Environmental Health Division (EHD)

INSECTS: CLIMATE CHANGE, ECOSYSTEM SERVICES AND AGRICULTURAL BIODIVERSITY

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African Insect Science for Food and Health

OUTLINE OF PRESENTATION

1. Importance of insects for functional agrobiodiversity and ecosystem services
2. Current knowledge on insect responses to climate change
3. Knowledge gaps and research opportunities

INSECT ECOSYSTEM SERVICES

Insects contribute to 7 of the 17 Ecosystem Services recognised by Turner et al 2007:

1. Food production
2. Soil formation
3. Nutrient cycling
4. Pollination
5. Biological control
6. Waste treatment
7. Raw materials

Insects contribute to 11 of the 21 agricultural benefits from biodiversity recognised by GEO4 2007:

1. Food and nutrients
2. Animal feed
3. Medicines
4. Fibres and cloth
5. Materials for industry
6. Pollination
7. Pest regulation
8. Soil formation
9. Nutrient cycling
10. Agricultural lifestyles
11. Genetic material reservoirs

50% of over 1700 wild species are already affected by climate change - Parmesan & Yohe 2003.

Key reference for insects

Menéndez R. 2007. How are insects responding to global warming? *Tijdschrift voor Entomologie,* **150**: 355–365

Phenology

Early adult emergence:

- Aphids in UK - Zhou et al. 1995, Harrington 2007
- Butterflies in UK, Spain, and California - Roy & Sparks 2000, Stefanescu et al. 2003, Forister & Shapiro 2003
- Microlepidoptera in the Netherlands - Ellis et al. 1997
- Odonata in the UK - Hassall et al. 2007
- Lepidoptera, Coleoptera, Diptera and Hymenoptera - Gordo & Sanz 2005

Phenology

Earlier larval emergence:

- Winter moth eggs hatching earlier in the Netherlands - Visser & Holleman 2001
- Eastern spruce budworm eggs hatching earlier in North America (inferred from model) – Visser & Both 2005

Earlier migration:

- Migratory aphids arriving earlier in the UK - Zhou et al. 1995, Harrington 2007
- Red Admiral arriving earlier in Britain - Sparks et al. 2005

Phenology: Generalities

- All recorded changes consistent with global warming trends
- Significant increase in the strength of advancement of spring events in the northern hemisphere with increasing latitude – Parmesan 2007.
- BUT latitude explained only 4% of overall variation of phenological changes – Parmesan 2007.

Distribution: Latitudinal Shifts

North expansions and south contractions in Northern hemisphere:

- Lepidoptera in Europe - Parmesan et al. 1999, Hill et al. 2002 , Franco et al. 2006, Mikkola 1997
- Checkerspot butterfly in North America - Parmesan 1996
- Sachem skipper butterfly in North America - Crozier 2003
- Garden Tiger Moth in UK - Conrad et al. 2002
- Odonata, Coleoptera, Neuroptera and Orthoptera in UK - Hickling et al. 2006

Distribution: Altitudinal Shifts

Uphill expansions and downhill contractions:

- Lepidoptera in Europe - Konvicka et al. 2003, Wilson et al. 2005
- Pine Processionary Moth in Italy and Spain - Battisti et al. 2005, Hódar & Zamora 2004
- Checkerspot butterfly in North America - Parmesan 1996
- Mountain Ringlet butterfly in UK – Franco et al. 2006;
- Mountain Apollo butterfly in the Alps - Descimon et al. 2006.
- Odonata, Coleoptera, Neuroptera, Heteroptera and Orthoptera in UK - Hickling et al. 2006

Expansion of tropical species into temperate areas

- Dragonflies from Cuba and the Bahamas to Florida (Paulson 2001)
- African Queen butterfly in Spain (Haeger 1999, García-Barros et al. 2004)
- Violet dropwing dragonfly into southern Europe (Bonet-Betoret 2004).

Distributional Changes: Generalities

- All recorded changes consistent with temperature changes: north and uphill expansion, south and downhill contraction
- Range expansions more frequently recorded than range contractions (artefact: absence harder to establish than presence?) - Menéndez 2007
- Altitudinal changes respond to tolerance of minimum and maximum temperatures but former rising at twice the rate of latter – Franco et al. 2006, Wilson et al. 2005, Crozier 2004

Microevolutionary responses

- Chromosomal-inversion polymorphisms in *Drosophila*: warm-adapted genotypes favoured in Europe. Australia, North and South America – refs in Menéndez 2007
- Pitcher-plant mosquito initiated diapause nine days later in US 1996 than in 1972 - Bradshaw & Holzapfel 2001
- Hostplant preferences in two butterfly species in US and Britain - Singer & Thomas 1996, Thomas et al. 1996, Thomas et al. 2001
- Colonisng genotypes favoured - Hill et al. 1999a, 1999b, Hughes et al. 2003, Simmons & Thomas 2004

Microevolutionary responses: Generalities

- Short generation times, large populations and high reproductive rates favour micro-evolutionary responses in insects
- Colonising genotypes favoured by range expansion - Hill et al. 1999, Hughes et al. 2003, Simmons & Thomas 2004
- Low genetic variation in tolerance of minimum temperatures may constrain microevolutionary responses – Crozier 2004
- No evidence yet for evolutionary responses at the species level (extinction, speciation) - Menéndez 2007

Species interactions

- Uphill expansion of Pine Processionary Moth led to utilisation of new tree hostplant - Hódar & Zamora 2004
- Maladaptive early hatching of winter moth eggs before oak leaf bud burst in the Netherlands - Visser & Holleman 2001
- Red admiral butterfly in Britain arriving before host plant flowers - Sparks et al. 2005
- Phenological mismatches in timing of bird migration and peaks in insect prey species – Vsser & Both 2005
- Two Lepidopteran stem borer species recently expanded from wild grasses to maize in Kenya (forced by habitat changes?) – Leru pers. com.

Species interactions: Generalities

- Trophic decoupling of food web phenology can outstrip evolutionary responses (prey - predator, plant - insect)
- Potential disruption of mutualisms (pollination)
- Potential biodiversity losses due to mismatches in response times to climate change between interacting species
- New trophic encounters and relationships can arise from expansions in distribution
- Modeling of tritrophic interactions (plant – herbivorous insect – parasitoid) suggests potential for pest outbreaks – Hance et al 2007

Species extinctions

None yet recorded, but:

- Local population extinctions reported for four species of butterflies in Britain at lower altitudes and latitudes – Franco et al. 2006
- Habitable areas for 16 mountain species in Spain reduced by one third - Wilson et al. 2005
- Modeling suggests that parasitoid extinctions could result from extreme weather events – Hance et al 2007

Community Changes

- Differential range expansions, phenological and evolutionary responses, interacting mismatches, and species extinctions will reshuffle communities
- Generalist butterflies in Britain better able to expand range than specialists - Menéndez 2007
- Butterfly communities in Spain show altitudinal shifts (+ 293 m) consistent with movements of annual isotherms (+225 m) - Wilson et al. 2007

Knowledge gaps and research opportunities

IPCC Report	Insect	Pest	Pollin-(ation)	Biodiver-sity
WG2.5: Food,Forests and Fibre	13	28	0	14
WG 2.4: Ecosystems, goods, services	18	9	1	3
WG 2.9: Africa	3	7	0	10
WG 2: Technical summary	7	6	0	21
WG 2: Policy Summary	2	2	0	20
TOTALS	43	52	1	68

Knowledge gaps and research opportunities

1. *Geographical:* IPCC summary of significant changes in biological systems that may be attributable to climate change from 1970 to 2004: **28,115 changes recorded in Europe, but only 2 for Africa.**
2. *Agrobiodiversity:* Despite clear evidence for climate change affecting wild insects, very few records exist re FAB
3. *Taxonomic:* Lepidoptera, especially butterflies, hugely over-represented in insect climate change research.
4. *Pollination:* Despite major economic impacts from pollinator losses (CCD in US), very little research on effects of climate change on pollinators.
5. *Monitoring actual changes:* Some FAB modeling but very few (none?) long term FAB monitoring programmes in place

Knowledge gaps and research opportunities

1. FAB monitoring against existing model predictions for spread of invasives, e.g. stemborers.
2. Understanding multitrophic interactions in climate change context – plant/herbivore, pest/parasitoid, predator/prey
3. FAB monitoring to detect distributional shifts in ecotones - montane ecosystems act as biotic thermometers and proxies for climate change
4. Phenological monitoring across crop-pest-natural enemy food chains to detect emerging mismatches
5. Monitoring of host shifts and agrobiodiversity exchanges between cultivated and natural habitats