History and meaning of the word “Ecology”

A. Definition
1. Oikos, ology - the study of the house - the place we live

B. Etymology - origin and development of the word
1. Earliest - Haeckel (1869) - comprehensive science of relationship of organism and environment
2. Elton (1927) - scientific natural history
3. Andrewartha (1961) - Scientific study of the distribution and abundance of organisms
4. Krebs (1985) - scientific study of the interactions that determine the distribution and abundance of organisms

C. Note that all talk about “scientific”

WHY???

Definitions

A. Individual
1. Live, reproduce, die
2. Have unique genotypes
3. Are the units of selection
4. Are autonomous of other organisms

B. Population
1. Interact with one another
2. Interbreed

C. Species
1. Individuals, naturally capable of interbreeding and producing fertile offspring

D. Community
1. A group of populations in a given place - usually implies that populations interact

E. Ecosystem
1. A biotic community and its abiotic (physical) environment

Basic Population Biology - Unlimited Growth = Malthusian Growth or exponential growth

Logic:

Population at time $t = N_t$
Population at time $t + 1 = N_t + \text{birthrate (b) + immigration (i) + emigration (e)} + \text{death rate (d)}$

Where $t = \text{time t and t+1 = sometime after that}$
Basic Population Biology - Losses may matter

**Exponential Growth**

Assumptions:
1) Emigration = immigration, then
\[ N_{t+1} = N_t + \text{births (b)} - \text{deaths (d)} \]
where b and d are instantaneous estimates
2) Generations overlap
3) **Resources are unlimited**

Now let the instantaneous per capita rate of growth (r) equal the birth – death rate:
\[ r = b - d \]

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**Exponential Growth - calculation**

\[ N_t = N_0 e^{rt} \]

- \( N_0 \) = population at time 0
- \( r \) = per capita rate of growth (b – d)
- \( t \) = time
- \( e \) = base of the natural log (~2.72)

*Essentially same formula as compounded interest*

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**Exponential Growth - an Understanding of Rates**

**Let \( r = 0.09 \)**

Rate of growth = \( \frac{\Delta N}{\Delta t} \) of population

Using calculus we can derive a function for the instantaneous rate of growth of populations. The rate of change of the population is equal to growth rate \( x \) the population:
\[ \frac{dn}{dt} = rN \]

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**Exponential Growth - why is growth unlimited?**

The assumption is that the per capita growth rate (r) is unrelated to population size (N). This means:
1) Birth rates are unaffected by population size, and
2) Death rates are unaffected by population size
3) **Does this make sense?**

remember \( r = b - d \)

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Limited Growth

Assumptions:
1) Resources become limited as populations increase
2) Thus, per capita rate of growth must decrease with increasing population

Limited Growth – density dependence

Exponential rate of population growth
\[ \frac{dn}{dt} = rN \]

Logistic (limited) rate of population growth
\[ \frac{dn}{dt} = rN\left(\frac{K-N}{K}\right) \]
K = carrying capacity

Logistic (limited) growth – implications for conservation I

Excess Adults

K / 2
Logistic (limited) growth – implications for conservation II

*Excess Juveniles - Compensation*

Basic Population Biology - *Extra* may matter

**Excess or Resource – should the buffers be given away?**

1) Provides buffer for cumulative effects
2) Provides buffer for natural and anthropogenic impacts

**Basic questions are:**

1) Do density dependent processes produce excess individuals (that are essentially wasted) or population buffers that
   A) Provide a safety mechanism against
      I) Natural variability
      II) Natural disturbances
      III) Additional anthropogenic impacts
2) Are population (demographic) buffers the property of the general public or industry
Limited Growth – caused by changes to birth and death rates that are density dependent

\[
\frac{dn}{dt} = rN(K-N)
\]

\[
\frac{dn}{dt} = \frac{(b-d)N(K-N)}{K}
\]

Where \( b = \) birth rate and \( d = \) death rate

What are the assumptions??

But – does birth rate = input rate?

The issue

Population (N) vs. Time

Birth rate
Death rate

Population (N)
Settlement vs Recruitment

1. Settlement occurs when an individual makes an irreversible transition from the larval form (metamorphosis) and habitat (pelagic) to the adult form and habitat. It is a specific point in time.
   - Only production and those factors occurring in the plankton can affect settlement (fecundity, larval survivorship, oceanographic forcing, larval behavior)

2. Recruitment is a term that refers to the first time humans take note of the individual. The term therefore is non-specific and only makes sense in the context of the observer.
   - All factors affecting settlement and post-settlement mortality affect recruitment

Back to the the issue

\[
\frac{dn}{dt} = \frac{rN(K-N)}{K}
\]

\[
\frac{dn}{dt} = (b-d)N(K-N)K
\]

Where b = birth rate and d = death rate

Does logistic growth makes sense for species with open life histories??

Why Not?
And
Does it matter?
The issue
\[ \frac{dn}{dt} = \frac{rN(K-N)}{K} \]

\[ \frac{dn}{dt} = \frac{(b-d)N(K-N)}{K} \]

Where \( b \) = birth rate and \( d \) = death rate

Does logistic growth makes sense for species with open life histories?
\textbf{NO}

Why Not?
\textbf{Because one the two sources of population feedback are removed (birth rates)}

Does it matter?
\textbf{Sometimes}

Here is the new paradigm of population regulation or lack of it for species with open life histories:

\textbf{Recruitment Limitation}

1. Lack of linkage between local production of babies and population of the next cohort
   • Local resources, physical stresses and biological interactions do not affect local settlement
2. Populations and communities should be destabilized (lack of regulation) if
3. Settlement is reflected in subsequent adult abundances

Return to Density Dependence – the only ecological mechanism that can regulate populations
OK what is the truth?

1. Species cannot be dichotomized into open vs closed. Instead there is a continuum that cuts across species, times and locations – sometimes this just adds to the noise.
   - Evidence for local replenishment
     a) Oceanographic evidence - Tasmanian Lobster
     b) Genetic evidence - Log(F_{st}) by distance
     c) Tags
       - Natural - Swearer et al 1999
       - Man Made - Jones et al 1999

2. Even species with open life histories sometimes display density dependence. Connell 1985

Figure 1 Map of Lizard Island on the northern Great Barrier Reef, showing the location of the six 150-m stretches of reef edge where all embryos of *Pomacentrus amboinensis* were marked over a three-month period (October–December 1994). Light traps were placed at three sites to collect incoming larvae ready to settle onto the reef, with four light traps at the windward site, two at the lagoon site and two at the back reef site. Dotted lines indicate the reef.
Why all the fuss?

1. If populations are recruitment limited, then populations are structured largely by events that affect larval production, dispersal, delivery and settlement.
2. If 1, then degree of openness will destabilize populations because there will lack of feedback between population in time 1 and that in time 2: input comes from somewhere else and is not regulated by local forcing.
3. Populations and communities will be unpredictable in time and space – they will be in essence non-deterministic. That is there will be no attractor.
4. The essence of science is prediction: determinism – the ability to produce rules of assembly. The lack of it creates??

Logic of community organization under determinism

- If populations and communities are deterministic, like species cannot coexist unless resources are unlimited
  - Niche concept
  - Competitive exclusion
- Hence, diversity will be lost unless
  - Populations are kept below levels causing competitive exclusion
- Mechanisms that affect competitive exclusion
  - Intraspecific competition
  - Predation
  - disturbance
- Models of community and population organization
  - Deterministic and non-deterministic

Models of Population and Community Organization

<table>
<thead>
<tr>
<th>Recruitment modified by post-recruitment processes</th>
<th>Recruitment not modified by post-recruitment processes</th>
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| **Competition Model** (Connell, Menge Sutherland) | **Predation - Disturbance Model** (Paine, Dayton, Andrewartha and)

**Hybrid model** – Hixon and Carr

**Lottery Model** (also **Storage Effects Model** (Sale, Warner and Chesson))

**Recruitment Limitation Model, Behavior Model** (Connell, Victor, Raimondi)

Figure 2. The 30-day per capita mortality rates of newly settled C. cyanus on experimental reefs under four different predation regimes in 1996. Regression statistics by treatment (n = 8 reefs each, solid circles): (A) all predators present—the unmanipulated control ($r^2 = 0.804, P = 0.003, m = 0.015, b = 0.309$); (B) only resident predators present ($r^2 = 0.024, P = 0.717, m = 0.005, b = 0.325$); (C) only transient predators present ($r^2 = 0.211, P = 0.252, m = 0.012, b = 0.112$); and (D) all predators absent ($r^2 = 0.001, P = 0.896, m = 0.001, b = 0.275$). Note that the y intercepts of the four regressions are similar and that the sum of the regression slopes (m) from (B) and (C) (0.017) nearly equals that from (A) (0.015), indicating additive average effects of the different predators (see Fig. 1). Plotted for comparison are results (mean ± SEM) of the 1995 predator-manipulation experiment (open squares, n = 6 reefs each) and the 1996 microtagging experiment (open triangle, n = 4) (19).