In employing plants and/or animals to reconstruct past climates and environments, each organism or assemblage is in this way referred to as a proxy record or proxy indicator.
This lecture aims to …

Examine the usefulness of land snails as a tool in palaeoenvironmental research in the north Queensland region by,

• introducing non-marine molluscan research overseas and in Australia

• testing the relationship between variations in land snail shell size and climatic conditions through a modern control test

• via fossil test sites, provide a palaeoenvironmental record for the Chillagoe region and examine the nature and timing of such a record against established palaeo-sequences
• The phylum Mollusca is the second largest of the animal kingdom, after the arthropods
• Molluscs are soft-bodied animals without body segmentation, with a hard external calcareous shell for protection
• The Gastropods are the only class of molluscs to have conquered the land
• Key biological feature for use in environmental reconstruction: sensitivity to moisture regimes
• Habitat and behavioural traits are largely controlled by local moisture patterns and vegetation systems
• Close tie to vegetation communities
• Identifiable to species
• Visible in the field
• Present/abundant in numerous depositional contexts
Understanding palaeoenvironmental use …

• Qualitative and quantitative methodological approaches
• Use of modern ecological requirements to understand the environment of fossil individuals or assemblages
• Division of taxa into ecological categories
• Absolute numbers or the relative abundance – and the changing proportions through time
The use of land snails in Australia can be informed on their value and application in the UK

• Study of gastropod molluscs from archaeological deposits began in the 19th century – but much early work was concerned with taxonomy
• Mid 20th century, and molluscs became associated with palaeoclimatic reconstructions and as a means of identifying geological events
• Adopted in recognition of the limitation of pollen (geographically)
• Various scales (temporal and spatial) of analysis …
  a signature within sediment horizons, assisting in the distinction between interglacial, interstadial and glacial stages
  fine-grained determinations in understanding the timing/extent of human vegetation and landscape change
Buckskin Barrow (Hampshire) … changing frequencies of molluscan faunas
Southernhan Grey Pit (Caburn) … mollusc histogram
Land snail analysis in Australia (archaeology and palaeoecology)

• Not a lot of information by way of example. Stanisic and Ingram (1998) consider invertebrates as an ill-considered populace
• Site reports concentrate on artefacts and vertebrate fauna
• Examples do include …

Warren Cave, southwest Tasmania: land snails employed to provide a local palaeoenvironmental record as context for archaeological research. Three phases of vegetation change identified from the last glacial max

Pulbeena Swamp, northwestern Tasmania: use of land snails to inform on the presence of open environments during the glacial maximum

Echidna’s Rest, northeast Queensland: land snails recovered from an archaeological deposit and classified as dry or wet adapted taxa to reveal broad climatic trends during the Holocene
Land snail analysis in Australia … why the lack of use?

- Inadequate ecological and taxonomic knowledge surrounding modern land snail taxa: Australian land snails are poorly known
- Australia maintains a high level of molluscan diversity in comparison with the UK. This diversity, however, over-rides abundance.
- Small land snails lost through archaeological sampling methods, leaving behind a biased sub-sample
- People vs climate question. In the UK people have been responsible for changes in vegetation, with climate influences minor in comparison. The degree to which vegetation communities have changed with time in Australia is not of the scale to which change occurred in the UK: do we know how Australian land snails respond to subtle shifts in the landscape?
The learning curve of land snail analysis in Australia … additional considerations/cautions

- Stratigraphic considerations (1): soil sample and subfossil assemblage vs death assemblage vs living community and environment

1= stages in the formation of a subfossil assemblage
2= stages in analysis and interpretation
3 = factors controlling composition of snail communities
The learning curve of land snail analysis in Australia …
additional considerations/cautions

- Stratigraphic considerations (2): where sediment profiles may have been altered, eroded or obscured, to the extent that stratified data may no longer reflect prehistoric or palaeoenvironmental patterns. Consider …
  - the erosion of fine particles
  - physical damage through shell travel via erosion
dilution through deposition
- Biological considerations: relative abundance of individual taxa within a community is (in part) controlled by hereditary factors. Consider …
  - ratios btw taxa may be a function of patterns of reproduction (prolific or not)
  - thin-shelled taxa vs robust shells
  - (ability following burial to withstand chemical/mechanical pressures)
Study region: northeastern Queensland and the Chillagoe Formation
### Rainfall figures for Mitchell-Palmer

<table>
<thead>
<tr>
<th></th>
<th>jan</th>
<th>feb</th>
<th>mar</th>
<th>apr</th>
<th>may</th>
<th>jun</th>
<th>jul</th>
<th>aug</th>
<th>sep</th>
<th>oct</th>
<th>nov</th>
<th>dec</th>
<th>total</th>
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<tbody>
<tr>
<td>Palmerville mean (mm)</td>
<td>260</td>
<td>259</td>
<td>183</td>
<td>49</td>
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<td>5</td>
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<td>Bellevue mean (mm)</td>
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<td>72</td>
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<td>2</td>
<td>3</td>
<td>6</td>
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### Rainfall figures for Chillagoe-Mungana

<table>
<thead>
<tr>
<th></th>
<th>jan</th>
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<th>mar</th>
<th>apr</th>
<th>may</th>
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<th>nov</th>
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<td>Rookwood mean (mm)</td>
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<td>210</td>
<td>130</td>
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<td>8</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>12</td>
<td>64</td>
<td>128</td>
<td>850</td>
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<tr>
<td>Chillagoe mean (mm)</td>
<td>219</td>
<td>213</td>
<td>141</td>
<td>30</td>
<td>14</td>
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<td>4</td>
<td>4</td>
<td>5</td>
<td>15</td>
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<td>140</td>
<td>854</td>
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<tr>
<td>Almaden mean (mm)</td>
<td>226</td>
<td>193</td>
<td>137</td>
<td>34</td>
<td>16</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>8</td>
<td>18</td>
<td>67</td>
<td>132</td>
<td>852</td>
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<tr>
<td>Chillagoe mean # rain days</td>
<td>16</td>
<td>15</td>
<td>9</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<td>1</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>64</td>
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The selection of a suitable land snail proxy

- The first step is a control test – the collection and analysis of modern specimens in order to gain an insight into the relationship between land snail and climate
- Numerous land snail species are known from the Chillagoe Formation

<table>
<thead>
<tr>
<th>Species</th>
<th>Family</th>
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<tbody>
<tr>
<td><strong>Tarocystis antiqua</strong></td>
<td>(Family Helicanionidae)</td>
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<tr>
<td><strong>Gastrocepta biformata</strong></td>
<td>(Fam. Pupillidae)</td>
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<tr>
<td><strong>Xanthomelon pachystylum</strong></td>
<td>(Fam. Camaenidae)</td>
</tr>
<tr>
<td><strong>Discocharopa aperta</strong></td>
<td>(Fam. Charopidae)</td>
</tr>
<tr>
<td><strong>Pleuropoma extincta</strong></td>
<td>(Fam. Helicinidae)</td>
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<tr>
<td><strong>Gastrocepta pediculus</strong></td>
<td>(Fam. Pupillidae)</td>
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<tr>
<td><strong>Tolgachloritis jacksoni</strong></td>
<td>(Fam. Camaenidae)</td>
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<tr>
<td><strong>Pupoides pacificus</strong></td>
<td>(Fam. Pupillidae)</td>
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<tr>
<td><strong>Georissa sp.</strong></td>
<td>(Fam. Hydroconidae)</td>
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<tr>
<td><strong>Gastrocepta musseri</strong></td>
<td>(Fam. Pupillidae)</td>
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<td><strong>Melostrachia glomerans</strong></td>
<td>(Fam. Camaenidae)</td>
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<tr>
<td><strong>Mussonene campbelli</strong></td>
<td>(Fam. Camaenidae)</td>
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<tr>
<td><strong>Glyliotrachela australis</strong></td>
<td>(Fam. Pupillidae)</td>
</tr>
<tr>
<td><strong>Gastrocepta servilis</strong></td>
<td>(Fam. Pupillidae)</td>
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<tr>
<td><strong>Spurlingia gemma</strong></td>
<td>(Fam. Camaenidae)</td>
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<tr>
<td><strong>Stenophylis coarctata</strong></td>
<td>(Fam. Helicodiscidae)</td>
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<td><strong>Charopidae spp.</strong></td>
<td>(Superfamily Ariorodae)</td>
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<td><strong>Eremonpean tuckeri</strong></td>
<td>(Fam. Subulinidae)</td>
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<tr>
<td><strong>Spurlingia prachadra</strong></td>
<td>(Fam. Camaenidae)</td>
</tr>
<tr>
<td><strong>Glytopupoides egregia</strong></td>
<td>(Family: Pupillidae)</td>
</tr>
</tbody>
</table>
The selection of a suitable land snail proxy

• The first step is a control test – the collection and analysis of modern specimens designed to provide insights into the relationship between land snail and climate
• Numerous land snail species are known from the Chillagoe Formation
• From the list of known species – narrow down to one suitable candidate
• Require a set of criteria for selection … the snail proxy needs to,
  1) Be shared btw the two areas of study
  2) Show a biological sensitivity to changes in climate, and
  3) Such an environmental response requires to in some way be easily measured and analysed
  4) Be resistant to weathering and breakage with burial
  5) Be a species which does not burrow
  6) Be available in sufficient numbers

• In meeting all such criteria *Pleuropoma extincta* was chosen as a potential proxy indicator of palaeoenvironments
Pleuropoma extintcta

- Prosobranch gastropod snail, not a pulmonate
- A small species: approx 2 – 6mm in diameter and 2 – 5.5mm in height
- top shaped
- sculpture with obvious spiral-cords
- periphery is angulate
- shell is relatively thick
- widely distributed in study region
- obligate vine-thicket dweller
- distributed in vine-thicket patches now separated by sclerophyll vegetation
- limestone a secondary habitat
Pleuropoma extincta … what to measure?

• Goodfriend (1986) notes numerous studies documenting geographical variation in shell form, and on the relationship of shell form to environmental influences: most shell form is environmentally induced

• Shell height, width, whorl number, colour and thickness can vary – environmental moisture characteristics are the most documented correlate

• Greater moisture levels produce a larger adult size by increasing the growth rate of snail and shell.

• Importantly, a larger adult shell size occurs through whorl expansion

• In *P. extincta*, size varies according to the length and quality of feeding activity during growth from juvenile to adult, over a period of two wet seasons

• In *P. extincta*, an interrupted or reduced moisture supply during the growth phase can lead to adults with lower whorl numbers and shell size
Pleuropoma extintcta ... methods

- Hand collection of specimens from numerous sites within the Mitchell-Palmer and Chillagoe-Mungana areas
- At the microscope specimens were categorised as adult, juvenile or unclear
- Whorl number, shell height and shell width measured to nearest 0.05mm
- A total of 1144 adult shells measured
- From measurements, mean and standard deviations calculated for each site and region; numerical range also noted
- Regression analysis performed to describe and quantify relationships btw measurements
Regional results … relationship between parameters for Chillagoe Formation

In the one regional analysis a strong positive correlation is evident btw each parameter
Sub-regional results … Chillagoe-Mungana vs Mitchell-Palmer

**Chillagoe-Mungana**

\[ y = 0.7477x + 1.3932 \]

\[ R^2 = 0.0735 \]

**Mitchell-Palmer**

\[ y = 0.9996x + 0.8938 \]

\[ R^2 = 0.2227 \]
Sub-regional results … Chillagoe-Mungana vs Mitchell-Palmer

Chillagoe-Mungana

\[ y = 0.8628x - 0.3298 \]
\[ R^2 = 0.153 \]

Mitchell-Palmer

\[ y = 1.4084x - 2.0885 \]
\[ R^2 = 0.4352 \]
Sub-regional results … Chillagoe-Mungana vs Mitchell-Palmer

Chillagoe-Mungana

\[ y = 0.8512x + 1.726 \]
\[ R^2 = 0.4637 \]

Mitchell-Palmer

\[ y = 0.7283x + 2.2981 \]
\[ R^2 = 0.539 \]
Sub-regional results … Chillagoe-Mungana vs Mitchell-Palmer

- Measurements from the two regions are clearly separated
- The data indicate that the average largest shells and highest average whorl counts occur among the Mitchell-Palmer specimens
- Height and diameter correspond to an increment of over 1.0mm and whorl count is greater by half and whorl
- Less variation apparent btw local collection sites than sub-regions

Meaning,

- Evidence of greater extrinsic (external) rather than intrinsic (internal) factors at work
- Differences in mean shell size between Mitchell-Palmer and Chillagoe-Mungana correlate with differences in the local rainfall regime btw the two areas
- Chillagoe-Mungana has lower average annual rainfall and number of rain days
- The analysis of *P. extincta* shell features has the potential to contribute to palaeoenvironmental reconstructions
Fossil test sites ... application to archaeological assemblages

Hay Cave
Fossil test sites … application to archaeological assemblages

Mitchell River Cave
Fossil test sites … radiocarbon dating results

- Eight dating samples (charcoal and freshwater mussel shell) collected from Hay Cave and five from Mitchell River Cave

<table>
<thead>
<tr>
<th>Site</th>
<th>XU</th>
<th>Depth (cm)</th>
<th>Age (BP)</th>
<th>Lab no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay Cave</td>
<td>XU2</td>
<td>1.4</td>
<td>350±55</td>
<td>Wk-6053</td>
</tr>
<tr>
<td>Hay Cave</td>
<td>XU6</td>
<td>8.0</td>
<td>660±75</td>
<td>OZD-006</td>
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<tr>
<td>Hay Cave</td>
<td>XU12</td>
<td>17.1</td>
<td>870±65</td>
<td>OZD-007</td>
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<tr>
<td>Hay Cave</td>
<td>XU26</td>
<td>46.0</td>
<td>2,590±80</td>
<td>OZD-008</td>
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<tr>
<td>Hay Cave</td>
<td>XU34</td>
<td>64.0</td>
<td>3,100±60</td>
<td>OZD-009</td>
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<td>XU45</td>
<td>91.0</td>
<td>13,450±150</td>
<td>OZD-011</td>
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<tr>
<td>Hay Cave</td>
<td>XU49</td>
<td>102.8</td>
<td>13,600±180</td>
<td>OZD-422</td>
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<tr>
<td>Hay Cave</td>
<td>XU56</td>
<td>118.2</td>
<td>19,300±140</td>
<td>OZD-012</td>
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<td>Mitchell R. Cave</td>
<td>XU2</td>
<td>5.1</td>
<td>930±70</td>
<td>Wk-1717</td>
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<tr>
<td>Mitchell R. Cave</td>
<td>XU4</td>
<td>12.6</td>
<td>1,140±100</td>
<td>Wk-1718</td>
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<td>Mitchell R. Cave</td>
<td>XU9</td>
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<td>13,208±68</td>
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<td>?</td>
<td>18,610±110</td>
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<tr>
<td>Mitchell R. Cave</td>
<td>XU17</td>
<td>67.8</td>
<td>15,910±200</td>
<td>NZA-1556</td>
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</table>
Fossil test sites … shell per excavation unit

XU: Mitchell River Cave

Land snail shell (g)

XU: Hay Cave

Land snail shell (g)
Fossil test sites … material per excavation unit (Hay Cave)

- CaCO$_3$ concretions observed as inorganic indicators of water supplied to the study site. Precipitated out of water upon entering the cave and deposited
Fossil test sites … *Pleuropoma extincta* at Hay Cave

- 295 adult shells recovered
Fossil test sites … *Pleuropoma extincta* at Mitchell River Cave

- 970 adult shells recovered
Reconstruction of palaeoenvironments for the Chillagoe Formation

Prior to 18,600 years BP

- Mitchell River Cave only
- Measurements show small shell sizes and low whorl counts, and a low overall weight of shell per excavation unit
- Trends suggest dry climatic environs (low precipitation and humidity level)
- Prominent dry-adapted vegetation (sclerophyll) and a restricted distribution of rainforest habitat

- Consistent with estimates of environments across northern Australia and Queensland at the last glacial maximum
- Increased continentality and reduced ocean temps suppressing precipitation
- Dry continental southerly and southeasterly winds
- Sclerophyll woodland communities at the Atherton Tablelands: Poaceae, Myrtaceae, *Casuarina* and *Callitris* pollen recorded
Reconstruction of palaeoenvironments for the Chillagoe Formation
18,600 to 13,200 years BP

• Sequence of results indicate two phases – a transitional period
• Initial low land snail shell and CaCO$_3$ concretions per XU, and lower shell measurements, followed by,
• A shift toward greater shell and CaCO$_3$ weight and an escalation in shell size
• Dry environs of the previous phase at first maintained, after which environments for *Pleuropoma* began to improve.
• Sclerophyll vegetation present, subject to invasion by rainforest habitat
• Data supports yet conflicts with existing information
• Rainforest development varies according to site at the Atherton Tablelands; broad expansion not recorded until the Holocene
• A lag in vegetation response? *Pleuropoma* responding quickly?
• Chillagoe Formation aligned to a greater extent with changes as they occur in the Gulf of Carpentaria; the initiation of Lake Carpentaria
Reconstruction of palaeoenvironments for the Chillagoe Formation

13,200 to 3100 years BP

• Larger, including peak, shell measurements at both sites, along-side a greater record of shell and CaCO$_3$ concretions per XU

• Environmental conditions in the study region were wettest btw 13,200 and 3100 yr BP, supporting maximum development of rainforest thus expanding the *Pleuropoma* habitat.

• High year-to-year environmental stability for *Pleuropoma*; consistent wet-seasons suggested

• Incorporating a record of the Holocene climatic optimum, as referenced in other sites in northern Australia

• Consistent with pollen records from the Atherton Tablelands; at numerous sites a maximum rate of rainforest increase, with taxa typical of lower montane rainforest. Suggestive of widespread rainforest across northern Queensland

• Rising and highstand sea-levels (reduced continentality) promoting an increase in precipitation and reduced seasonality.
Reconstruction of palaeoenvironments for the Chillagoe Formation
3100 to 350 years BP

• Reduction in CaCO₃ and land snail weight per XU
• Decline in shell measurements (although an increase in shell size evident at Mitchell River Cave in the last 1000 years)
• A drying of climatic conditions occurred at the Chillagoe Formation in the last 3000 years, with some site-to-site variability. Environments not as dry as at the last glacial maximum
• Trends suggest a loss of vegetation cover through a decline in rainforest habitat. Sclerophyll (eucalypt) distribution increases to that of today
• Populations of *Pleuropoma* isolated in now separated patches of habitat
• Consistency with existing palaeoenvironmental records is maintained, which suggest overall drier conditions or increased seasonality
• Pollen assemblages include greater eucalypt and Poaceae percentages
• Lower lake levels and reduced availability of surface water
• ENSO related disturbance
• Promotion of fire events
Land snails as palaeoenvironmental indicators ... conclusions

• The presence and value of land snails in archaeological deposits was recognised more than a century ago, yet their detailed investigation has only recently begun in Australia.

• Australian studies of fossil land snail shell requires greater taxonomic and ecological studies of modern molluscs to be undertaken.

• Given *Pleuropoma extincta*’s, modern and fossil abundance ability to be identified to species demonstrated value as a proxy indicator of measurable environmental sensitivity palaeoenvironments in strong affinity to rainforest vegetation types north Queensland.

• In using *P. extincta* it has been possible to examine environmental change in the Chillagoe Formation for almost the last 20,000 years.

• North Queensland was subject to considerable environmental variability; region-to-region changes were of a similar trend but not entirely synchronous not of an equal degree.

• *P. extincta* highlights the vine thickets of the Chillagoe Formation were once part of a more extensive flora and may require conservation/management efforts in the future.