

Introduction. The study of animal communication can facilitate the development of tools for both conservation and pest control, while providing rich insights into ecology and evolution. Insect chemical communication is well understood, and not only provides key case studies of the dynamic evolution of inter-sexual communication, but has also formed the basis for effective pheromone-based pest control. Although spiders also use pheromones, we are only just beginning to understand their complex chemical communication systems^{1,2}. My PhD will advance our understanding of pheromonal communication in the neurotoxic widow spiders (genus *Latrodectus*), with a focus on pheromones of males.

Study species. Widows are medically important throughout a global distribution, and while some species are threatened, others are synanthropic and invasive pests. Established, tractable methods for the study of pheromones in the field and lab, and their well-studied mating systems and behaviour³⁻⁶ make widows attractive research subjects. Past work (by me⁶ and others³⁻⁵) demonstrated the efficacy of pheromone traps for field studies, and suggest traps remove significant numbers of males from local populations. Traps utilize silk-bound pheromones produced by *Latrodectus* females that attract potential mates and apparently include some components that are recognized by heterospecifics^{3,7}. *Latrodectus* males also produce pheromones⁷, and these can modify development (*L. hasselti*⁸), and may affect attraction of rival males to females' webs (*L. hesperus*⁶). In widows, contact with female pheromones elicits male courtship, including web reduction (males cut out sections of web and wrap them in their own silk)⁶. Web reduction reduced the attractiveness of *L. hesperus* females' webs to rival males by two thirds at my field site⁶, but it is unclear whether silk or male pheromones are responsible for this effect. Males also produce and apply silk (and likely pheromones) throughout mating, but the function of this behaviour is unclear. In general, male pheromones in spiders are poorly studied^{1,2}.

Objective. I will examine the role of male silk in inter- and intra-sexual communication during mate searching and courtship in widow spiders. I will assess the function and structure of male pheromones in two *Latrodectus* species: *L. hesperus*, which ranges from central BC to Mexico, and is considered a pest in vineyards; and *L. hasselti*, native to Australia, and an invasive pest in New Zealand and Japan. I will test hypotheses about communication within each species, seek common components in male pheromones and assess the feasibility of male pheromone traps in the field.

Proposed research. I will first test whether the presence of males' silk outside female's webs affects the decisions of mate-searching males at established field sites in BC (*L. hesperus*) and Australia (*L. hasselti*), using successful methods identified during my MSc. I predict that the draglines will be attractive to males if they provide social information indicating high female quality. Alternatively, males may avoid webs surrounded by draglines of rival males, if the draglines indicate intense local competition. Second, I will compare the attractiveness of webs reduced by males experimentally manipulated to permit or prevent the deposition of pheromone-laden silk, to determine if silk drives the decreased attractiveness of reduced webs to other males in the field⁶. Third, I will explore the role of male silk in inter-sexual communication by staging mating trials in the laboratory, and measuring female aggressive responses and/or receptivity to courting males with or without the ability to deposit silk. Fourth, I will identify, synthesize and bioassay silk-bound semiochemicals of males, compare these between species and test their efficacy as attractants or repellents in the field. Behavioural techniques are feasible and well-worked out in my own research⁶, or the Andrade lab. Identification and synthesis of pheromones will follow approaches used in my MSc work and will complement ongoing collaborations between the Andrade, Schulz, and Gries labs focusing on pheromones of *Latrodectus* females^{6,9}.

Significance of the proposed research. This work will lead to a comprehensive understanding of the complex chemical communication systems of widow spiders and inform the development and testing of synthetic pheromones as part of integrative pest management strategies for widow spiders in vineyards.

¹Schulz. 2013 *J. Chem. Ecol.* 39:1-14; ²Gaskett. 2007 *Biol. Rev.* 82:27-48; ³Kasumovic & Andrade. 2004 *Can. J. Zool.* 82:1027-1034; ⁴Andrade & Kasumovic. 2005 *Integr. Comp. Biol.* 45:838-847; ⁵MacLeod & Andrade. 2014 *Anim. Behav.* 89:163-169; ⁶Scott. MSc; ⁷Ross & Smith. 1979 *J. Arachnol.* 7:69-77; ⁸Kasumovic & Andrade. 2006 *Curr. Biol.* 7:R242-3; ⁹Jerhot et al. 2010 *Angew. Chem.* 49:2037-2040.

Part I – Contributions to research and developments

a. Articles published or accepted or in refereed journals

1. McCann, S., Moeri, O., Jones, T., **Scott, C.**, O'Donnell, S. and Gries, G. Falconid raptor rivals predatory impact of army ants on social wasps. *Insectes Sociaux* submission INSO-D-14-00033; accepted pending revisions 17 May 2014 (collaboration during my MSc)
2. Vibert, S., **Scott, C.**, and Gries, G. (2014) A meal or a male? The 'whispers' of black widow males do not trigger a predatory response in females. *Frontiers in Zoology* 11(1): 4 (Undergraduate work)
3. McCann, S., Moeri, O., Jones, T., **Scott, C.**, Gries, R., Khaskin, G., O'Donnell, S. and Gries, G. (2013) Strike Fast, Strike Hard: the Red-throated Caracara Exploits Absconding Behavior of Social Wasps during Nest Predation. *PLOS ONE* 8(12): e84114 (collaboration during my MSc)
4. **Scott, C.**, Vibert, S. & Gries, G. (2012) Evidence that web reduction by western black widow males functions in sexual communication. *The Canadian Entomologist* 144: 672–678. (Undergraduate work)

d. Non-refereed contributions (Conference type: ^aInternational, ^bNational, ^cProvincial)

1. **Scott, C.** The truth about spider bites: “aggressive” spiders and the threat to public health. (Talk^c) Annual meeting of the Entomological Society of BC, Burnaby, BC, Oct. 25, 2014. *Invited talk.
2. **Scott, C.**, Kirk, D., McCann, S. Gries, R., Khaskin, G. & Gries, G. Web reduction behaviour and the chemical communication system of the western black widow, *Latrodectus hesperus*. (Talk^b) Joint Annual Meeting of the Entomological Societies of Canada and Saskatchewan, Saskatoon SK, Sept. 28 – Oct. 1, 2014. *Invited talk in Graduate Student Symposium after competitive application process.
3. **Scott, C.**, Kirk, D., McCann, S. & Gries, G. Web reduction behaviour in black widows: a story of attraction, courtship, manipulation, and rivalry. (Talk^c) Annual General Meeting of the Entomological Society of BC, Victoria BC, Nov. 2013.
4. **Scott, C.**, Kirk, D., McCann, S. & Gries, G. Web reduction behaviour in black widows: a story of attraction, courtship, manipulation, and rivalry. (Talk^b) Joint Annual Meeting of the Entomological Societies of Canada and Ontario, Guelph ON, Oct. 2013. *President's Prize for best student talk.
5. **Scott, C.**, Gries, R., Khaskin, G. & Gries, G. Identification of a silk-borne pheromone component of the western black widow *Latrodectus hesperus*. (Talk^b) Joint Annual Meeting of the Entomological Societies of Canada and Alberta, Edmonton AB, Nov. 4 – 7, 2012.
6. **Scott, C.***, Vibert, S. & Gries, G. Analysis of courtship behaviour in the western black widow, *Latrodectus hesperus*, with insights into vibratory and chemical signals. (Poster^a) Annual meeting of the International Society of Chemical Ecology, Burnaby BC, July 2011. *Honorable mention
7. **Scott, C.**, Vibert, S. & Gries, G. Courtship behavior and mating success in the black widow *Latrodectus hesperus*. (Talk^b) Joint Annual Meeting of the Entomological Societies of Canada and BC Vancouver BC, Oct. 31 – Nov. 3, 2010.

Part II – Most significant contributions to research and development

1. **Scott, C.**, Kirk, D., McCann, S. & Gries, G. Love was in the air: web reduction by male black widows renders pheromone-emitting webs of females less attractive to rival males. *In prep.* (MSc work)
I designed this study, carried out the fieldwork, and analyzed the data in collaboration with my undergraduate mentee (DK) and a fellow grad student in the Gries lab (SM). I wrote the paper, which will be submitted to *Proceedings of the Royal Society B*. I expect it will be of broad interest because of our strong results showing male interference with female chemical signaling in the field.
2. **Scott, C.**, McCann, S., Gries, R., Khaskin, G. & Gries, G. *N*-3-methylbutyryl-*O*-methylpropanoyl-*L*-serine methyl ester – pheromone component of western black widow females? *In prep.* (MSc work)
I designed the experiments and protocols for this study in collaboration with another grad student (SM). I am especially proud of the T-rod bioassay we developed, which is a new and highly effective way to test relevant behavioural responses to spider pheromones. I collected and analyzed behavioural data, and assisted collaborators with chemical analyses. I wrote the paper, which will be submitted to the *Journal of Chemical Ecology*. It is a significant contribution to the relatively young field of spider chemical communication as one of very few chemical identifications of spider pheromone components.

Part III – Applicant’s statement

a. Research Experience

Through completing a BSc in mathematics, as well as undergraduate and graduate courses in biology, I have developed diverse skills and strengths that continue to serve me as a graduate student. During my BSc, I worked on a project with the Human Mobility Research Centre at Queen’s University to develop a method of analyzing CT (computed tomography) scans to estimate bone density. I gained valuable analytical skills as I learned about mathematical modeling and computer programming. Later I was able to draw on this skill set to write a computer program to analyze video polarimetry data being collected by collaborators in the Gries lab. As an undergraduate research trainee at GKSS Research Centre in Germany, I worked in an interdisciplinary research group and gained experience using both chemical and metallographic techniques. I worked simultaneously on several aspects of a large project, which gave me good practice in organizational planning and prioritization, multi-tasking and efficiency.

As an undergraduate at SFU, I gained extensive research experience in collaboration with my PhD mentor Samantha Vibert. I gained experimental design, data collection, data analysis, and scientific writing skills. I developed my creative design skills by helping to design and build a device to play back recordings of vibrations through spider webs. This collaboration led to two publications, one on which I was first author, giving me first-hand experience with peer-review and the scholarly publication process. During my MSc research I have drawn extensively on these skills to design successful field and laboratory experiments and to prepare manuscripts for publication. Furthermore, I have continued to come up with creative solutions to research problems, including designing low-cost, lightweight field traps for black widows. I have also collaborated with PhD student Sean McCann to study to foraging ecology of birds and army ants in French Guiana and Honduras. This has given me experience assisting with organization and logistics of two separate month-long research expeditions to remote field sites. I also gained experience in planning and carrying out fieldwork in a highly time- and cost-efficient manner, as well as solving research problems in the field in a high-stress environment.

b. Relevant Activities

Communication. I have cultivated excellent oral communication skills by giving presentations at conferences. I won an award for giving the best talk in my session at a national conference, and an honourable mention for a poster presentation as an undergraduate competing against graduate students at an international conference. I have also worked to become an effective writer, and I maintain a blog (spiderbytes.org) that communicates spider related biology and natural history to the general public.

Teaching. I have loved teaching science since my BSc, when I worked as a tutor in the math help centre and a TA for the first year ‘Math Investigations’ program at Queen’s University. I received the Norman Miller Fellowship in Mathematics Education (\$1000) as a course coordinator responsible for leading TA meetings and planning curriculum. As a graduate student TA for an introductory biology course I designed and built an interactive website to facilitate online learning and class discussions.

Outreach. As a passionate advocate for science, with a particular interest in sharing the fascinating biology of spiders and dispelling spider-related myths, I have organized and presented interactive displays about spiders for public events at SFU (Oct. 2013), Richmond Nature Park (Sept. 2013 and 2014), and Iona Beach Park (Sept. 2014). I also wrote a blog post about black widow defensive behaviour on Scilogs.com, which was viewed more than 1500 times in the 24 h after it was published.

Supervision/Mentorship. During my MSc I have had the pleasure of training, mentoring and learning from two exceptional undergraduate students. I continue to engage in rewarding collaborations with both; they are each a co-author on a current manuscript in preparation and now pursuing MSc degrees.

Elected and volunteer positions. I have held elected positions as a member of the Biology Graduate Student Caucus at SFU, on the Events Committee (2011-2012) and as a Teaching and Support Staff Union representative (2012-2013). I also volunteer for the Entomological Society of Canada; I was an AV operator at the annual general meeting in 2013, and am currently working on a project to scan all issues of the Society’s bulletin since the 1960s so that they can be made publicly available online.