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LEVERHULME EARLY CAREER FELLOWSHIP
MATCHING FUNDING SCHEME

Department	Zoology
Surname	Logan
Title	Dr
First name	Corina
Date of PhD viva*	13 December 2011
Date PhD awarded*	19 May 2012

*Where a special case is to be made for an award to a candidate who has not yet been awarded the PhD degree, please leave above sections blank and fill in anticipated dates below.

Anticipated date of PhD viva

Anticipated date of PhD Award

Current Research - Corina Logan

My postdoctoral research at the SAGE Center for the Study of the Mind at the University of California Santa Barbara focuses on cognition in two innovative bird species with differing relative brain sizes: large brained New Caledonian crows and smaller brained great-tailed grackles. I am investigating whether these birds are capable of causal reasoning and social learning. By carrying out the same tests on both species, I eliminate noise in the data that comes from tests being performed in different labs, and determine what potential advantages a large brain might provide a problem solver. I found that crows can attend to causal cues that indicate functional differences between objects, substrates, and volume differences when solving a water displacement task, however they do not expect a hidden causal mechanism when presented with a task that gives confusing causal cues (Logan et al. *in prep.*). The crows also appear to use many forms of social learning in addition to learning by personal exploration when presented with a novel foraging task (Logan et al. *in prep.*). This work has implications for how they learn to make and use tools, which is hypothesized to be an example of technological cumulative culture. I have set up the wild grackle field site at the Santa Barbara Zoo, where my research is a Zoo exhibit called 'Science in Action', and I have started to conduct the comparative tests on grackles.

Proposed Research - Corina Logan

What makes a large brain? Drivers of intraspecific variation in brain size

There is extensive debate about the cognitive capabilities of large-brained species, yet almost nothing is known about what produces a large brain and whether it increases survival or reproduction in the wild (Sol et al. 2005). To understand cognitive mechanisms in context, it is important to identify the mechanisms driving variation in brain size, for which intraspecies studies are required. While intraspecies investigations exist, all of those concerning non-genetic factors compare populations from different habitats (see Gonda et al. 2011 for a review), thus limiting the ability to determine which of these factors influence brain size within a population experiencing similar selection pressures. To understand the mechanistic factors exerting selection pressure on brain size on a population from a single habitat, I will take advantage of an unprecedented opportunity to analyse brain size data on 1,000 intact skulls from red deer (*Cervus elaphus*) and relate this variable with reproductive fitness, and socioecological and genetic factors.

This project will provide answers to the following questions:

1) What are the costs and benefits of having a large brain? While large brains might provide individuals with cognitive benefits, they are metabolically expensive (Nilsson 1999), potentially leading to a trade off in life history factors. I will examine these trade offs to determine whether brain size is related to reproductive rate and longevity, both of which are energetically demanding. It has been shown in fruit flies (Djawdan et al. 1996) and humans (Westendorp & Kirkwood 1998) that an inverse relationship exists between longevity and reproductive success. I predict that larger brains in red deer may endow their owners with increased survival tactics, thus benefiting from longer life spans, while those with smaller brains may have shorter lives and invest more in reproduction. Using lifetime breeding records for each individual, I will perform a selection analysis using generalised linear models to determine which factors increase or decrease in magnitude relative to brain size.

2) Is brain size, thus potentially cognition, heritable? If larger brains have more cognitive processing power and if these capabilities confer advantages, then selection for larger brains may be occurring through genetic inheritance. Laboratory studies on primates, including humans, show that brain size is heritable (Cheverud et al. 1990, Bartley et al. 1997, Rogers et al. 2007). However, it is unknown to what degree brain size variation in the wild can be explained by genetic factors, though it is also likely to be heritable. By using pedigrees associated with the skulls, the heritability of brain size will be calculated using the 'animal model' (Wilson et al. 2010).

3) Do maternal effects influence brain size? Maternal genes, behaviour, and environment can provide adaptive benefits to offspring (Curley et al. 2008 & 2009). For example, in mice, mothers reared in a social environment provided higher quality maternal care to their offspring, showing that individuals may learn key behaviours from being in contact with others at an early life stage (Curley et al. 2009). Additionally, the lack of maternal care in mice can lead to neophobic offspring that are impaired in their ability to care for their own offspring (Curley et al. 2008). In red deer, I predict that offspring will have larger brains when their mothers were of a higher nutritional status indicated by the location of their home range and body mass, gave birth at an age in the peak of their reproductive abilities, and were of a higher dominance rank. To determine how maternal effects influence brain size in offspring, I will use linear mixed models to examine correlating factors including the heritability of brain size, body mass, nutritional status during pregnancy (i.e., the quality of habitat within the mother's home range), age at parturition, and dominance rank.

4) Do brains develop flexibly after birth? In addition to genetics (Bartley et al. 1997) and prenatal maternal effects (Martin 1981), brain size may also be determined by environmental (Rosenzweig & Bennett 1969) or social (Smith et al. 2010) factors. Gerbils housed in an enriched environment have heavier brains than those housed in an impoverished environment (Rosenzweig & Bennett

1969), and sweat bees from the social caste that reproduces have larger brain volumes than their solitary or social worker counterparts (Smith et al. 2010). As well, the social reproductives have increased brain growth rates particularly at an early life stage (Smith et al. 2010). I predict that red deer females may have increased brain sizes at young ages due to their larger social network and parental care: they live in herds of females that raise offspring outside of the breeding season and in harems during the breeding season. Males may not benefit from an increase in brain size due to their social environment because they live in loose herds of males outside of the breeding season and maintain harems during the breeding season, which may result in a smaller social network. Using generalized linear mixed models to examine variation in brain size across life stages by including individuals that died at different ages, I will determine which factors influence brain growth: sex, age at death, and range location (to estimate habitat complexity).

I will access the long-term dataset from the red deer research project on the Isle of Rum, Scotland, which contains data on pedigrees, sociality, habitat use, and lifetime breeding records since 1972 (Clutton-Brock et al. 1982). Skulls from deceased individuals are available on the Isle of Rum in Scotland, but have not been analysed for inclusion in the database. Brain size will be estimated using cranial volume, which is an accurate proxy (Iwaniuk & Nelson 2002), and relative brain size (brain volume corrected for body size) will be used in analyses. To measure cranial volume, 2mm diameter glass beads will be poured into the skulls until the cranium is full, and then poured out and measured with a graduated cylinder. This method has been validated to ensure it is an accurate approximation of actual endocranial volume (Logan & Clutton-Brock 2013). Relative brain sizes will be inserted into the long-term database for analysis.

Variation in brain size across species is likely tightly linked with variation in cognitive abilities, however direct evidence is lacking. We also do not know what causes variation in brain size in the first place, making it impossible to understand how brain size variation and cognitive variation interact. Ecological, genetic, and behavioural factors examined in this study will determine what produces variation in brain sizes and whether large brains provide survival benefits or increased fitness in the wild. Additionally, this project examines the ontogenetic development of brain sizes to further understand the biological mechanisms underlying the causes of variation in brain size.

While the long-term study on red deer has addressed the similar questions for other morphological traits (e.g., birth weight: Albon et al. 1983, Albon et al. 1987; antler size: Kruuk et al. 2002, Schmidt et al. 2001), investigating brain size in this context is important for informing cognitive studies by providing evolutionary reasons why brain sizes should vary. This is particularly relevant for informing the choice of appropriate proxies that correlate with brain size in cross species comparisons, and for developing cognition research in the context of the selection factors influencing these abilities.

Results should motivate the exploration of natural selection on brain size and cognition in more detail and in other species. Knowing which selection pressures affect brain size will allow us to understand why certain species possess complex cognitive capacities, what fitness benefits might be conferred by having a large brain, and facilitate more appropriate comparisons across species.

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Gonda A, Herczeg G, Merila J. 2011. Population variation in brain size of nine-spined sticklebacks (*Pungitius pungitius*) - local adaptation or environmentally induced variation? *BMC Evolutionary Biology* 11:75.

Iwaniuk AN, Nelson JE. 2002. Can endocranial volume be used as an estimate of brain size in birds? *Canadian Journal of Zoology* 80:16-23.

Kruuk LEB, Slate J, Pemberton JM, Brotherstone S, Guinness F, Clutton-Brock T. 2002. Antler size in red deer: Heritability and selection but no evolution. *Evolution* 56:1683-1695.

Logan CJ, Clutton-Brock TH. 2013. Validating methods for measuring endocranial volume in individual red deer (*Cervus elaphus*). *Behavioural Processes* 92:143-146. doi:10.1016/j.beproc.2012.10.015.

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Rogers J, Kochunov P, Lancaster J, Shelledy W, Glahn D, Blangero J, Fox P. 2007. Heritability of brain volume, surface area and shape: an MRI study in an extended pedigree of baboons. *Human Brain Mapping* 28:576-583.

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Publications - Corina Logan

In preparation

Logan CJ, Jelbert SA, Breen AJ, Gray RD, Taylor AH. (*In prep.*). Mapping the limits of physical cognition in New Caledonian crows.

Logan CJ, Taylor AH, Breen AJ, Gray RD, Hoppitt WJE. (*In prep.*) Social learning in New Caledonian crows.

Taylor AH, Jelbert SA, Breen AJ, Gray RD, **Logan CJ**. (*In prep.*). Tool experience produces stone dropping in New Caledonian crows.

Submitted

O'Donnell S, Kumar A, **Logan C**. (*Submitted*). Life zone differences in army ant raid attendance by Nearctic migrant birds in Costa Rican montane forest. *Wilson Journal of Ornithology*.

Published

Logan CJ, Longino JT. 2013. Adult male coatis play with a band of juveniles. *Brazilian Journal of Biology* 73:353-355. doi: 10.1590/S1519-69842013000200015

Logan CJ, Ostojic L, Clayton NS. 2013. Rook, but not jackdaw, post-conflict third-party affiliation reduces aggression for aggressors. *Ethology* 119:1-9. doi: 10.1111/eth.12078

Logan CJ, Emery NJ, Clayton NS. 2013. Alternative behavioral measures of post-conflict affiliation. *Behavioral Ecology* 24:98-112. doi: 10.1093/beheco/ars140

Logan CJ, Clutton-Brock TH. 2013. Validating methods for measuring endocranial volume in individual red deer (*Cervus elaphus*). *Behavioural Processes* 92:143-146. doi:10.1016/j.beproc.2012.10.015.

O'Donnell S, **Logan C**, Clayton NSC. 2012. Specializations of birds that attend army ant raids: an ecological approach to cognitive and behavioral studies. *Behavioural Processes.* doi:10.1016/j.beproc.2012.09.007.

Logan CJ, O'Donnell S, Clayton NS. 2011. A case of mental time travel in ant-following birds? *Behavioral Ecology* 22(6):1149-1153. doi: 10.1093/beheco/arr104

O'Donnell S, Kumar A, **Logan C.** 2010. Army ant raid attendance and bivouac checking behavior by Neotropical montane forest birds. *Wilson Journal of Ornithology* 122:503-512.

Logan CJ, Montero C. 2009. *Bothrops asper* (Terciopelo) scavenging behavior. *Herpetological Review* 40:352.

Logan CJ, Pepper JW. 2007. Social learning is central to innovation, in primates and beyond. *Behavioral and Brain Sciences* 30:416-417. doi: 10.1017/S0140525X07002476

CORINA LOGAN

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EDUCATION

PhD	Experimental Psychology, University of Cambridge, UK	2012
BS	Biology, The Evergreen State College, Olympia, WA, USA	2004
AA	Skagit Valley College, Mount Vernon, WA, USA	2002

SELECTED AWARDS AND SCHOLARSHIPS (see www.CorinaLogan.com for full list)

2012-2014	National Geographic Society / Waitt Grant	$14,172
2012-2014	Junior Research Fellowship, SAGE Center for the Study of the Mind, UCSB	
2011	Best Talk (out of 12), Murray Edwards College Graduate Symposium	£50
2010-2011	Cambridge Philosophical Society Travel Grants (conferences)	£685
2009-2011	Gates Cambridge Trust Research Grants (conferences)	£2,111
2009-2011	Murray Edwards College Research and Travel Grants (conferences)	£895
2009	Science Writing Prize, Assoc. for the Study of Anim Behav & *New Scientist*	£1,000
2009	2nd prize Best Student Talk (out of 50), International Ethological Congress	£40
2008-2011	Gates Cambridge Scholarship (awarded to top 8% of applicants)	£75,000
2008-2011	Murray Edwards College International Bursary	£3,000
2002	Skagit Valley College: graduated with high honors and the President's Medal (top 1.8%), grades (GPA): 3.91/4.00	

SELECTED POPULAR SCIENCE ARTICLES & BLOGS

Logan CJ. 2013. Life in the Field: New Caledonian crow research. *National Geographic Explorers Journal*.

Logan CJ. 2011. Following the army ant following birds. *Oxford University Press* blog.

Logan CJ, Emery NJ, Clayton NS. Jun 2011. Squabbles and snuggles: how corvids handle conflict. *Natural History Magazine*, pp. 18-19.

Logan CJ. 7 Jul 2010. Settling arguments, the corvid way. *New Scientist*.

INVITED TALKS

- Who are you calling a bird brain? Dept. of Psychology, University of Washington, Nov 2013.
- What to do after a fight? University of California, Santa Barbara, Oct 2012 (Psychology) & Mar 2013 (NCEAS).
- Corvid post-conflict affiliation and red deer brain size. Wild Evolution Group, University of Edinburgh, Apr 2012.
- The sociality, ontogeny, and function of corvid post-conflict affiliation. University of Cambridge, Nov 2011.
- How corvids support each other after fights. Dept. of Biology, University of Washington, Jul 2011.
- The sociality, ontogeny, and function of corvid postconflict affiliation. University of Neuchâtel, Switzerland, Mar 2011.

CONFERENCE PRESENTATIONS

- Formalizing a broad post-conflict affiliation hypothesis. For the symposium I organized on *Post-conflict affiliation: applications for conflict management in humans*. Behaviour 2013, Newcastle, UK, Aug 2013.
- The sociality and ontogeny of corvid postconflict affiliation. Behaviour 2011, Bloomington, IN, USA.

- Does social support reduce stress in corvids? International Behavioral Ecology Congress, Perth, Australia, Sep 2010.
- The evolution and ontogeny of postconflict third-party affiliation in corvids. International Ethological Congress, Rennes, France, Aug 2009.

RESEARCH AND TEACHING EXPERIENCE

Junior Research Fellow September 2012-current
SAGE Center for the Study of the Mind, University of California Santa Barbara, CA USA

- Investigating whether complex cognition exists outside of the large brained birds and if innovation rates and cognition are directly linked in wild great-tailed grackles.
- Comparing physical and social cognition in innovative bird species with differing brain sizes: larger-brained New Caledonian crows and smaller-brained grackles.
- Co-teach *Interdisciplinary Approaches to Brain and Behavior* (Psych 594).
- Guest lecturer: Animal Cognition for *Ethology and Behavioral Ecology* (EEMB 138), Conflict Management in Avian Close Relationships for *Social Psychology of Close Relationships* (Psych 149).
- Supervise three undergraduate research projects and one research assistant.

Post-doctoral Research Associate Summer 2012
Dept. of Zoology, University of Cambridge Cambridge, UK

- Validated methods for measuring endocranial volume in red deer (*Cervus elaphus*) with Prof. Tim Clutton-Brock.

Tropical Research Assistant 2007
University of Washington Seattle, WA USA

- Collected observational data of bird species attending army ant raids in a tropical cloud forest in Costa Rica. Analyzed migrant bird attendance across an elevation gradient.
- Investigated bivouac checking behavior in high-elevation birds.

Natural Resources Research Technician III 2005-2008
Washington State Department of Natural Resources Olympia, WA USA

- Coordinated the development of the DNR Long-term Conservation Strategy for the marbled murrelet, a threatened seabird.
- Completed the marbled murrelet Science Team Recommendations Report: technical writing, editing, and coordinating with Science Team members to finish this 300+ page document.
- Supervised northern spotted owl habitat effectiveness monitoring on timber sales under the DNR Habitat Conservation Plan.
- Conducted fieldwork for a retrospective study on stream buffers, which contributed to the development of a habitat conservation plan for headwater streams in Washington.
- Hired and trained field staff and supervised crews of up to four people.
- Technical editor for the Lynx Habitat Management Plan on DNR-Managed Lands (2006).