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Conservation strategies for adaptation of biodiversity to climate change

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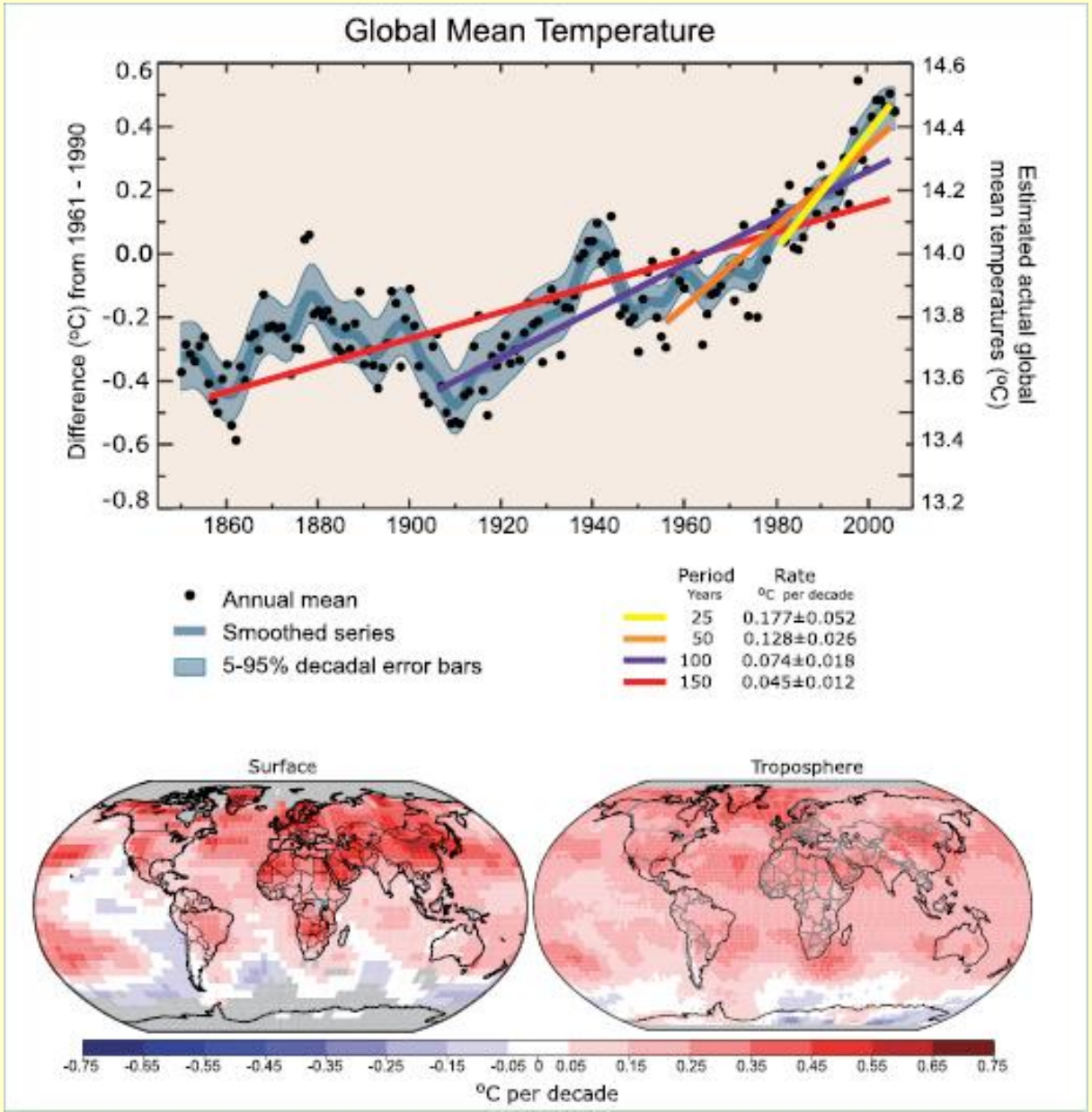
Recent warming

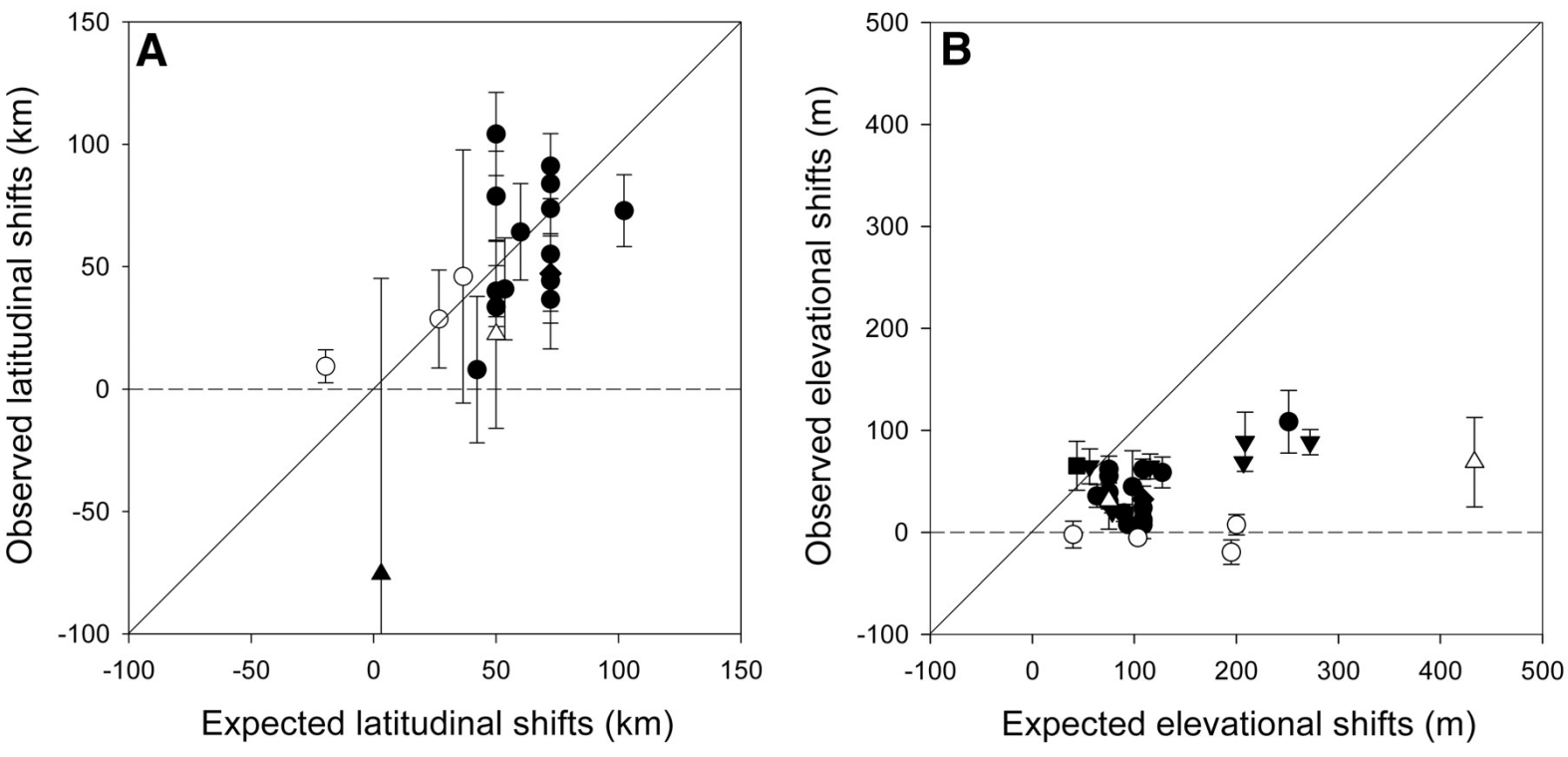
Global climates are estimated to have warmed by approx. 0.74°C during the past 100 yrs (IPCC AR4).

Species could:

- **Shift their ranges and track climate**
- **Adapt to changes *in situ***
- **Go extinct**



Species responses to recent warming



Species are shifting 2-3 times faster than previously reported, and there is an association between amount of shift and degree of warming. But there is a lot of variation among species.

Relationship between observed and expected range shifts in response to climate change, for birds, mammals, arthropods, plants, herptiles, fish and molluscs.

Chen *et al*. *Science* (2011) **333**, 1024-1026.

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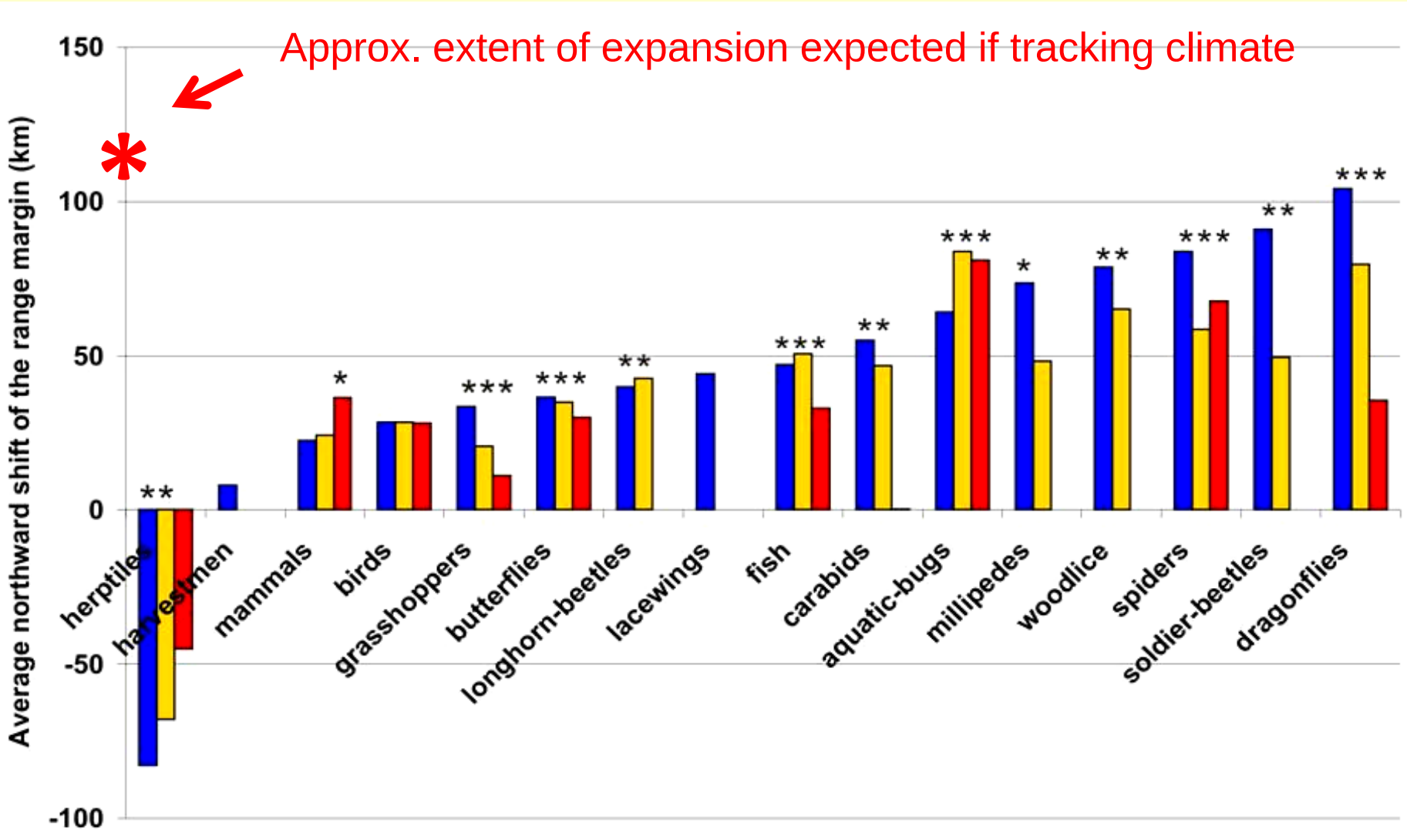
Range expansions and lags in UK taxa



Hickling *et al.* (2006) *Global Change Biology* **12**, 450-455

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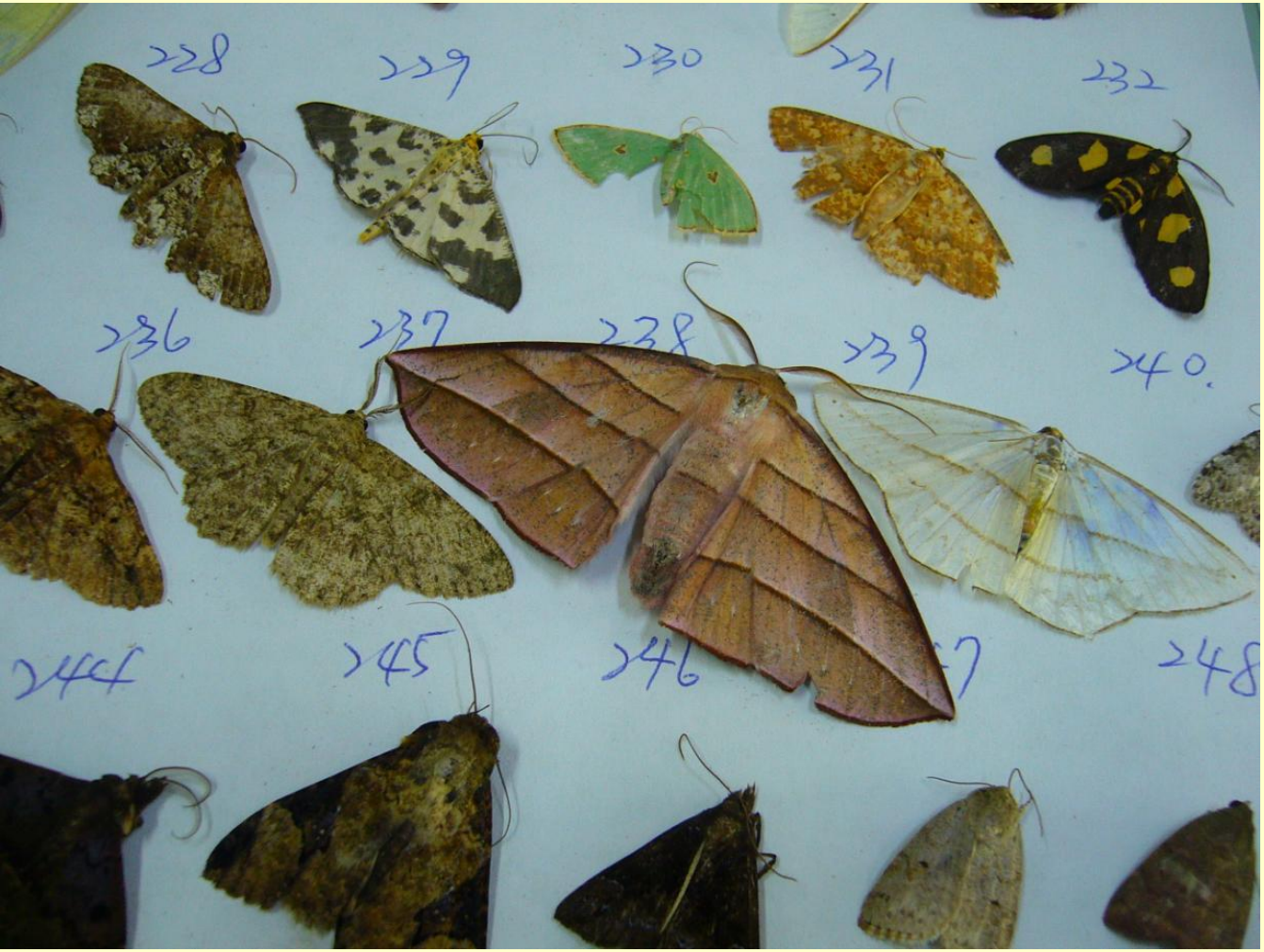
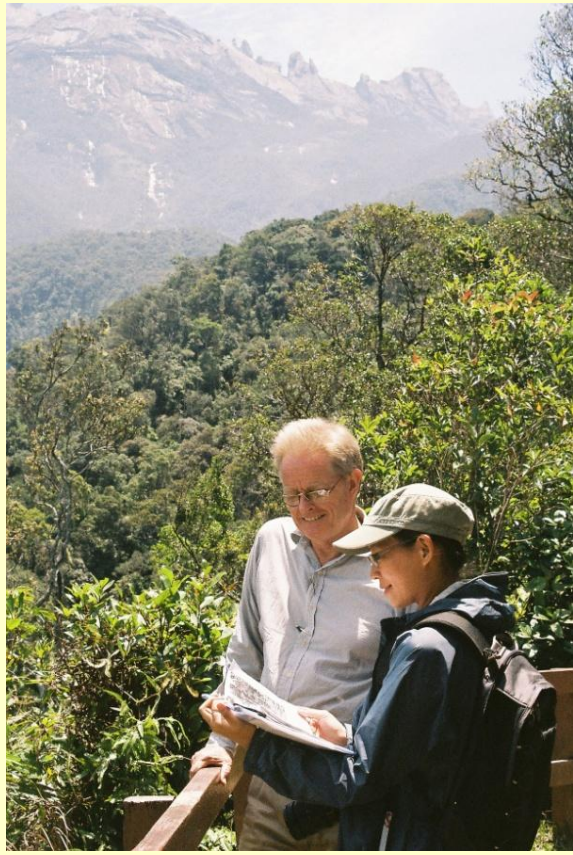
Tropical species also respond to climate





Moths on Mt Kinabalu (Malaysian Borneo) were re-surveyed in 2007 along a transect first sampled in 1965.

Chen *et al*. (2009) *PNAS* 106: 1479-1483

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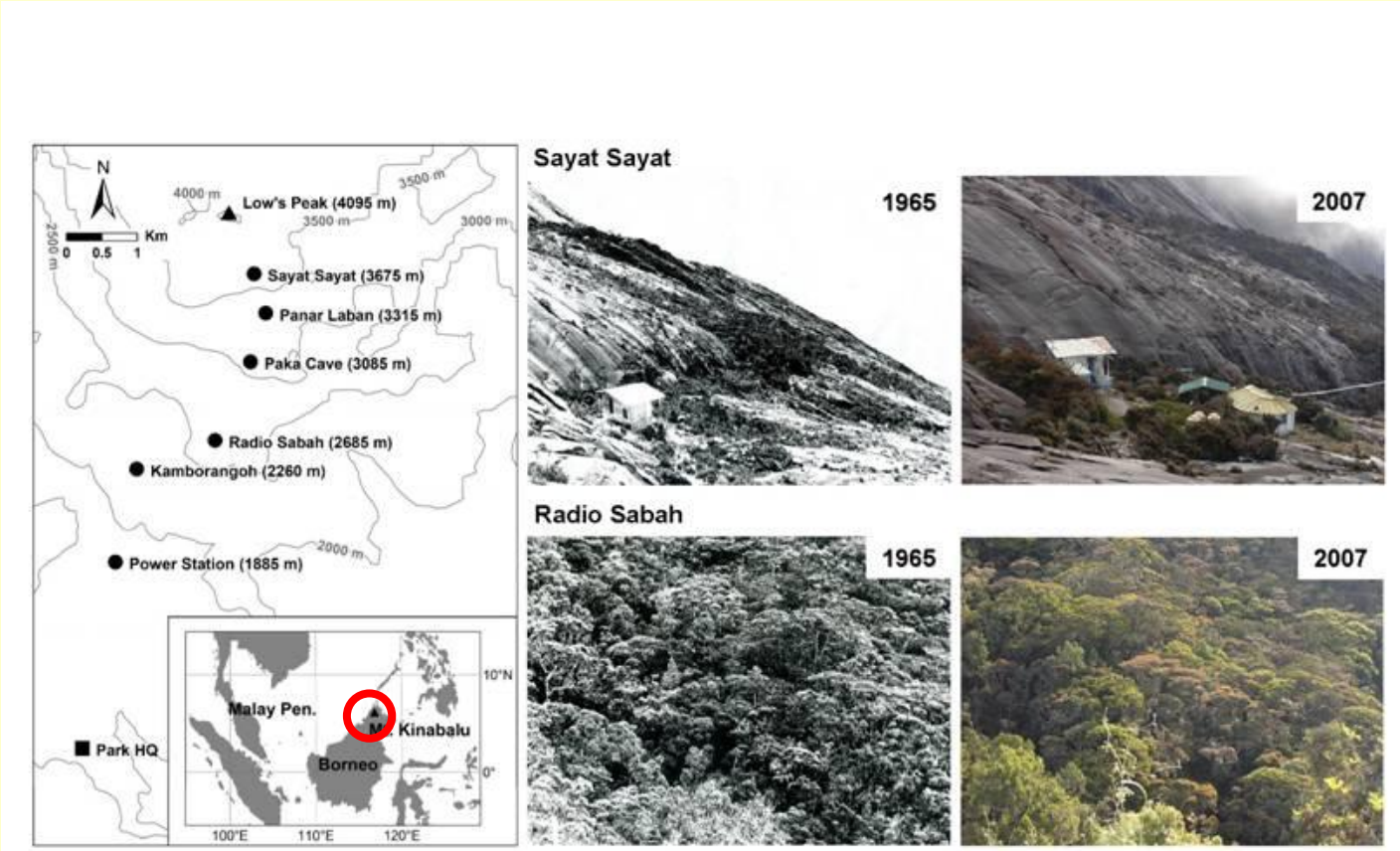
Shifts uphill and lags in tropical species



Data for 102 geometrid moth species. Distributions shifted uphill by an average of 67.2 m per species. Shifted less than expected for ~+0.7 deg of regional warming that occurred over 42 yrs (expected 127m shift).

Habitat fragmentation effects

Species must respond to climate warming and shift their distributions across fragmented landscapes

Cambridgeshire woodland

Oil palm plantations on Borneo

Climate change adaptation

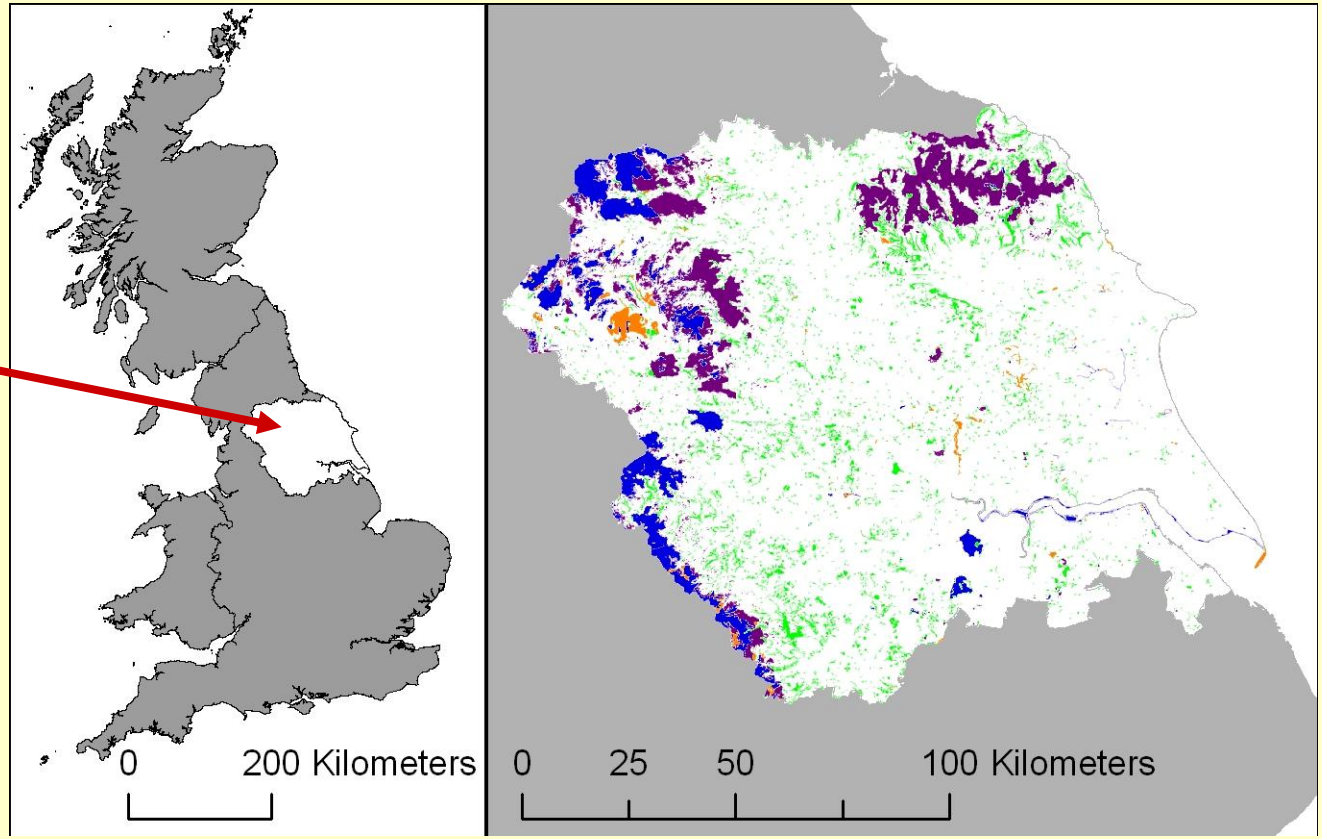
Facilitating expansion at leading edge range margins, and delaying extinction at trailing edges

1. Role of habitat corridors, ‘stepping stones’, and increasing habitat connectivity (physical and functional)
2. Habitat heterogeneity
3. Translocations and ‘assisted colonisation’ of species
4. Protected Areas

1. Habitat creation and range expansion

Can habitat re-creation increase range expansion rates ?
E.g. from the UK

Yorkshire study area



Green = woodland, **purple** = heathland, **orange** = grassland, **blue** = mire/fen/bog.

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Habitat creation in the UK

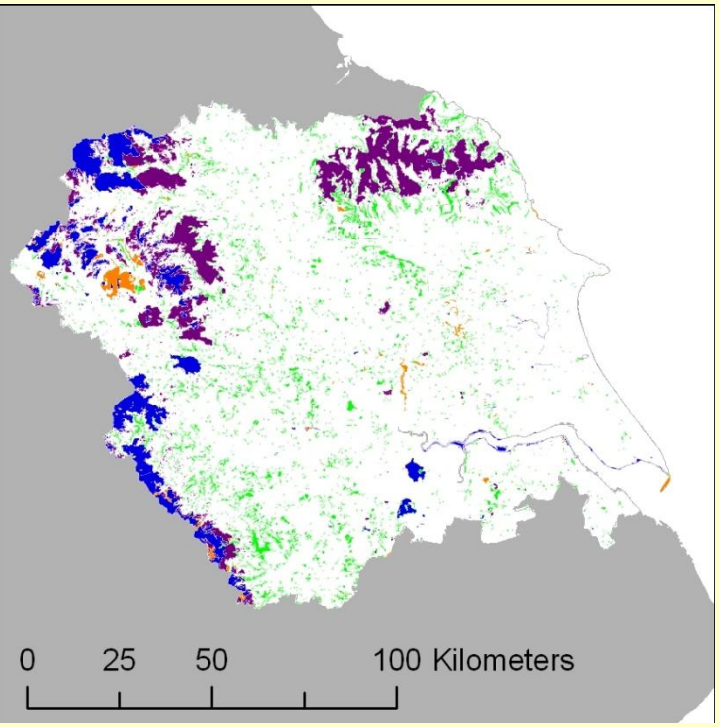
Will increased connectivity help species shift their ranges?

- Natural habitats are very fragmented in Yorkshire (0.7% -~7%).
- Natural England has targets to increase habitats by 0.2% -~15%).
- We imagine 6 habitat recreation strategies (e.g. ask stakeholders, add at random, evenly, most connected etc.)
- We simulate species undergoing range expansion across the landscape
- We compare strategies in terms of speed of range expansion

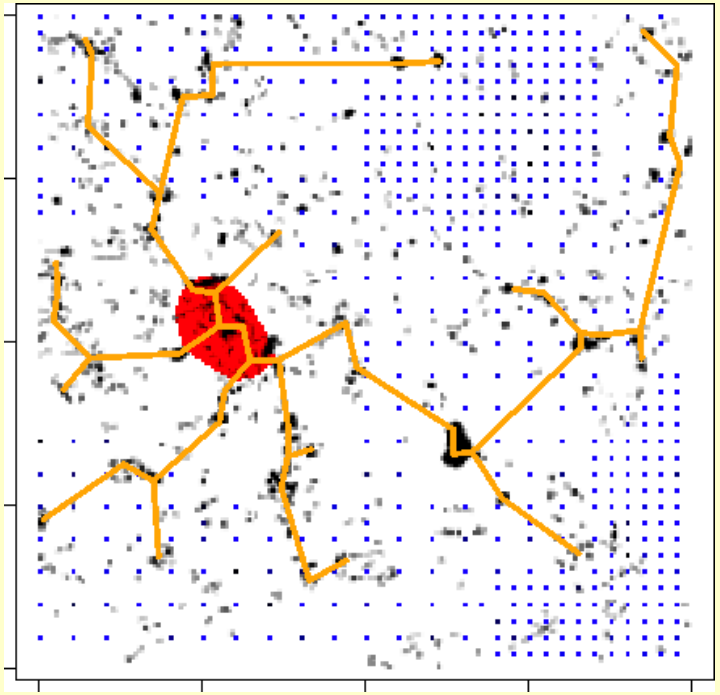
Yorkshire stakeholder workshop

Hodgson *et al*. (2011) *Conservation Letters* 4, 289-297.

Habitat creation

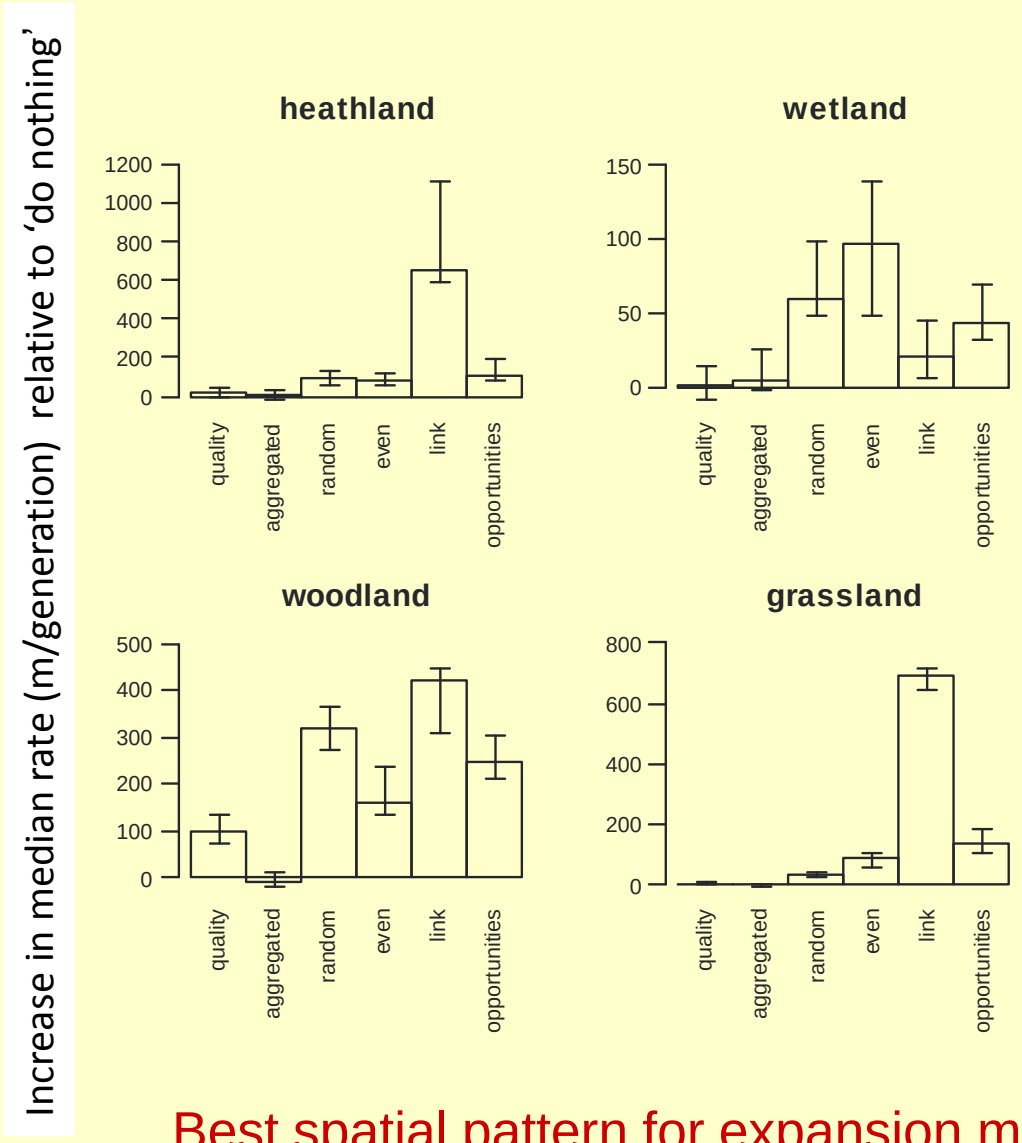


- Measure how long it takes for a species to cross the study area.
- Add new habitat according to different rules; random, even (blue), aggregated (red), link (orange), opportunities, quality.



- Wetland added according to wetland feasibility study, and re-creation was only possible in 7% of the landscape

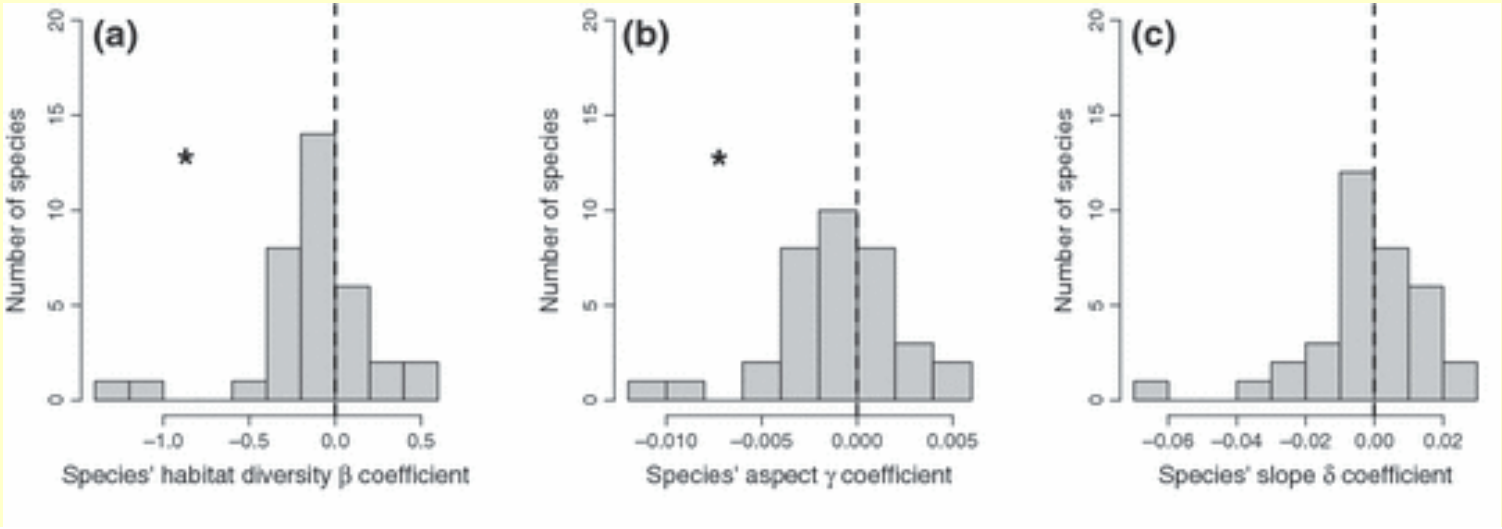
Habitat creation



- Study region is high fragmented (~15% is natural habitat in total).
- Compared habitat addition strategies to 'do nothing'.
- 'Link' strategy tends to be best in all habitats.
- 'Aggregated' not much better than 'do nothing'.
- More habitat added, the better the improvement.
- Best strategy relatively insensitive to species' dispersal ability or density.
- Some species never expanded.

Best spatial pattern for expansion may be different from that for persistence, but persistence is a prerequisite for expansion.

2. Habitat heterogeneity

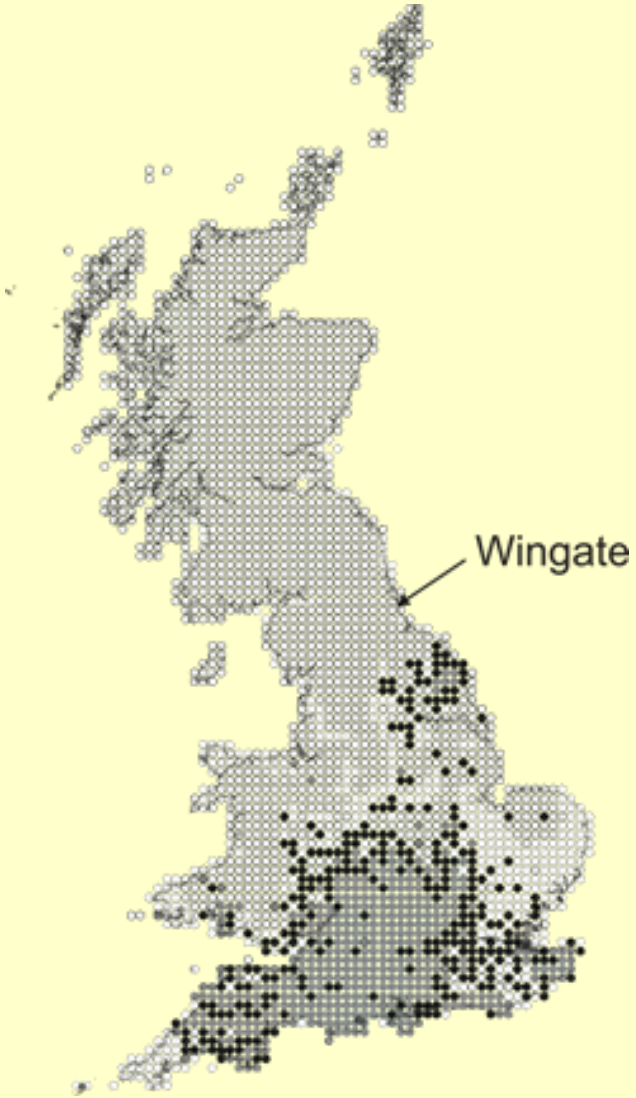


Relationships between population variability (measured by the standard deviation SD of log10(N+1) from time series) and the habitat and topographic diversity in areas of 1 km radius around study sites. Panels (a–c) show results from analyses of UKBMS transect data for **35 butterfly** regression models.

Heterogeneous landscapes promote population stability, and may buffer species against climate change.

Oliver *et al*. (2010) Ecology Letters 13, 473-484

3. Species translocations

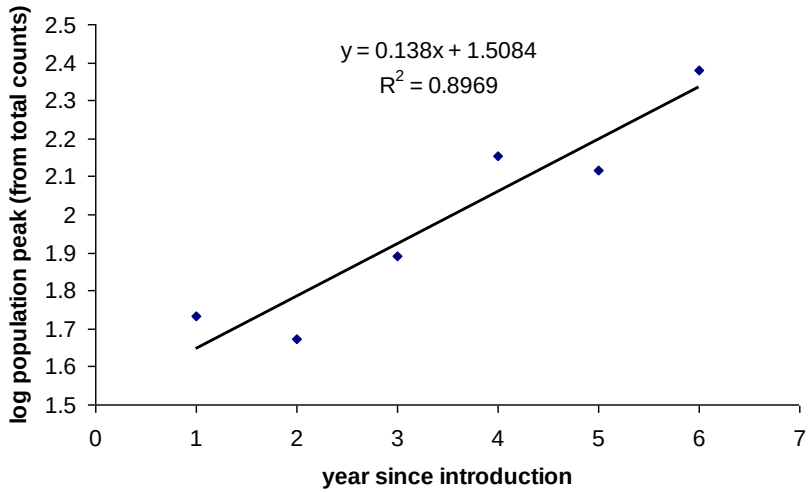


Melanargia galathea

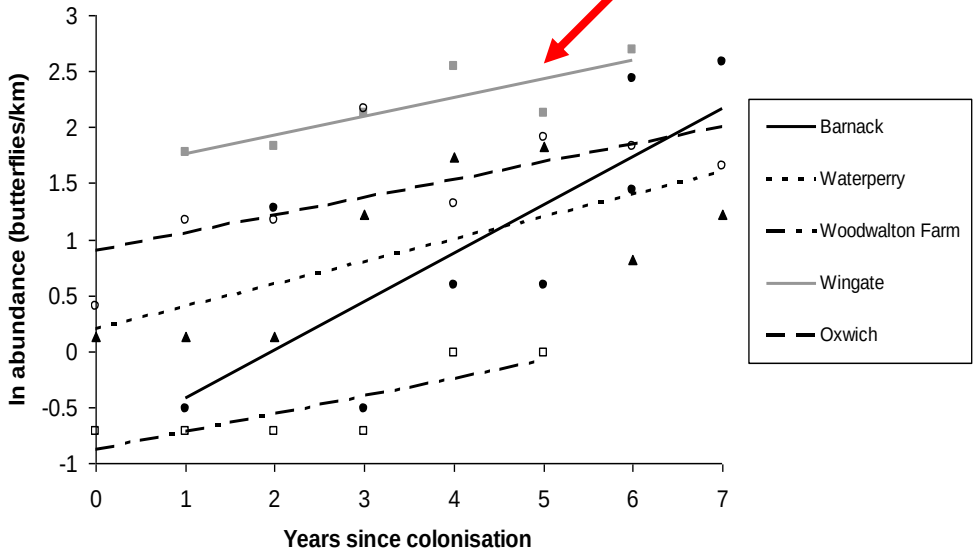
Marbled white

translocations

Population increase after introduction



Wingate Quarry-Introduction site



Population growth rates similar to naturally-colonised sites

Willis *et al*. (2009) *Conservation Letters* **2**, 46-52.

4. Protected Areas and range shifts

Concerns that PAs may be in the ‘wrong’ place to maintain their role in conserving biodiversity, or too isolated to enable species to shift their ranges.

Two examples: from (i) range expanding species and UK PA network, and (ii) tropical PAs on Borneo.

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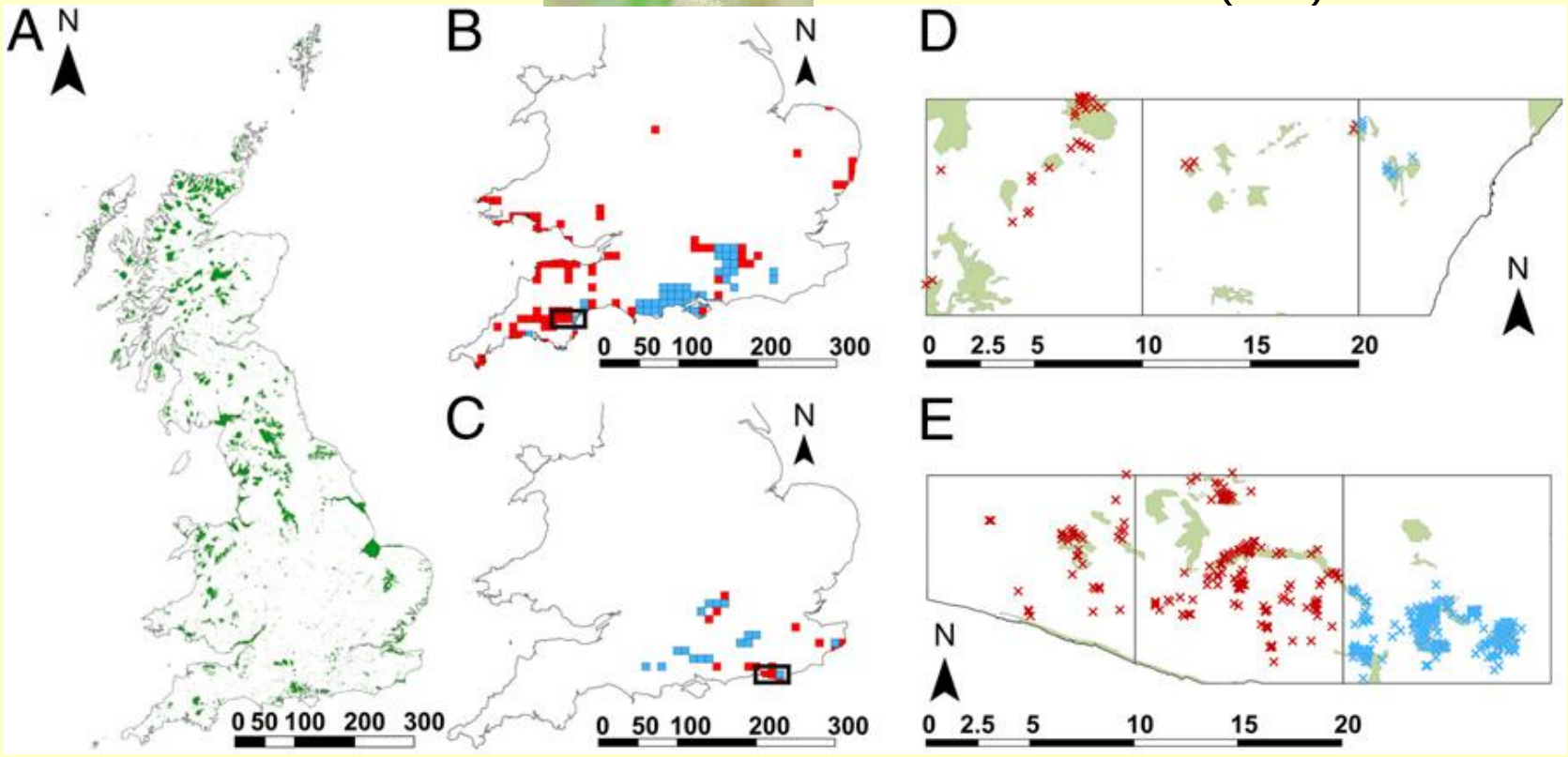
(i) Role of PAs in range expansion

Dartford warbler; core (**blue**) and colonised sites (**red**)

UK PA network



Colonisations are disproportionately associated with PAs

Silver spotted skipper; core (**blue**) and colonised sites (**red**)

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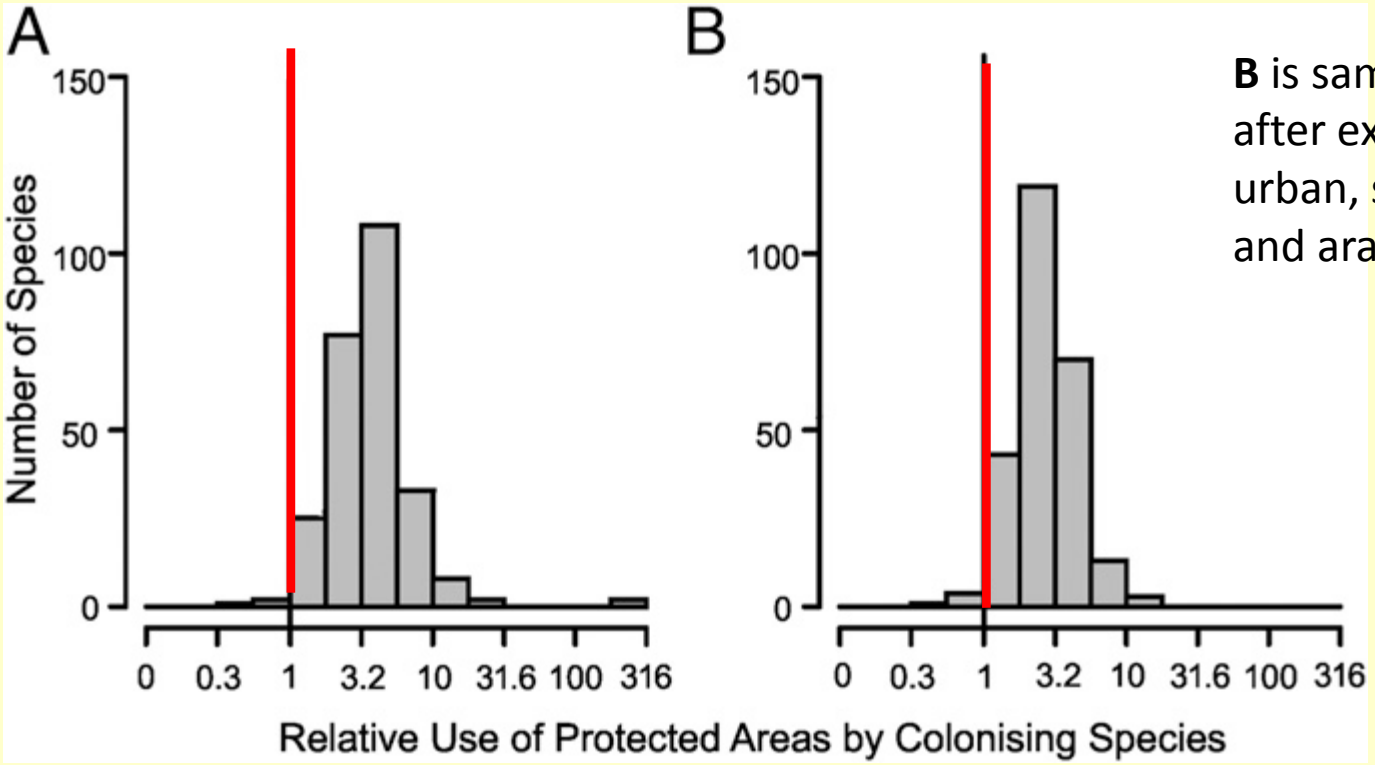
Use of PAs by colonists

Analysis of 256 invertebrate species



B is same as **A,** but after exclusion of urban, suburban, and arable land.

Value > 1 means species more likely to colonise PAs than expected from availability of PAs in the landscape. **Colonisations are disproportionately associated with Protected Areas.**

Thomas *et al.* (2012) PNAS 109, 14063–14068

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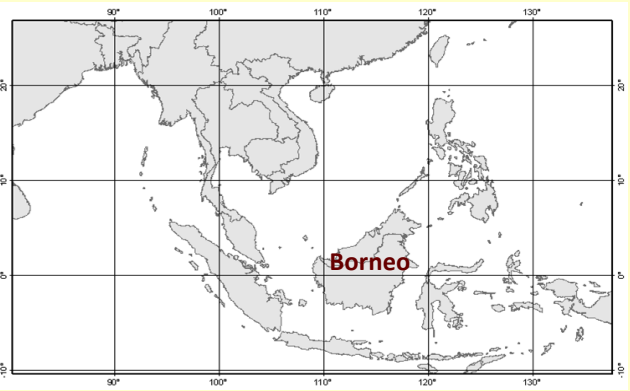
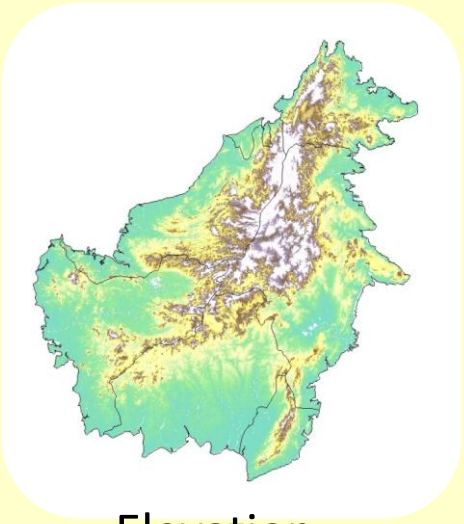
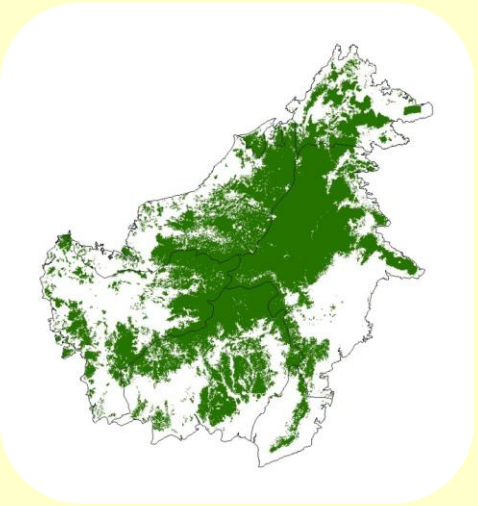
(ii) Location of tropical PAs

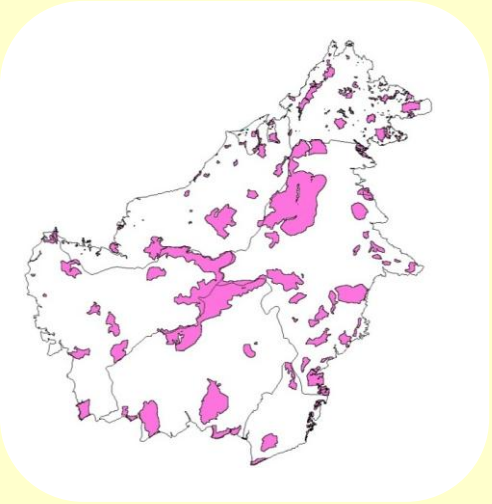




Elevation



Forest cover



Protected Areas

Forest (primary and selectively logged) covers ~50% of Borneo, and PAs cover ~16%

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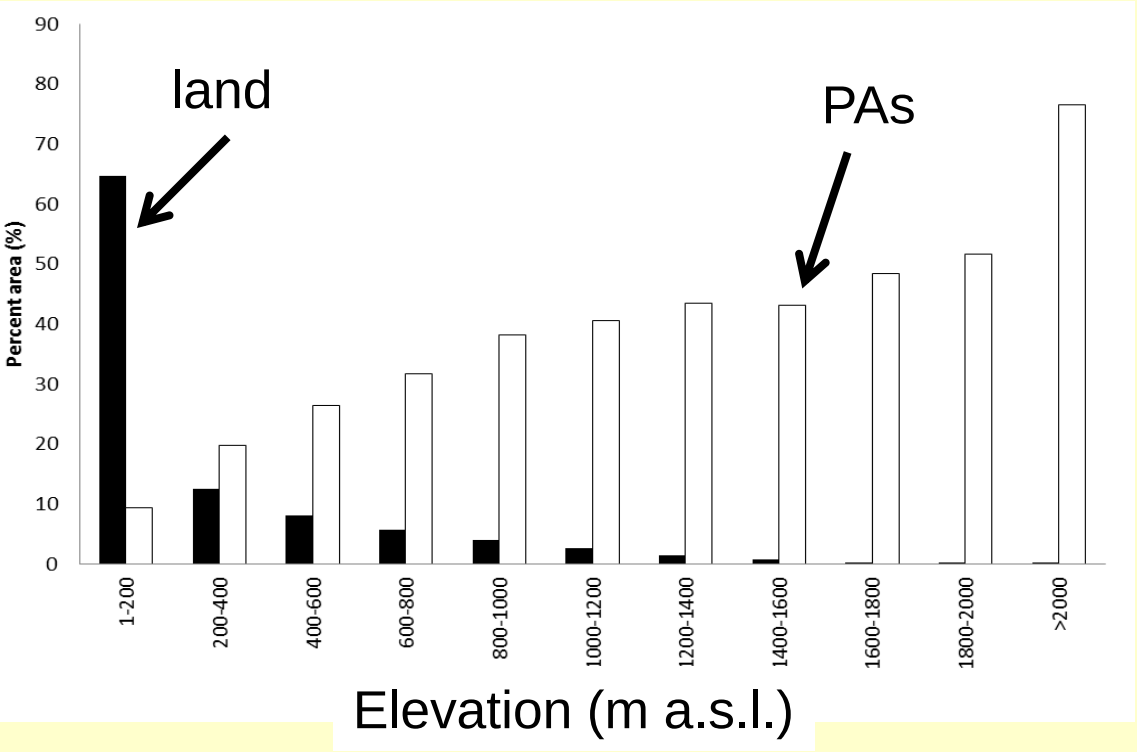
More high elevation land is protected

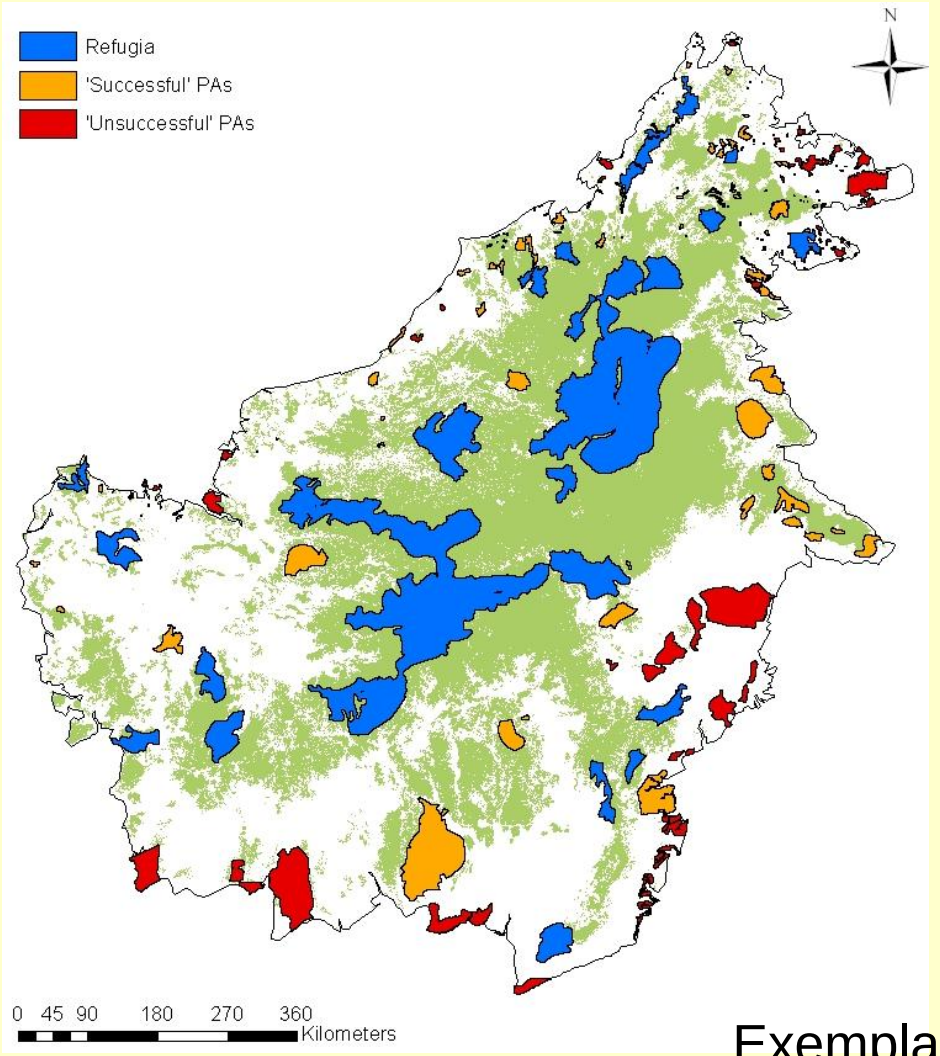


Most land on Borneo is at low elevation (black bars), but a greater proportion of protected land is at high elevation (white bars)

Can species reach cooler PAs?

- We assume species must move to PAs that are 3 deg C cooler (average warming of A2 scenario)
- Some PAs are topographically diverse and contain cooler areas – so no need to move - but other PAs do not contain cooler locations.
- We make assumptions about species dispersal ability, and include current forest availability, and we model species success at reaching new PAs
- Many low-lying PAs are too isolated for refugees to reach new habitats unless have v high dispersal ability.

Some PAs are isolated



Location of existing PAs and distribution of forest (green). PAs are either:

1. **Refugia** (blue) – move in situ,
2. **Successful** – movement out of PAs was successful and refugia were reached,
3. **Unsuccessful** – movements out of PAs failed to reach refugia (assuming ~2 km dispersal per generation).

Exemplar output for a species dispersing ~ 2 km per generation)

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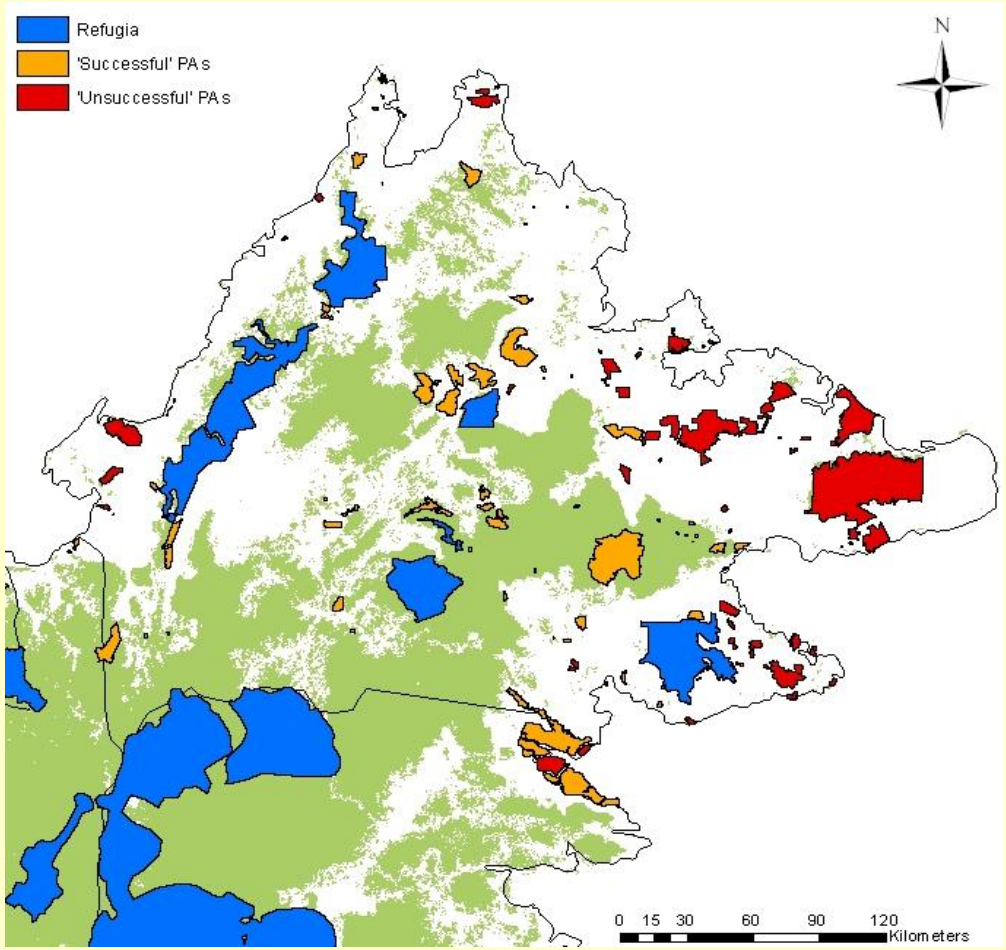
...especially in the State of Sabah

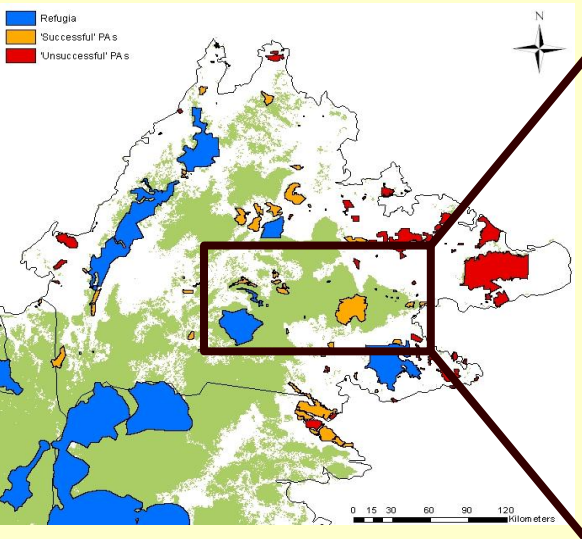


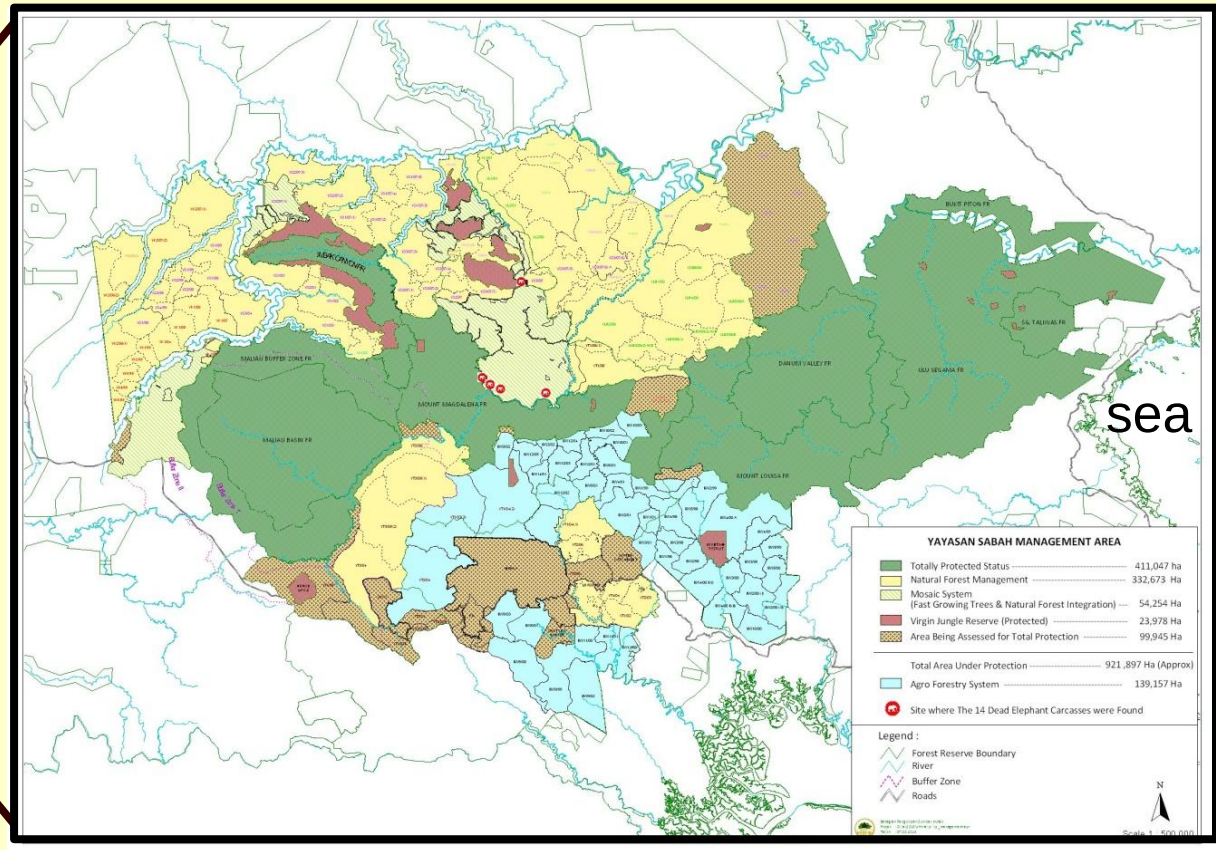
Many PAs may hold species that will not be able to reach new cooler PAs, necessary to track climate change (red PAs)

Improving forest cover in PAs helps.

Areas without current forest cover are mainly oil palm plantations

Elevation 'corridors'





Proposal to increase the status of forest areas (**brown**) to full protection (**green & purple**), and to provide a forest corridor from sea level to high elevation (1600m a.s.l.). This landscape-scale change was possible because the entire area is State land.

Conclusions

- Species are shifting their distributions up hill and polewards. ‘Biotic attrition’ may occur in low elevation tropical locations. Translocations?
- Habitat creation to increase connectivity may help range expansion, and range shifts uphill. But may primarily help those species that are already doing OK
- PAs facilitate range expansion at leading edges of distributions, but low elevation PAs are very isolated in tropical regions
- Continue conservation management in existing PAs to boost local population abundance – management for habitat heterogeneity.

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Thank you...

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CEH

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Colin McClean
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I-Ching Chen
Academia Sinica

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