Evolutionary paleoecology and the biology of extinction

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Introduction and theory

Brachiopods, environmental preference, and extinction

Ecology and survival in Cenozoic mammals

Community connectedness in Cenozoic mammals

Framework

Questions

- Why do certain taxa go extinct while others do not?
- How is emergence "formed?" When should it be invoked?
- Is extinction risk taxon–age independent?
- When should we expect global, regional, or local processes to dominate?

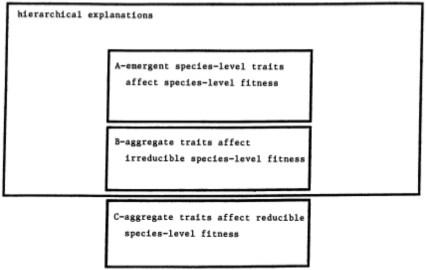
Evolutionary paleoecology

. . . the consequences of distinct ecological factors on differential rate dynamics, particularly rates of faunal turnover and diversification.

(Kitchell 1985 Paleobiology)

ecological interactions $\rightarrow$ macroevolution

Emergent properties



(Grantham 1995 Ann. Rev. Ecol. Syst.)

Species level

Trait that cannot be reduced to organismal level

Product of one or more traits/factors

Range size

Large range size means lower origination and extinction rates than small range size.

Range size is emergent

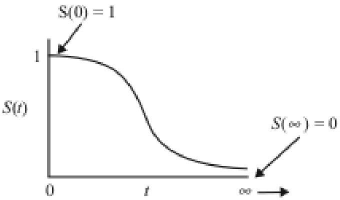
Probability of survival

Survival function

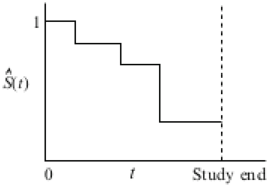
$$S(t) = P(T > t)$$

- T: survival time (≥ 0)
- t: specified time

Theoretical $S(t)$:



$\hat{S}(t)$ in practice:



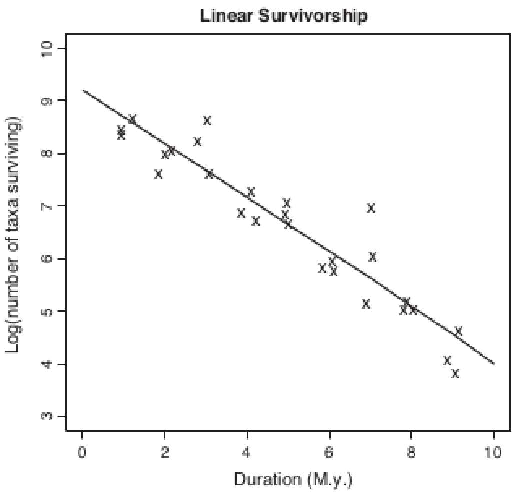
(Kleinbaum and Klein 2012)

Instantaneous potential of failure (extinction)

Hazard function $\equiv$ conditional failure rate

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t | T \geq t)}{\Delta t}$$

Van Valen's observation of survival



(Liow et al. 2011 TREE)

Law of Constant Extinction

Definition

Extinction risk in a given adaptive zone is taxon–age independent.

(Van Valen 1973 Evol. Theory)

translation: hazard is constant with respect to time (exponential)

$$h(t) = \lambda \iff S(t) = \exp^{-\lambda t}$$

Brachiopods and mammals: a comparison

brachiopods

- Permian ($\sim$ 47 My)
- marine
- Australasia
- global warming
- sessile

mammals

- Cenozoic ($\sim$ 65 My)
- terrestrial
- North America, Europe, South America
- global cooling
- motile

Series of related questions

- generic level survival in brachiopods
  - effect of ecological traits (emergence)
  - distribution of survival
- specific level survival in mammals
  - generic versus specific survival
  - anagenesis/species:genus simulation
  - distribution of survival
- community connectedness in mammals
  - global versus regional versus local scale processes

Traits relating to environment and range size

- substrate affinity
  - physical, chemical
  - availability
- habitat preference
  - energetics
  - availability
- affixing strategy
  - energetics
  - optimality

Substrate affinity

- carbonates, clastics, mixed
- lithology/deposition environment
- Pharenozoic decrease in carbonates:clastics

Habitat preference

- on-shore, off-shore, none
- sea-level and energetics
- Pharenozoic decrease in on-shore:off-shore

Affixing strategy

- pedunculate, reclining, cementing
- pedunculate:on-shore, reclining:off-shore
- environmental energetics

Assigning substrate and habitat

Probability of assignment

$$P(H_1|E) = \frac{P(E|H_1)P(H_1)}{P(E|H_1)P(H_1) + P(E|H_2)P(H_2)}$$

(Simpson and Harnik 2009 Paleobiology)

Models

Preliminary results

Ecological traits

- dietary category
  - energetics
  - availability
- locomotor category
  - availability
  - dispersal
- body size
  - energetics
  - home range size

Predictions: dietary category

Predictions: locomotor category

Predictions: body size

Methodology

Biases to survival: a simulation study

Community connectedness

Definition

The degree to which localities are composed of endemic versus cosmopolitan taxa, and how similar this ratio is across localities.

Average relative number of endemics

$$E = \frac{\sum_{i=1}^{L} \frac{u_i}{n_i}}{L}$$

- L: number of localities
- u: number of taxa unique to a locality
- n: number of taxa at a locality
- $0 \leq E \leq 1$

Average relative occupancy per taxon

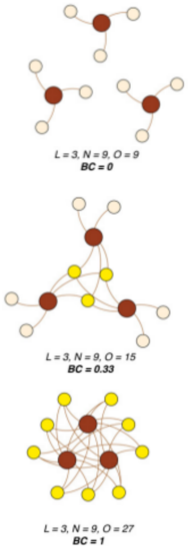
$$Occ = \frac{\sum_{i=1}^{N} \frac{l_i}{L}}{N}$$

- N: total number of taxa
- l: number of localities a taxon occurs at
- L: number of localities
- $0 \leq Occ \leq 1$

Biogeographic connectedness

$$BC = \frac{O - N}{LN - N}$$

- O: number of occurrences
- N: total number of taxa
- L: number of localities
- $0 \leq BC \leq 1$



(Sidor et al. 2013 PNAS)

Code length

Global versus regional versus local scale processes

Global predictions

Expectations: dietary category

Expectations: locomotor category

Community connectedness of North America

Community connectedness of Europe

Community connectedness of South America

Methodology

- biogeographic network
  - taxa: species
  - locality: 2x2 equal–area map projection grid
- 2 My intervals
- PBDB, NOW, museum (FMNH, AMNH), compilations

Preliminary results

Summary of proposed research

Questions

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