Food for thought: Does malnutrition influence bee cognition?

Université Paul Sabatier - Toulouse III

NICOLAS BAUDIN
INTERNSHIPS IN FRANCE INITIATIVE

Name of the hosting institution in France	Université Paul Sabatier - Toulouse III
Name of the host laboratory / research team	Centre de Recherches sur la Cognition Animale (CRCA)
Address	CRCA/CBI Université Paul Sabatier - Toulouse III Bat4R3, 118 route de Narbonne 31062 Toulouse, France
Web site	http://crca.cbi-toulouse.fr/en/home/
Name of the supervisor	Mathieu Lihoreau
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Internship offer

Topic of the internship (title)	Food for thought: Does malnutrition influence bee cognition?			
Proposed dates of the internship*	Start	2020-09-01	End	2021-02-28

* The supervisors have indicated the dates proposed are flexible and are able to be postponed subject to COVID-19 border closures.

Scientific and academic objectives of the internship (detailed description of the internship content, work expected from the intern and expected outcomes):

Context: Bees are ecologically and economically vital pollinators. The ongoing widespread declines of wild and domesticated bee species have made their study an absolute societal priority. Environmental stressors such as pesticides and parasites have long been identified as major causes of colony losses by acting on the physiology and cognition of individuals (Goulson et al. 2015). However much less is known about the potential impact of malnutrition resulting from the fast and extensive modifications of foraging landscapes associated to human activities. Bees acquire proteins and lipids from pollen and carbohydrates from floral nectar. Recent laboratory studies indicate that individual bees, just like us, attempt to carefully balance their acquisition of pollens and nectars (Vaudo et al. 2016) to avoid deficits in key nutrients (such as the omega 3) that impair learning and memory (Arien et al. 2015). In the real world, however, the challenge of acquiring a balanced diet for these animals is much more complex. Because they are social insects, bees must collect foods to simultaneously address the divergent nutritional needs of all colony members including the non-foraging workers that need carbohydrate as a source of energy, as well as the queen and the growing larvae that need protein and lipids (Dussutour and Simpson 2009). Since floral resources are patchily distributed across the landscape and greatly vary in shape, colours, odours, and nutritional rewards, the task is not trivial and may rely on complex cognitive abilities (Lihoreau et al. 2012).

Aims: The aim of this project is to examine the effects of nutrient imbalance on the behaviour and the cognition of bees in ecologically realistic yet tightly controlled laboratory setups. We will combine experimental approaches of neuroethology and nutritional ecology to explore these effects both at the level of individuals and colonies, using the buff-tailed bumblebee (Bombus terrestris) as model system. Preliminary experiments in the host laboratory
(CRCA) indicate that bumblebees can be raised on artificial chemically defined diets (nectars and pollens) varying in their concentration and ratios of protein, carbohydrates and lipids (Kraus et al. 2019). The intern will run new experiments to test the effects of these diets on bee cognition.

Work plan:

1. We will characterise how nutritionally imbalanced diets affect the cognitive abilities of individual bees. Bees will be fed artificial diets (nectars and pollens varying in their ratio and concentration of protein, carbohydrates and lipids) and tested in standard protocols of learning and memory of different levels of complexity (e.g. absolute learning, discriminative learning, concept learning) to test the influence of nutrition on different brain circuits. We will prioritise the utilisation of well-established protocols of conditioning of the proboscis extension response (PER) (Matsumoto et al. 2012).
2. We will examine how nutrient imbalance affects the foraging behaviour of bees (flower choices, foraging performances) and colony performances (growth, size, composition). This will be done in the lab by quantifying artificial food intakes in colonies of bumblebees provided with either one or several diets for extended periods of times. Performances of bumblebees will be quantified and analysed using fitness maps (Morimoto and Lihoreau 2019).
3. We will explore how changes in the spatiotemporal distribution of nutrients affects these foraging dynamics and the interactions among foragers in complex environments. This final step will involve observing bees foraging in arrays of artificial flowers providing artificial diets in a large flight cage (Lihoreau et al. 2012). We will study whether individual foragers visit flowers by specialising on one type of nutrients or whether they can mix nutrients from different flowers to balance nutrient collection for the colony. Working environment: The study will be conducted at the *Centre de Recherches sur la Cognition Animale* (CRCA), a department of the new *Centre de Biologie Intégrative de Toulouse* (CBI) at the University Paul Sabatier-Toulouse III.

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The CRCA is arguably the largest department of Animal Behaviour in France, hosting many world-leading specialist of insect behaviour and cognition. Indoor experiments will be performed in dedicated experimental rooms for bee cognition research. Outdoor experiments will be conducted at the experimental apiary on campus (4000m2 equipped with flight cages and lab spaces). In Lihoreau's group, the student will interact with several postdocs, PhD students and Master students working on insect cognitive ecology, with projects ranging from modelling bee movements to investigating bee parasites. Operational language is English. The student will benefit from the help of a PhD student working on bee nutrition (Stéphane Kraus) who designed artificial diets and artificial flowers for testing bees. Kraus is partly funded by the company Koppert (bumblebee provider). The project will also benefit from a long-standing collaboration between Lihoreau and a colleague developing nutrition models at the University of Adelaide (Prof. Jerome Buhl). Techniques that will be used by the student: The candidate will manipulate bumblebee colonies, design artificial diets and conduct various learning experiments. Behavioural experiments will involve testing free flying bees in arrays of electronic artificial flowers delivering controlled volumes of artificial diets for testing their abilities in spatial learning (Lihoreau et al. 2012). Complementary approaches may involve testing harnessed bees for exploring their fine scale abilities in visual and olfactory learning (Arien et al. 2015).

References: Arien Y, Dag A, Zarchin S, Masci T, Shafir S. 2015. Omega-3 deficiency impairs honey bee learning. Proc Natl Acad Sci USA 112:15761–15766. Dussutour A, Simpson SJ. 2009. Communal nutrition in ants. Curr Biol 19:740–744. Goulson D, Nicholls E, Botias C, Rotheray EL. 2015. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. Science 347:1255957. Lihoreau M, Buhl J, Charleston MA, Sword GAS, Raubenheimer D, Simpson SJ. 2015. Nutritional ecology beyond the individual: a conceptual framework for integrating nutrition and social interactions. Ecol Lett. 18:273-286. Lihoreau M, Raine NE, Reynolds AM, Stelzer RJ, Lim KS, Smith AD, Osborne JL, Chittka L. 2012. Radar tracking and motion-sensitive cameras on flowers reveal the development of pollinator multi-destination routes over large spatial scales. PLoS Biol 10:e100139. Morimoto J, Lihoreau M. 2019. Quantifying nutritional trade-offs across multidimensional performance landscapes. Am Nat 193:E168-E181. Matsumoto T, Menzel R, Sandoz JC, Giurfa M. 2012. J Neurosci Methods 211 :159-167. Vaudo AD, Patch HM, Mortensen DA, Tooker JF, Grozinger CM. 2016. Macronutrient ratios in pollen shape bumble bee (Bombus impatiens) foraging strategies and floral preferences. Proc Natl Acad Sci USA 113:E4035-E4042.

Name of industrial partner	Koppert France
Role of the industrial partner in the internship project	Lihoreau has a long-standing collaboration on bee nutrition with Koppert. The proposed project is satellite to the Lihoreau-Koppert collaboration. The proposed project will benefit from the artificial diets developed in the collaboration.
Main contact at the French industrial partner	Damien Facci
Email	DFacci@koppert.fr
Name of the Australian partner institution	The University of Adelaide
Name of lab/department/team involved in the collaboration at the Australian partner institution	School of Agriculture, Food and Wine
Main contact in the Australian partner institution	Jerome Buhl
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Outside of this ongoing collaboration, will applications coming from students of other eligible Australian universities be considered by the hosting institution in France?	Yes

Expected profile of applicant

Level of study	Honours or PhD student
Discipline	Biology
Required qualities, knowledge and skills	- Experience in working with bees - Knowledge in behavioural biology - Design and implementation of behavioural experiments - Dealing with large datasets.