoral Fellowship Program

Each year AARMS conducts a competition to award Postdoctoral Fellowships to highly qualified personnel who received their PhD within the last 4 years. AARMS provides a portion of the funding for these positions, which must be at least matched by other research funding from the host university. The program is successful in attracting highly qualified young researchers to universities in New Brunswick and the rest of the Atlantic region. Starting in autumn 2018 we have also made available a travel grant of $1,500/year for each postdoc.

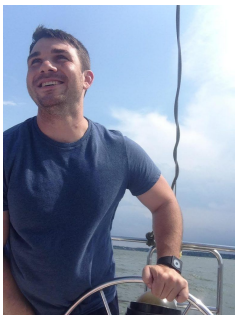
Postdoctoral Fellow Biographies

The following postdoctoral fellows have been supported by AARMS in the past year:

Matthew Amy completed his doctorate in 2019 from the University of Waterloo, Canada. Beginning in November 2019 he will be working as a postdoctoral fellow at Dalhousie University with Julien Ross and Peter Selinger. His research interests include formal mathematical models of quantum computation and their application to the practical problems of quantum programming and compilation.

Rosalinde Cameron was a postdoctoral fellow at Memorial University of Newfoundland, working with David Pike. She received her PhD from Monash University in 2017 and her research interests include graph theory and combinatorial design theory.

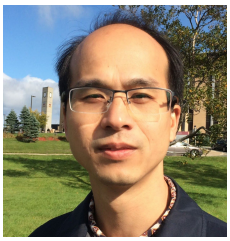
Marco de Cesare was a postdoctoral fellow at the University of New Brunswick. He received his PhD in 2017 from King's College London. His main research interests are in quantum gravity, modified gravity, and cosmology.



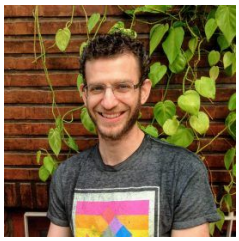
Jonathan Gallagher finished his PhD from the University of Calgary in 2018, and is now working as a postdoc with Geoff Cruttwell and Dorette Pronk at Dalhousie University. The project they are pursuing is to use recent developments in category theory to advance the use of differential geometry in diverse settings: from machine learning and deep learning to orbifolds.

Dr. Qingzhong Huang received his PhD from Shanghai University in 2014. He was a postdoctoral fellow at Memorial University under the supervision of Professor Deping Ye. His research interests include convex geometry, geometric analysis, and geometric functional analysis

Suzanne Lanéry received her PhD in 2015 from the University of Erlangen–Nuremberg, Germany, and is currently a postdoctoral fellow at the University of New Brunswick. Her research interests lie in the mathematical foundations of Quantum Field Theory, especially the topics of coarse-graining, refinement and renormalization, as well as their applications to quantum gravity.



Shuaibing Luo graduated from the University of Tennessee-Knoxville with a PhD in Operator Theory and Complex Analysis. He was working as a postdoctoral fellow at Memorial University under the supervision of Jie Xiao.

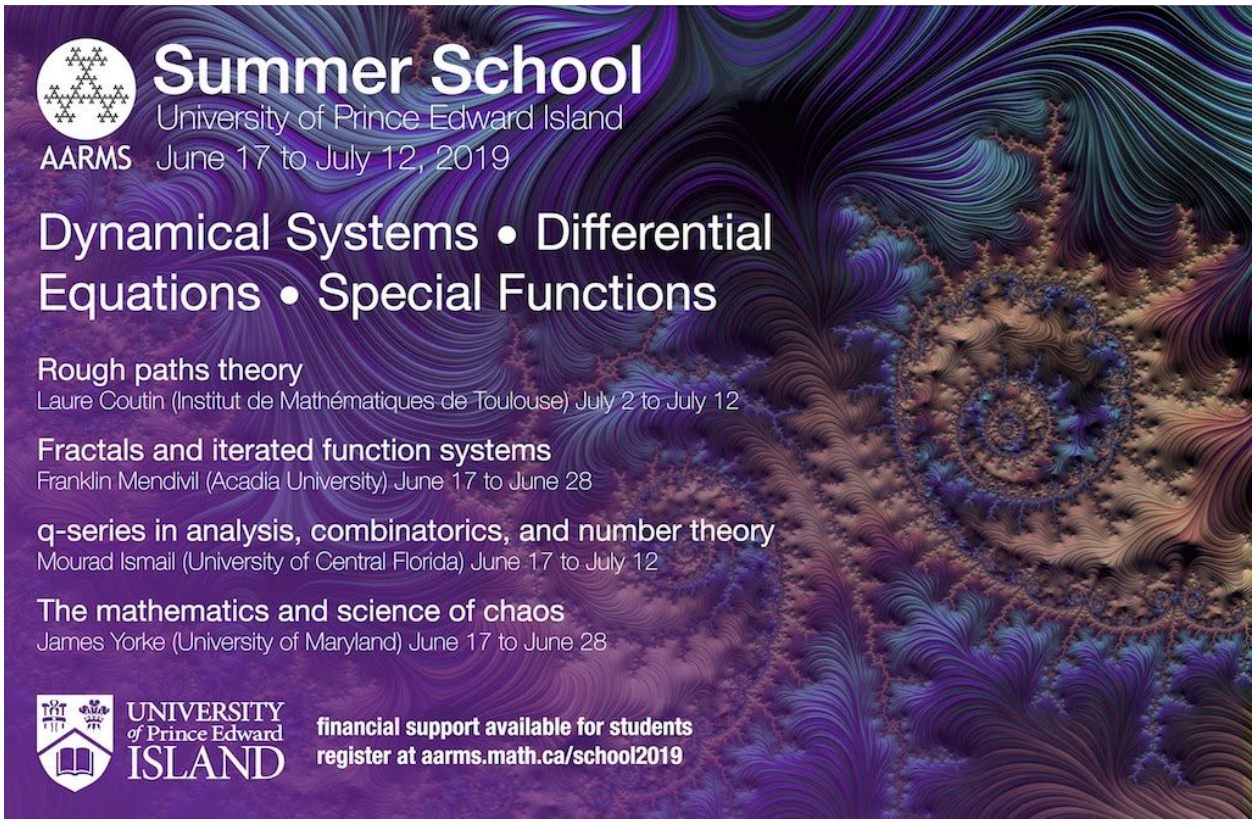


Martin Szyld completed his PhD in 2015 from the University of Buenos Aires, Argentina, where he also worked as a postdoctoral fellow with Eduardo Dubuc. Starting in February 2020 he will be at Dalhousie University working with Dorette Pronk. His main research interests are in topos theory and in higher category theory.

Daniele Turchetti completed his doctoral studies at the University of Versailles and the Institut de Mathématiques de Jussieu. He held positions at Leiden University, the Max-Planck-Institute for Mathematics, and the University of Caen. He is currently pursuing his research in arithmetic geometry at Dalhousie University and his math communication interests in the framework of AARMS outreach initiatives.

We held our annual postdoctoral fellowship competition in the autumn of 2019. Abraham Westerbaan will be the newest AARMS postdoctoral fellow starting at Dalhousie University under the supervision of Peter Sellinger in September 2020.

4.3 AARMS Summer School



The eighteenth AARMS Summer School took place at UPEI in Charlottetown June 17 - July 12, 2019 on the theme of Dynamical Systems, Differential Equations, Special Functions, and is described in detail in section 2.3. The summer school was attended by 30 students from the following institutions:

- AIMS, South Africa
- Arizona State University
- Bishop's University
- Concordia University, Montreal
- Dalhousie
- Dhaka, Bangladesh
- Georgia State university
- Guelph
- Hong Kong University of Sci & Tech
- Kyoto, Japan
- McMaster
- Moncton

- Mount Allison University
- Mount Saint Vincent
- Nagoya University, Japan
- Ottawa University
- Saint Marry's
- UNB
- University of Toronto
- UPEI
- Waterloo

4.4 Workshops and Conferences

4.4.1 Complete Listing

In 2019 AARMS has funded or partially funded the following workshops, conferences and events, or has made a commitment to do so.

Data Visualization Competition
Fredericton
November 21, 2019

Surface Braid Groups and Mapping Class Groups
Memorial University (St. John's Campus)
November 4, 2019 - November 8, 2019

Borders in public health and mathematical epidemiology
Fields Institute
October 21, 2019 - October 25, 2019

CANSSI National Case Study Competition 2019
University of New Brunswick (Fredericton Campus)
September 9, 2019

Symposium: The Future of Evolutionary Game Theory
Fredericton Convention Centre
August 20, 2019

Workshop: Agent based Models and the mathematical equations that describe them
Fredericton Convention Centre
August 19, 2019

East Coast Combinatorics Conference
Saint Francis Xavier University
August 13, 2019 - August 14, 2019

Nonassociative algebras and geometry
Bonne Bay Marine Station, MUN
August 12, 2019 - August 16, 2019

Diversity in Mathematics: an undergraduate summer school for women in mathematics
PIMS at UBC and SFU
July 22, 2019 - August 8, 2019

Minisymposium for the annual meeting of the Society for Mathematical Biology
McGill University
July 21, 2019 - July 26, 2019

AARMS Industrial Problem Solving Workshop 2019
University of New Brunswick (Fredericton Campus)
July 15, 2019 - July 19, 2019

Special Session: Assessment in Mathematics Education Session (2019 CMS Summer Meeting)
University of Regina
June 7, 2019 - June 10, 2019

Special Session: Categorical Approaches to Geometry and Topology (2019 CMS Summer meeting)
Regina
June 7, 2019 - June 10, 2019

Canadian Mathematics Education Study Group Conference
Saint Francis Xavier University
May 31, 2019 - June 4, 2019

CanaDAM 2019
Simon Fraser University
May 28, 2019 - May 31, 2019

Atlantic General Relativity Meeting
University of New Brunswick (Fredericton Campus)
May 27, 2019 - May 31, 2019

Calculus Instruction in Atlantic Canada Symposium 2019
Mount Saint Vincent University
May 24, 2019 - May 25, 2019

PIMS Workshop on Mathematical Sciences and Clean Energy Applications
Vancouver
May 21, 2019 - May 24, 2019

AARMS CRG/CANSSI MSHSCC workshop: Statistical analysis and machine learning
Dalhousie University
May 9, 2019 - May 10, 2019

Data Science Practitioners East Meetup

University of New Brunswick (Fredericton Campus)
April 25, 2019

StFX Integration Challenge 2019
Saint Francis Xavier University
February 27, 2019

Mini-course "Representations of simple finite dimensional and affine Lie algebras"
Memorial University (St. John's Campus)
January 21, 2019 - January 25, 2019

4.5 Outreach

In 2019, AARMS has supported the outreach activities described below.

4.5.1 Ongoing Activities

4.5.1.1 Big Data for the Mi'qmaq Elementary and High school Students

An extracurricular program in Big Data for 13 First nations schools in Nova Scotia. Sponsored jointly by Uloonweg, AARMS and CANSSI, the program delivered 12 hrs of training in 4 sessions to two groups of children, aged 9-10 and 15-17, respectively. A total of 180 First Nations students were involved and trained. A pilot program for the younger group was developed and tested with a group of students in May, 2018. Curriculum for the older children was developed with the assistance of an expert group from University of Toronto and from the Oceans of Data Institute at UCLA, including hands on experience with prepared software and data (CODAP and GapMinder). The Uloonweg project sponsors the development and partial delivery of the program in the schools; funding from AARMS is used to complete the training and delivery.

4.5.1.2 Connecting Math to Our Lives and Communities

A focused after school, in-community mathematics outreach program created for and reaching 200 Mi'kmaw and African Nova Scotian youth annually. The program is built on community relationships and run in full partnership with four Mi'kmaw and three African Nova Scotian communities. Throughout the academic year, St. Francis Xavier University (StFX) students travel to local communities to engage youth in meaningful, hands-on investigations of mathematics related to their everyday lives. A final celebration day provides a culminating experience for all participants on campus at St.FX. The goal of the program is to have students see the role mathematics plays in reading and writing the world, and identify themselves as mathematicians in a way that also honors their ways of being.

4.5.1.3 Enhancing math appreciation through community outreach

An ongoing program for developing public appreciation of mathematics: by creating a recreational mathematics exhibit, displayed in libraries; by implementing a public lecture series in

the Fredericton Library; and by interactive visits to schools. Organized by John McLoughlin (staffed by volunteers from the UNB Faculty of Education, UNB).

McLoughlin is also the recipient of the **2013 Adrien Pouliot Award** from the Canadian Mathematical Society in recognition of his outstanding contributions to mathematics education in Canada:

"What is significant about John is his deep humanity and his mentorship of both students and teachers, those with strong ability in the subject as well as those who approach mathematics with caution and nervousness," said Keith Taylor, President of the Canadian Mathematical Society. "As a professional he is an effective bridge between the worlds of Mathematics and Math Education."

4.5.1.4 Nova Scotia Math League

Designed to stimulate and challenge high school students across the province, the NSML is based on the very successful Newfoundland Math League which has been running since 1987. The first game was run in Halifax in 2002 by Richard Hoshino and Sarah McCurdy. Since then there has been no looking back.

4.5.1.5 The Math Challenge Club

The club meets once a week at Dalhousie University to have fun with challenging math problems, specifically, teaching the techniques needed to solve math contest problems and work on problems as a group. We hope to see more students from Halifax participating in the international math competitions, such as the APMO (the Asian Pacific Math Olympiad), the European or Asian Girls Math Olympiad, and the IMO (the International Math Olympiad).

4.5.1.6 Acadia Math Outreach with the Annapolis Valley Regional School Board

Based on the Math Circles format and also including groups interested in participating in the Nova Scotia Math League this initiative comprised a variety of outreach activities involving faculty members from Acadia University and school children from different age groups.

4.5.2 Outreach Events

StFX Integration Challenge 2019
Saint Francis Xavier University
February 27, 2019

Girls STEM Up
University of New Brunswick (Fredericton Campus)
March 23, 2019

New Brunswick Math League
University of New Brunswick (Fredericton Campus)
April 11, 2019

2019 CMS – UPEI – AARMS Math Camp
University of Prince Edward Island
May 3, 2019 - May 5, 2019

New Brunswick Mathematics Competition
University of New Brunswick (Fredericton Campus)
May 10, 2019

AARMS-Girl Guides Event: "All SySTEMs Go" 2019
Dalhousie University
May 11, 2019 - May 12, 2019

Blundon Seminar Math Camp
Memorial University (St. John's Campus)
May 15, 2019 - May 17, 2019

STFX Math Camp
St. Francis Xavier University
May 17, 2019 - May 19, 2019

Valley Math and Computer Science Camp
Acadia University
July 8, 2019 - July 12, 2019

AARMS-CMS-Dal math camp for high school students
Dalhousie University
July 14, 2019 - July 19, 2019

AARMS annual outreach meeting
Dalhousie University
November 23, 2019

Discovery Days: Beyond Puzzling
Discovery Centre
November 27, 2019

Income and Expenditure Account
2019

Income (1)		2018
	$	$
Carried forward from previous year	254,533	354,905
Mathematical Institutes	115,325	71,766
Universities	81,000	89,000
Provinces	30,000	51,000
NSERC other grants	35,000	50,000
Other Revenue	43,985	3,140
Total Income	**559,843**	**619,811**
Expenditure		
Summer School	66,970	62,025
Workshops and Events (2)	90,829	82,340
Outreach (3)	116,107	87,617
PDF Program (4)	89,637	55,476
Collaborative Research Groups (5)	116,000	20,000
Administrator Salary	33,039	33,211
AARMS Online system (6)	5,372	5,915
Travel	2,998	3,674
Office Expenses	2,188	2,020
Dalhousie Overheads	13,000	13,000
Total Expenditure	**536,142**	**365,278**
Surplus: Income Less Expenditure	**23,701**	**254,533**

Notes

1. For a breakdown see Appendix 1
2. See Appendix 2
3. See Appendix 2
4. See Appendix 3
5. See Appendix 4
6. See Appendix 5

Balance Sheet
31/12/2019

Assets	$	$
Surplus from Operations (Income less expenditure)		23,701
Accounts Receivable1		
2019 University support (UNB)	15,000	
2019 Institutes support (PIMS)	16,475	
2019 Other	11,256	
2020 University support	106,000	
2020 Institutes Support	98,850	
2020 Provinces support	120,000	
2020 Other (NSERC PS)	30,000	
		397,581
Total Assets		**421,282**

Liabilities		
Accounts Payable2		
2016 Conferences & Workshops	5,552	
2018 Conferences and Workshops	7,500	
2018 Outreach	1,500	
2019 Postdocs	35,000	
2019 Conferences & Workshops	37,800	
2019 Outreach	7,800	
2019 Other	4,300	
2020 CRGs	40,000	
2020 Postdocs	119,250	
2020 Conferences and Workshops	29,255	
2020 Outreach	51,539	
2020 Summer School	60,000	
2020 Administrator	32,000	
2020 Dal overheads	13,000	
2020 Travel, office, poster expenses	2,600	
2020 Online systems expenses	6,000	
		453,096
Unallocated funds - for AARMS activities		-31,814
Total Liabilities		**421,282**

Notes

1. Fees due to be collected in 2020
2. Funding Commitments in 2020

Annual Accounts 2019

Appendix 1

Revenue Breakdown

Provinces		
New Brunswick	0	
Newfoundland	0	
Nova Scotia	30,000	
		30,000
Mathematical Institutes		
CRM	62,950	
Fields	35,900	
PIMS	16,475	
		115,325
NSERC other grants		
PromoScience	30,000	
Odyssey	5,000	
		35,000
Universities		
Acadia	5,000	
Cape Breton	1,000	
Dalhousie	35,000	
Memorial	0	
Moncton	1,000	
Mount Allison	1,000	
Mount Saint Vincent	1,000	
Saint Francis Xavier	1,000	
Saint Mary's	1,000	
UNB	30,000	
UPEI	5,000	
		81,000
Other Revenue		
book royalties	1,349	
Girl Guides Registrations	24,603	
Girl Guides support	7,000	
ACOA for IPSW	5,000	
	6032	
		43,985
total:		**305,310**

Annual Accounts 2019

Appendix 2

Workshops and Scientific Events

2017 Combinatorics of Group Actions	6,205
2017 Hopf Algebras and their Generalizations	3,004
2017 Atlantic General Relativity	3,190
2018 AAC minicourse by Professor Matej Bresar	2,900
2018 Quantum Physics and Logic	1,037
2018 Math. Foundations of Programming Semantics	897
2018 Calculus Instruction in Atl. Canada	2,600
2018 CMS Session: Dynamical Systems	1,967
2018 CMS Session: Categories and Topology	2,000
2018 CMS Poster Session	1,000
2018 Tensor Categories and Topological Field Theory	2,190
2018 International Conference on Fibonacci Numbers	5,000
2019 Calculus Instruction in Atlantic Canada	3,320
2019 CanaDAM	2,000
2019 PIMS Clean energy workshop	2,500
2019 Agent Based Models	900
2019 Atlantic General Relativity	7,069
2019 AAC Miniscourse: Futorny	2,615
2019 Science Atlantic	1,500
2019 MSRI Membership	6,555
2019 Minisymposium: Society for Mathematical Biology	3,223
2019 IPSW	29,158.15
total	**90,829**

Outreach

2018 Big Data for Mi'qmaq schools	4,974
2018 Math Challenge Club	2,500
2018 NB Math League	575
2019 Connecting Math to Our Lives	10,000
2019 Math Camps (UPEI, STFX, Acadia, Dal)	15,737
2019 Girls STEM up	1,000
2019 John McLoughlin Outreach	1,700
2019 NB Jr. High Math Competition	1,000
2019 Acadia Math Buffet	764
2019 Acadia Middle School Outreach	575
2019 Tau Day	65
2019 Annual Outreach meeting	317
2019 Girl Guides Camp	56,902
2019 Outreach Coordinator	20,000
	116,107

Annual Accounts
2019

Appendix 3

Postdoctoral Fellowships

Qingzhong Huang	3,500
Rosalind Cameron	7,000
Shuaibing Luo	3,500
Jonathan Gallagher	26,250
Daniele Turchetti	12,613
Suzanne Lanery	17,500
Matthew Amy	8,750
Marco de Cesare	8,750
Postdoc Travel fund	1,775
total	**89,637**

Appendix 4

Collaborative Research Groups

2016 Numerical Analysis and Scientific Computing	18,000
2017, 2018 Dynamical Systems and Spatial Models in Ecology	40,000
2018 Statistical Learning for Dependent Data	18,000
2019 Computational Aspects in Finance and Insurance	20,000
2019 Groups, Rings, Lie and Hopf Algebras	20,000
total	**116,000**

Annual Accounts
2019

Appendix 5

Online System Expenditures

MathJobs Fee	588
Wizehive annual fee	4784
total	**5,372**