

Tangible results obtained as a direct result of the Canadian Fisheries Research Network (from CFRN Final Report to NSERC dated August 31, 2016)

Project	Tangible Result	Prototype / Pilot	New process / product / service / knowledge	Improved process / product / service / knowledge	Knowledge applied (or applicable) toward policy or regulation	New spin-off
1.1 - Fisheries Evaluation Framework	Framework for comprehensive evaluation of fisheries (in preparation)	Pilot framework for scenario comparison and decision support	Provides a framework for development of objectives, identification of potential management options, and comparison of scenarios in integrated fisheries management plans	Versions of the framework linked to Canadian fisheries policy statements, to an extensive list of potential performance indicators, and comparison with frameworks developed elsewhere	Enables more structured and comprehensive inclusion of ecological, social, economic and institutional aspects of management in an integrated decision-making framework	
1.1 - Fisheries Evaluation Framework	Interdisciplinary academic, industry and government collaboration on knowledge requirements for ecosystem-based management		Knowledge of the scope of ecological, economic, social and institutional requirements for emerging ecosystem-based and integrated management approaches	Enhanced collaboration among industry, academics and government in development of understanding and appreciation of the complexity of interdisciplinarity and of diverse perspectives.	Enhanced ability of industry, academics and government to contribute to co-construction of research and to participatory management processes	
1.1 - Fisheries Evaluation Framework	Case studies in implementation of the Fisheries Evaluation Framework		This project developed and tested application of candidate objectives and performance indicators, especially in relation to social, economic and institutional indicators of sustainable fisheries management.	Publications arising from case studies introduce new awareness around specific indicators (e.g., distribution of benefits, regional development).	The Framework is being considered in fisheries management plans where receptive audiences in bureaucracy exist.	
1.1 - Fisheries Evaluation Framework	Analysis of Integrated Fisheries Management Plans (S. Paul)		Gap analysis of the objectives and information in Canadian Integrated Fisheries Management Plans (IFMPs) in relation to the CFRN framework for comprehensive evaluation of fisheries	Increased awareness of the predominance of biological considerations and relative absence of economic and social information and analysis in fisheries management planning		

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1.1 - Fisheries Evaluation Framework	Evaluation of methods to integrate ecological, economic, social and institutional aspects of fisheries (A. Benson)		Inventory and comparison of methods that have been proposed as being able to incorporate social and economic aspects in fisheries evaluation	Appreciation of the strengths and weaknesses of analytical methods in relation to strategic and tactical decision-support.		
1.1 - Fisheries Evaluation Framework	A policy report on ‘Fisheries Allocation Policies and Regional Development: Successes from the Newfoundland and Labrador Shrimp Fishery’ prepared for <i>The Leslie Harris Centre of Regional Policy and Development, Memorial University of Newfoundland</i> (<u>published</u> – Harris Centre Policy Report and two peer-reviewed academic journal articles). (P. Foley)		This project was the first to develop social scientific knowledge about the relationship between fisheries allocation policy and development outcomes in the economically significant northern shrimp fishery, with a focus on three regions in Newfoundland (Southeast Labrador; the northern tip of the Northern Peninsula; Fogo Island).	Provides new knowledge and evidence on the social dimensions of fisheries management; improved understanding of the role of social considerations into fisheries allocation policy; improved understanding of the wide range of development impacts of fisheries in coastal communities. Findings are consistent with body of literature suggesting that fisheries policy can effectively integrate social principles into decision making. Outcomes of allocation policies in these cases measure up well against the objectives of social sustainability contained in the Project 1.1 framework and various fisheries management frameworks in Canada and around the world.	Provides useful information to support inclusion of social considerations into decision making. The results of this study suggest that community-oriented allocations (for community organizations and for small scale harvesters) should play a stronger role in fisheries policies in the future. The study provides evidence for the role that community-based organisations can play in developing successful business models in remote coastal communities.	New co-constructed project (Funded by the Harris Centre’s Applied Research Fund – 2014-2015) extending the research on fisheries allocation policy and regional development into indigenous communities in Northern Labrador.

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1.1 - Fisheries Evaluation Framework	Case study of innovative institution for integrated management of coastal zone (in preparation) (C. Parlee)		Assessment of Southwest New Brunswick Marine Advisory Committee (MAC) institutional development.	This PhD thesis compared local Community Values Criteria as a basis for decision making with the developing Fisheries Evaluation Framework, and highlighted need for measures of institutional sustainability.	Recommendations provided to the MAC Secretariat.	
1.1 - Fisheries Evaluation Framework	Data on institutional and social indicators for the Fisheries Evaluation Framework (C. Parlee)		The collection of case study data on characteristics of novel social and institutional indicators, including dispute resolution, and distribution of benefits.		These data provide useful indicators to support fisheries management plans.	PhD funding support from SSHRC successfully obtained for C. Parlee thesis research.
1.1 - Fisheries Evaluation Framework	Case study of decisions for season change in lobster fishery (LFA 34) (in preparation) (R. Messenger)		Documents problems around decision making to respond to market or climate change - SWNS LFA 34 season change voting process.	This Master of Arts thesis documented problems with the operation of species management boards and lack of transparency in decision making.	Relevant to issues around participatory governance.	
1.1 - Fisheries Evaluation Framework	Case study in concentration of access in British Columbia salmon and herring fisheries (published) (A. Haas)	Pilot application of a methodology to understand distribution of fisheries access over a time period encompassing significant changes in fisheries licensing policy. This was achieved through consulting with industry representatives on user-group definitions.	Harnesses methodologies from other economic disciplines, in conjunction with publicly available data and collaboration with industry representatives, and applies them to Pacific salmon and herring case studies to produce a new overview of distribution of benefits from these important fisheries resources.	This study improves the understanding of fisheries access distribution following licensing reforms, showing higher degrees of concentration of licenses by dominant fish processors, and decreased fisheries access by owner-operators.	Applicable to implementation of policies similar to the Policy for Preserving the Independence of the Inshore Fleet in Canada's Atlantic Fisheries (PIIFCAF).	

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1.1 - Fisheries Evaluation Framework	Development of a methodology for analysing the benefits accruing from fisheries and how the distribution of these benefits is changing over time. Application of the methodology to the case of Grand Manan and the Bay of Fundy. (D. Mombourquette)	Pilot application of the methodology to the case of Grand Manan and the Bay of Fundy.	Evaluation of the changes over time in contribution of herring, groundfish and lobster fisheries to the communities of Grand Manan, New Brunswick.	Methodology for analysing the benefits accruing from fisheries, and how the distribution of these benefits is changing over time.	Enables policymakers and stakeholders to more comprehensively understand the range of benefits from fisheries, and their distribution across communities and over time, including how government policy and regulation affects this, which should lead to better policy in the future.	
1.1 - Fisheries Evaluation Framework	Case study in evaluation of human dimensions of fisheries (E. Angel)		Examination of wellbeing, equity and governance in the Skeena River salmon fisheries		Recommendations on improved governance	
1.1 - Fisheries Evaluation Framework	Case study on distribution of fishery benefits resulting from decision to expand number of participants in Eastern Nova Scotia Snow Crab fishery (in preparation) (K Squires)		Evaluation of the changes in distribution of benefits in the Nova Scotia snow crab fishery following expansion of access in 2005.	This case study allowed industry participants to reflect on their experiences with this policy decision, and to provide suggestions on how fishery benefits could have been retained within local communities. Comparison of similar fishery expansions in other areas demonstrated less community-loss of fishery benefits and identified organizational factors that contributed to benefit-retention.	Completed study to be distributed to various fishery management personnel and legal professionals consulted in the course of the study: complete document, as well as condensed version, to be made available to industry informants and their organizations for consideration in the course of future policy development.	

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1.1 - Fisheries Evaluation Framework	Review of DFO experience with participatory resource management processes (M. Saunders)		Summary of the performance of recent processes aimed at increased participation and treatment of more diverse objectives	Identification of improved/best practices for participatory resource management processes		
1.1 - Fisheries Evaluation Framework	Meta-analysis of literature providing evidence of changes to distribution of benefits under various management regimes (<u>published</u>) (A. Barnett)		Case studies: SWNS LFA 34 assessment of distribution of benefits	This study provided empirical evidence that changes to the distribution of benefits is transforming fishing communities.	Relevant to discussions around licence stacking, Individual Transferable Quotas (ITQs), and owner-operator fleets and the Policy for Preserving the Independence of the Inshore Fleet in Canada's Atlantic Fisheries (PIIFCAF).	
1.1 - Fisheries Evaluation Framework	Study of key principles of marine ecosystem-based management (<u>published</u>) (R. Long)		Synthesis of key principles of ecosystem-based management from the literature and demonstration of differences between fishing industry priorities and literature priorities		This study produced a refined definition of ecosystem-based management. Resolving differences in industry vs literature priorities is important to implementation of ecosystem-based management.	
1.1 - Fisheries Evaluation Framework	Integrating fishers' knowledge research in science and management (<u>published</u>) (R. Stephenson et al)		Synthesis of international experience in integrating fishers' knowledge in science and management		This paper defines the types of information and degree of integration of fishers' knowledge in practical research and management.	

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1.1 - Fisheries Evaluation Framework	Studies of the importance of coastal community well-being in the evaluation of fisheries policies (<u>published</u>) (E. Pinkerton)		New knowledge and analysis of moral economy, strategies for rebuilding fisheries management institutions, and policy control			Insight Grant in 2016 for \$200K from the Social Sciences and Humanities Research Council of Canada: “Involving people in the management of natural resources” (Principal Investigator: Divya Varkey, postdoctoral fellow, Institute for the Oceans and Fisheries, University of British Columbia).
1.2 - Lobster Node	The incorporation of the “Lobster Node Inc.” as a new collaborative platform to secure funding for, and to conduct, co-constructed research in support of the lobster fishery in Canada.		New formalized collaborative platform involving lobster fishermen and their associations, government scientists (and to a lesser extent managers), and academics.	This new collaborative platform brought together existing strengths/capacity within the government and industry, and it attracted new participants from academia in lobster research in Canada.		In addition to the research done under the auspices of the CFRN, the Lobster Node Inc. is a partner of a successful NSERC Strategic Project Grant (SPG) on lobster genomics and is part of a recent application to the NSERC CREATE training program.
1.2 - Lobster Node	The development and use of standardized tools and protocols to quantify, while sampling alongside fishermen, the abundance and size of egg-bearing females, as well as their production of eggs, in all 5 provinces of eastern Canada.		This project is the first to develop and apply standard protocols and tools, such as a standard measuring gauge, standard clutch staging sheets, and a common web-based database, to obtain and reposit data on lobster over the species’ range in Canada.			

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1.2 - Lobster Node	Data on the catch-per-unit-effort (CPUE) and size of egg-bearing female lobsters in all 5 provinces of eastern Canada in 2011, 2012, 2013 and 2014.		The collection of data on characteristics of lobster stocks in a standardized manner throughout the range of the species in Canada is novel.		These data provide useful indicators to support lobster stock assessment exercises, and were in fact included in the last assessment exercise in Newfoundland.	New co-constructed Master's project (NSERC Postgraduate Scholarship) prompted by fishermen who reported that the incidence of females with "abnormal clutches" had increased in recent years in certain areas (see result #4).
1.2 - Lobster Node	Data on the incidence of female lobsters with "abnormal clutches" in all 5 provinces of eastern Canada in 2011-2014 (in progress).		Females with abnormal clutches are found across the species' range in Canada, and their incidence varies at a relatively small scale of ≈200km (no larger patterns). There is some evidence that abnormal clutches result from the cumulative "natural" loss of small quantities of eggs over the development period, which may be accentuated by repeated catch and release during the fishing season.		Data on abnormal clutches provide a useful indicator to support lobster stock assessment exercises.	
1.2 - Lobster Node	Lab experiments and field surveys assessing the contribution of food availability and sperm limitation to the incidence of female lobsters with "abnormal clutches" (in progress).		Evidence that sperm limitation, but not food availability, contributes to the incidence of female lobsters with abnormal clutches in Canada.			

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1.2 - Lobster Node	Development of statistical models to use data on egg-bearing females collected by the Lobster Node to assess spatial variation in female abundance and egg production in Canada (in progress).		The standard tools and protocols developed by the Lobster Node enable estimates of spatial variation in lobster egg production throughout Canada, which provides useful information concerning stock health and will also be used to enhance our larval dispersal model (see below).		These data and models will help detect shifting zones of productivity (e.g., due to climate change), which will help inform decisions concerning new licences and fishing effort.	Confirming the usefulness of these data/analyses has led to a new Masters project (start fall 2016) to assess variability in egg production and hatch time along 5 transects in the Gulf of St. Lawrence/Cape Breton, as part of the new NSERC SPG on connectivity and genetic structure at “small spatial scale”.
1.2 - Lobster Node	Meta-analysis of literature data providing evidence of reduction of female lobster size at sexual maturity in many (but not all) regions in Canada over the past 50-100 years (in preparation).			This study provides the most comprehensive empirical evidence that lobster size at maturity has decreased over time in many areas, and it suggests that fishing has contributed to this decline.	Analyses are still underway, but these findings will be relevant to discussions concerning minimum legal size and its effect on phenotypic traits and egg production in lobster.	
1.2 - Lobster Node	Analysis of DFO data on egg-bearing females suggesting that timing of hatch in the Gulf of St. Lawrence has been advancing over the past 25 years, and that warmer waters during development of ovaries and embryos have contributed to this pattern (in preparation).		This pattern of advancing hatch time, and its underlying mechanisms, represent new knowledge.		Shifts in lobster phenology such as this may become useful to decision making regarding the timing of fishing activities in different regions.	These findings have led to an Honours project to validate the use of a method developed in the lab to predict hatch time in nature based on measurements of embryo eye size (proxy for development) and water temperature (see result #9).

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1.2 - Lobster Node	Validation of a technique developed in the lab to predict hatch timing of lobster in nature based on measurements of embryo eye size (proxy for development) and water temperature (published).		Confirms that the lab technique is “transferrable” to nature, but performance differed between temperature-dependent development functions (more research needed on this).		This tool may enable hatch time to be “easily” estimated based on samples of eggs obtained with fishermen during the fishing season. Shifts in lobster phenology such as those related to hatch time may become useful to decision making regarding the timing of fishing activities in different regions.	These findings have led to a new Master’s project aiming to further validate the technique and development functions to predict hatch time in two regions with contrasting summer sea-surface-temperatures (in progress).
1.2 - Lobster Node	Preliminary empirical evidence that hatch of lobster prezoaea is adaptively timed to coincide with warmer sea-surface – temperature resulting in faster larval development and reduced dispersal (in progress)			This study provides data supporting a pattern that may have been predicted based on other species, but that had not been empirically substantiated in lobster.	Shifts in lobster phenology such as this may become useful to decision making regarding the timing of fishing activities in different regions.	
1.2 - Lobster Node	Results of a lab experiment suggesting that lobster larvae from the Gaspé region develop more rapidly in cold water than do larvae from warmer-water regions (published).		Rates of development of lobster larvae from a “cold-water population” were quantified for the first time in the lab and compared to published results for “warmer-water populations”.		These findings are consistent with, although not an unequivocal demonstration of, “local adaptation”, which is relevant to the definition/location of management zones.	

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1.2 - Lobster Node	Preliminary results of laboratory experiments suggesting geographic variation (Toney River, Anticosti, Gaspé, Caraquet) in survival, development rate, and size of lobster larvae raised in a common environment (in progress).			These findings are consistent with a small body of literature suggesting geographic variation in phenotypic characteristics of lobster larvae raised in a common environment. These studies suggest, although they do not prove (<i>e.g.</i> , maternal effects), geographic genetic differentiation.		
1.2 - Lobster Node	A bio-physical model to predict dispersal of lobster larvae over the species' range in Canada and the United States (completed).		This new large-scale model has been used to estimate patterns of connectivity among management areas in Canada via larval dispersal.		These data will provide useful information to support discussions concerning the definition/location of management areas.	These findings have led to a new Doctoral project (part of the new NSERC SPG) aiming to enhance the spatial resolution of the bio-physical model and validate its predictions (in progress).
1.2 - Lobster Node	Empirical evidence that the abundance of lobster postlarvae in the water column (sampled by light traps) is correlated to the abundance of young-of-year in "bio-collectors" deployed in different embayments in southwest Bay of Fundy (published).		The light traps did capture lobster postlarvae in nature, but in insufficient numbers for this to represent a cost-effective sampling tool, at least in the Bay of Fundy where water turbidity is high.	This study supports the use of the "bio-collector" as a tool to estimate the supply of competent lobster postlarvae to an area.		

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1.2 - Lobster Node	Laboratory experiment demonstrating that sand shrimp, and to a lesser extent green crabs, may be important predators of settling and newly-settled lobsters in nature (published).		This study was the first to document sand shrimp rapidly attacking lobster postlarvae attempting to settle on complex bottom, and demonstrating that green crabs could seek and capture hidden lobsters. It suggests the value of investigating these interactions in nature.			
1.2 - Lobster Node	Results of three years of sampling (2010-2012) indicating that patchiness in lobster benthic recruitment in the Bay of Fundy is greatest at the spatial scale of 0.4-4 km² (published).			Improved understanding of the scale underlying patchiness of lobster benthic recruitment.	The abundance of young-of-year (YOY) lobsters is a useful indicator of stock health and predictor of future landings; it is now officially used in stock assessments in the United States, and is receiving consideration in Canada. This study provides guidance concerning the spatial scale at which to monitor the abundance of YOY, to improve accuracy of estimates while minimizing sampling effort.	

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1.2 - Lobster Node	Preliminary results of multivariate statistical models identifying the North Atlantic Oscillation (NAO) Index, fetch, juvenile abundance, depth, and sea surface temperature as factors affecting benthic recruitment of lobster in the Bay of Fundy (in progress).			Improved understanding of the mechanisms underlying patchiness of lobster benthic recruitment.		
1.2 - Lobster Node	Results of three years of sampling (2010-2012) indicating that lobster spatial patterns established at settlement in the Bay of Fundy remain largely unchanged until the adolescent phase (in progress).			These results support the poorly validated expectation that the different stages of juvenile lobster do not disperse much after settling on nursery grounds.	These results are consistent with the expectation that juvenile lobsters are inconsequential to the connectivity between management areas and/or stocks of lobster.	
1.2 - Lobster Node	Results of lab experiments demonstrating that competent lobster postlarvae settle as soon as they encounter cobble substrate, delay settlement if swimming over mud, and delay to a greater extent if swimming over sand, to the point of incurring development costs (in preparation).		This laboratory experiment provides novel empirical evidence of the effect of substrate on settlement decisions and development costs of lobster postlarvae, as well as data that will be useful to enhance the settlement algorithm of our bio-physical model of larval dispersal once substrate characteristics are added to the model.			

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1.2 - Lobster Node	Sampling using passive collectors demonstrating that postlarvae likely settle on mud bottom in Maces Bay, Bay of Fundy (in preparation).		These field data, combined with those associated with the previous “tangible result”, provide evidence that mud bottom may offer a demographically meaningful settlement/early development habitat to lobster.			Findings of this and the previous tangible result led to two Honours projects that compared the adequacy of mud and cobble bottom as nursery habitat for juvenile lobsters (see result #21).
1.2 - Lobster Node	Morphometric and molecular analyses indicating that growth and body condition of juvenile lobsters sampled from mud bottom (“secondary habitat”) in Maces Bay, Bay of Fundy, were comparable, or perhaps even slightly better, than for juveniles sampled from preferred cobble-bottom habitat in the same Bay (published).		Growth rates estimated on the basis of “growth bands” in ossicles of the gastric mill suggest that juvenile lobsters sampled from mud bottom grow slightly faster, but have somewhat lower body mass at length, than juveniles sampled from cobble habitat. The RNA/DNA ratio and protein content of the abdomen of juveniles sampled on mud and cobble were comparable.			Findings of the last three “tangible results” have led to a new Doctoral project (part of the new NSERC SPG) aiming to assess the relative contribution of mud bottom and cobble bottom to benthic recruitment of lobster in Maces Bay, Bay of Fundy (in progress).

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1.2 - Lobster Node	First empirical data on activity levels and movements of juvenile lobsters in nature (based on ultrasonic telemetry) in the Bay of Fundy that both confirm and challenge current understanding based on lab experiments and limited field observations (<u>published</u>)		Results of this tracking study confirm that juvenile lobsters are mostly nocturnal and return to shelter following foraging excursions. They also reveal evidence of tidal rhythmicity in a highly tidal system. However, they do not show increasing activity during ontogeny of the different juvenile stages, as suggested by the literature.		These results are consistent with the expectation that juvenile lobsters are inconsequential to the connectivity between management areas and/or stocks of lobster.	Doctoral student sought and obtained funding from Atlantic Lobster Sustainability Foundation to do a pilot study, based on satellite tagging technology, of seasonal migrations of egg-bearing females in the Bay of Fundy in relation to embryo development.
1.2 - Lobster Node	Empirical data on activity levels and movements of juvenile and adolescent lobsters in nature (based on ultrasonic telemetry) in the Baie des Chaleurs, Gulf of St. Lawrence (in preparation).		This study covered a much larger area than our Bay of Fundy tracking study ($\approx 2.5 \text{ km}^2$ versus $\approx 0.005 \text{ km}^2$), it was conducted in a different geographic region, and it involved adolescent lobsters in addition to juveniles. Results were largely consistent with those of our Bay of Fundy study and they demonstrated markedly greater movements by adolescents than juveniles.		These results are consistent with the expectation that juvenile lobsters are inconsequential to the connectivity between management areas and/or stocks of lobster, and that adolescents begin displaying activity levels and movement patterns that may be relevant to these questions.	

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1.2 - Lobster Node	Analysis of 33 historic tagging studies conducted with fishermen between 1980-1996 suggesting that the movements of adult lobsters lead to meaningful genetic, but limited demographic, connectivity between management areas in the Gulf of St. Lawrence when considering the movements of individuals (rather than a “group average”) over multiple (rather than a single) years (in progress).			A new and more in-depth analysis of an older data set that seems to confirm (still in progress) conclusions of earlier analyses concerning the negligible role of benthic movements to demographic connectivity between management areas in the Gulf of St. Lawrence, while revealing their potential importance to demographic connectivity between fishing ports and to genetic connectivity between management areas.	These results are consistent with earlier analyses suggesting that management areas in the Gulf of Saint Lawrence are sufficiently large to be considered independent of one another from the perspective of demographic connectivity mediated by adult movements.	
1.2 - Lobster Node	Successfully tagged 2 egg-bearing female lobsters in the Bay of Fundy with satellite tags in Fall 2013, with tag release as programmed in Spring 2014 (completed).	This pilot study was the first to demonstrate that this technology can be applied to a benthic invertebrate.				This successful pilot study has led to new funding from the New Brunswick Innovation Foundation to support the research of a Master’s student (NSERC PGS) to apply the technology to study seasonal migrations of egg-bearing females in relation to embryo development in the Bay of Fundy (see result #26).

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1.2 - Lobster Node	Developing models to map likely movement trajectories of eight egg-bearing females equipped with satellite tags in the Bay of Fundy during the embryo incubation period (in progress).		This project will enable tests of the link between temperature and seasonal migrations of egg-bearing females in the Bay of Fundy, which is relevant to larval hatch (time and location) and connectivity, particularly in the context of rapidly warming waters.			
1.2 - Lobster Node	Improved map of lobster genetic stock structure based on 10,000+ single nucleotide polymorphisms (SNPs) applied to lobster samples from 17 locations throughout the species' range (published).		The results reveal the existence of a hierarchical genetic structure, first separating lobsters from the northern and southern parts of the range and then revealing weaker but significant "fine-scale" population structuring within each region.	These results demonstrate that using a large number of molecular markers and cutting-edge molecular and statistical techniques improves fine-scale population structure delineation and population assignment success in a context of weak genetic structure.		These findings have led to a new Doctoral project (part of the new NSERC SPG) aiming to: 1) enhance the spatial resolution of our "lobster genetic map", 2) investigate variability of this map among genders and life stages, and 3) explore factors that may explain this variability (in progress).
1.2 - Lobster Node	Empirical demonstration of the contribution of circulation-mediated larval dispersal to lobster genetic stock structure, and of geographic variation in adaptive genetic polymorphisms, including evidence of "cold-adaptation" genes (in preparation).		This study provides the best empirical support to date for the contribution of larval dispersal to lobster (neutral) stock structure and for evidence of adaptive geographic variation in lobster genotype.		These findings confirm the importance of larval dispersal to lobster stock structure, and they are consistent with "local adaptation" of lobster within the species' range in Canada. Both of these findings are relevant to the definition/location of management zones.	

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1.3 - Lobster Node	Original data set and video documentation of lobster larval behaviour in relation to water temperature			Provides knowledge to be used in future modelling of larval dispersal in relation to behaviour and temperature. Provides knowledge for fishermen with regard to settlement and recruitment processes.	Enables more comprehensive and realistic modelling for management	
1.3 - Lobster Node	Original data set and video documentation of lobster larval behaviour (including larval development and larval physiological condition) in relation to water temperature, water stratification and origin of berried females			Provides knowledge to be used in future modelling of larval dispersal in relation to behaviour, development, water stratification and temperature. Provides knowledge for fishermen with regard to settlement and recruitment processes.	Enables more comprehensive and realistic modelling for management	
1.3 - Lobster Node	Original data set and video documentation of lobster larval behaviour in relation to sediment modification (including larval age and larval physiological condition)			Provides knowledge to be used in future modelling of larval settlement in relation to behaviour and sediment types. Provides knowledge for fishermen with regard to optimal settling grounds.	Enables more comprehensive and realistic modelling for management	

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1.3 - Lobster Node	Original data set and video documentation of lobster larval behaviour in relation to benthic predators			Provides knowledge to be used in future modelling of larval settlement in relation to behavior and presence of benthic predators. Provides knowledge for fishermen with regard to optimal settling grounds.	Enables more comprehensive management with regard to invasive species (green crabs) and impact on lobster settlement	
1.4 - Freshwater Node	An assessment of the effect of harvest on key life-history attributes related to productivity of commercially harvested fish stocks			Contrary to evidence from several marine systems, there is no detectable effect of harvest on variation in length at maturity among 4 principal harvested fish stocks on Lake Erie.	Neither fishing induced-evolution, nor simple phenotypic change, are among important factors that might affect productivity of 4 commercially harvested fish stocks in Lake Erie, contrary to opinion in the popular press among advocates for sport fisheries along the Lake Erie south shore.	Discovery that length at maturation has fluctuated widely and synchronously among all 4 commercially harvested species suggests, instead of harvest effects, a widespread, ecosystem-level environmental factor yet to be identified.

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1.4 - Freshwater Node	An assessment of risk of overexploitation associated with pre-spawning harvest		Demonstrated framework to assess risk of overexploitation associated with pre-spawn harvest, using a simple method to model recruitment before and after spawning with available data, taking into account that not all aged-2 fish are fully recruited as spawners, and without increasing model complexity	At observed levels of constant fishing mortality of Lake Erie Walleye, there was little difference in the risk of overexploitation from pre-spawn harvest allocations up to as much as half of total allowable catch.	Lake Erie Walleye quite likely to withstand moderate increases in the proportion of total allowable catch permitted during the spring pre-spawning period, thereby potentially offsetting risk to fall-spawning Whitefish as Walleye by-catch	Method to model recruitment before and after spawning with available data, taking into account that not all aged-2 fish are fully recruited as spawners, and without greater model complexity, adopted for Walleye stock assessment model used for stakeholder-engaged management strategy evaluations by multi-agency harvest management committee on Lake Erie.
1.4 - Freshwater Node	An assessment of the relative contributions of fish ages and condition, stock abundance, and biotic and abiotic environmental covariates, on recruitment	Prototype	Methods to identify, select and incorporate environmental factors into stock recruitment models to improve reliability and reduce effects of non-stationarity on stock assessment	Stock abundance is virtually the least important factor driving recruitment in Lake Erie Yellow Perch; physical environmental factors, larval food abundance and predation by young Walleye are more important determinants of survival of aged-0 and aged-1 Yellow Perch to recruit.	Lake Erie Yellow Perch is more likely not recruitment-driven through variation in stock abundance, suggesting, in turn, (1) little effect of harvest that affects stock abundance on recruitment; and (2) greater capacity to sustain moderate increases in quota without impairing recruitment	Importance of including key environmental covariates that actually drive recruitment in Yellow Perch stock-recruitment model used for stakeholder-engaged management strategy evaluations, communicated to Lake Erie multi-agency management committee

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1.4 - Freshwater Node	An assessment of sustainability of a multispecies fishery from the perspective of consumer-resource (food web) theory	Prototype	Demonstrated approach to cohesive assessment of socio-ecological stability of a multi-species gillnet fishery, rather than simply individual fish stocks	Within a food web module for Lake Erie characterized by (1) commercial harvesters, 2 quota and 2 non-quota harvested species, (2) strong harvester prey preferences dictated by landed value, and (3) adaptive prey switching by harvesters among them, commercial harvesters achieve 'balanced harvest' by default (if not design)	Knowledge facilitates change to conventional narratives about negative ecological effects of human harvest that may lead to overly conservative harvest policies and foregone socio-economic benefits; suggests policy directions that strengthen those aspects of current management practices that maintain entire ecological structures and processes	Reconsideration of conventional wisdom regarding presumed negative ecological effects of non-native, non-quota species as, instead, integral structural components of food webs that contribute to the socio-ecological stability of the entire fishery

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1.4 - Freshwater Node	An assessment of the sustainability of commercial and sport fisheries from the perspective of consumer-resource theory applied to manager-harvester-stock interactions	Prototype	Graphical and statistical methods to assess responsiveness of quota-driven commercial, and open-access sport, fisheries to changes in stock abundance	For the Lake Erie Walleye fishery, commercial effort and catch were strongly entrained by changes in quota that, at the time, appeared not lagged behind changes in abundance, but actually were, increasing risk of fishery collapse; quota changes in response to changes in estimated abundance have not generally become more responsive with development of a more complex stock assessment model that has not apparently alleviated managers' concerns about model uncertainty; quota, effort and catch still periodically over- and under-compensate to various degrees for estimated changes in stock size, perpetuating risk to stocks; angler effort and catch more quickly respond to changes in stock abundance	Managers and stakeholders require confidence in stock assessment models to reduce model uncertainty that contributes to quota changes lagged behind changes in stock abundance which can destabilize fisheries and increase risk of collapse; policy should encourage stakeholder-engaged, participatory modelling based, as appropriate, on multi-model inference among parsimonious models of stock assessment that also include environmental drivers of recruitment	

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1.4 - Freshwater Node	An assessment of means to improve interdisciplinary approaches to pragmatic risk governance for fisheries		Demonstrated parallels between traditions of Bayesian inference by natural scientists, and hermeneutic traditions of social scientists, for improving interdisciplinary approaches to pragmatic risk governance for fisheries	From the perspective of encouraging co-learning to improve reliability of knowledge for participatory decision analysis among stakeholders, scientists, policy-makers and managers, the traditions of natural and social scientists are less in conflict than is often argued, boding well for improving interdisciplinary approaches to pragmatic risk governance for fisheries	Greater reliance on interdisciplinary approaches to improve pragmatic risk governance can and should be encouraged among decision-makers.	During the course of Project 1.4, largely at the behest of industry partners who had initiated parallel research as early as 2003, the multi-agency harvest management committee on Lake Erie moved significantly to improve transparency and modelling approaches to better engage stakeholders in quota setting, as required by Marine Stewardship Council (MSC) certifications.
1.4 - Freshwater Node	New methods of stock assessment, and value-of-information analysis, applied to a data-poor fishery	Prototype	Graphical Bayesian inference for stock assessment; dynamic Bayesian decision network for fishery simulations to estimate value-of-information to improve stock assessment	Despite considerable uncertainty about the Lake Nipigon Whitefish fishery, fishable biomass appears well above biomass at maximum sustained yield; expected value of information to reduce uncertainty was considerable at 1/3 of expected cumulative operating profit.	Lake Whitefish stock on Lake Nipigon very likely to sustain increases in harvest, especially with investment in new information to better assure balance between ecological and socio-economic risk	Graphical Bayesian state-space surplus production model appropriate for communicating complex risk analysis in multi-stakeholder, participatory management arenas; dynamic Bayesian decision network for value-of-information analysis for data poor fisheries

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1.4 - Freshwater Node	An assessment of model complexity and multi-model inference on reliability of estimates of stock abundance contrasted with extant single, high-parameter, data-intensive stock assessment models	Prototype	Demonstrated framework for contrasting reliability of stock assessment models of varying numbers of parameters, with model-averaged output and with output of models currently in use on Lake Erie	Stock assessment models ranging widely in complexity, and model-averaged output, all yielded similar time-series of stock abundance across each of 4 harvested species; low-parameter, time-varying surplus production models were most parsimonious (achieved best trade-off between uncertainty and accuracy with fewest parameters); current models for 2 quota species generate similar time series of stock abundance	Current stock assessment models for 2 quota species on Lake Erie exceed the number of parameters of all but 1 of the model formats evaluated, suggesting that they may not be as parsimonious as is otherwise possible for reduced cost, an important consideration for agencies and industry	Stock assessments as required for MSC certification completed for 2 non-quota harvested species, for neither of which there were existing stock assessments; importance of consequences of model complexity for reliability of models used in stakeholder-engaged management strategy evaluation communicated to Lake Erie multi-agency harvest management committee
2.2 - Seabed Impacts	A novel (aligned) trawl footgear that reduces seabed impacts of shrimp trawls	Prototype	Developed a novel footgear for inshore shrimp trawls in which the components are 'aligned' with the direction of tow.	Reduces seabed contact of a bottom trawl by 61% without affecting commercial catch rates.	Knowledge of seabed impacts of bottom trawls can inform decisions about permitting fishing operations near vulnerable marine ecosystems (VMEs).	The technology has been commercialized by a Canadian trawl manufacturer (Vónin Canada Ltd.).
2.2 - Seabed Impacts	A novel (wheeled) trawl footgear that reduces seabed impacts of shrimp trawls	Prototype	Developed a novel footgear for inshore shrimp trawls in which the components are 'wheeled'.	Reduces seabed contact of a bottom trawl by 69% without affecting commercial catch rates. However increased bycatch was observed for some species, suggesting more research and development is required before the technology can be commercialized.	Knowledge of seabed impacts of bottom trawls can inform decisions about permitting fishing operations near vulnerable marine ecosystems (VMEs).	

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2.2 - Seabed Impacts	Capacity in numerical modelling of bottom trawls		Developed capacity to evaluate novel trawl technologies using numerical modelling softwares.	Memorial University now uses 3 different software products for modelling the hydrodynamic performance of trawls (survey, bottom, and midwater).		This software can be used as a training tool for Canadian Coast Guard Ships or industry platforms to teach crew about the importance of standardizing survey trawl fishing operations.
2.2 - Seabed Impacts	Underwater camera observations of snow crab behaviour in response to approaching bottom trawls.		Developed a technique for quantifying the behaviour of sensitive species in the path of an approaching bottom trawl.		Knowledge has been used to assist decision making about the timing of shrimp trawling in areas where soft-shelled crab co-occur with shrimp trawling.	
2.2 - Seabed Impacts	Developed habitat suitability models for cold-water corals and sponges in Hecate Strait, British Columbia	Prototype	Identified areas of probable occurrence for three coral orders and one sponge order in Hecate Strait, British Columbia	Better understanding of the extent of overlap between bottom trawl fishing and sensitive benthic habitat	Habitat suitability modelling is important for a scientific approach to Canada's Marine Protected Area policy	These habitat suitability models are specific to the region, but the general approach to modelling is being extended to other areas such as seamounts
2.2 – Seabed Impacts	An assessment of the trade-offs between habitat protection for cold-water coral and sponges and trawl fishery catch	Prototype	Demonstrated that extensive protection for cold-water corals and sponges would probably not be overly costly in terms of fishery trawl landings	Developed efficient methods for incorporating spatially-explicit fishery catch and habitat suitability models in a spatial optimization	Spatial optimization is applicable for designing marine protected areas that balance the needs of fisheries and habitat protection	Methods currently being applied to the Sablefish trap fishery operating within the S'Gaan-Kinghlas – Bowie Seamount Marine Protected Area

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2.2 – Seabed Impacts	Developed deep-sea camera systems, software, and analyses to directly observe habitats and species	Prototype	Trap cameras are a new product – funded 100% by our industry partner (Canadian Sablefish Association) that allow for efficient acquisition of new knowledge of deep-sea habitats and species distributions	Trap cameras improve the science needed to balance habitat protection and fisheries	Direct video observations of seabed habitats are critical for effectively designing marine protected areas	Currently investigating trap camera spin-off to longline hook gear, which will provide similar information for new fisheries and help meet Marine Stewardship Council habitat protection standards
2.2 – Seabed Impacts	Developed habitat suitability models for cold-water corals and sponges at S'Gaan Kinghlas – Bowie Seamount Marine Protected Area	Prototype	Identified areas of probable occurrence for Gorgonian corals	Better understanding of the extent of overlap between Sablefish trap fishing and Gorgonian coral habitat	Habitat suitability models are being used to develop a benthic habitat protection protocol for the Sablefish fishery at S'Gaan-Kinghlas – Bowie Seamount Marine Protected Area	
2.2 - Seabed Impacts	Developed a model to map benthic habitat based on environmental data in the Gulf of St. Lawrence		These findings allow the identification of sensitive habitats in the Gulf of St. Lawrence with a model that could be applied in some other areas of Canada.		Enhanced marine spatial planning and designation of sensitive and vulnerable habitats	
2.2 - Seabed Impacts	New information on the impacts of shrimp trawling on benthic habitats in the Gulf of St. Lawrence over the long- (ca. 20 years), mid- (ca. 10 years), and short-term (ca. 4 years)		Results suggest that benthic communities in the Gulf of St. Lawrence reached a disturbed state of equilibrium decades ago on which current trawling disturbance has limited or no further impacts.	Results suggest that a critical level of disturbance was attained by the first gear passes which occurred decades ago and had irreversible impacts on the seabed by removing vulnerable taxa and structures that provided three-dimensional habitats.	Enables key fisheries to identify and avoid sensitive and vulnerable habitats, and of use in marine spatial planning	

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3.1 - Closed Areas	Scorecard for evaluating Closed Areas impacts on fisheries and biodiversity	Pilot scoring of both international and Canadian Closed Areas		Provides a scorecard method for evaluating areas closed to fishing (including Marine Protected Areas) under Ecosystem Based Management	Enables inclusion of information from fishermen, industry and science, and evaluation of achievement of Closed Areas objectives	
3.2 - Marine Mammals	Stock assessment model framework incorporating natural mortality of cod by grey seals as residual natural mortality	Prototype		Provides possible predation scenarios fit to observed data	Portfolio of management strategies for mitigating predation natural mortality based on known uncertainties	
3.2 - Marine Mammals	Collation of fishermen values with respect to interactions with grey seals	Prototype		Provides baseline information about most commonly observed interactions between grey seals and fishing gear by type and fishing location	Cost associations by type and location of interactions to be used as metrics in a structured decision making framework	
3.2 - Marine Mammals	Bayesian Belief Network	Pilot		Provides comprehensive framework for trade-offs of various seal management strategies	Compiles fishermen values, risk and economic indicators in structured decision making	
3.2 - Marine Mammals	Stock assessment model framework incorporating natural mortality of Chinook and coho salmon by harbour seals	Prototype		Provides possible predation scenarios, functional relationships, and density dependent effects of hatchery conspecifics fit to observed data	Portfolio of alternative management strategies for mitigating predation natural mortality based on known uncertainties	
3.2 - Marine Mammals	Bioenergetics model for evaluating impacts of harbour seals on juvenile and adult Chinook and coho salmon	Prototype	New bioenergetics model that quantifies consumption and mortality rates from harbour seal predation	Quantifies effects of predation on salmon populations	Outputs may be used to update/improve existing ecosystem modelling frameworks, and develop new assessment model frameworks	

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3.2 - Marine Mammals	Bioenergetics framework for evaluating competition between pinnipeds and fisheries	Pilot bioenergetics model was constructed based on Steller sea lion data to compare model outputs with previous studies.	New bioenergetics model that predicts the food requirements of different demographic groups of seals and sea lions.		Provides a framework for comparing the energetic requirements of multiple species of pinnipeds to help inform government regarding species-specific management plans.	
3.3a - Management Strategy Evaluation	Spatial-seasonal stock assessment model for B.C. groundfish	Pilot stock assessment methodology for B.C. offshore lingcod stocks	Provides a new method to evaluate consequences of different management options when seasonal movements differ between males, females, mature and immature fish	Provides improved understanding of the consequences of ignoring seasonal migrations in groundfish fisheries management and how to improve management to take into account seasonal migrations of groundfish	Enables development of management methods that can increase fishery yields and reduce the risk of stock depletion by accounting for seasonal movements of different groundfish population components	SSHRC Insight grant for research to improve transparency and stakeholder engagement in fisheries management decisions will build on existing B.C. groundfish and salmon troll case studies and CFRN collaborations. Awarded \$209,160 for 3 years (2016-2019).
3.3a - Management Strategy Evaluation	Comprehensive model of financial costs for groundfish vessel operators	Pilot assessment of trends in annual financial costs for B.C. small boats vessel operators	New methodology to quantify annual financial cost components for B.C. groundfish vessel operators	Provides a more comprehensive and updated approach to quantify the financial costs of B.C. groundfish vessel operators	Enables a more comprehensive evaluation of cost outcomes for groundfish vessel operators that may result from different fishery management methods	
3.3a - Management Strategy Evaluation	Interdisciplinary framework for evaluation of individual transferable quota (ITQ) management systems for groundfish fisheries	Pilot evaluation from an interdisciplinary perspective of the consequences of a decade of implementation of the ITQ management system for B.C. groundfish	New interdisciplinary methodology to evaluate the performance of ITQ management systems for groundfish	Provides a broader conceptual framework with which to evaluate the performance of ITQ management systems for groundfish	Provides a broader evaluative framework with which to understand the consequences of implementing ITQ management methods	

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3.3a - Management Strategy Evaluation	Bayesian decision network model to evaluate management options for groundfish fisheries when recovery of low productivity stocks is of interest	Pilot Bayesian network for evaluating the risks and benefits of different management options to bring about the recovery of depleted B.C. inshore rockfish stocks	A new Bayesian decision network model to evaluate different risks and benefits of groundfish management options for recovering pinchpoint species.	Provides an improved decision support tool for understanding the potential risks and benefits of different methods to recover depleted rockfish stocks	Enables a more comprehensive risk-benefit evaluation of management methods intended to recover depleted low productivity groundfish stocks	
3.3a - Management Strategy Evaluation	Simulation evaluation model to evaluate spatial and non-spatial multi-species groundfish management options	Pilot simulation evaluation model for evaluating the biological and economic consequences of different spatial and non-spatial management methods intended to bring about the recovery of depleted B.C. inshore rockfish stocks	A new simulation model to account for seasonal and spatial movements of key groundfish species when evaluating the potential consequences of different management options.	Provides a new simulation evaluation tool to evaluate the potential biological and economic consequences of spatial and non-spatial multi-stock groundfish management approaches	Enables evaluation of spatial as well as non-spatial multi-stock management methods for B.C. groundfish	
3.3b - Management Strategy Evaluation	Optimization models for in-season salmon management	Operational framework, not adopted by DFO		Provides balanced harvest policies for dealing with target and weak stocks in multi-species management	Enables better balancing of conservation and harvest management objectives for gauntlet fisheries	

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3.3c - Management Strategy Evaluation	A crustacean fishery moult group monthly time step (MGM) population dynamics model	Pilot stock assessment model for Hecate Strait Dungeness crab.	A new stock assessment methodology that accounts for variation in the growth rates and moult timings within cohorts of crabs and predicts how different within-season fishing effort schedules can impact crab abundance and availability of legal sized hard shell male crab to the fishery.	Provides a new stock assessment model to improve understanding of the performance of different in-season management methods	The model is being applied to assess the abundance and fishing mortality rates of Dungeness crab in Hecate Strait in recent years.	
3.3c - Management Strategy Evaluation	Evaluation of crab vulnerability hypotheses and implications for resource availability to the fishery using the MGM model	Application of the model to Hecate Strait Dungeness crab to evaluate the sensitivity of estimates of crab abundance and fishing mortality rates to different vulnerability hypotheses		Improved understanding of the sensitivity of estimates of crab availability, abundance and fishing mortality rates with respect to different hypotheses on crab vulnerability dynamics	Formulation of different versions of a crab fishery management evaluation model that account for different hypotheses about crab vulnerability dynamics	
3.3c - Management Strategy Evaluation	Evaluation of different in-season crab fishery management options using the MGM model	Application of the model to Hecate Strait Dungeness crab to evaluate the performance of different in-season management options under different crab vulnerability hypotheses		Improved understanding of the potential consequences for Dungeness crab fisheries of in-season management methods including basing openings on a softshell survey, fixed opening dates, and male only retention and a minimum size limit	Evaluation of current and alternative candidate in-season management methods for Hecate Strait Dungeness crab using a moult group model and accounting for different hypotheses about crab vulnerability	

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3.3d - Management Strategy Evaluation	A cross-boundary migration simulation evaluation model (CBLM) that represents seasonal movement of fish using a Lagrangian formulation	Application of the model to the US-Canadian fishery for Pacific hake to represent seasonal migrations of Pacific hake from US into Canadian waters.	A new statistically compact formulation for representing in-season fish migrations.	Improved mathematical-statistical formation of movement dynamics models and understanding of the set of parameters that can and cannot be estimated from fishery and fishery independent survey data	Formulation of a new spatial-seasonal management strategy evaluation model for the joint Canada-US Pacific hake technical committee	
3.3d - Management Strategy Evaluation	Extension of the CBLM to represent different ecological hypotheses for factors that drive seasonal transboundary fish migrations	Application of the model to the US-Canadian fishery for Pacific hake to account for different hypotheses for ecological factors that drive hake migrations.		Improved understanding of the potential consequences of different hypotheses for drivers of seasonal fish movements for interpretations of historical stock abundance and fishing mortality rates.	Formulation of a new simulation evaluation model that can account for alternative hypotheses on the drivers of cross-boundary seasonal fish migrations.	
3.3d - Management Strategy Evaluation	Evaluation of current and alternative management options for cross boundary hake stocks.	Application of the model to the US-Canadian fishery for Pacific hake to evaluate current and alternative management options.		Improved understanding of the performance of different management options for Pacific hake.	Identification of management methods for Pacific hake that are robust to different drivers of seasonal cross-boundary migrations.	
3.3d - Management Strategy Evaluation	A multi-stock spatial simulation evaluation model of the Pacific herring fishery in B.C. (MSPH model)	Application of the MSPH model to stock assessment and tagging data for Pacific herring in B.C. waters.	New understanding of how stock status of Pacific herring on the B.C. coast can be sensitive to different hypotheses about stock structure and stock mixing.			

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3.3d - Management Strategy Evaluation	A fine-scale spatial spawn distribution model to predict how the extent of herring spawn varies with Pacific herring abundance (FSDPH model).	Application to time series of observations of herring spawn densities and spatial locations of herring spawn for B.C. Pacific herring stocks.	New understanding of how the spatial extent, densities and locations of herring spawn may vary with regional herring population abundance.			
3.3d - Management Strategy Evaluation	A simulation evaluation of different in-season harvest control procedures using the MSPH and FSDPM models.	Application of the MSPH and FSDPM models to evaluate current and some alternative management procedures for the B.C. Pacific herring fishery.			Improved understanding of the short- and long-term performance of current and alternative management procedures for the B.C. Pacific herring roe fishery that account for ecological and yield outcomes at regional and local scales.	
3.3e - Management Strategy Evaluation	A statistical model to estimate the spatio-temporal distribution on B.C. coastal salmon troll fishery grounds of the key stock groups of Chinook and mature coho salmon (STDCS).	Application of the STDCS model to estimate the monthly spatial distribution for six stock groups of Chinook salmon in ten fishery management areas off of the West Coast of Vancouver Island (WCVI). DFO's coded wire tag data set and WCVI salmon troll effort data set will be applied.		Improved knowledge of the monthly spatial distribution of mature coho and Chinook salmon stocks off of the WCVI	Improved ability for fishery managers to meet conservation and harvest targets for individual Chinook salmon stock groupings.	SSHRC Insight grant for research to improve transparency and stakeholder engagement in fisheries management decisions will build on existing B.C. groundfish and salmon troll case studies and CFRN collaborations. Awarded \$209,160 for 3 years (2016-2019).

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3.3e - Management Strategy Evaluation	A fine-scale spatio-temporal simulation evaluation model of management procedures for a salmon troll fishery (FSTTF model)	Fitting the model to commercial catch and effort data and tagging data from the WCVI salmon troll fishery.		Improved understanding of the historic fishing mortality rates from the WCVI salmon troll fishery on Chinook and coho stocks.		
3.3e - Management Strategy Evaluation	Evaluation of the performance of current and alternative management procedures for the WCVI salmon troll fishery using the FSTTF model.	Application of the FSTTF model to test current and alternative management procedures for the WCVI salmon troll fishery.	New understanding of the performance of current and alternative management procedures for the WCVI salmon troll fishery based on indicators of conservation success and financial viability for the fishery.		Identification of management procedures that are robust to uncertainty about the spatio-temporal distribution of Chinook and coho salmon stocks on the fishing grounds and that are likely to meet conservation targets and maintain the financial viability of the fishery.	