Population Regulation, Density Dependence and Ecological Determinism

Limited Growth – density dependence

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

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

K = carrying capacity

Limited Growth – caused by changes to birth and death rates that are density dependent

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

Where b = birth rate and d = death rate

The issue

What are the assumptions??

Rate

Birth rate

Death rate

Population (N)

Population (N)

Time
But – does birth rate = input rate?

**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.

<table>
<thead>
<tr>
<th>Closed Life History</th>
<th>Open Life History</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>Adults</td>
</tr>
<tr>
<td>Fecundity (Birth rate)</td>
<td>Larvae</td>
</tr>
<tr>
<td>Survivorship</td>
<td>Juveniles</td>
</tr>
<tr>
<td></td>
<td>Settlement Recruitment</td>
</tr>
<tr>
<td></td>
<td>Adults</td>
</tr>
<tr>
<td>Survivorship</td>
<td>Adults</td>
</tr>
<tr>
<td>Somewhere else</td>
<td>~100% coral reef fish</td>
</tr>
<tr>
<td></td>
<td>85% of corals</td>
</tr>
</tbody>
</table>
**Back to the the issue**

\[
dn / dt = rN(K-N) / K
\]

\[
dn / dt = (b-d)N(K-N) / K \quad \text{Where } b = \text{birth rate and } d = \text{death rate}
\]

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

Why Not?
And
Does it matter?

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**The issue**

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\]

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

**NO**

Why Not?

Because one the two sources of population feedback are removed (birth rates)

Does it matter?

Sometimes

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**Closed life history**

![Closed life history graph]

**Open life history**

![Open life history graph]

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

**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

![Recruitment Limitation graph]
**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(Fst) by distance
     c) Tags
       - Natural - Swearer et al 1999
       - Man Made - Jones et al 1999

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**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.
OK what is the truth?
2. Even species with open life histories sometimes display density dependence. Connell 1985

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

Post-Recruitment Competition

<table>
<thead>
<tr>
<th>Intense</th>
<th>Weak</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Competition Model</strong></td>
<td><strong>Predation - Disturbance Model</strong> (Paine, Dayton, Andrewartha and Birch)</td>
</tr>
<tr>
<td>(Connell, Menge Sutherland)</td>
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<tr>
<td><strong>Lottery Model</strong> (also Storage Effects Model)</td>
<td><strong>Recruitment Limitation Model, Behavior Model</strong> (Connell, Victor, Raimondi)</td>
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<tr>
<td>(Sale, Warner and Chesson)</td>
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<tr>
<td><strong>Hybrid model</strong> - Hixon and Carr</td>
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</table>

Recruitment modified by post-recruitment processes

Recruitment not modified by post-recruitment processes

Deterministic

Possibly Non-Deterministic

Figure 2. The 30-day per capita mortality rates of newly settled C. cyanea on experimental reefs under four different predation regimes in 1996. Regression statistics by treatment (n = 9 reefs each, solid circles): (A) all predators present—the unmanipulated control ($r^2 = 0.804, P < 0.005, m = 0.015, b = 0.309$); (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 ($r^2 = 0.001, P = 0.996, m = 0.0001, b = 0.275$). Note that the y intercepts (b) 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).