Climate change, biodiversity and ecosystem service provision through time and space
1980/90s
Biodiversity conservation prioritisation schemes

WWF Ecoregions
Millennium Ecosystem Assessment
(MA, 2005, www.maweb.org)

- MEA changed the political landscape for biodiversity conservation
- Highlighted the importance of biodiversity and ecosystems to human livelihoods
- Where ecosystem services are “the set of ecosystem functions that are useful to humans” (Kremen, 2005)
- Biodiversity and ecosystems viewed as an economic commodity
Millennium Ecosystem Assessment Framework

MA 2005 Volume 1 Current State and Trends
Ecosystem services framework

- Provisioning
- Supporting
- Regulating
- Cultural
- Ecosystem Services
Spatial concordance of global biodiversity priorities and ecosystem service value

Turner et al, 2007 BioScience Vol. 57 No. 10

Green: ecosystem service value
Red: biodiversity priority
White: low values of both
Black: high values of both
• Established in April 2012, as an independent intergovernmental body open to all member countries of the United Nations.

• IPBES aims to become the leading intergovernmental body for assessing the state of the planet's biodiversity, its ecosystems and the essential services they provide to society.
Knowledge gaps

1. Understanding how ecosystem processes vary in time and space
2. Understanding how final ecosystem services are influenced by changes in ecosystem processes
3. Understanding the factors that lead to sustainable supply of ecosystem goods
Key knowledge gap

Longest temporal dataset used in Millennium Ecosystem assessment <50 years...
How can palaeo-data contribute to knowledge on ecosystem service provision in space and time?

Talk outline

- Ecosystem processes:
  - Changes in biomass
  - Nutrient cycling

- Final Ecosystem services:
  - Crops

- Sustainability of ES through time
  - Persistence
  - Recovery rates
1. Trends in biomass

- What is the variability in land-cover over time?
- How is this related to changes in biomass?
Determining land-cover change using pollen data

Theory of quantitative reconstruction of vegetation I: pollen from large sites
REVEALS regional vegetation composition
Shinya Sugita
(Department of Ecology, Evolution and Behavior; University of Minnesota, St Paul, MN 55108, USA)

Theory of quantitative reconstruction of vegetation II: all you need is LOVE
Shinya Sugita
(Department of Ecology, Evolution and Behavior; University of Minnesota, St Paul, MN 55108, USA)

Holocene land-cover reconstructions for studies on land cover-climate feedbacks
M.J. Gaillard1, S. Sugita1, P. Mazier1, A.K. Treudmain1, A. Broström1, T. Hickler1, J.O. Kaplan1, E. Kjellström1, U. Kukfle1, P. Kunet1, C. Lamme1, P. Miller1, J. Olefonsos1, A. Pecka1, M. Rundgren1, B. Smith1, G. Strandberg1, R. Fyfe1, A.B. Nielsen1, T. Alemas1, L. Balaskas1, L. Barakow1, H.J.B. Birks1, A. Bjune1, L. Björkman1, T. Gieske1, K. Hjelle1, L. Kalius1, M. Kangur1, W.O. van der Kaap1, T. Koff1, P. Lagerkr1, M. Latafows1, M. Leydet1, J. Lechterbeck1, M. Lindblad1, B. Odgaard1, S. Pegg1, U. Segerström1, H. von Stedingk1, and H. Seppa1

Mapping Ancient Forests: Bayesian Inference for Spatio-Temporal Trends in Forest Composition Using the Fossil Pollen Proxy Record
Christopher J. Paciorek and Jason S. McLachlan
Thresholds of Potential Concern as benchmarks for the management of African savannas

• Kruger National Park management plan incorporates the concept of natural variability

• Intervention will occur when woody cover has decreased below 80% of its “highest ever value”

• This 80% threshold set by ecosystem managers to define the upper and lower level of accepted variation in this ecosystem.

Sediment cores collected from pans in the north of the KNP
Fossil pollen analysis and translation to long-term vegetation change in the KNP

1. Changes in fossil pollen over time
2. Investigating the pollen-vegetation relationship
3. Changes in vegetation over time

Diagram:
- Palaeo-pollen data
- Modern pollen data
- Modern Vegetation data
- Simulated pollen data
- Simulated vegetation data
- Palaeo-woody vegetation cover
- Link equation
Results: Estimated woody cover at Mafayeni
Conclusions and Implications for Management

- During the past 2000 years, the estimated woody vegetation land-cover has never fallen below 80% of its “highest ever value”
- Management intervention in these locations in the park is unnecessary at present

Conversion of fossil pollen data into biomass measurements

Modern biomass (volume m$^3$ ha$^{-1}$) of *Picea abies* in Fennoscandia

Table 1. The modern PAR (grains cm$^{-2}$ year$^{-1}$) and biomass values of *Picea abies* in Finland and Sweden, at sites ranging from *P. abies*-dominated southern boreal forest to beyond the northern distribution limit of *P. abies* in northern Fennoscandia. The modern *P. abies* above-ground biomass values (t ha$^{-1}$) were obtained from the National Forestry Inventory Statistics and are shown for zones ranging from 500 to 4500 m measured from the shores of the lakes (Seppä *et al.* 2009). The modern PAR value is defined as the average of the last 150 years.

<table>
<thead>
<tr>
<th>Site</th>
<th>Latitude (North)</th>
<th>Longitude (East)</th>
<th>Size (ha)</th>
<th>Modern PAR</th>
<th>Modern biomass 500 m range</th>
<th>Modern biomass 1000 m range</th>
<th>Modern biomass 4500 m range</th>
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<tr>
<td>Laihalampi</td>
<td>61°29′18″</td>
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<td>5</td>
<td>0</td>
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</table>

PAR = pollen accumulation rates

Enables determination of changes in biomass of *Picea* associated with climatic change
2. Trends in nutrient cycling

What is the relationship between nutrient cycling, climate change and human impact?
Progressive Nitrogen Limitation Hypothesis

Hypothesis: Increased atmospheric CO$_2$ leads to N limitation

i) Increased plant demand for N

→ increased plant uptake of N (then stored in woody biomass)
  → depletes labile N pool in soil

ii) Increased microbial C availability in soils

→ increased biosynthetic demand for N by microbes
  → depletes N availability to higher plants

History of terrestrial N availability detected in record in $\delta^{15}$N from 857 tree-ring wood segments (22 trees)

- Declining $d^{15}$N values and total N
- Other studies indicate shift often pre-dates high anthropogenic N deposition


Mirror Lake watershed, US
Global Synthesis of $\delta^{15}$N Records in lake sediments

3. Trends in final ecosystem services

Where will be the best regions for economically valuable species in relation to future climate change?
Where will biota move to in response to climate change?

Song thrush (*Turdus philomelos*)

Future distribution changes calculated using species distribution models

Blue = gain
Turquoise = overlap
Red = Loss
Species distribution models (SDMs)

- Are highly sensitive to the ‘assumptions, algorithms and parameterizations of different methods’ (Araújo et al., 2005)

- Assume equilibrium between species and their environment

- Understanding the percentage of error in the predictions is an area where temporal studies have much to offer

- Through the backward prediction of the models (hind-casting) accuracy of the models can be tested
Testing the accuracy of SDMs for economically valuable species in Europe

• Devised a methodology to hindcast SDMs for 7 economically valuable Europe tree species

• Three climatically distinct periods considered:
  – Medieval Warm Period (A.D. 900-1300)
  – Little Ice Age (A.D. 1600-1850)
  – 20th Century warming.

• Modelled distribution compared against actual distribution as displayed in European fossil pollen database

Species distributions examined:

- *Abies alba*
- *Fagus sylvatica*
- *Quercus ilex*
- *Castanea sativa*
- *Olea europaea*
- *Picea abies*
- *Vitis vinifera*.

For each species, distribution modelled using SDMs (8 models tested) + palaeoclimatic data from the coupled General Circulation Model ECHO-G.

Ensemble species distribution projections for 20$^{th}$C warming over a 1° grid

Predicted distribution using suite of species distribution models

Actual distribution as evidence from fossil pollen

Abies alba

Fagus sylvatica
Results:

- High model performance statistics in all cases

- A tendency to a decrease in performance (but still high) in more human-managed species distributions (e.g. *Vitis vinifera, Olea europaea*)

- Future predicted modelling of these species in Europe using SDMs is robust

- Results also demonstrates individual characteristics of species e.g. rates of response to climate warming
e.g. *Picea abies*, southern range expansion in LIA, southern range contraction in MWP and 20\textsuperscript{th}C
4. Sustainability of ecosystem services

Which landscapes contain provide the persistent ecosystem services despite climatic perturbations?

What factors (biotic, abiotic) lead to persistence /loss of ecosystem services?
Thresholds and resilience of the Madagascar’s coastal forest in response to sea-level change

K.J. Willis et al., 2007, Phil Trans Roy Soc B., 362, 175.
Fragmentation, resilience and recovery of Madagascar’s littoral forest to late Holocene sea level rise

Holocene sea-level rise in Madagascar

From: Camoin et al., 2004, Camoin et al., 1997, Battistini, 1976
Open Upaca woodland – once threshold passed converted to heathland

Littoral forest: more resilient to original disturbance & returning to forest

Two sites in Madagascar ~5km apart undergoing same environmental perturbations (sea-level rise, aridity)
Summary

• Palaeo-records offer vast potential in addressing knowledge gaps relating to ecosystem service provision in time & space
• With a few exceptions this potential has yet to be realised by international community
• Much excellent relevant work on-going but need to reframe and also consider what temporal and spatial scales are most relevant to measure ES
• PAGES & wider palaeo-community need to be involved in IPBES from the outset...