Nova Scotia Agricultural College

Wild Blueberry Entomology Research Chair

FINAL REPORT

Submitted to:

Nova Scotia Agricultural College
Nova Scotia Department of Agriculture
Wild Blueberry Producers Association of Nova Scotia
Agri-Futures Nova Scotia

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1 Background and General Project Status

Wild blueberries are one of the most important horticultural commodities in Nova Scotia and eastern Canada. Continued competitiveness of the wild blueberry industry is contingent upon not only high volume production, but also satisfying modern, global markets that are increasingly concerned with health and environmental issues surrounding agricultural practices. These issues have brought increasing and new challenges to the wild blueberry industry. Key among these is the need for insect pest management programs that focus on both economic and ecological sustainability, while promoting and preserving beneficial insect species.

To address emerging entomological challenges, the Wild Blueberry Producers Association of Nova Scotia (WBPANS) recently partnered with the Nova Scotia Agricultural College (NSAC), the Nova Scotia Department of Agriculture, and the provincial ACAAF organizations of Nova Scotia, New Brunswick, Prince Edward Island, Newfoundland and Labrador and Quebec, to establish the Wild Blueberry Entomology Research Chair (the "Chair"). Dr. Chris Cutler accepted the Chair position in the spring of 2007, officially joining the Department of Environmental Sciences at NSAC on June 11, 2007.

2 Establishment of New Infrastructure

As an initial step towards infrastructure development, an award valued at $125,181 was applied for in October 2007 through the Leaders Opportunity Fund of the Canadian Foundation for Innovation (CFI). In March and October 2008 the CFI and Nova Scotia Research and Innovation Trust (NSRIT), respectively, agreed to fund the wild blueberry entomology infrastructure project in full. Final approval to proceed with purchasing was granted by CFI in March 2009. Among key materials obtained were a hand-held plot sprayer, insect rearing cages, Malaise traps, a GPS mapper, Potter spray tower, microapplicator and Tullgren funnels. To support this new infrastructure, the Department of Environmental Sciences has allocated over 1600 square feet of laboratory space with adequate bench space and fume hoods, and has provided generous access to environmental chambers and greenhouse facilities. Dr. Cutler has also purchased new computers, a digital camera for microscopy, an ATV sprayer, and a PCR thermal cycler for work in blueberry insect molecular ecology.

3 Research Projects

The following are funded projects in wild blueberry entomology. See Tables 1 and 2 for funding details for these projects.

3.1 G.C. Cutler. Habitat management to promote wild pollinators in wild blueberries – NSDA Technology Development 2000. Cross-pollination is critical for wild blueberry fruit set. Producers therefore rely heavily upon pollination services from managed and wild bees. This project examines how non-crop vegetation within and around

wild blueberry fields affects native bee diversity and abundance. These funds were used to provide M.Sc. candidate Pamela Craig (a NSERC CGS-M scholar) additional stipend support, as well as funds for summer students, materials and travel. Components of this project are linked with CANPOLIN (see 3.3 and Appendix 1).

Progress – <u>Ongoing</u>. Pamela has completed her field work, attended bee identification workshops, and presented her results at several regional meetings and conferences. Data analysis and thesis writing was underway, but Pamela unfortunately has withdrawn from the program for personal reasons. We nonetheless intend to publish the work derived from Pamela's efforts.

3.2 G.C. Cutler. Assessing the potential of biorational technologies for blueberry spanworm management – NS Dept. of Agriculture Technology Development 2000. Funds from this project support M.Sc. candidate Krilen Ramanaidu in his laboratory and field experiments investigating effects of novel insecticides and biopesticides against an important insect pest, blueberry spanworm, *Itame argillacearia*. Krilen is also assessing the toxicity of some of these products to bumble bees, valuable wild and managed pollinators in wild blueberry. Components of this project are linked with CANPOLIN (3.3), the PMC Biopesticides Initiative (3.10) and industry partners (Table 2).

Progress - <u>COMPLETE</u>. Krilen successfully defended his thesis in December 2010. He has presented his results at national and international conferences, and has thus far published one paper published one peer-reviewed paper from his thesis; a second paper is in the advanced stages of development. Krilen currently provides me valuable research support as a technician in my laboratory. A final report as submitted to the NS Technology Development program.

3.3 P. Kevan. Canadian Pollinator Initiative (CANPOLIN) – NSERC Strategic Networks Grant (2009-2013; C. Cutler and 39 others are co-applicants). CANPOLIN consists of a network of pollinator and pollination experts across Canada. The team is undertaking five years of research to tackle a wide number of questions and concerns surrounding pollinators (wild and managed) and pollination. See http://www.uoguelph.ca/canpolin/index.html. Dr. Cutler is involved with two CANPOLIN working groups investigating wild blueberry questions related to impacts of pesticides on bees, and diversity and abundance of native bee species. Dr. Cutler is also the coordinator of the "blueberry hit-team" whose objective is to undertake intense data collection in blueberries in areas of pollination related to bees and syrphid flies, fruit-set limitations, gene flow, floral characteristics and breeding systems.

Progress – <u>Ongoing</u>. Three seasons of CANPOLIN data collection are complete. Current key collaborators are Dr. Cory Sheffield (York University), Dr. Luise Hermanutz (Memorial

University), Dr. C. Scott-Dupree (Guelph), and Dr. P. Kevan (Guelph). Funding to Dr. Cutler was recently approved for a fourth year for research in wild blueberry pollination.

3.4 K. Hillier, Acadia University. Integrated Research, Development and Commercialization of Pheromones and other Semiochemical Products for the Management of Insect Pests in Agriculture and Forestry – Atlantic Canada Opportunities Fund (2011-2016; Cutler is a co-investigator). In an attempt to reduce chemical inputs, we have proposed a five-year project to develop, test and commercialize products from pheromones and other semiochemicals: natural chemical compounds that pose significantly less risk to human health and the environment than traditional chemical insecticides. The project draws on regional expertise in both forestry and agriculture.

Progress – <u>FUNDING SECURED</u>. The project was approved by ACOA, but no funds have yet been received. Project planning is underway, including semiochemical studies with blueberry spanworm and blueberry flea beetle. A Post-doctoral fellow will be initiating research in June 2012 to identify and synthesize the blueberry fruit fly oviposition deterrence pheromone.

3.5 G.C. Cutler. Integrated management of insect pests in wild blueberry – Advancing Canadian Agriculture and Agri-Food Program (ACAAF) (2009-13). Funds from this proposal support a full-time research technician for my laboratory, dedicated to studies in wild blueberry entomology.

Progress - <u>Ongoing</u>. Mr. Jason Sproule accepted the position in May 2009 and continues to provide excellent support as a research technician. Interim reports have been submitted to ACAAF.

3.6 G.C. Cutler, K. Hillier, P. Silk. *Itame argillacearia* sex pheromone identification and isolation in wild blueberries – NSDA Technology Development 2000. Use of pheromone lures for insect monitoring or trapping has proved highly successful in numerous agricultural systems, but has received scant attention in the wild blueberry industry. With Dr. Kirk Hillier (Acadia University; insect chemical ecologist), a co-investigator on this project, we will identify and isolate sex pheromones that govern blueberry spanworm behavior. Funds obtained will be dedicated mainly towards support of a M.Sc. student.

Progress – <u>Ongoing</u>. Chaminda Amal De Silva replaced the originally recruited MSc candidate for this project and initiated his studies in September 2010. Amal had an excellent season of research in 2011, demonstrating attraction of male moths to female sex pheromone gland extracts and synthetic compounds. Importantly, Amal has elucidated the structure of the sex pheromone produced by female spanworm moths that she uses to attract males for mating. This research will be completed in 2012.

3.7 K.N. Hillier, Acadia University. Pheromone identification for red-striped fireworm control in wild blueberries – NSDA Technology Development 2000. The rationale and objectives of this project are similar to that described in section 3.6 above, but the target pest will be red-striped fireworm, *Aroga trialbamaculella*. Dr. Kirk Hillier is the project lead and Dr. Cutler is a co-investigator for the project.

Progress - COMPLETE. Ms. Jillian Kelly has recently defended her MSc thesis on this research. A final report as submitted to the NS Technology Development program.

3.8 G.C. Cutler and F. Drummond. Utility of Botanigard® against insect pests of wild blueberry – AAFC Pest Management Centre Biopesticides Initiative. Blueberry fruit fly has been identified as a priority pest of the PMRA, AAFC, IR-4 and EPA, and one favored for biopesticide cooperative research between Canadian and US scientists. Dr. Cutler, in cooperation with Dr. Francis Drummond (University of Maine), will investigate strategies for use of the biopesticide *Beauveria bassiana* (formulated as Botanigard) against blueberry fruit fly, spanworm and flea beetle.

Progress - COMPLETE. A Final Report for this project was submitted to the AAFC Pest Management Centre (a confidentiality agreement is in place) in March 2010. Laboratory data indicates that the pests are somewhat susceptible to Botanigard, but the tested use pattern does not appear suitable to control these pests. More work is needed to evaluate the biology of the pest/pathogen interaction and identify vulnerable stages in pest lifecycles.

3.9 N. Boyd. Impacts of sheep sorrel on wild blueberry production. NSDA Technology Development 2000. Sheep sorrel is significant weed in wild blueberry. Experiments will be conducted to evaluate new potential herbicide products, optimize application timing of registered products, estimate impact of sheep sorrel on pollination, and determine if sheep sorrel presence encourages botrytis infection. The project is led by Dr. Nathan Boyd and C. Cutler is a cooperator and graduate committee member on the study.

Progress - COMPLETE. Ms. Angela Hughes defended her MSc thesis on this research in April 2012. Dr. N. Boyd has submitted a final report as submitted to the NS Technology Development program.

3.10 G.C. Cutler. Reduced-risk products for insect pest management – Agro-Chemical Industry Support (2008-current). Several international agro-chemical companies are working with Dr. Cutler to evaluate the efficacy of their novel products – with reduced risks to the environment, applicators and consumers – for insect pest control in wild blueberry IPM programs. See Table 2 for a list of cooperating companies and target pests examined 2008-2012.

Progress - <u>Ongoing</u>. Highly efficacious pest management compounds for blueberry spanworm, flea beetle and fruit fly have been identified. Field and/or laboratory experiments evaluating efficacy of products against blueberry fruit fly, blueberry spanworm, blueberry leaftier and blueberry flea beetle were completed each summer since 2008 and will hopefully continue in the coming years.

3.11 G.C. Cutler. Conservation of predatory ground beetles. Habitat management is an ecologically based approach aimed at managing agro-ecosystems to enhance survival, fecundity, longevity and behaviour of natural enemies, thereby increasing the effectiveness of biological control and decreasing reliance on chemical control. The strategy has received little attention in wild blueberry production. Studies are underway to determine the diversity and abundance of predatory beetles in wild blueberries, along with development of strategies to promote population growth of beneficial species.

***Progress - <u>Ongoing</u>*.** Populations of ground beetle predators (Carabidae) were assessed in adjacent sprout and crop fields at four sites in Colchester Co. in 2008 and 2009. Using pit-fall traps to capture beetles, we found that carabid populations were significantly greater in sprout fields than crop fields but that captures did not vary whether traps were at the field edge (0 m) or 25 m into the field, indicating an even distribution of beetles throughout the field. Mr. Chris Majka, housed at the Nova Scotia Museum and an international expert on Coleoptera, is currently assisting in species identifications. We also examined the predatory activity of several ground beetle species against blueberry spanworm and blueberry fruit fly. Future work will assess the toxicity of various ago-chemical to these beetle predators, and will examine tactics habitat management tactics for conservation biological control. A manuscript on this research was recently accepted for publication in the *Canadian Entomologist*, and another manuscript has been submitted to the *Journal of Pest Science*.

3.12 G.C. Cutler. Asiatic Garden Beetle. Cutler and Rogers identified the Asiatic garden beetle, *Maladera castanea*, in a wild blueberry field in Fox Point, Cumberland Co., a new record for Atlantic Canada. Subterranean larvae (white grubs) of the beetle were found feeding on blueberry roots. The field was underperforming, but it is not clear whether or not this was due to feeding by Asiatic garden beetle larvae.

***Progress - <u>COMPLETE</u>*.** The results of this work were recently published in the *Journal of the Entomological Society of Ontario*.

3.13 G.C. Cutler and C. Scott-Dupree (University of Guelph). Acute and sublethal toxicity of new reduced risk pesticides to bees. NSDA Technology Development 2000, Dow AgroSciences, NSERC-CANPOLIN. Toxicological impacts of xenobiotics go beyond lethal effects. This study will determine the sublethal effects – longevity, reproductive outputs, progeny development, etc. – of several new insecticides proposed for use in the wild blueberry industry against bumble bees and alfalfa leafcutter bees.

Progress - <u>COMPLETE</u>. We identified several pesticides used in wild blueberry production that are hazardous to bumble bees and alfalfa leafcutter bees, but also new products that should pose low risk to pollinators. This work has been published in the *Canadian Entomologist* and the *Journal of Pest Science.*

3.14 N. Boyd and G.C. Cutler. Biological control of dogbane using dogbane beetle. NSDA Technology Development 2000. This project will examine the potential of dogbane beetles, a highly specific herbivore of dogbane, in the biological control of dogbane, an important weed in wild blueberry. A combination of laboratory and field experiments will be conducted.

Progress - ongoing. Megan MacEachern began her M.Sc. studies on this project in May 2010. She has completed her research and plans to defend her MSc thesis in the summer of 2012.

3.15 G.C. Cutler. The occurrence and mechanisms of hormesis in insects exposed to sublethal doses of insecticide. **NSERC Discovery.** Sublethal doses of insecticide have been shown to stimulate numerous biological endpoints in insects, including reproductive outputs, longevity and growth. This phenomenon, known as hormesis, has implications for pest resurgence and population explosion and acceleration of insecticide resistance in wild blueberries and other crops. This project explores patterns and mechanisms of hormesis in insects.

Progress - ongoing. This project runs from 2009-2014. Mural Mohan began his Ph.D. studies on this project in January 2010. He is nearing completion of his experiments, and writing of thesis chapters and manuscripts is ongoing. NSERC USRA recipient Kenton McNutt completed a project on insect hormesis during May-August 2010. Dr. Cutler was invited to speak on the topic of insect hormesis at the International Dose Response Society Annual Meeting at the University of Massachusetts in 2010 and recent published an invited review on this topic in the journal *Dose Response.*

3.16 G.C. Cutler. Bees as vectors of biopesticides for disease control on wild blueberries. NSDA Technology Development 2000, NSERC-CANPOLIN. Bumble bees and honey bees have recently demonstrated potential to vector microbial biological antagonists of insect and disease pests in a few greenhouse and agricultural setting. Preliminary work in PEI in 2009 suggests bumble bees may be able to effectively vector biopesticides for control of disease in wild blueberry. This project builds on the 2009 experiment and will assess the vectoring potential of bees in blueberry for control of monilinia and botrytis blight

Progress - <u>COMPLETE</u>. Kevin Reeh began his M.Sc. studies on this project in May 2010 and is defending this thesis this April 2012. Publications from this work as pending.

3.17 G.C. Cutler and L. Hermanutz (Memorial University). Ecology of native pollinators in wild blueberry in Newfoundland. **NSERC-CANPOLIN, Newfoundland and Labrador**

Department of Environment and Conservation (Wildlife Division). The island of Newfoundland has a small wild blueberry industry. That relatively few fields utilize managed bee to supplement pollination service presents a unique opportunity to assess the contributions of wild bees to blueberry pollination. This project will assess pollination contribution by wild bees in representative wild blueberry field across Newfoundland and examine ecology factors that contribute to their diversity and abundance.

Progress – ongoing*.* Margie Wilkes began her M.Sc. studies on this project in May 2010. Margie hopes to defend her MSc thesis on this research in December 2012.

3.18 G.C. Cutler. Molecular ecology of predatory carabid beetles for biological control in wild blueberry fields. NSDA Technology Development 2000. We are currently determining what predatory carabid beetle species occur in Nova Scotia wild blueberry fields, and how the distribution and abundance of such species may shift over space and time. Based on these data we can then select the most promising taxa for laboratory and field experiments, examining their potential for pest control while deciphering optimal habitat management options to promote their populations. Here we will identify feeding preferences of prominent carabid beetle species found in wild blueberry field; develop molecular techniques to analyze the gut contents of predatory carabid beetles collected from blueberry fields; and quantify, through gut content analyses, field predation of blueberry maggot (*Rhagoletis mendax*), blueberry spanworm (*Itame argillacearia*), and/or blueberry flea beetle (*Altica sylvia*) by prominent carabid species.

Progress – ongoing. We have completed a series of experiments examining the predatory behavior of several species of carabid beetles found in blueberry fields against blueberry spanworm and blueberry maggot. A manuscript on this work has been submitted to the *Journal of Pest Science.* Post-doctoral fellow Dr. Justin Renkema has also been making good progress in developing species specific molecular primers for the pest species. This summer (2012) we will conduct experiments to determine if we can elucidate feeding behaviors of carabid beetles by using these molecular markers.

3.19 G. Williams, D. Shutler, C. Cutler et al. Pollen in Nova Scotia honey bee hives: preferences and nutritional quality. NSERC-CANPOLIN. There is a lack of information concerning the availability of non-crop pollen for honey bees, and the nutritional content of these pollens. During a recent meeting with Dr. Cutler, the NS Beekeepers Association listed this as their no. 1 research priority. This project will collect pollen samples from honey bee hives throughout NS and PEI to determine foraging preferences of bees, while correlating these data with results from nutritional analyses (e.g. lipid and amino acid content).

Progress - ongoing. Pollen was collected in the Atlantic provinces throughout the summer. CAAP funding for this project has been approved and additional research is underway. MSc student Megan Colwell is working on this project.

3.20 C. Cutler. Honey bee hive pesticide residues and interactions with Varroa mites and Nosema. Canadian Agricultural Adaptation Program. Honey bees used for pollination are in integral component of wild blueberry production in the Maritime provinces. Concurrently, beekeepers face mounting challenges in management and bee suffer from various biotic and abiotic stressors. This pan-Maritime project is a partnership between the provincial beekeeper associations of NS, NB and PEI. The research examines: pesticide loads in representative bee hives in each province; whether pesticide loads in these hives are related to incidence of parasitic Varroa mites and *Nosema* (an important pathogen); and whether these stressor impact bee learning and memory.

Progress – ongoing. Hive residue data have been collected, and parasite and pathogen data have been obtained from these same hives. Bee learning experiments are underway.

3.21 C. Cutler. SuperBoost™ honey bee brood pheromone to improve blueberry pollination. NSERC Engage program. SuperBoost is a synthetic formulation of a naturally occurring honey bee brood pheromone that has been shown to boost hive vigor and worker foraging. Less is known about the effects of SuperBoost on crop pollination and subsequent yields. This project tested the hypothesis that the addition of SuperBoost to honey bee hives would increase their pollination on blueberry, and subsequently increase blueberry yields.

Progress – COMPLETE. Significant increases in pollen loads of workers returning to SuperBoost treated hives were detected. However, we did not see an significant increase in berry yield from fields that contained honey bee colonies containing SuperBoost.

3.22 C. Cutler. Blueberry maggot ecology and control in split fields. NSDA Technology Development 2000. Blueberry fruit fly is the most important pest of wild blueberry. Little is known about the dynamic of blueberry fruit fly movement in or across fruit-bearing and vegetative fields, strategies to control overwintering pupae or emerging flies in sprout fields before they are able to move into crop fields, and the role of non-blueberry host plants in supporting fruit fly population. This project examines: the dynamics of fly movement from sprout field into crop fields; the feasibility of insecticide and biopesticides applications/drenches to sprout fields to reduce fly emergence; the feasibility of shallow soil milling/aeration, alone or in conjunction with insecticide applications, of mowed fields in fall to reduce fly emergence in

summer; whether or not selected native host plants around blueberry fields can support blueberry fruit fly development.

Progress – ongoing. Data have been collected showing movement of male and female flies spatially and temporally from vegetative into fruit-bearing fields. Experiments are underway examining effects of soil drenches and aeration on fruit fly emergence. Non-blueberry hosts will be mapped in late summer.

3.23 K. Hillier and C. Cutler. Ecology and management of blueberry flea beetle NSDA Technology Development 2000. Blueberry flea beetle is an important defoliator of blueberries throughout eastern Canada and Maine. In an attempt to reduce reliance on insecticides, we will undertake laboratory and field studies to: identify biologically active compounds for blueberry flea beetle, including pheromones and host plant odours which may be attractive or repellent; use electroantennography to test the sensitivity of flea beetles to the candidate attractant components; test the behavioural attraction of to these compounds.

Progress – ongoing. A MSc student (Jesse Saroli) initiated his studies on this project in May 2012.

3.24 C. Cutler and N. Boyd. Seed predation by beetles in wild blueberry. Canadian Agricultural Adaptation Program. Failure to manage perennial grasses in wild blueberry fields results in significant reductions in yield. Blueberry producers rely almost exclusively on herbicides to manage grasses. However, these often to not deliver satisfactory results, and use of herbicides falls short of grower and consumer goals of reduced chemical inputs and increased development of ecological methods of pest management in blueberry production. It has been suggested that weed seed predation is largely underestimated in ground beetles. The objectives of this project are to determine: if different beetles differ in their seed eating preferences and consumption rates; rates of grass seed removal by insects in blueberry fields; susceptibility of seed-eating beetles to pesticides used in wild blueberry production.

Progress – ongoing. A MSc student (Gurminder Chahil) initiated his studies on this project in May 2012.

3.25 C. Cutler. Nocturnal pollination of wild blueberry. NSERC CANPOLIN. The role of honey bees in wild blueberry pollination is well recognized, but little is known about the potential role of non-Apidae pollinators for this crop. We are conducting experiments to determine whether nocturnal pollination of blueberry can occur, and what night-active insects might be carrying blueberry pollen.

Progress – ongoing. An experiment was completed in 2011 showing nocturnal pollination may make significant contributions to wild blueberry fruit set. In 2012 we are collecting

insects from blueberry at night to determine which of these may be contributing to wild blueberry pollination.

3.26 C. Cutler, N. Faraone, K. Hillier, P. Silk. Host marking pheromone of blueberry fruit fly. Atlantic Innovation Fund, ACOA. Blueberry fruit fly is the most important insect pest of blueberries in North America. Upon deposition of an egg in fresh blueberry fruit, female fruit flies smear a host-marking pheromone that deters other female fruit flies from laying eggs in the same fruit. We are attempting to identify and synthesize this host-marking pheromone, with hopes of producing it for applications in pest management.

Progress – ongoing. A post-doctoral fellow (Dr. Nicoletta Faraone) initiated her research on this project in May 2012.

4 Research Support

Several grants were applied for or have been received (Table 1). A research support summary (June 2007 – March 2011) follows:

Table 1. Wild Blueberry Entomology Research Chair record of research funding (public support, principal investigator).

Year	**Title**	**Agency**	**Amount**
Principal Investigator, Public Support *			
2008-2010	Habitat management to promote wild pollinators in wild blueberries	NS Dept. Agriculture	$40,000
2008-2010	Assessing the potential of biorational technologies for blueberry spanworm management	NS Dept. Agriculture	$40,000
2008	Development of wild blueberry insect IPM programs	Canada Foundation for Innovation (CFI)	$125,115
2009-2014	Integrated management of insect pests wild blueberry (HR support)	Advancing Canadian Agriculture and Agri-Food Program (ACAAF)	$245,033
2009-2011	*Itame argillacearia* sex pheromone identification and isolation	NS Dept. Agriculture	$40,000
2009-	The occurrence and mechanisms of hormesis	NSERC Discovery	$115,000

2014	in insects exposed to sublethal doses of insecticide		
2009-2011	Field sanitation techniques for wild blueberry production (with Dr. D. Percival, NSAC)	NS Dept. Agriculture	$40,000
2009-2010	Botanigard biopesticide for insect pest control in wild blueberry	AAFC Pest Management Centre	$25,000
2010-2012	Bees as vectors of fungal antagonists for disease control on wild blueberries	NS Dept. Agriculture	$40,000
2010-2012	Acute and sublethal toxicity of new reduced risk pesticides to bees.	NS Dept. Agriculture	$40,000
2011-2013	Sublethal effects of spinosyns on diamondback moth	NS Dept. Agriculture	$40,000
2011-2013	Predatory behavior of carabid beetles in blueberry pest management	NS Dept. Agriculture	$40,000
2011	Honey bee hive pesticide residues and interactions with Varroa mites and Nosema	Canadian Agricultural Adaptation Program (AAFC)	$60,333
2011	SuperBoost™ honey bee brood pheromone to improve blueberry pollination	NSERC Engage	$25,000
2012-2014	Blueberry maggot ecology and control in split fields	NS Dept. Agriculture	$40,000
2012	Slug control with the carabid beetle *Pterostichus melanarius* (with Dr. J. Renkema)	Organic Crop Improvement Association, MicroGrants	$1500
2012-2014	Ecology and management of blueberry flea beetle (co-PI with Dr. K. Hillier, Acadia)	NS Dept. Agriculture	$40,000
2012-2013	Seed predation by beetles in wild blueberry	Canadian Agricultural Adaptation Program (AAFC)	$69,525
Funding Totals as Principle Investigator (Received, 2008-Present)			**$1,066,506**
* Does not include industry contributions (~$90,000)			
<u>Funding as a Co-Applicant on Major Grants</u>			
2008-	Canadian Pollination Initiative (Dr. P. Kevan,	NSERC Strategic Network	$5,000,000

2013	U of Guelph)		($56,325 in Years 1-3)
2011-2016	Integrated Research, Development and Commercialization of Pheromones for Insect Pest Management (Dr. K. Hillier, Acadia)	ACOA Atlantic Innovation Fund	$6,884,005 ($278,750 in Years 1-5)
Funding Totals as Co-Applicant (2008-Present; not yet all received)			**$335,075**
TOTAL FUNDING 2008-present			**$1,401,581**

Significant cash support from industry partners was also obtained (Table 2). Several major agro-chemical companies have requested research trials evaluating efficacy of novel reduced-risk products against key insect pests and bees in wild blueberry. Generous in-kind support was also obtained from these companies (chemical for pesticide trials), as well Koppert Canada Ltd. (bumble bees), Laverlam International (Botanigard biopesticide samples), Contech Inc., and Bragg Lumber Co. (field use and access).

Table 2. Wild Blueberry Entomology Research Chair support from agro-chemical industry partners, 2008-2010.

Partner	Year	Target insect	Funds received *
Bayer CropScience	2008	Blueberry spanworm	$4000
	2009	Blueberry spanworm	$3000
	2009	Blueberry fruit fly	$5250
	2010	Blueberry fruit fly	$13,500
Dow AgroSciences	2008	Blueberry spanworm	$7800
	2008	Blueberry fruit fly	$1600
	2009	Blueberry flea beetle	$3000
	2009	Blueberry fruit fly	$3500
	2010	Blueberry flea beetle	$3560
	2010	Blueberry spanworm	$4503
	2010	Bumble bees	$16,125
Dupont	2008	Blueberry fruit fly	$5800
	2009	Blueberry fruit fly	$6000
	2009	Blueberry flea beetle	$5200
	2010	Blueberry spanworm	$6765
	2010	Blueberry flea beetle	$4576
TOTAL			**$94,179**

5 Key Research Collaborations

Dr. Cutler has been very active in establishing collaborations with other scientists. See section 3 and Table 3 for details.

Table 3. Key research collaborators of the Wild Blueberry Entomology Research Chair program (2008-2012; listed on grant proposals).

Institution	**Name**
NSAC	Dr. N. Boyd Dr. A. Hammermeister Dr. D. Lynch Dr. V. Nams Dr. D. Percival Dr. B. Prithiviraj Dr. N. MacLean
Acadia University	Dr. K. Hillier Dr. D. Shutler
University of Guelph	Dr. C. Scott-Dupree Dr. P. Kevan Dr. J. Sutton Dr. Almuhanad Melhim
Canadian Forest Service, Fredericton	Dr. Peter Silk
AAFC, Harrow	Dr. L. Shipp
Contech Inc.	Dr. John Borden
AAFC, Kentville	Dr. Kenna MacKenzie Dr. Sonia Gaul Dr. Debra Moreau Mr. Steve Javorek
University of Maine	Dr. F. Drummond
University of Lethbridge	Dr. Dan Johnston
York University	Dr. C. Sheffield Dr. L. Packer
Memorial University	Dr. L. Hermanutz

6 Scholarly Activities

6.1 Meetings/conferences attended (2007-2012)

Invited Talks (Conferences, Industry, Seminar Series - Selected)

1. Insect management in blueberries. ***Note****: I regularly give research-based seminars or workshops on insect pest management and pollination to several regional blueberry grower associations at their annual meetings. Presentations/workshops have been as follows (**~25 total**):*
    a. Wild Blueberry Producers Association of Nova Scotia
        i. Seminars: 24 March 2012; 18 November 2011; 26 March 2011; 19 November 2010; 27 March 2010; 28 March 2009; 22 November 2008; 31 March 2008; 16 November 2007
        ii. Field-days: 27 July 2010; 11 July 2009; 15 July 2008 (insect displays and information sessions)
        iii. Twilight meetings: 2012, 2011, 2010, 2008, 2009 (3 separate mini-workshops in June)
    b. PEI Wild Blueberry Producer Association
        i. Seminars: 29 November 2011, 29 November 2010; 28 November 2009; 4 April 2009
        ii. Field-day: 10 July 2010
    c. Bleuet NB Blueberries
        i. Seminars: 30 March 2012; 31 March 2011; 5 February 2010; 15 March 2008
2. Honey bee issues and research. ***Note***: *I regularly give research-based seminars to several regional beekeeper associations at their annual meetings. Presentations have been as follows:*
    a. Nova Scotia Beekeepers Association: 5 March 2011; 13 March 2010; 7 March 2009
    b. New Brunswick Beekeepers Association: 12 March 2011
3. Development of semiochemical management tools for blueberry spanworm and blueberry fruit fly. Annual Meeting of the ACOA AIF Team on Insect Semiochemical Research, Wolfville, 5 June 2012.
4. Manufacturing contempt: public controversy and scientific complexity in pollinator toxicology. Department of Environmental Sciences Seminar Series, Nova Scotia Agricultural College, Truro, 15 December 2011.
5. Considerations when assessing impacts of pesticides on bees. Pollinators and Pollination Symposium, Annual Meeting of the Entomological Society of Canada, Halifax, 7 November 2011.
6. Towards ecological management of insect pests in wild blueberry. Vaccinium Symposium, Annual Meeting of the Entomological Society of Canada, Halifax, 8 November 2011.
7. Blueberry research and implications for Honey bees. Maritime Bee Tour, host by Nova Scotia Beekeepers Association, 18 July 2011.

8. Impacts of pesticides on pollinators. Teaming-Up for Biodiversity, Toxicology Expert Panel, NB Environmental Network, February 23, 2011.
9. The good, the bad and the bugly: studies in insect toxicology. St. Mary's University Seminar Series, January 14, 2011.
10. Insecticides and insect hormesis in pest management. International Dose-Response Society Annual Meeting, Amherst, Massachusetts, April 27-28, 2010.
11. Pollinators in agricultural systems. Atlantic Pollination Forum, Moncton, NB, March 19, 2010.
12. Climate change: Implications for insects in crop production systems. Canadian Society of Agronomy, Atlantic Agronomy Workshop, Charlottetown, PEI, January 19, 2009.
13. Pollinator research at the Nova Scotia Agricultural College. Sustainable Pollination Forum, ACORN's Atlantic Organic Berry Network, Charlottetown, PEI, June 12, 2009.
14. When poison is good for you. Acadia University Department of Biology Seminar Series, Wolfville, NS, March 19, 2009.
15. Impacts of novel insecticides on beneficial insects. Kentville Agricultural Centre Seminar Series, AAFC Atlantic Food and Horticulture Research Centre, Kentville, NS, March 17, 2008.
16. Insect pest management in wild blueberry. Cavendish Wild Blueberry Information Meeting, Parrsboro, NS, March 14, 2008.
17. The good, the bad, and the bugly: Studies in insect toxicology. Fridays @ 3:00 Seminar Series. Nova Scotia Agricultural College. September 14, 2007.

Scientific Conference, Industry Meeting Presentations (selected; students I have trained in bold)

1. **Reeh, K.W**., G.C. Cutler. Biovectoring: Effects of dispenser design on foraging behaviour and disease management. Annual Meeting of the Entomological Society of Canada, Halifax, 7 November 2011.
2. **Mohan, M**., C.D. Scott-Dupree, G.C. Cutler. Molecular, individual and population-level chemical hormesis in green peach aphids. Annual Meeting of the Entomological Society of Canada, Halifax, 7 November 2011.
3. **De Silva, E.C.A**., P.J. Silk, N.K. Hillier, G.C. Cutler. Identification of sex pheromone components of the blueberry spanworm, *Itame argillacearia*. Annual Meeting of the Entomological Society of Canada, Halifax, 7 November 2011.
4. **De Silva, W.C**., O. Wally, C. Cutler, R. Robinson, A. Critchley, B. Prithiviraj. Potential use of *Ascophyllum nodosum* (L.) extracts for the management of Green peach aphid, *Myzus persicae.* Graduate Student Symposium, Annual Meeting of the Entomological Society of Canada, Halifax, 7 November 2011.
5. **MacEachern, M.C**., N.S. Boyd, G.C. Cutler. Prospects for spreading dogbane management with the dogbane leaf beetle. Annual Meeting of the Entomological Society of Canada, Halifax, 7 November 2011.
6. **Renkema, J.M**., D.H. Lynch, G.C. Cutler, K. MacKenzie, S.J. Walde. Predation by *Pterostichus melanarius (*Illiger) (Coleoptera: Carabidae) on immature *Rhagoletis mendax* Curran (Diptera: Tephritidae) in semi-field and field conditions. Vaccinium Symposium, Annual Meeting of the Entomological Society of Canada, Halifax, 8 November 2011.

7. **Wilkes, M.A**., L. Hermanutz, G.C. Cutler. Relying on "free bees"? Lowbush blueberry crop pollination in the absence of commercial pollinators. Annual Meeting of the Entomological Society of Canada, Halifax, 7 November 2011.
8. Sheffield, C.S., M. Chagnon, C. Cutler, V. Fournier, J. Moisan-De Serres, M. Wilkes, J. Gibbs. The bee pollinators of lowbush blueberry. Pollination Symposium, Annual Meeting of the Entomological Society of Canada, Halifax, 8 November 2011.
9. Cutler, G.C. and **Ramanaidu, K.** 2011. Hazard to honey bees of pesticides used in lowbush blueberry production. Western Apicultural Society Annual Conference, Kona, HI, Sept. 13, 2011 (poster).
10. **Gradish, A.**, C. Scott-Dupree, and C. Cutler. The sub-lethal effects of pesticides used in wild blueberry production to alfalfa leafcutter bees (*Megachile rotundata*). Western Apicultural Society Annual Conference, Kona, HI, Sept. 13, 2011 (poster).
11. **Wilkes, M.A.**, Hermanutz, L., and Cutler, C. 2011. Growing wild? Pollination of managed lowbush blueberry without commercial pollinators. Canadian Society of Ecology and Evolution, Banff, AB, May 13-14 (poster).
12. **Wilkes, M.A**., Hermanutz, L., and Cutler, C. 2011. Comparing farmed and wild blueberry pollinator diversity. Newfoundland Native Pollinator Workshop, St. John's NL, April 27 (poster).
13. **Wilkes, M.A**., Hermanutz, L., and Cutler, C. 2011. Growing wild? Pollination of managed lowbush blueberry without commercial pollinators. NSERC-Canadian Pollination Initiative Annual Meeting, Guelph, ON, Feb. 26, 2011 (oral).
14. **Reeh, K.** and Cutler, G.C. 2011. Bumble bees as vectors of a bio-fungicide for *Botrytis* control in wild blueberry. NSERC-Canadian Pollination Initiative Annual Meeting, Guelph, ON, Feb. 26, 2011 (oral).
15. **Ramanaidu, K.,** C.D. Scott-Dupree and G.C. Cutler. 2010. Evaluation of bee susceptibility to several reduced-risk and microbial pesticides. Entomol Society of America, San Diego, CA. Dec 13 (oral).
16. **Renkema, J.,** S.J. Walde, G.C. Cutler, K. MacKenzie and D.H. Lynch. 2010. Effects of mulches and weeds on predators (Carabidae and Staphylinidae) and their potential prey in highbush blueberries. Entomol Society of America, San Diego, CA. Dec 13 (oral).
17. **Kelly, J.,** K. Hillier, T. Avery, S.O. Gaul, C. Cutler and K. MacKenzie. 2010. Development of a pheromone-based monitoring system for red striped fireworm (*Aroga Trialbamaculella* Cham), a pest of wild blueberries. Entomol Society of America, San Diego, CA. Dec 13 (poster).
18. **Kelly, J.,** K. Hillier, C. Cutler, K. MacKenzie and S. Gaul. 2009. Development of a pheromone-based monitoring system for red striped fireworm (*Aroga Trialbamaculella* Cham), a pest of wild blueberries. WBPANS Annual Meeting, Truro, NS. November 21 (poster).
19. **Mohan, M., K. McNutt**, C.D. Scott-Dupree and G.C. Cutler. 2010. Effects of sublethal doses of imidacloprid and spirotetramat on green peach aphid. Entomol Society of Canada, Winnipeg, MB. November 1 (oral).
20. Gradish, A., C. Scott-Dupree, and C. Cutler. The sub-lethal effects of pesticides used in wild blueberry production to alfalfa leafcutter bees (*Megachile rotundata*). Ontario Pest Management Conference, Guelph, ON, November 2010 (poster).

21. **Ramanaidu, K.** and G.C. Cutler. 2010. Impact of Movento, Botanigard and Serenade on bumble bee micro-colony development. Entomol Society of Canada, Winnipeg, MB. November 1 (poster).
22. **Reeh, K.W**. and G.C. Cutler. 2010 Bumble bees as vectors of biological control agents for disease control in lowbush blueberry. Entomol Society of Canada, Winnipeg, MB. November 1 (poster).
23. **Kelly, J.,** Hillier, K., Cutler, C., MacKenzie, K. and Gaul, S. 2009. Development of a pheromone-based monitoring system for red striped fireworm (*Aroga Trialbamaculella* Cham), a pest of wild blueberries. WBPANS Annual Meeting, Truro, NS. November 21 (poster).
24. Gradish, A., C. Scott-Dupree, and C. Cutler. The sub-lethal effects of pesticides used in wild blueberry production to alfalfa leafcutter bees (*Megachile rotundata*). Entomological Society of Ontario Annual Meeting. Grand Bend, Ontario, October 2010 (poster).
25. **Ramanaidu, K.,** A. Gradish, C. Scott-Dupree, C. Cutler, D. Percival and M. Hardman. 2009. Impacts of reduced-risk insecticides on blueberry pests and bees in wild blueberry. WBPANS Annual Meeting, Truro, NS. November 21 (oral).
26. **Craig, P**., C. Cutler, V. Nams and K. MacKenzie. 2009. Influence of landscape and field characteristics on native bees in wild blueberry habitats. WBPANS Annual Meeting, Truro, NS. November 21 (oral).
27. Cutler, G.C. 2009. Stimulatory effects of insecticides on insects. Entomological Society of Canada Annual Meeting, Winnipeg, MB. October 19. (oral)
28. **Craig, P**., Cutler, G.C., Nams, V. and MacKenzie, K. 2009. Influence of landscape and field characteristics on native bees in wild blueberry habitats. Entomological Society of Canada, Winnipeg, MB. October 19. (oral)
29. **Ramanaidu, K**., Gradish, A., Scott-Dupree, C. and Cutler, G.C. 2009. Impacts of reduced-risk insecticides on insect pests and pollinators in wild blueberry. Entomological Society of Canada, Winnipeg, MB. October 19. (oral)
30. **Renkema, J.**, Cutler, C., Lynch, D., MacKenzie, K. and Walde, S. 2009. Management of blueberry maggot (Diptera: Tephritidae) using mulches in organic highbush blueberries. Entomological Society of Canada, Winnipeg, MB. October 19. (oral)
31. Cutler, C. 2009. Stimulatory effects of insecticides on insects. Acadian Entomological Society Annual Meeting, Corner Brook, NL, August 4. (oral)
32. **Ramanaidu, K**., Gradish, A., Scott-Dupree, C. and Cutler, G.C. 2009. Impacts of reduced-risk insecticides on insect pests and pollinators in wild blueberry. Acadian Entomological Society Annual Meeting, Corner Brook, NL, August 4. (poster)
33. **Craig, P.,** Cutler, G.C., Nams, V. and MacKenzie, K. 2009. Influence of landscape and field characteristics on native bees in wild blueberry habitats. Acadian Entomological Society Annual Meeting, Corner Brook, NL, August 4. (poster)
34. Cutler, C., **Ramanaidu, K.** and **Brown, E.** 2008. Toxicological and ecological studies with insects in wild blueberries. WBPANS Fall Information Meeting, November 21. (oral)
35. Cutler, C. 2008. Insects – Crop Protection Session. Wild Blueberry Produces Association of Nova Scotia (WBPANS) Winter Information Meeting, March 29. (oral)

36. Scott-Dupree, C. and C. Cutler. 2008. Exposure to Clothianidin Seed Treated Canola has no Impact on Honey Bees. Symposium on "Colony Health", Canadian Honey Council Annual Meeting, Calgary, AB, January 25, 2008 (Invited Speaker).
37. Percival, D., Zaman, Q. and Cutler, C. 2007. Annual PEI Blueberry Growers Meeting, Charlottetown, PEI, November 24 (Oral).
38. Cutler, C. 2007. Implementation of the Wild Blueberry Entomology Research Chair. WBPANS Annual Winter Meeting, Truro, NS, November 17.

6.3 Publications (2007-2012)

Peer Reviewed (HQP I have trained are indicated in Bold)

1. **Renkema, J.M., Manning, P.**, and Cutler, G.C. Predation of lowbush blueberry insect pests by ground beetles in the laboratory. (in revision, J. Pest Sci.)
2. **Wu, L.** Boyd, N.S., Cutler, G.C., Olson, A.R. Spreading dogbane (*Apocynum androsaemifolium*) development in wild blueberry fields. (submitted, Weed Sci.)
3. Cutler, G.C., **Ramanaidu, K.**, Wendelberg, B., Dripps, J., and Scott-Dupree, S.D. Residues of spinosad and spinetoram on lowbush blueberry and effects on the pollinator *Bombus impatiens*. (submitted, J. Econ. Entomol.)
4. **Renkema, J.M.**, Lynch, D.H., Cutler, G.C., MacKenzie, K. and Walde, S.J. Ground and rove beetles (Coleoptera: Carabidae and Staphylinidae) are affected by ground floor management in highbush blueberries. (accepted, Environ. Entomol.)
5. **Renkema, J.M.**, Cutler, G.C., MacKenzie, K., Lynch, D.H. and Walde, SJ. Staphylinidae in agroecosystems. (in revision, Agric Forest Entomol).
6. **Kelly, J. A.**, Avery, T.S., Stewart, D.T., Cutler, G.C., Gaul, S.O., MacKenzie, K.C. and Hillier, K.N. New Gelechiidae and Noctuidae species records for continental Canada and Nova Scotia from non-target captures during Lepidoptera pheromone-based trapping. (accepted, Can. Entomol.)
7. Boyle, D. and Cutler, G.C. Some factors that limit virulence of *Beauveria bassiana* towards *Blissus leucopterus hirtus.* (accepted, J Pest Science)
8. Cutler, G.C., **Renkema, J.M**., Majka, C.G. and **Sproule, J.M**. Distribution and abundance of Carabidae in Nova Scotia wild blueberry fields. (accepted, Can. Entomol.)
9. **Renkema, J.M.**, Walde S. J., Lynch D.H., Cutler GC, and MacKenzie, K. Ground beetles (Carabidae) are affected by mulch in organic highbush blueberries. (accepted, Acta Hort).
10. Cutler, G.C., **Reeh, K.W., Sproule, J.M. and Ramanaidu, K.** Berry unexpected: nocturnal pollination of lowbush blueberry. (in press, Can J. Plant Sci. 92: 707-711)
11. Cutler, G.C. Insects, insecticides and hormesis: evidence and considerations for study. (in press, Dose Response, DOI: 10.2203/dose-response.12-008.Cutler)
12. **Gradish, A.E.**, Scott-Dupree, C.D. and Cutler, G.C. 2012. Lethal and sub-lethal effects of insecticides for use in wild blueberry on *Bombus impatiens.* Can. Entomol. 148: 478–486
13. **Renkema, J.M.**, Lynch, D.H., Cutler, G.C., MacKenzie, K. and Walde, S.J. 2012. Emergence of blueberry maggot flies (Diptera: Tephritidae) from mulches and soil at various depths. Environ. Entomol. 41: 370-376.

14. **Gradish, A.E.**, Scott-Dupree, C.D. and Cutler, G.C. 2012. Susceptibility of *Megachile rotundata* to some insecticides used in wild blueberry production in Atlantic Canada. J. Pest Sci. 85: 133–140.
15. Traugott, M., Athanassiou, C., Cutler, C., Desneux, N., Horowitz, R., Rainer, M., Shipp, L., Stauffer, C., Weber, D.C., Zalucki, M.P. 2012. Editorial 2012: Shaping the profile of Journal of Pest Science. J. Pest. Sci. 85: 1-3.
16. **Renkema, J.M.**, Cutler, G.C., Lynch, D.H., MacKenzie, K. and Walde, S.J. 2011. Pupation depth of blueberry maggot (Diptera: Tephritidae) is affected by mulch type and moisture level in the laboratory. J. Pest. Sci. 84: 281-287.
17. **Renkema, J.M.**, Lynch, D.H., Cutler, G.C., MacKenzie, K. and Walde, S.J. 2011. Predation by *Pterostichus melanarius* (Illiger) (Coleoptera: Carabidae) on immature *Rhagoletis mendax* Curran (Diptera: Tephritidae) in semi-field and field conditions. Biol. Control 60: 46-53.
18. **Ramanaidu, K**., Hardman, J.M. and Cutler, G.C. 2011. Laboratory and field susceptibility of blueberry spanworm *Itame argillacearia* Packard (Lepidoptera: Geometridae) to conventional and reduced-risk insecticides. Crop. Prot. 30: 1643-1648.
19. Cutler, G.C. and Rogers, R.E.L. 2009. New record of the Asiatic garden beetle, *Maladera castanea* (Arrow), in Atlantic Canada. J. Entomol. Soc. Ontario 140: 40-45.
20. Cutler, G.C., **Ramanaidu, K**., Astatkie, T. and Isman, M.B. 2009. Green peach aphid, *Myzus persicae* (Hemiptera: Aphididae), reproduction during exposure to sublethal concentrations of imidacloprid and azadirachtin. Pest Manag. Sci. 65: 205-209.

Book Chapters

1. Cutler, G.C. and Scott-Dupree, C.D. 2012. Pesticides and honey bees. In: Honey Bee Disease and Pests. Canadian Association of Professional Apiculturalists. (in press)

Technology Transfer Publications:

1. Cutler, C. and **Sproule, J.** 2012. Blueberry gall midge. Wild blueberry factsheet. NS Dept of Agriculture, and the Wild Blueberry Producers Association of Nova Scotia.
2. Cutler, C. 2011. Honey bee research at NSAC. Nova Scotia Beekeepers Association Newsletter, 17 October 2011.
3. Cutler, C. 2010. Attaining sustainability in agriculture. Sustainable Futures (Spring 2010 Issue): 10-13. (**invited contribution**)
4. Cutler, G.C and **Sproule, J.** 2010. Bees in Wild Blueberry. (Grower Technology Transfer Poster)
5. Cutler, G.C. 2009. Insect Pests of Wild Blueberry. (Grower Technology Transfer Poster).

6.4 Affiliations and Membership in Learned Societies

Entomological Society of Canada
Entomological Society of America
Acadian Entomological Society
Society of Environmental Toxicology and Chemistry
International Dose-Response Society

Nova Scotia Institute of Agrologists
Dalhousie University Faculty of Graduate Studies
Acadia University, Adjunct Professor
University of Guelph, Assoc. Graduate Faculty, School of Environmental Sciences

6.5 Awards (2007-2012)

- Agriculture Institute of Canada Sustainable Futures Award, 2010 (the award recognizes imminent leaders who are advancing and applying innovative scientific knowledge on the sustainable use of agricultural resources; includes $1,000 and a five-year AIC membership)
- NSERC Discovery Grant Supplement (awarded to promising early career holders of a Discovery Grant; $5000)

6.6 Record of Academic Service (2007-2012)

University Service

- *Nova Scotia Agricultural College*
  - Faculty Council
    - Honours and Awards Committee (2012-present)
    - Graduate Programs Committee (2008-2012)
    - Library Committee (2008-21012)
  - Department of Environmental Sciences
    - Acting Dept Head (2-13 August 2010)
    - Graduate Studies Working Group
    - Pest Management Working Group
  - PhD Program Planning Committee
  - Ad-Hoc Enrolment Planning Group
  - Plant Programs Review Planning Group
  - VP Research Search Committee (February 2009)
  - Environmental Sciences Dept Head Search Committee (December 2010)

Other Academic Service

- Entomological Society of Canada
  - Co-Chair of the 2011 Annual Meeting (Halifax)
  - Publications Committee (2008-present)
  - Elections Committee (2004-2006)
- Vice President of the Acadian Entomological Society
- Advisory Board, Organic Agriculture Centre of Canada
- NSERC CANPOLIN “Blueberry Hit-Team” co-ordinator
- External Reviewer for Proposals
  - Agriculture and Agri-Food Canada – Peer Pairs Program, Environment and Ecology Panel (2012)

    - OMAFRA - U of G Research Program (2011, 2012)
    - Canadian Agricultural Adaptation Program, AAFC (2011)
    - Binational Agriculture research and Development Fund, United States-Israel (2008)
- Associate/Subject Editor
    - Journal of Pest Science (Springer)
- Peer Reviewer (multiple and regular reviews for many journals over the past 5-6 years)
    - *Acta Horticulturae, Biological Control, Biocontrol, Biocontrol Science and Technology, Chemosphere, Dose-Response, Journal of Applied Entomology, Journal of Economic Entomology, Journal of Insect Science, New Zealand Journal of Crop and Horticultural Science, Pest Management Science, Pesticide Biochemistry and Physiology, Phytoparasitica, Phytoprotection, Canadian Entomologist, International Journal of Tropical Insect Science*
- Adjudicator duties
    - Chignecto West Regional Science Fair, Truro NS (2010, 2011)

7 Training of Highly Qualified Personnel

Continued supervision of undergraduate and graduate students is underway and anticipated (Table 4).

Table 4. Training of HQP by the Wild Blueberry Entomology Research Chair, June 2007 – present.

Name	Degree	Year	Thesis title
Graduate Students			
Jesse Saroli (co-supervise)	M.Sc.	2012-present	Chemical ecology of blueberry flea beetle
Ashley Mullins (co-supervise)	M.Sc.	2012-present	Habitat management for promotion of beetle predators in soybean
Daniel O'Neail	M.Sc.	2012-present	Stressor interaction effects on honey bee learning
Andony Melathopolus (co-supervise)	Ph.D.	2011-present	A critique of ecosystem services through contemporary debates over the conservation of wild bees in agro-environmental landscapes
Margie Wilkes (co-supervise)	M.Sc.	2010-present	Wild bee population dynamics in Newfoundland lowbush blueberry
Murali Mohan (co-supervise)	Ph.D.	2010-present	Hormesis in insects exposed to sublethal doses of insecticide

Pamela Craig *	M.Sc.	2008-2010	Influence of landscape and field characteristics on native pollinators in wild blueberry habitats
Megan McEachern (co-supervise)	M.Sc.	2010-present	The beetle *Chrysochus auratus* as a biological control agent for spreading dogbane **(to Defend August 2012)**
E. Chaminda Amal De Silva	M.Sc.	2010-present	Pheromone identification for blueberry spanworm control in wild blueberry **(to Defend August 2012)**
Chaminda De Silva Weeraddana (comm. member)	M.Sc.	2010	Seaweed extract as insect anti-feedants in control of *Myzus persicae* **(Defended May 2012)**
Kevin Reeh	M.Sc.	2010-2012	Bees as vectors of biopesticides in lowbush blueberry **(Defended May 2012)**
Jillian Kelly (comm. member)	M.Sc.	2009-2012	Ecology and chemical ecology of red-striped fireworm **(COMPLETED)**
Angela Hughes (comm. member)	M.Sc.	2009-2012	Sheep sorrel, honey bee and blueberry interactions **(COMPLETED)**
Crystal Bridson *	M.Sc.	2009-2010	Pheromone identification for blueberry spanworm control in wild blueberry
Lin Wu (comm. Member)	M.Sc.	2009-2011	Development of a Management Plan for Spreading Dogbane (*Apocynum androsaemifolium* L.) in Wild Blueberry Fields **(COMPLETED)**
Krilen Ramanaidu	M.Sc.	2008-2010	Biorational insecticides in blueberry spanworm integrated pest management programs **(COMPLETED)**
Justin Renkema (comm. member)	Ph.D.	2007-2011	Management strategies for blueberry maggot (*Rhagoletis mendax* Curran) using mulch in highbush blueberries **(COMPLETED)**
Undergraduate (4th year research projects, NSERC USRA, NSAC)**			
Nimllash Tangham	B.Sc.	2012	Response of diamondback moth to sublethal doses of spinetoram (4th year research project)
Sergio Sani	B.Sc.	2012	Wild bueberry pollination success as a function of crop species homogeneity (NSERC USRA)
Paul Manning	B.Sc.	2012	Identifying the nocturnal pollinators of lowbush blueberry (NSERC USRA)

Emily Grant	B.Sc.	2012	Assessing honey bee learning with a T-tube assay (4th year research project)
Paul Manning	B.Sc.	2011	Predatory behavior of carabid beetles for biological control in wild blueberries (NSERC USRA)
Janis Nams	B.Eng.	2011	Development of a mini-sprayer tower for biopesticide bioassays (NSERC USRA)
Kenton McNutt	B.Sc.	2010	(1) Mechanisms of deltamethrin resistance in green peach aphid (NSERC USRA); (2) spirotetramat induced hormesis in green peach aphid (4th year research project)
Eileen Beaton	B.Sc.	2010	Earthworms as bio-indicators of biosolid hazard (4th year research project)
Colette Wyllie	B.Sc.	2009	Honey bee spatial distribution and pollination in blueberry (4th year research project)
Shawn Loo	B.Sc.	2009	Size and scent affect prey choice of the beetle *Pterostichus melanarius* (4th year research project)
Julie Berkshire	B.Sc.	2008	Varroa mite resistance to miticides in NS honey bee colonies (4th year research project)
Yang Lin	B.Sc.	2008	Wild pollinators in organic vs. conventional wild blueberry (4th year research project)
External Examiner			
Catherine Little	M.Sc.	2012	Interactions among *Varroa, Nosema,* chemotherapy and honey bee immunocompetence
Robyn Auld	Ph.D.	2012	Life history, morphology, and host choice among populations of hairy chinch bug in QC and Atlantic Canada (Memorial University)
Clayton D'Orsay	M.Sc.	2011	Influence of pasture management intensity on species richness and abundance of beetles (Coleoptera: Carabidae, Staphylinidae and Curculionoidea) on a managed Nova Scotia pasture (University of PEI)
Elisabeth Frost	M.Sc.	2010	Effects of fluvalinate miticide on honeybee learning and memory (Acadia University)

Post-Docs, Technicians			
Nicoletta Faraone	2012-present		Post-doctoral fellow
Justin Renkema	2011-present		Post-doctoral fellow
Krilen Ramanaidu	2011-present		Laboratory research technician
Eric Georgeson	2009-present		A.D. Pickett Entomology Museum technician
Jason Sproule	2009-present		Laboratory research technician

* Did not complete due to personal reasons.

ACKNOWLEDGEMENTS

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Support for research projects was provided by WBPANS, NSAC, the Canada Foundation for Innovation, NSDA Technology Development 2000 program, NSERC, NSERC-CANPOLIN, ACOA, CAAP, AAFC Pest Management Center, P.E.I. Wild Blueberry Growers' Association, the Nova Scotia Wild Blueberry Institute, the Wild Blueberry Research Center, Bragg Lumber Co., Oxford Frozen Foods, Koppert Biological Systems, DOW AgroSciences Canada Inc., Bayer CropScience Canada, and E.I. DuPont Canada Company.

Appendix 1 – Wild Blueberry Insect Pests Poster

Insect Pests of Wild Blueberry

Blueberry Fruit Fly
Rhagoletis mendax

Adults ~ 4.5 mm long; ~ 8mm wingspan

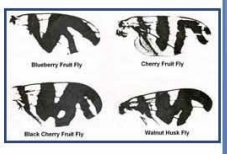
Distinct continuous "W" pattern on wings; note differences with that of related species

Adults may be found June-August; lay eggs in ripe fruit 7-10 days after emergence

Larvae feed 2-3 weeks; overwinter in soil

Monitor with Pheracon® AM traps
- Crop fields, 10m from edge, weedy areas, forest edge or next to sprout fields
- 1 trap/acre; 10-15 cm above plant; replace every 2-3 weeks

Action Thresholds
6 flies on all traps during 1 visit; 10 flies over multiple visits



Whitemarked Tussock Moth
Orgyia leucostigma

Infestations are cyclic, every 10-20 years, but sometimes more frequent

Adult male moths have a wingspan ~25-35 mm; grayish brown colour; wingless females

Larvae appear late June to mid July; grow to ~40 mm; late instars are black with cream stripes and tufts of hair

Larvae may feed on foliage for up to six weeks; damage occurs at critical growth periods in crop and sprout fields

Action Thresholds (suggested)
Crop: 12 larvae/25 sweeps; Sprout: 7 larvae/25 sweeps

INSECTICIDE INFORMATION SUMMARY

Product[1]	Insects[2]	Relative Toxicity		
		Bees	Applicator Oral	Applicator Dermal
acetamiprid (Assail)	FT	moderate[4]	moderate	low
Beauveria bassiana (Blazeby, Dipel, Foray)	SW, M	low	low	low
carbaryl (Sevin)	FF, SW	high	low	low
deltamethrin (Decis)	LT, SW	high	low	low
dimethoate (Cygon, Lagon)	FF	high	moderate	moderate
malathion (Vaithion)	FF	high	moderate	moderate
permethrin (Ambush, Pounce)	FF, SW	high	moderate	low
spinetoram (Delegate)	SW	moderate[4]	low	low
spinosad (SC-120, NF)	FF	moderate[4]	low	low
spinosad (Success, Entrust)	FB	moderate[4]	low	low
trichlorfon (Dylox)	FB, SF, SW			

[1] Pesticide registration may change; check for updates annually; some chemicals may be restricted. **Follow ALL label directions.** [2] FB=blueberry fruitworm; FF=blueberry fruit fly; LT=leafroller; SF=sawfly; SW=spanworm; TM=tussock moth. [3] Pre-harvest interval in hours; [4] Highly toxic when wet, but residues may

Blueberry Sawfly
Neopareophora litura

Occasionally cause severe defoliation

Adult wasp
- Emerge mid-late May
- Black and ~ 5mm long; rarely seen

Larvae
- Green, ~ 10 mm long; "legs" on all body segments
- Feed on leaves, sometimes blossoms; severe damage to crop at high levels

Action Threshold
Not established locally; 50 larvae per 10 sweeps recommended in Maine

Blueberry Leaftier
Croesia curvalana

Can be a serious problem at high population densities

Adult moth
- ~ 6 mm long, wingspan ~15 mm
- Wings yellow on fringe, reddish-brown on front, grey on back
- Seen in early-late July

Larvae
- Emerge around early May
- Greenish cream in colour with blackish head
- Feed on flower buds and leaves
- Form protective leaf shelters

Monitoring
- Pheromone traps no longer available
- No action thresholds established

Insect Pest Emergence Table [1]

	April 1	April 15	April 30	May 1	May 15	May 31	June 1	June 15	June 30	July 1	July 15	July 31	August 1	August 15	August 31
Blueberry fruit fly							Adults								
Blueberry spanworm							Larvae			Adults					
Blueberry flea beetle							Larvae			Adults					
Blueberry leaftier				Larvae						Adults					
Blueberry sawfly							Larvae								
Whitemarked tussock moth										Larvae					
Chainspotted geometer [2]										Larvae					
Blueberry thrips [2]										Leaf Curl – Adults & Nymphs					
Redstriped fireworm [2]										Adults			Larvae		

[1] *Emergence times/damage are approximate, will vary across field and regions, and will depend on management practices and yearly climatic conditions;* [2] *Other insect pests that may be encountered.*

Blueberry Spanworm
Itame argillacearia

A major defoliator; several species may be present but *I. argillacearia* is most prominent

Adult moths
- Grey to brown wings; wing span ~ 25 mm
- Emerge from fields in late July

Larvae
- Walk with a looping gait; 3-20 mm
- Young larvae: grey with black spots
- Old larvae: yellow-orange with rows of black spots/strips along the body
- May appear as early as mid-May

Damage
- Larvae feed on foliage and flower buds
- Sprout and crop fields; most active at night

Action Thresholds
Crop: 12 larvae/25 sweeps
Sprout: 7 larvae/25 sweeps

Blueberry Flea Beetle
Altica sylvia

A major defoliator of wild blueberry

Adult beetles
- 5-6 mm, copper-bronze or blackish in low light
- Strong jumpers

Larvae
- 3-20 mm, black or dark brown
- May appear as early as mid-May

Damage
- Mostly larval feeding; sprout and crop fields
- "Notched" feeding at leaf margins; severe infestations may completely defoliate plants

Action Thresholds
75-125 insects per 25 sweeps

Acknowledgements. This poster was developed through cooperative efforts and resources from WBPANS and the following institutions:

Nova Scotia Agricultural College · Nova Scotia Agriculture · Agra Point · Agriculture and Agri-Food Canada / Agriculture et agro-alimentaire Canada · Canadian Wild Blueberry Industry Research & Development Institute Inc. / L'institut canadien de recherche et de développement de l'industrie du bleuet sauvage

Prepared by: Chris Cutler, Wild Blueberry Entomology Research Chair, NS Agricultural College, with the cooperation of Lome Crozier, NS Dept. Agriculture

Photo credits: (1) Lome Crozier; (2) Graham Thurston, Canadian Forest Service, NB; (3) Jim des Rivieres, www.mothsca; (4) C. Cutler; (5) Chris Maund, NB Dept. Agriculture and Aquaculture

Appendix 2 – Wild Blueberry Pollinators Poster

Wild Blueberry Pollinators

Indigenous Pollinators

In Nova Scotia 157 species of indigenous bees forage on commercial crops. Of these, 78 species are known to visit lowbush blueberry fields. Most indigenous bees are solitary and make their nests in the ground or pre-existing cavities or crevices in trees, rocks or fallen logs. Though often ignored and undervalued, native bees are crucial to the sustainability of wild blueberry operations because they provide efficient and specialized pollination services for free. Many species are better adapted to and more successful at pollinating wild blueberry than managed bees primarily because both blueberry and bee have evolved with each other. On a bee per bee basis native bees can visit more flowers per minute, forage on harder to reach blossoms and deposit more pollen grains than managed bees. However, indigenous bees face many challenges. Application of pesticides, habitat alteration, cultural practices and monoculture of crops all have negative effects on wild bee populations. Many growers respond to declining wild bee populations by relying upon managed bees. Although there is nothing wrong with supplementing native bees with managed bees, greater effort should be made to improve conditions and increase population densities of indigenous bees. By providing habitat and making environmental conditions more favourable for wild bees, growers can expect better pollination and as a result, higher crop yields.

Tips for Enhancing Wild Bee Pollination

- Providing vegetative windbreaks adds habitat and enables flight on windy days.
- Irrigate fields at night when bees are less likely to be foraging.
- Eliminate ineffective cross pollination by removing other blueberry species from the area.
- Bloom is short. Ensure wild bees have a diversity of flowering plants before and after.
- Maintain a diverse habitat around fields i.e. water, meadow, forest, bare patches, shrubs.
- Avoid pesticide application during bloom. Pesticides can be lethal or modify bee behaviour.
- Use pesticides (especially insecticides) that demonstrate low bee toxicity.
- Native and managed bees compete for resources. Remove colonies promptly after bloom.
- Minimize field size. This ensures a large perimeter of woodland and other nest sites.
- Install pre-drilled wooden/plastic nesting blocks in trees or on posts around the field edge.
- Avoid yearly feast or famine situations by having equal size crop and sprout sections.
- Minimize clone size. Transplant other clones into the center of very large clones.
- Prune fields well after a heavy frost and well before spring emergence.

SOME ALTERNATIVE FORAGE TO ATTRACT NATIVE POLLINATORS

SPRING	EARLY SUMMER	MID SUMMER	LATE SUMMER - EARLY FALL
Alder	Alfalfa	Bee balm	Asters
Apple	Annise Hyssop	Borage	Autumn dandelion
Cherry: black, choke	Azalea	Echinacea	Chicory
Columbine	Blackberry	Fireweed	Goldenrods
Coltsfoot	Chives	Meadow sweet	Meadow sweet
Crocus	Hawthorn	Mullein	Oregano
Dandelion	Honeysuckle	Red clover	Ragweed
Lilac	Locust	Roses	Yarrow
Maple	Mints	St. John's wort	
Oak	Raspberry	Sweet clover	
Wild Strawberry	Sheep's laurel	Thistle	
Willow	White clover	Viburnum	

Acknowledgements: This poster was developed through cooperative efforts and resources from WBPANS and the following institutions:

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WILD BEE IDENTIFICATION

Andrenidae (Digger Bees) 7 - 14 mm Black, Moderately hairy, Solitary, Ground-nesting.	Andrena 1	Andrena 1
Halictidae (Sweat Bees) 3.5 - 15 mm Black , dark and sometimes metallic green, Sparse to moderately hairy, Ground or wood nesting.	Agapostemon 1	Lasioglossum 1
Osmia (Mason Bees) 8 - 15 mm Metallic blue or green, Moderately hairy, Solitary, Readily accepts artificial nesting blocks.	Osmia 3	Osmia 1
Colletidae (Cellophane or Masked Bees) 3.5 - 14 mm Colour and hair density varies greatly between species, Solitary, Ground & pithy stem nesting.	Colletes 1	Hylaeus 1
Artificial nesting blocks Made from pre-drilled wood or polystyrene blocks, Place on trees or posts 1- 1.5 m above the ground, Essential for domesticating and managing wild populations of *Osmia* bees.	3	3

SUMMARY OF KEY DIFFERENCES AMONG MANAGED BEES

		Bombus impatiens	*Apis mellifera*	*Megachile rotundata*
ENVIRONMENTAL LIMITATIONS	Flies At Temp	10 - 30°C	10°C	16.8°C
	Flight In Wind	Strong wind	< 30 km/hr	-
	Flight In Rain	Yes	Infrequently	Infrequently
	Average Forage Range	< 300 m	2 - 4 km	120 m radius
POLLINATION SUCCESS	Flowers Visited Per Minute	5 - 16	3 - 13	1 - 11
	Pollen Grains Deposited Per Visit	21 - 107	5 - 20	6 - 61
	% of Successful Pollination	92 - 97%	24%	15 - 85%
STOCKING	Bees /Un it	150 - 200/hive	10,000 - 25,000/hive	10,000/gallon
	Units/Hectare	3 - 4 hives	5 - 12.5 hives	3 - 5 gallons
	Place In Field At __ % Bloom	5%	25%	10-15%

Managed Bees

There are three types of managed pollinators commercially available to supplement the efforts of native bees. These may be employed where wild bee densities are low or simply to maximize blueberry yields. Although feral colonies of these species may exist, yields can be increased by purchasing or renting colonies of honey bees, bumble bees and alfalfa leaf-cutting bees.

Honey Bee (HB)

Apis mellifera

1

- Workers ~ 12 mm long
- Golden to golden-yellow, lighter and darker forms exist
- Moderately hairy

Honey bees are perennially social bees. A colony may have un to 50, 000 individuals divided into castes which perform necessary colony functions i.e. foraging, brood care, sanitation, wax building, etc. Honey bees are the tried, tested and true standard for wild blueberry pollination and are the most widely used managed pollinators for all crops.

Bumble Bee (BB)

Bombus impatiens

3

- Queens ~ 13-28 mm
- Workers ~ 5-20 mm
- Bands of black, yellow, brown, white and red
- Dense coat of soft fuzzy hair

Mated queens emerge in early spring. Each establishes her own colony in soil, old nests of mice or voles, or under dead vegetation. Queens begin foraging and building wax pots to rear young. Once the first adult workers emerge, the queen stays in the nest to lay eggs, while the workers take over both nest and foraging activities.

On a bee:bee basis with honey bees or alfalfa leaf-cutter bees, bumble bees:
- Handle more flowers per minute with a higher success rate.
- Fly earlier in the morning and later in the evening.
- Are less likely than HBs to stray from the crop.
- Have longer tongues allowing them to forage from some clones HBs and ALBs would avoid.
- Demonstrate higher levels of cross-pollination and deposit more pollen grains per visit.
- Fly in more adverse conditions i.e. rain, wind, low light, cool temperatures.
- Require less materials and labour (electric fencing may be necessary).

Alfalfa Leafcutting Bee (ALB)

Megachile rotundata

2

~8-9 mm long
- Black with pale yellow hair
- Conspicuous pale yellow to white bands on the abdomen
- Moderately hairy

A solitary cavity nesting bee. Large populations can be managed because these bees nest gregariously and will readily accept artificial nesting blocks. ALB cut circular discs from leaves to create cells inside cavities of trees and logs. Each cell contains an egg and provision of nectar and pollen. ALB will forage almost exclusively on the crop and their incubation period can be adjusted to synchronize their emergence with bloom.

Prepared by: (1) Chris Cutler, Wild Blueberry Entomology Research Chair NSAC, (2) Jason Sproule

Photo Credits: (1) Laurence Packer, (2) John Ascher / www.discoverlife.org (3) Chris Cutler & Jason Sproule NSAC

Appendix 3 – Blueberry Gall Midge Fact Sheet

Nova Scotia Agricultural College

WILD BLUEBERRY FACTSHEET

Blueberry Gall Midge

Also known as Cranberry Tipworm, Tip Midge

Introduction

Blueberry gall midge (*Dasineura oxycoccana* Johnson; Diptera: Cecidomyiidae) was first detected in Maine in 2004, and in Yarmouth Co., NS, and parts of New Brunswick in 2006. It has since been confirmed in other regions of NS and PEI. It is not yet clear if blueberry gall midge causes significant yield reductions in wild blueberry, but it is an important pest of cranberry, highbush blueberry and rabbiteye blueberry.

Description

Eggs (Fig 1a) are small, clear and oblong. **Maggots** (Fig 1b) grow approximately 2 mm long, transitioning in colour from clear, to white or whitish green, and finally to a peach-orange colour. **Pupae** reside in brown silk spun cocoons often hidden on the ground. **Adults** (Fig 1c) are small, delicate, long-legged flies, mosquito-like in appearance but only about 1/10 the size, growing to a maximum length of 3 mm (1/16 inch).

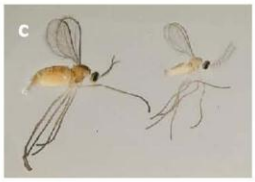

Fig 1. Blueberry gall midge egg (a), third instar maggot (b), and adult female (left) and male (right)

Life Cycle

Much of the biology of blueberry gall midge is not well understood. Adult females emerge in spring, mate and deposit eggs in the terminal shoots of new growth. A single shoot tip may host several eggs. Eggs usually hatch within 3 days and maggots feed on plant terminal growth, progressing through three instars over a period of 10-12 days. Mature maggots drop to the ground and form silk encased puparia. Depending on temperature, adults emerge within 5-10 days. Total development time from egg hatch to adult is usually only 2-3 weeks, which enables blueberry gall midge to have multiple overlapping generations during the summer. Blueberry gall midge overwinters as a pupa in soil or leaf litter.

Damage

Maggots feeding on young green shoot tips cause foliage curling and deformation (Fig 2a), and eventually tip death (Fig 2b). Plants respond to tip damage by increasing vegetative bud growth and side-branching. In sprout fields this may delay formation of flower buds, which may increase susceptibility to winterkill, reducing the number of viable flower buds in the crop year. Excessive side-branching may also increase susceptibility to disease and create difficulties during harvesting. In other *Vaccinium,* blueberry gall midge attacks flower buds but this does not seem to be the case in wild blueberry. Pest incidence is low in crop fields.

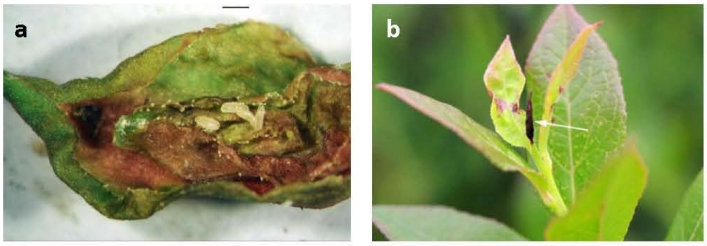

Fig 2. (a) Larvae feeding on a damaged tip; (b) blackened dead tip

Monitoring and Management

Research is needed to determine if or when control of blueberry gall midge is warranted. No insecticides are registered against gall midge on wild blueberry. Burning may suppress populations and fungicide applications to sprout fields in late July (e.g. to control leaf rust) will maintain healthy vegetative shoots, enabling late forming fruit buds to complete their development in the fall. Growers should monitor fields for incidence of gall midge. Stems in sprout fields should be examined early in the season (late April or early May) for blackened tips, malformed (cupped) leaves around tips, and excessive side branches. A sample of stem tips should be opened and examined under magnification to confirm presence of eggs or maggots. Shoot tips can also be wrapped in damp paper towel and placed in a sealable sandwich bag. Held at room temperature, maggots will emerge within 2 days and adults will appear after 2 weeks.

Photo Credits

1a, 1c: Kenna MacKenzie, AAFC; 1b: Food and Environment Research Agency (FERA), Crown Copyright; 2a, 2b: New Brunswick Department of Agriculture, Aquaculture and Fisheries.

Prepared by: Chris Cutler, NSAC, and Jason Sproule, NSAC, March 2011

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