Evolutionary shifts in host plant use in response to climate change in the UK Brown Argus butterfly

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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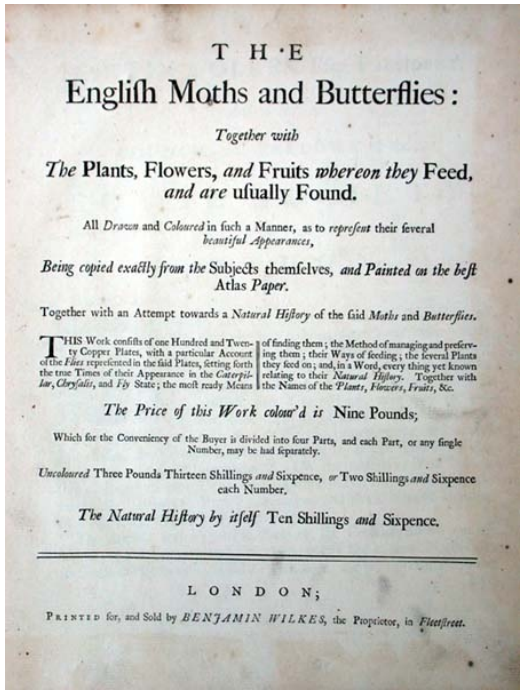
Butterflies provide valuable information about biological responses to environmental change



THE
English Moths and Butterflies:

Together with

The Plants, Flowers, *and* Fruits *whereon they* Feed, *and are* uſually Found.

All *Drawn* and *Coloured* in ſuch a Manner, as to *repreſent* their ſeveral *beautiful Appearances*,

Being copied exactly from the Subjects themſelves, *and Painted on the beſt* Atlas *Paper.*

Together with an Attempt towards a *Natural Hiſtory* of the ſaid *Moths* and *Butterflies.*

THIS Work conſiſts of one Hundred and Twenty Copper Plates, with a particular Account of the *Flies* repreſented in the ſaid Plates, ſetting forth the true Times of their Appearance in the *Caterpillar*, *Chryſalis*, and *Fly* State; the moſt ready Means of finding them; the Method of managing and preſerving them; their Ways of feeding; the ſeveral Plants they feed on; and, in a Word, every thing yet known relating to their *Natural Hiſtory*. Together with the Names of the *Plants*, *Flowers*, *Fruits*, &c.

The Price of this Work colour'd is Nine Pounds;

Which for the Conveniency of the Buyer is divided into four Parts, and each Part, or any ſingle Number, may be had ſeparately.

Uncoloured Three Pounds Thirteen Shillings *and* Sixpence, *or* Two Shillings *and* Sixpence each Number.

The Natural Hiſtory by itſelf Ten Shillings *and* Sixpence.

LONDON;

PRINTED for, and Sold by *BENJAMIN WILKES*, the Proprietor, in *Fleetſtreet.*

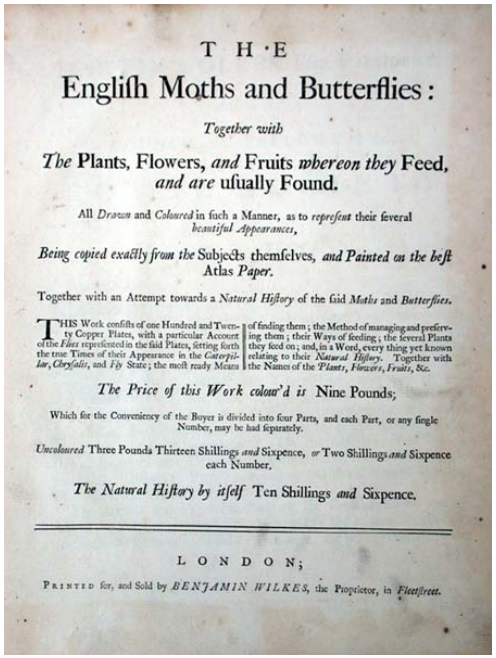
Easy to survey accurately and repeatedly

UK distributional data available for some species from C18 onwards

Adult and larval ecology and life history well known

Habitat specialisation limits range shifts in UK butterflies

Most generalists have moved north, most specialists (75%) have not



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Polyommatus icarus

VS

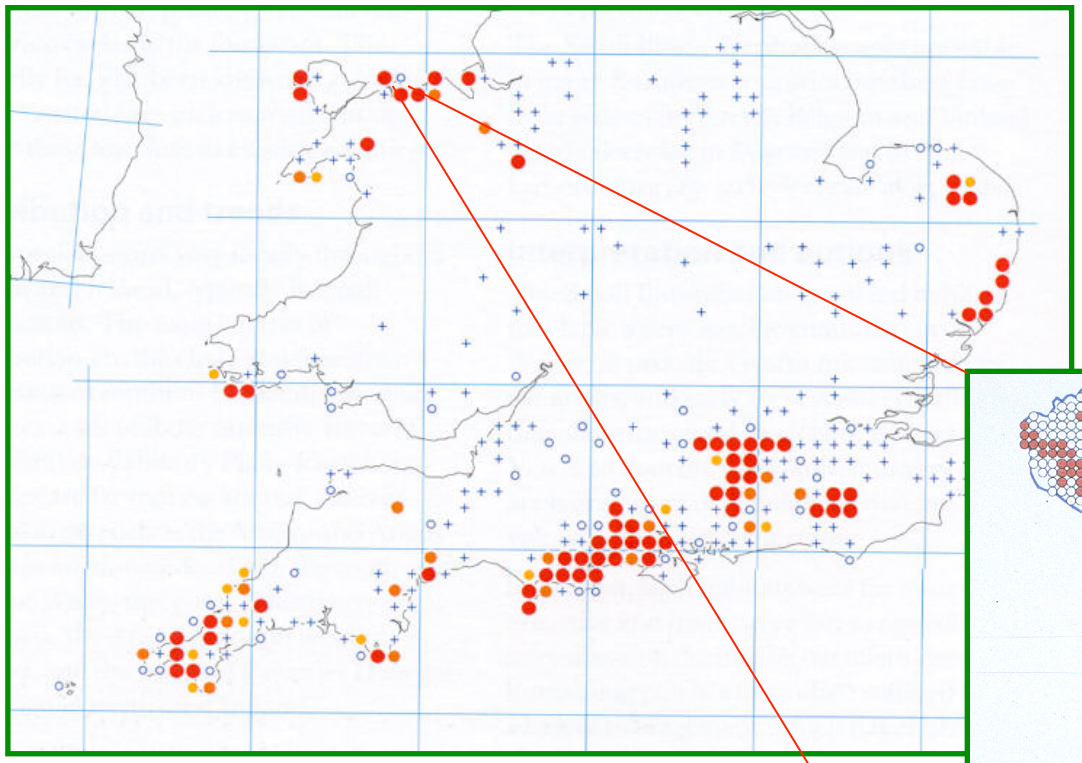
Polyommatus coridon
(needs chalk downland habitat)

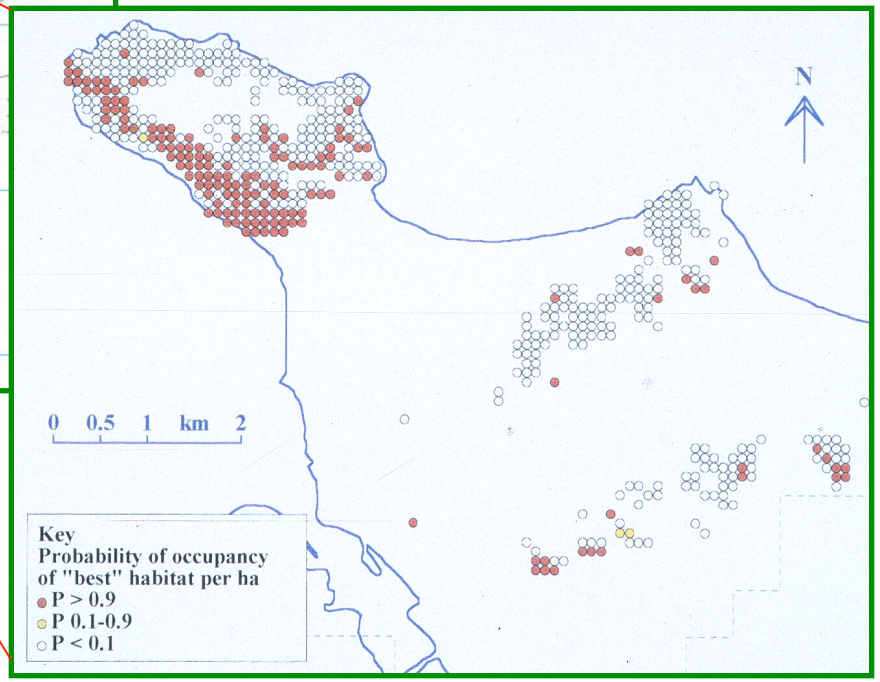
Range shifts and climate change

Ecological patchiness at many length scales limits range shifts in response to climate change

e.g. Chris Thomas *et al.*
Silver studded blue (*Plebjus argus*) in North Wales

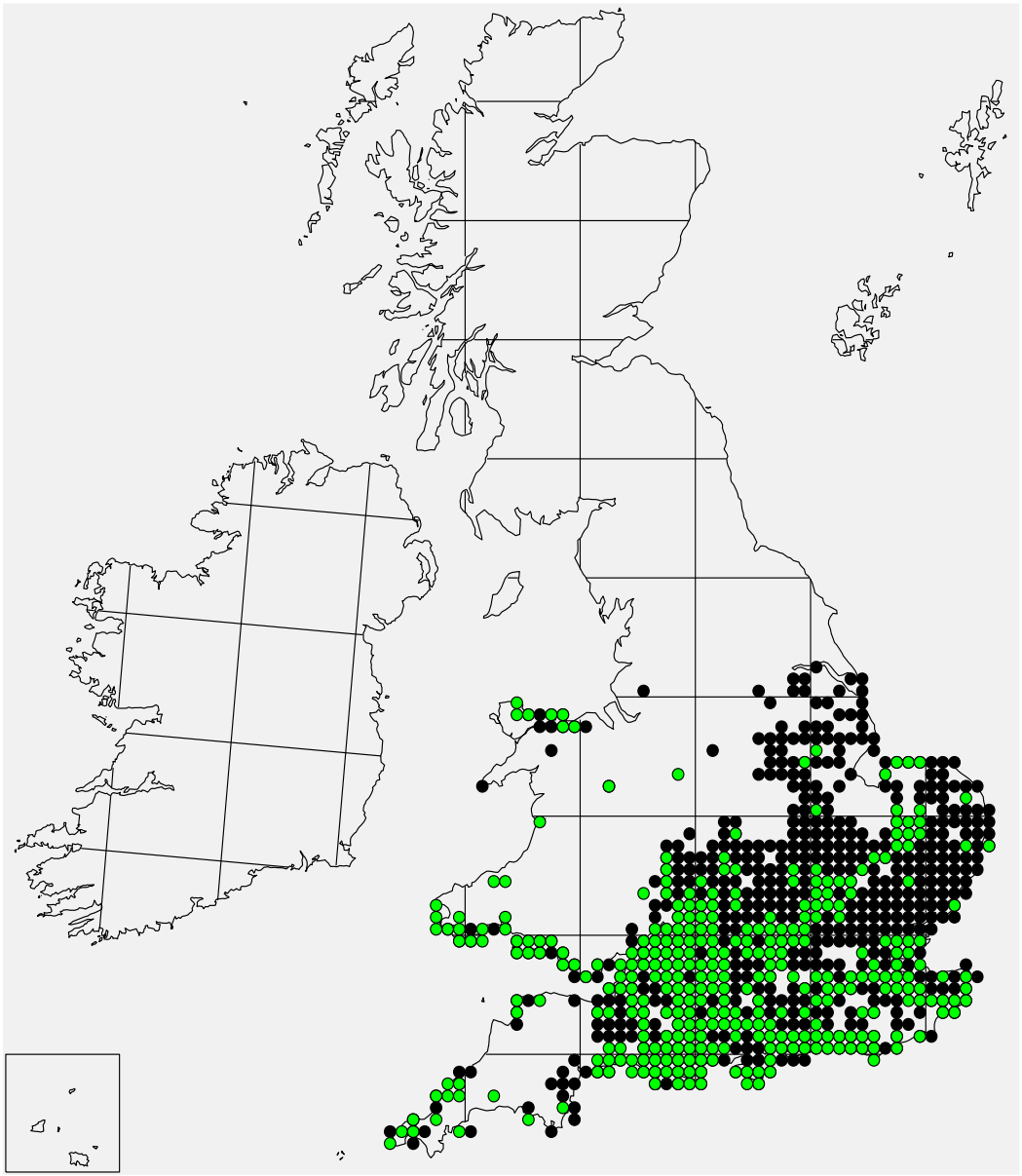
Warren *et a*l. (2001); Hill *et al*. (2011)





The “problem of the specialist”

Exception: recent range shift in the UK habitat specialist *Aricia agestis*



Established (1970-82)
New (1995-99)

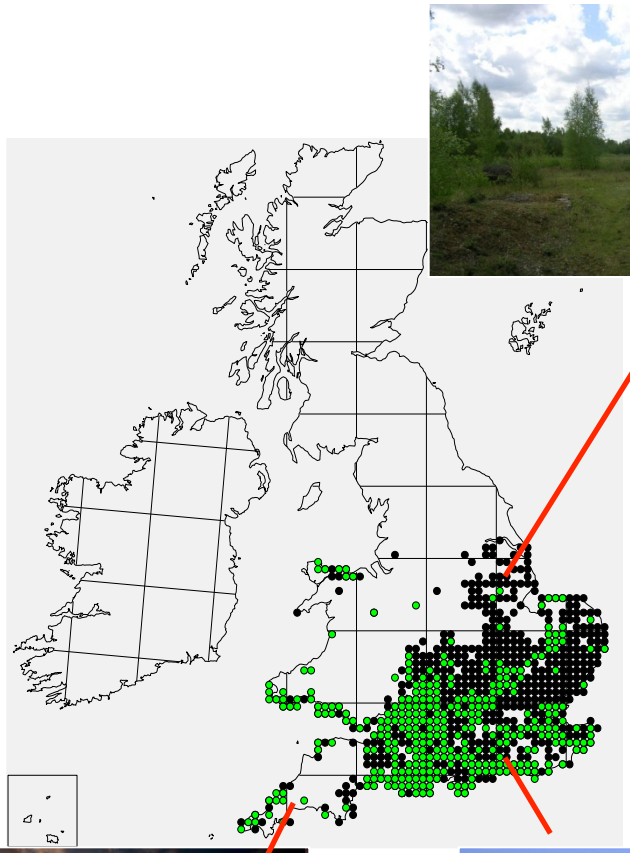
Chris Thomas

James Buckley

Range expansion is associated with changes in host plant use

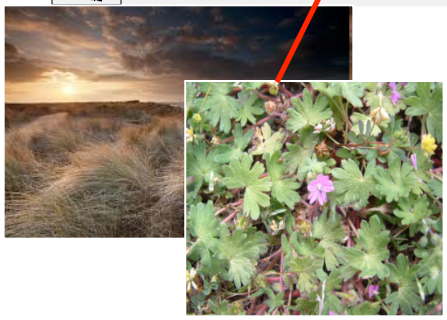
Thomas *et al.* (2001) *Nature*

Paterman *et al.* (2012) *Science*



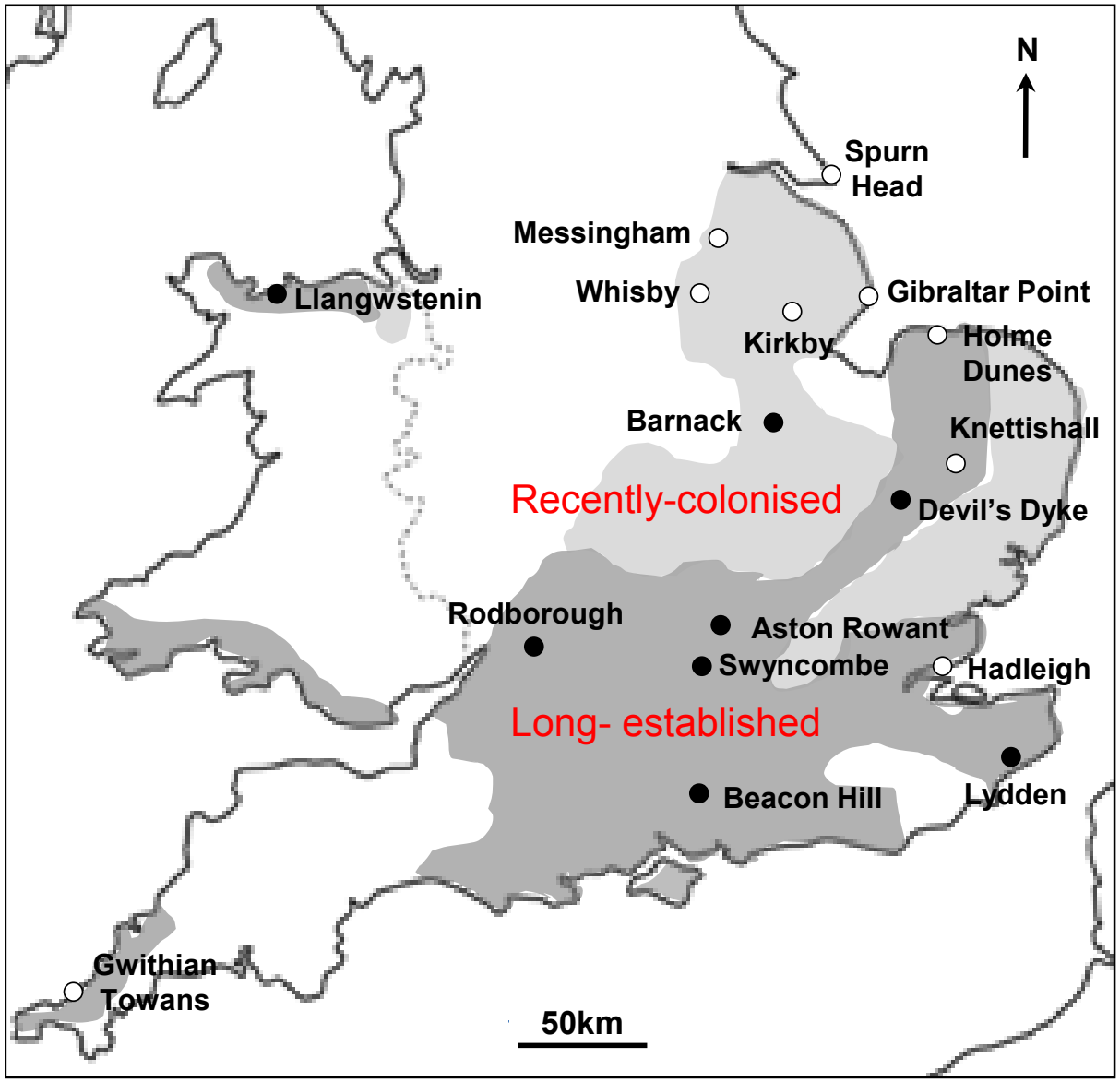
Geraniaceae spp

Helianthemum numularium (Rockrose)



Geraniaceae spp

Q: Has evolutionary change been necessary for this range shift?



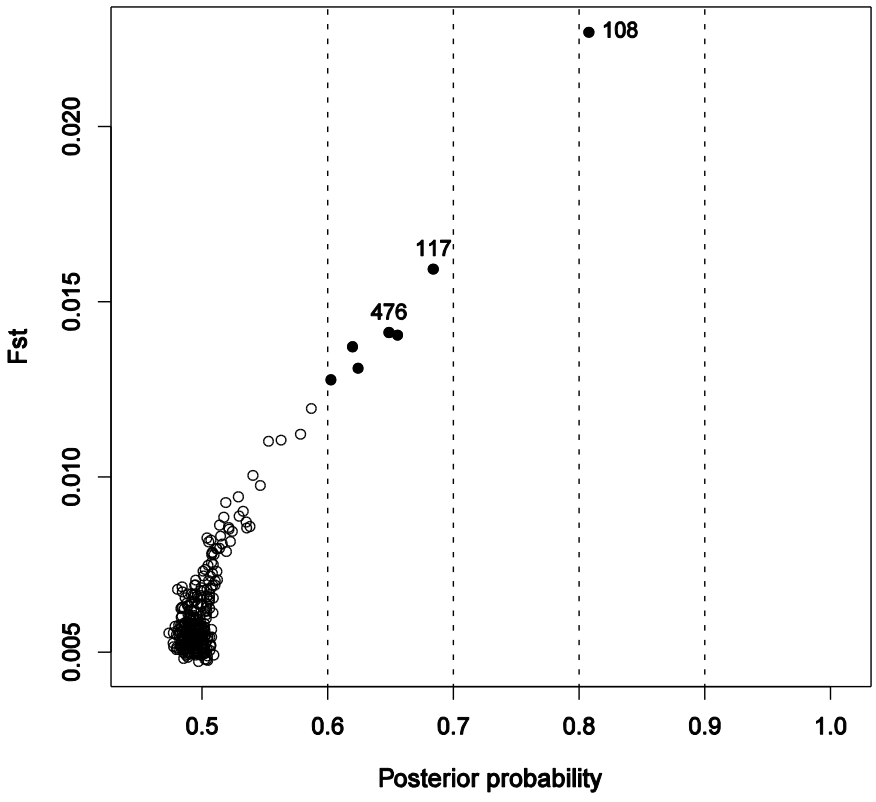
- Genome scans for selective sweeps based on within locus Fst at 300+ AFLPs
- **Field-based assays of host preference and individual fitness**

Tests for selection using AFLP loci

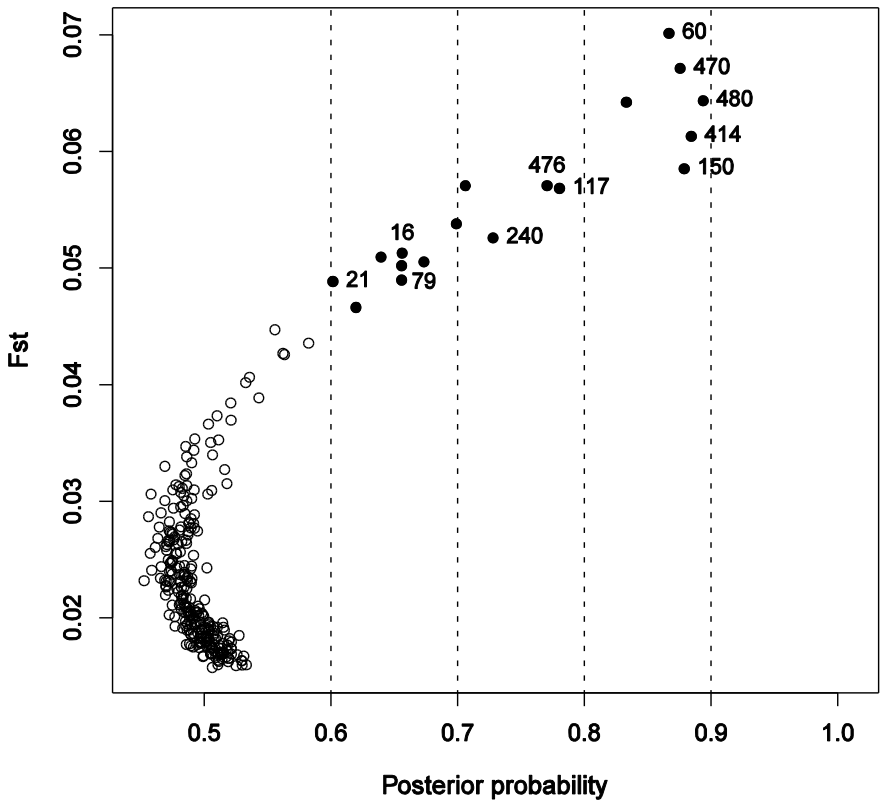
Loci associated with habitat differences in established areas

Loci associated with range expansion into new areas

G vs Rockrose (all Established)



All Established versus Recent



Estimates of within-locus probability of selection using Bayescan
(Foll and Gaggiotti, 2008, *Genetics*)

Buckley *et al*. *Mol. Ecol.* (2012)

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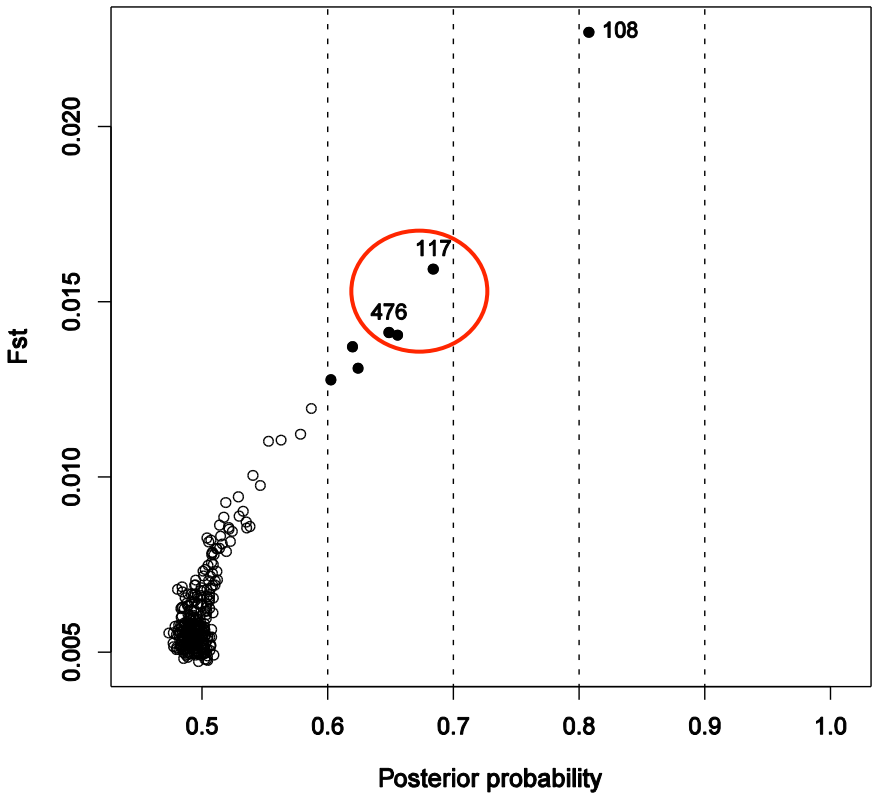

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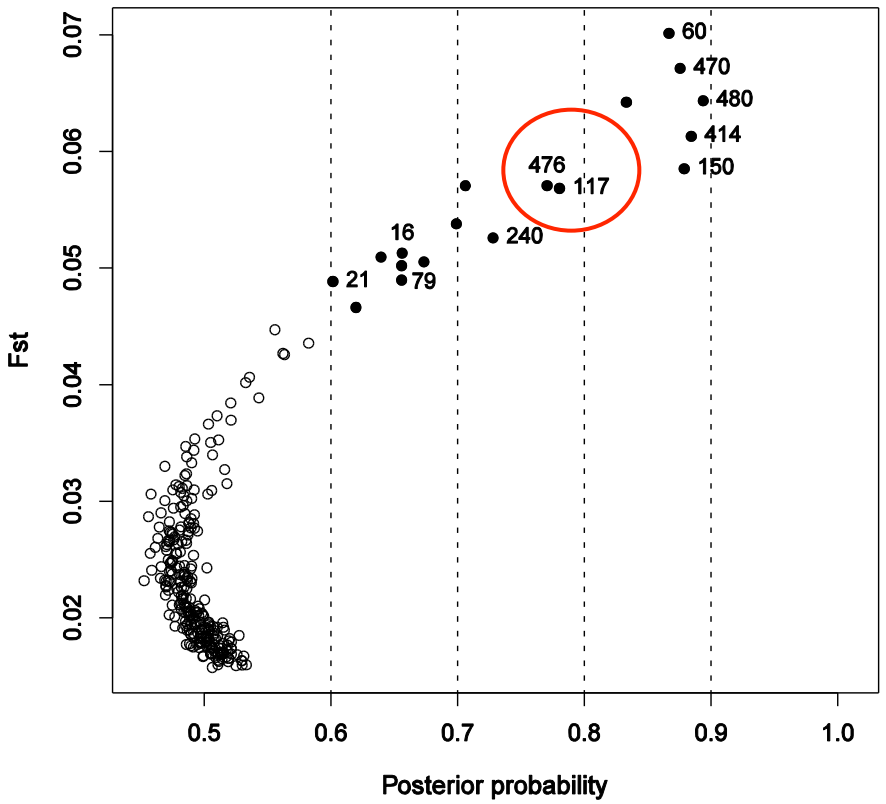

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Phenotypes: Host preference and relative fitness assays

(1) Laying rates of free-flying individuals on experimental host plants

(2) Individual female choice assays on experimental plants under cages at home site

(3) Laying rates of transplanted caged females onto natural hosts

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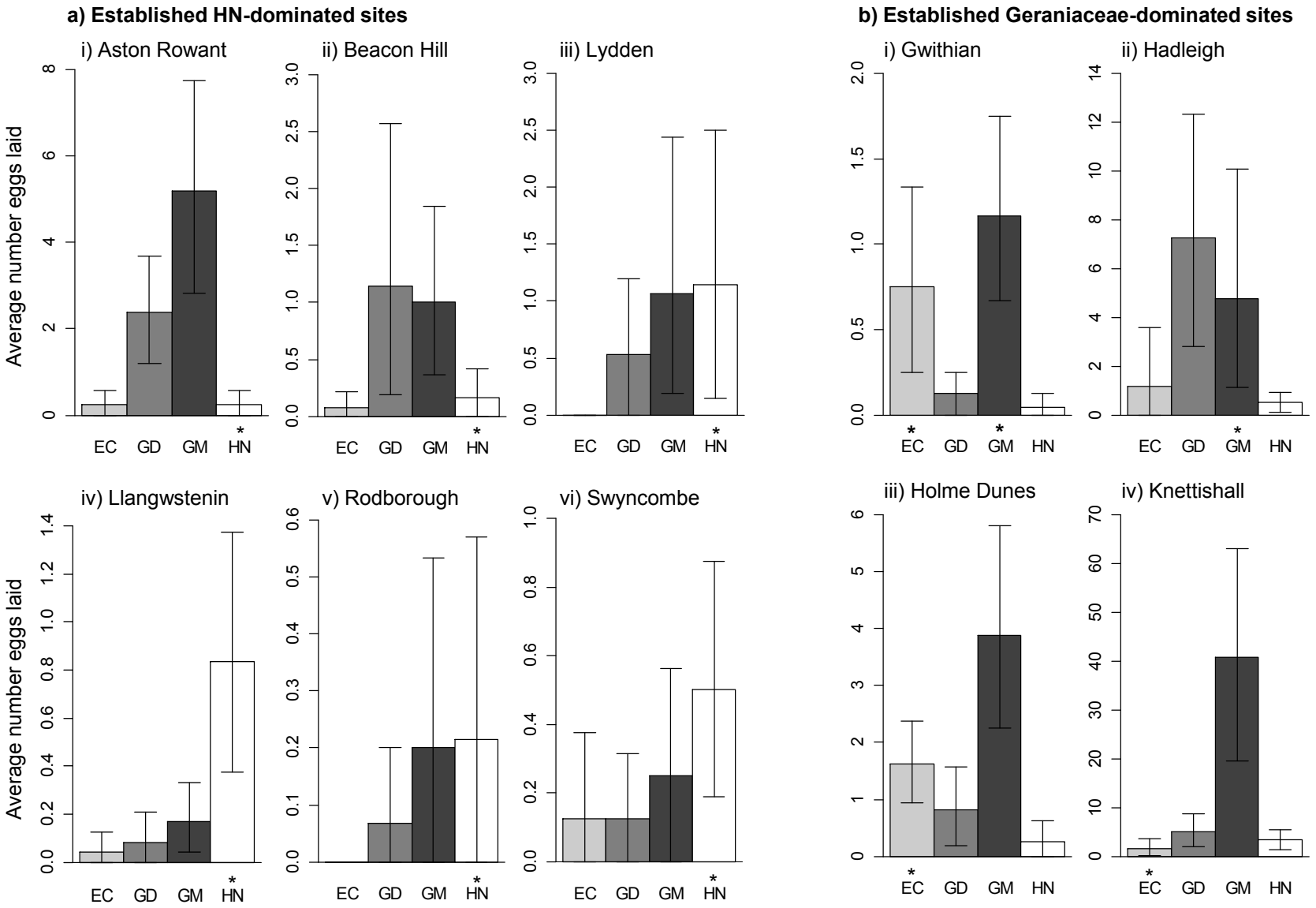
(1) Laying rates of free-flying individuals on experimental host plants

(2) Individual female choice assays on experimental plants under cages at home site

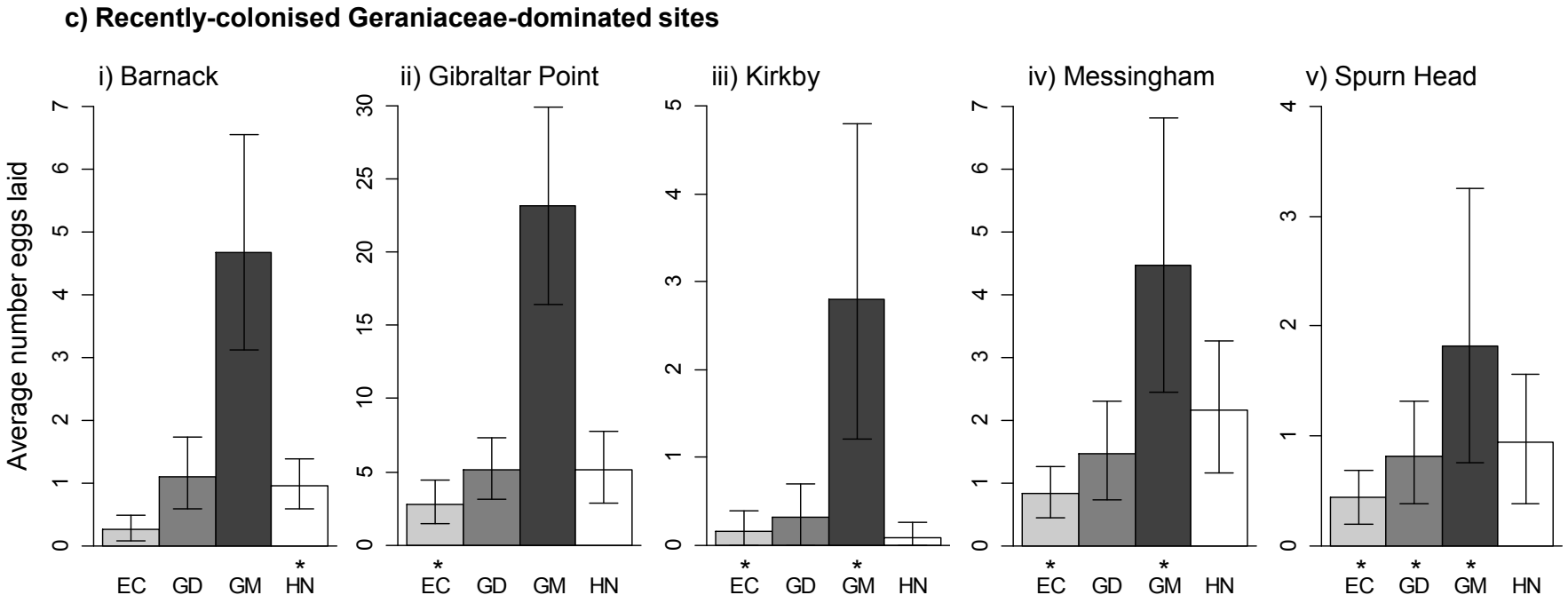
(3) Laying rates of transplanted caged females onto natural hosts

(1a) Lots of variation in host plant use across Established sites



Mean Rockrose preference: (a) 21% (b) 6% ($p<0.05$)

(1b) Hardly any variation in host plant use at Recently colonised sites



1. Preference profiles tend to match local host plant abundances in long-established parts of the range

2. Preference profiles in recently-colonised parts of the range show similar patterns regardless of local host plant abundance

(1) Analysis of host preferences by free-flying females

(a) Mean number of eggs laid per host plant species (GLMM)

	Among v within site variance (lnL)	*p*
All Long-Established (10)	92.1 (27)	<0.001
Geraniacieae L-E sites (4)	24.3 (9)	<0.004
Rockrose L-E sites (6)	34.9 (15)	<0.003
All Recently-colonised (4)	13.8 (12)	0.311

(b) Comparison of female choice among plant quartets

	% var among sites for long established sites	% var among sites for newly-colonised sites	*p*
Rockrose preference	69.2	15.7	0.095
Geranium molle preference	24.9	12.9	0.722

Bridle *et al.* (2014), *Proc. Roy. Soc. B*

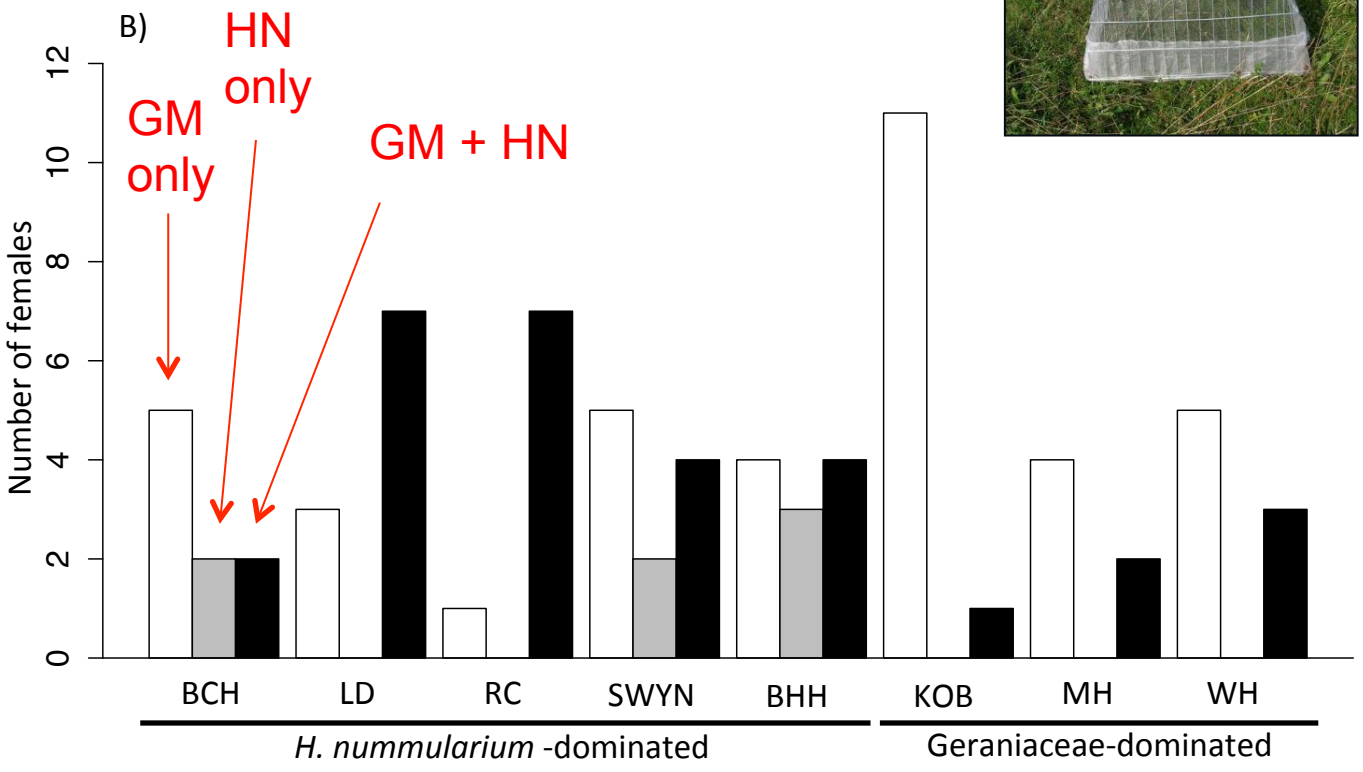
Phenotypes: Host preference and relative fitness assays

(1) Laying rates of free-flying individuals on experimental host plants

(2) Individual female choice assays on experimental plants under cages at home site

(3) Laying rates of transplanted caged females onto natural hosts

(2a) Preferences of individual females on experimental host plants



Rockrose

Geranium molle

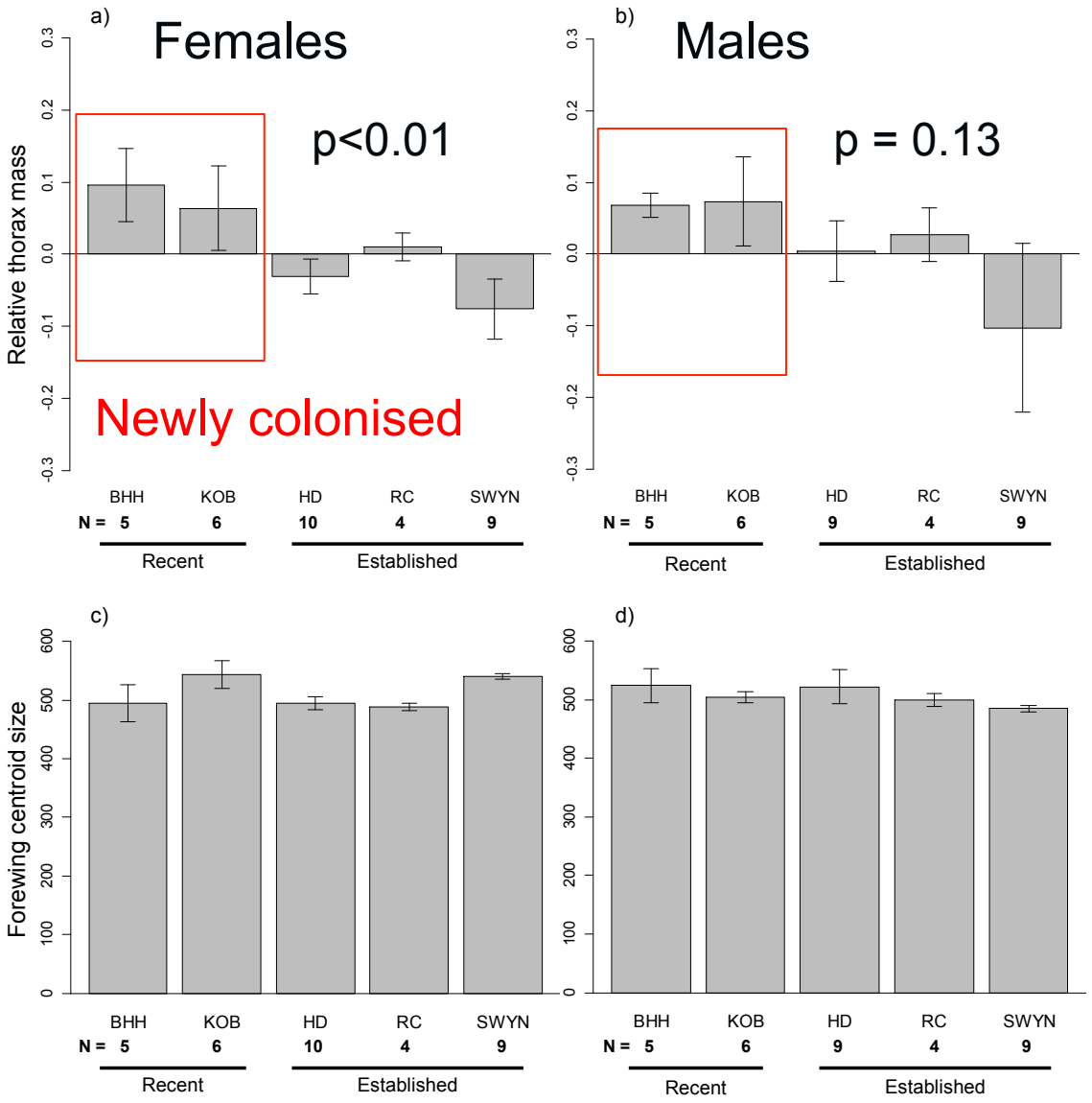
Range expansion is associated with reduced rockrose preference by females

(2b) Trait assays for families reared from individual females

Assay traits associated with flight investment

Families from newly-colonised sites show increased relative thorax size

High dispersal (and *Geranium* favouring) genotypes favoured during range expansion



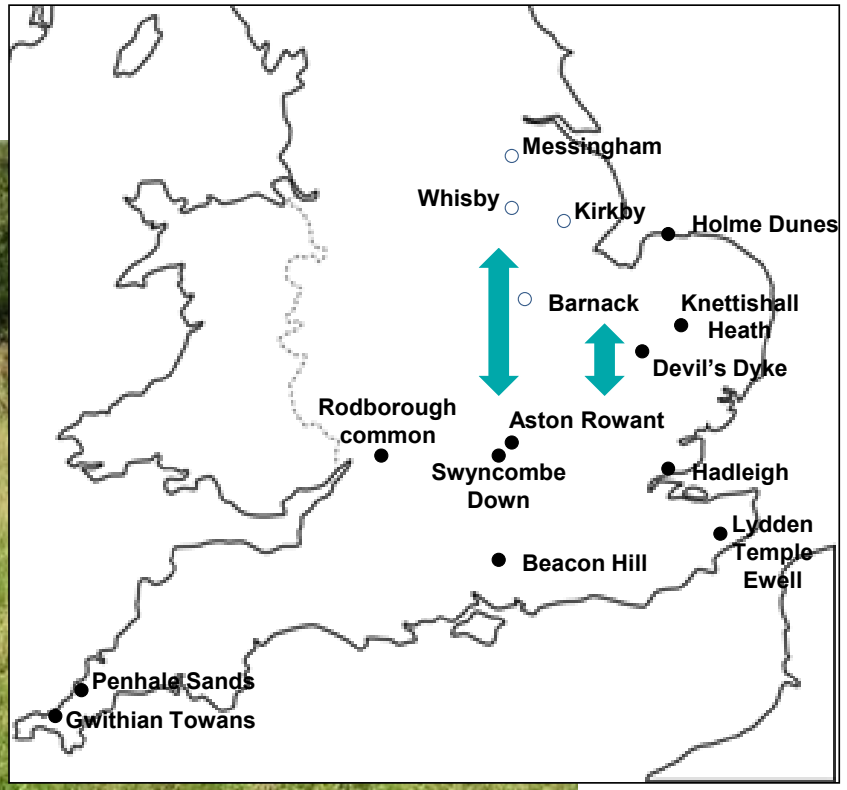
Phenotypes: Host preference and relative fitness assays

(1) Laying rates of free-flying individuals on experimental host plants

(2) Individual female choice assays on experimental plants under cages at home site

(3) Laying rates of transplanted caged females onto natural hosts

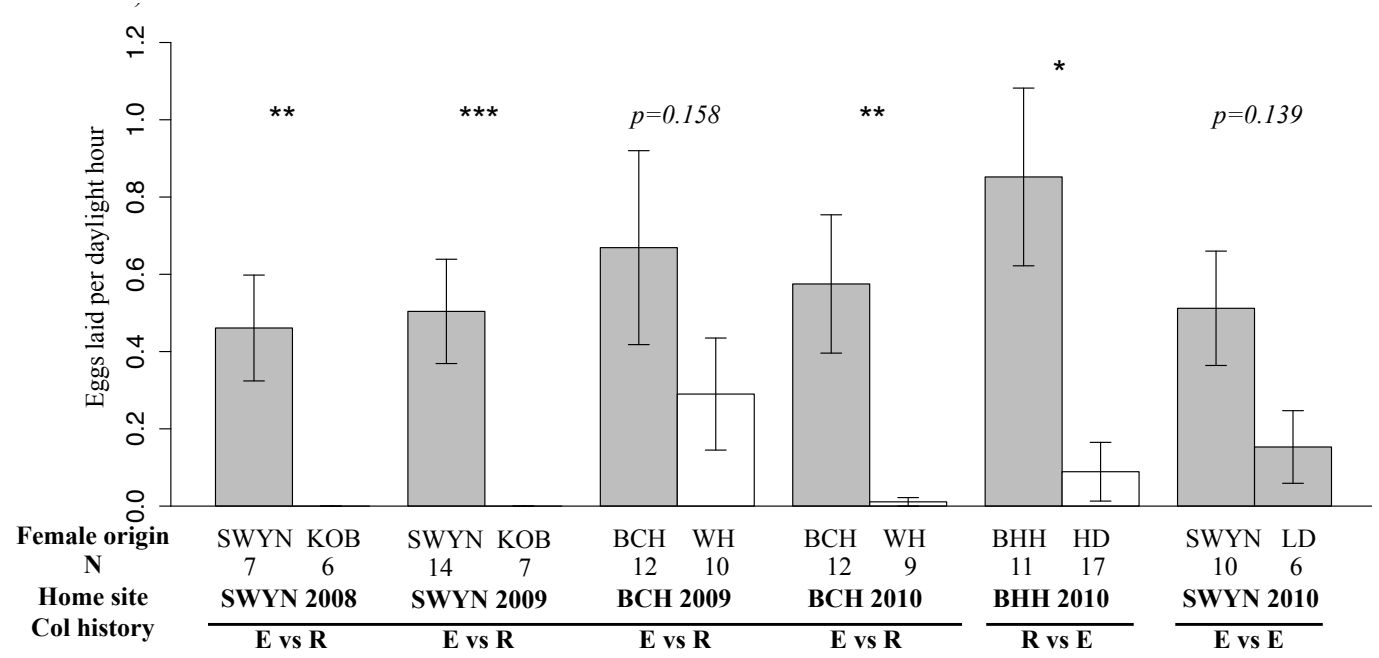
(3) Reciprocal transplants of females onto natural host plants



11 transplants, 300+ individuals, assay individual egg-laying rates

Test for evolutionary change and local adaptation

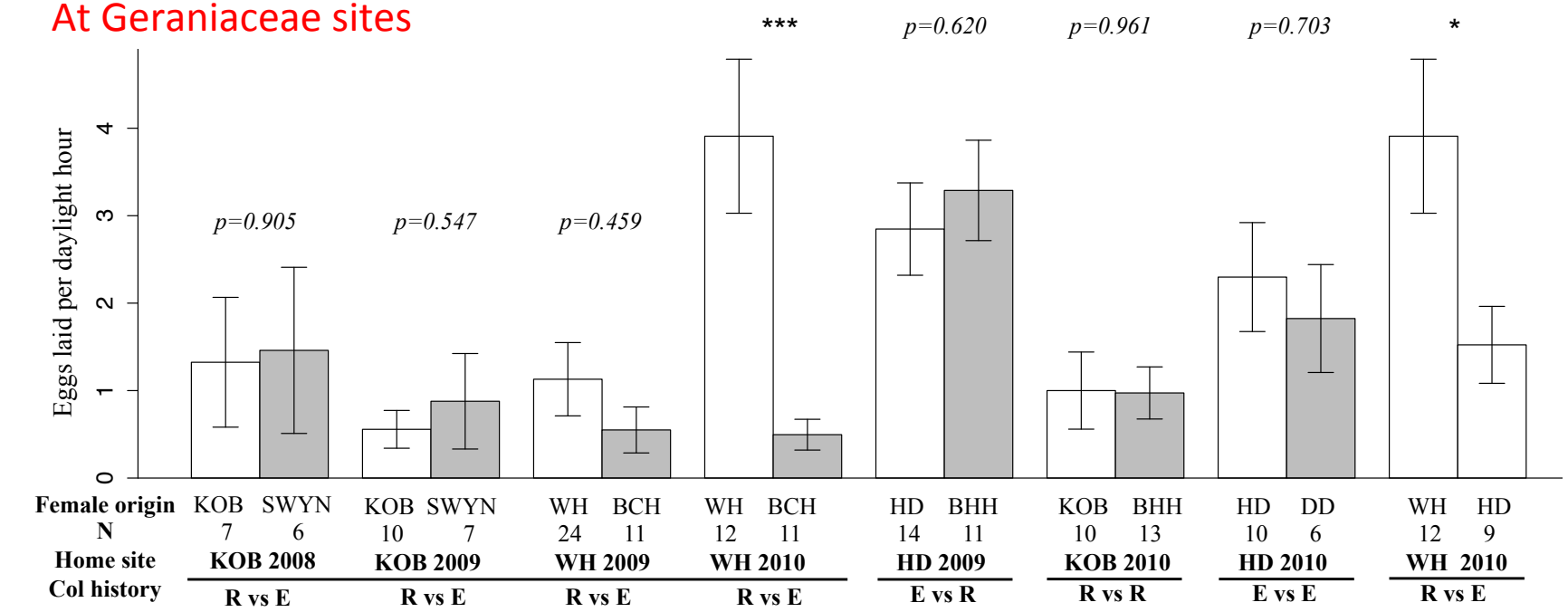
At Rockrose sites



(3) Reciprocal transplants onto natural host plants

Buckley & Bridle 2014)
Ecology Letters

At Geraniaceae sites

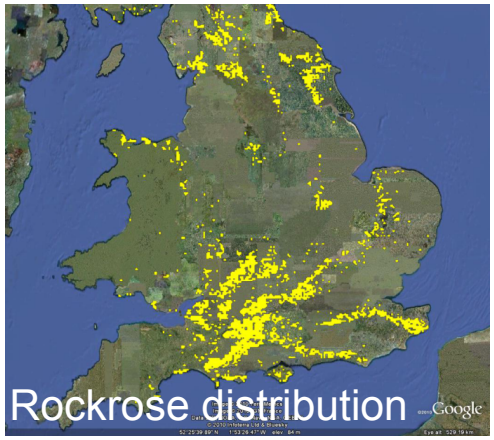


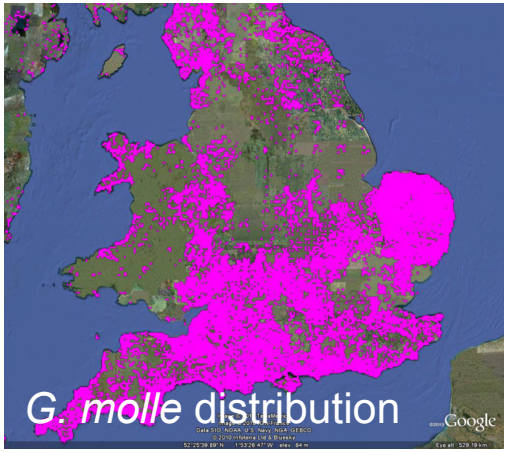
Evolution and climate change in the Brown Argus

1. Climate-driven range shift is associated with the selective spread of genes or genotypes that use locally rare but widespread host plants (*G. molle* rather than Rockrose)

2. UK Brown Argus now specialises on a single widespread host plant that (although locally rare) makes the ecological gradient less fragmented (i.e. more linear)

3. Rapid range shifts favour the loss of local adaptation





Ongoing work (2013-5)

1. Assays of host preference and laying rates of individual females on experimental host plant species under common garden field conditions

2. ddRAD genotyping of mothers:

   (i) genetics of host preference, microclimate use and fecundity

   (ii) population genomics of range expansion

With Maaike de Jong (MC Fellow)