Genetics of migration timing in bar-tailed godwits

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Dedicado a mis padres;

vosotros me disteis alas para volar.

Preface

In this thesis, I used molecular and genomic techniques to give insight on the genetic elements behind migratory timing behaviour in a very suitable natural population bird system: The New Zealand godwit. This thesis is structured as a series of related and connected manuscripts with exception of the introduction, which provides the terminology, background and founding of my thesis: Each chapter is a stand-alone piece of work, therefore, there will be some unavoidable repetition between them and the introduction. This thesis contains three main chapters (see listed below), which are intended to be published.

- Chapter 2: Parody-Merino A.M., Battley P.F., Verkuil Y. I., Conklin J.R., Prosdocimi F., Potter, M.A., Fidler A.E. Population genetic structure of New Zealand-overwintering bar-tailed godwits (*Limosa lapponica baueri*) in relation to breeding geography and migration timing.
- Chapter 3: Parody-Merino A.M., Battley P.F., Conklin J.R., Fidler A.E. No evidence for an association between *Clock* gene allelic variation and migration timing in a long-distance migratory shorebird (*Limosa lapponica baueri*).
- Chapter 4: Parody-Merino A.M., Battley P. F., Fidler A.E., Prosdocimi F., Lima N., Conklin J.R., Potter M.A., Cox M.P. Polygenic architecture underlies departure time in a long-distance migratory bird.

As part of a Marsden Grant project I developed the research questions addressed in this thesis, as well as most of the work (i.e. experiments, molecular data collection, analysis and writing), which was performed by me with the guidance of supervisors and some of the co-authors. The godwit behavioural data from previous years were collected principally by my supervisor Phil Battley and co-author Jesse Conklin; those from 2013 onwards were collected by Jesse Conklin (Manawatu), Tom Burns and Ian Southey (Miranda) and Peter Langlands (Catlins). I have collaborated in fieldwork and helped in the collection of behavioural data (in the Catlins) whenever I could. Yvonne Verkuil has been an important contributor to Chapter 2 by guiding in analyses and subsequent interpretation of results. Francisco Prosdocimi and Nicholas C. B. Lima were in charge of the bioinformatic process of the godwit genome assembly and annotation, which was crucial for Chapter 2 and Chapter 4. My co-author Murray Cox supervised and guided me for the analyses (i.e. bioinformatic steps) of Chapter 4, as well as helping resolve computational needs. He also made substantial contributions to the manuscript. All supervisors provided comments and contributed to framing of all the manuscripts.

Synopsis

“A hidden drive at the right time”

Ferdinand Johann Adam von Pernau

Bird migration is one of the most amazing behaviours observed in nature and it fascinates because of its diversity and its – still – unclear reasons and origin. My thesis converges primarily two big areas of research in biology: ecology and genetics/genomics. The ecology part is the bird system (the godwit), which has been extensively studied and whose individual departure date has been proven to be exceptionally consistent. Studies of this kind are not possible without a suitable system, and longitudinal behavioural records of the same individuals are not easy to obtain. The genetics and genomics are, without doubt, the biggest part of this thesis. What can we learn about how DNA encodes biological rhythms in natural populations taking godwits as an example?

There is a huge amount of literature on chronobiology, mainly based on experiments with model organisms or caged individuals. Thanks to these experiments the elements (i.e. proteins and genes) involved in the biological clock have been identified and the characteristics of circadian and circannual rhythms have been described. However, it remains unclear how these elements link to an individual’s timing behaviour in nature. Extensive research on the migration timing of bar-tailed godwits (*Limosa lapponica baueri*) in New Zealand gave rise to an intriguing observation: individual’s departure dates seemed to be primarily driven by an ‘internal signal’, and this ‘internal signal’ was quite consistent across the years, while the population showed a departure-span of approximately a month. This raised questions such as: Are there elements of the internal clock that determines such within species (population) diversity and such intra-individual consistency? In my thesis research I first I assessed the population genetic structure of godwits related to migration time, a step that is necessary when trying to link phenotypes with genotypes. Then I used genomic approaches and integrated behavioural data to understand whether elements related to the ‘internal clock’ are associated to individuals’ migratory departure time in godwits.

I found evidence of slight population genetic structure between northern and southern breeders as well as between earlier and later migrants departing from the stop-

over in Asia, but not between earlier and later migrants from New Zealand. Detailed analyses of migration timing in relation to polymorphisms in *clock* (a gene implicated in other studies as potentially influencing migration timing) found no support for *clock* having any role in godwit migration timing. Analysis of variation in 120 genes associated with the internal clock, photoreception, the physiology the Hypothalamic-Pituitary-Gonadal Axis – which modulates the internal clock –, and fat metabolism and storage indicates that individual migration timing of godwits has a genetic basis to some degree, but differences between individuals seem to be associated with large numbers of genes of small effect rather than a few genes of large influence. Godwit migration timing therefore appears to be a complex trait in which genetic differences between individuals explain some of the variation timing, but a large amount of the variation observed is not explained by the suite of genes studied. It is possible that key genes exist that were not studied, and/or that non-genetic factors may be influencing an individual's decision to migrate on a given day above and beyond the genetic influence. In general, this thesis contributes to the understanding of the nature of behaviours (i.e. genes-behaviour link) in natural populations, specifically in the area of chronobiology.

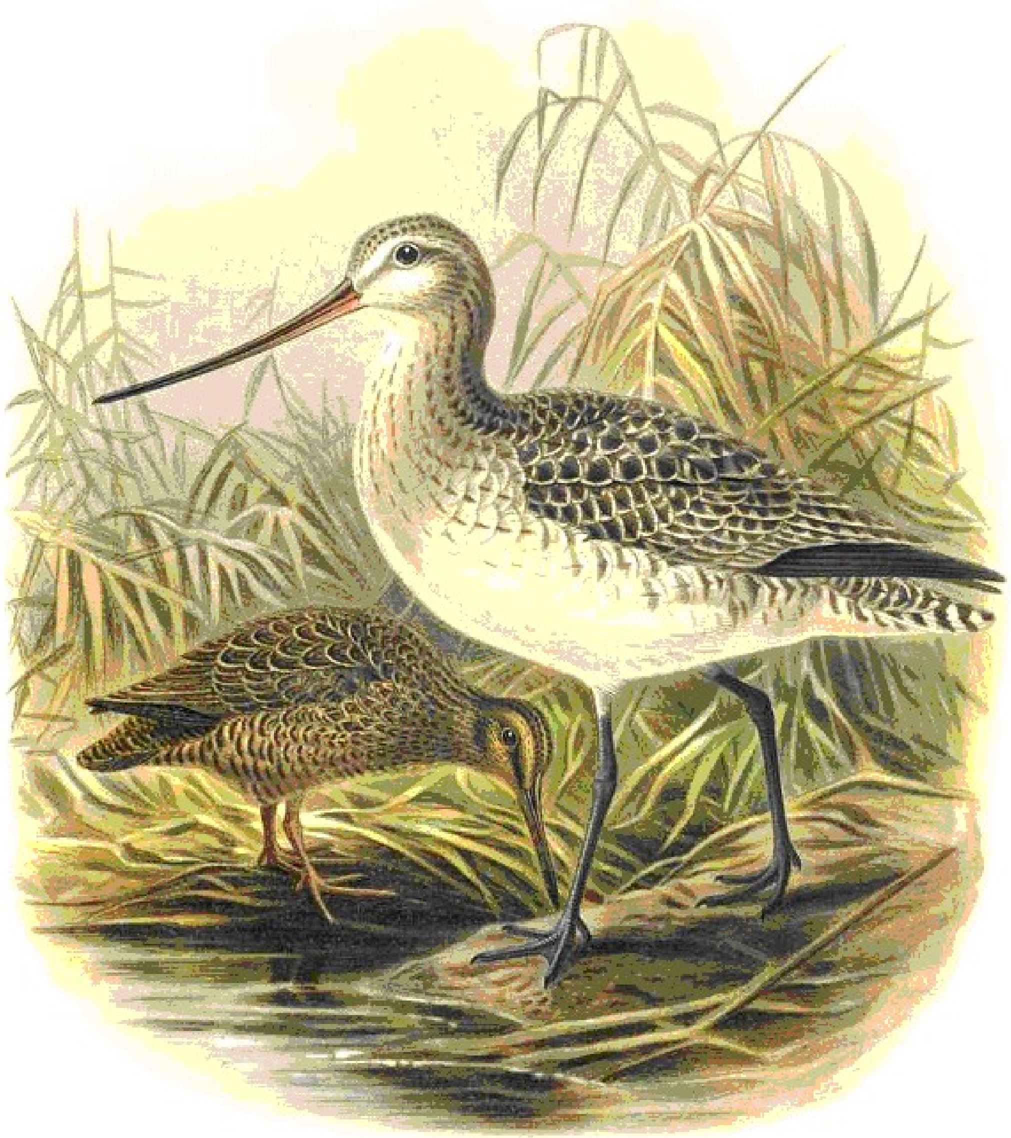
Te Reigna – rarangi mai ra te rangai kuaka/ kia tau hikohiko he pai tu waho

Flocks of godwits are gathering/ moving restlessly on the seaward cliffs

Part of a saying composed by Tumatahina of Te Aupouri.

“Kuaka” is the Māori name for the godwit.

Taken from: http://www.hekuaka.co.nz/



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Myself checking banded godwits in a beautiful day at the Catlins Coast (March 2014).

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