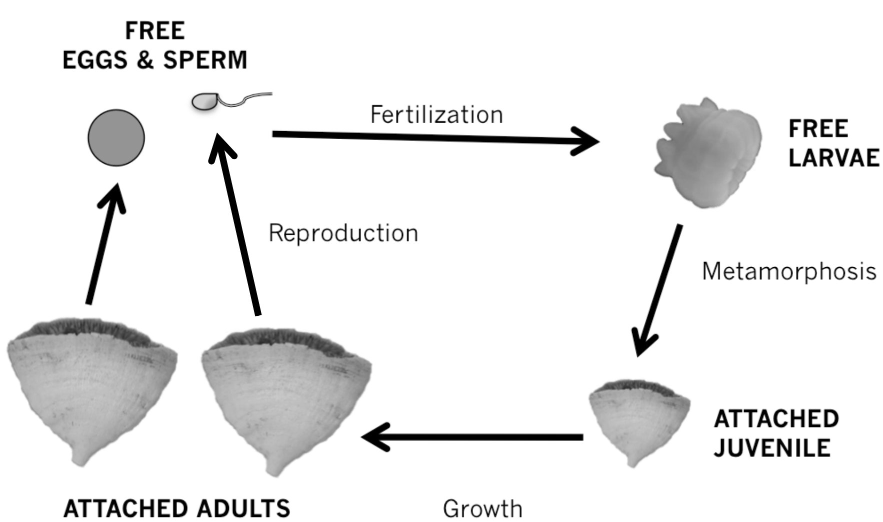
5. Reproduction and Recruitment

- Sexual vs Asexual Reproduction
- Reproductive effort
- Developmental types
- Developmental trends
- What is recruitment
- Factors affecting recruitment
- Process of larval habitat selection

Dr Rhian G. Waller
16th April 2010
Reading: Levinton, Chapter 5, "Reproduction, Dispersal and Migration"

General Development of Benthic Invertebrates



Sexual Reproduction

- **Gonochorism**
  - Single sexes
- **Hermaphroditism**
  - Dual sexuality
  - Simultaneous, Sequential, Cyclical
- **Semelparous**
  - Single reproductive effort
  - E.g., nudibranchs, nereid polychaetes
- **Iteroparous**
  - Multiple reproductive events
  - E.g., Corals, seastars

Asexual Reproduction

- Does not involve fertilization
- Only one parent involved
- Produces offspring genetically identical to parent
- Some organisms primarily (but not solely) reproduce asexually
  - Prokaryotes
- Some swing both ways!
  - Corals, fungi

Reproductive Effort

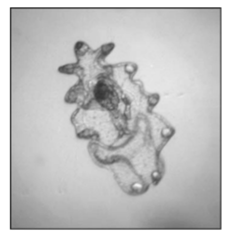
- It takes energy to reproduce
  - **Reproductive Effort**
- **Metabolic energy spent reproducing…**
  - Searching for mates
  - Copulation
  - Gamete formation
    - **Fecundity** = how many babies you produce
  - Fertilization mechanisms
  - Brood protection & parental care

Development Types

- Different types of larvae produced in benthic animals
  - Planktotrophic
  - Lecithotrophic
  - Direct Development
- Suitable for different strategies
  - Dispersing long distances
  - Surviving predators
  - Settling fast

Development Types

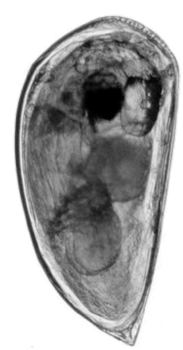
- **Planktotrophy**
  - Planktonic free living larvae
    - No parental care
    - Feeds in the plankton – phyto/zoo/bacteria/algae
    - Special cilary bands
  - In plankton – ~hrs to months
    - Can travel V. long distances!
  - High fecundity
  - High dispersal potential
  - Delayed metamorphosis can be possible



Thorson, 1961; Scheltema, 1988; Strathmann & Strathmann, 2007

Development Types

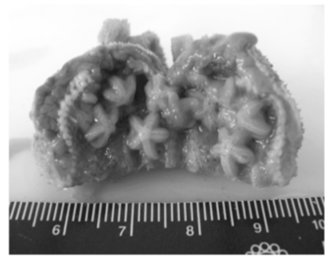
- **Lecithotrophy**
  - Planktonic free living larvae
    - Do not feed in the plankton
  - In plankton – ~hrs to months
    - Can also travel, but limited by food source
  - Medium fecundity
    - Large yolky oocytes
  - Evolutionary advantage
    - Correlation between lower fecundities yet still relatively high dispersal capabilities



Jaekle & Manahan, 1989

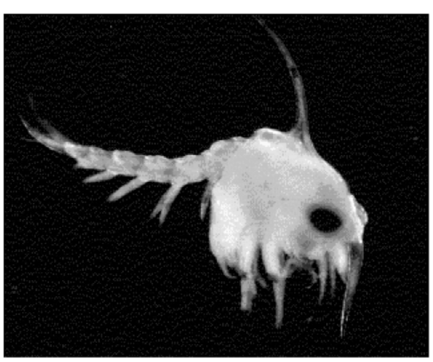
Development Types

- **Direct Development**
  - Brooding or egg masses
  - No free larvae
    - High parental care
  - Produces benthic juvenile
  - Lower fecundity
  - Little dispersal
    - Esp in sessile organisms



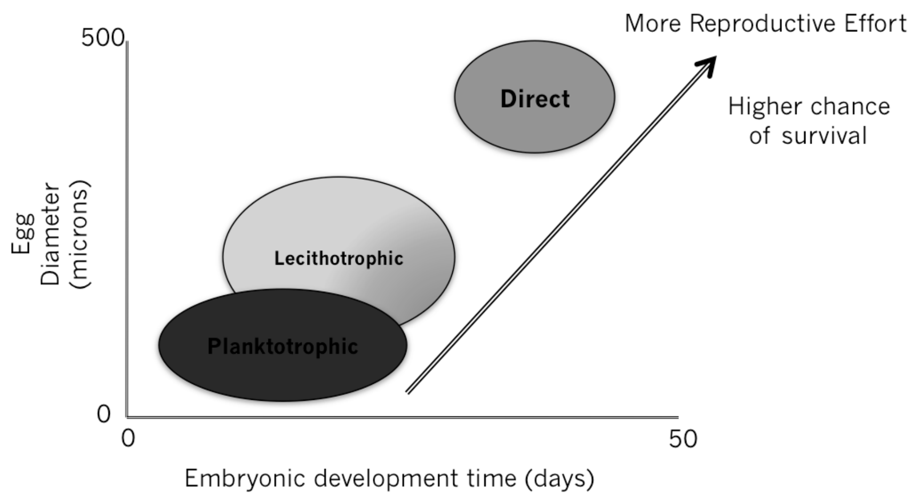
Development Types

- Mixed Development
  - Some brooding then a planktonic stage
  - Parental protection & higher dispersal
  - Best of both worlds??



Gallardo, 1977; Caswell, 1981

Development Time



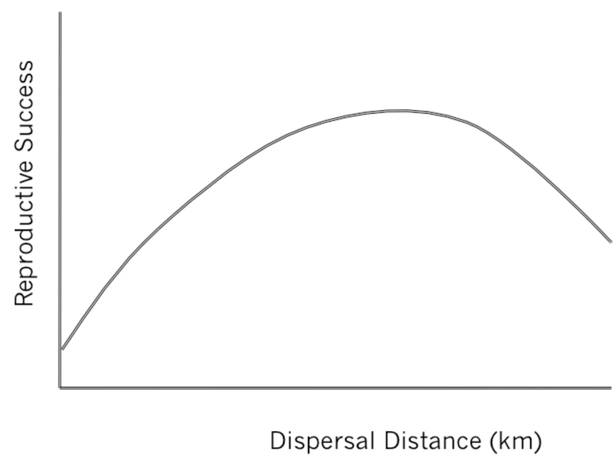
Todd and Doyle, 1981; Barnes & Hughes, 1998

Evolutionary Advantages

- Advection – Diffusion Dispersal
  - Advection – currents
  - Diffusion – random eddies
- Hill (1991) Model
  - High pelagic loses
  - Survival sensitive to mean advection
  - Minimum fecundity to overcome pelagic loses

Hill, 1991

Evolutionary Advantages



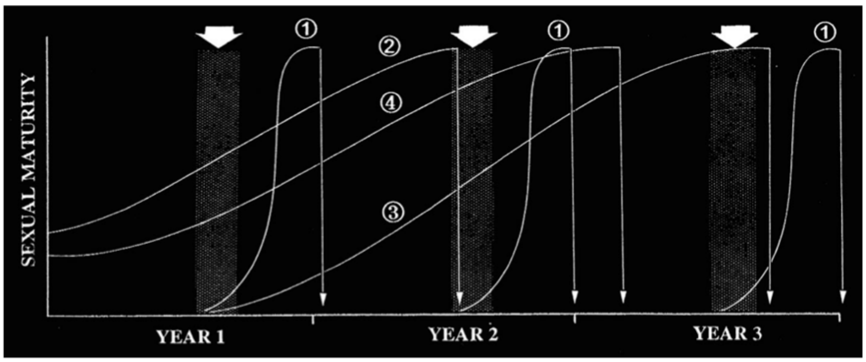
Palmer & Strathman, 1981; Hill, 1991

Timing of Reproduction

- When is a good time to reproduce?
- Energy
  - Fixed amount of energy to an organism
    - Growth & Reproduction
  - Food to benthos can be seasonal
- Energy Allocation
  - To Gametes
    - Use food pulses to start reproduction
  - To Larvae
    - Use food pulses to feed larvae

Timing of Reproduction

- Eckelbarger & Watling (1995)
  - 1 – Fast egg producers (immediate response to bloom)
  - 2 – Slow egg producers (spawn when conditions favor larvae)
  - 3 – Slow egg producers (use bloom to start repro)
  - 4 – No relationship to bloom



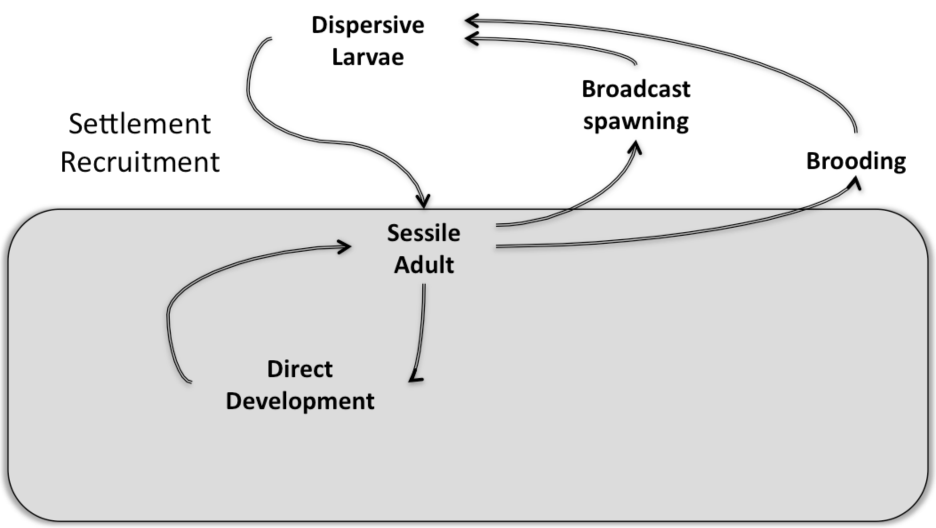
Development Trends

- **Low Latitudes**
  - ⇧ Planktonic development
  - ⇧ Planktotrophy
- **High Latitudes**
  - ⇧ Direct development
  - ⇧ Lecithotrophy
- **Deep Sea**
  - ⇧ Direct development

MANY EXCEPTIONS TO ALL OF THESE

Thorson, 1950; Young, 1994; Grassle, 1994; Pearse, 1994; Smith et al., 2006; Rex & Warren, 1985

Settlement and Recruitment



Settlement/ Recruitment?

- **Settlement**
  - Attachment to benthos, metamorphosis into adults
  - Site critical for sessile organisms
  - Availability of larvae, settlement cues, hydrodynamic factors, larval behaviour – all affect settlement
- **Recruitment**
  - Number of organisms that settle and survive in a population
  - Operationally defined, e.g., it occurs when an organism is first detectable on a settling plate or in a colonization tray.
  - Incorporates post-settlement mortality

Why study recruitment?

- Important process in determining community structure
- Cannot predict recruitment from reproduction
  - Just because you have high fecundity doesn't mean you have high recruitment
  - Post-Settlement Mortality
  - How can you predict recruitment?
- Two long standing hypothesis
  - **Supply Side Ecology**
    - Populations limited by factors affecting adults
  - **Larval Habitat Selection**
    - Populations limited by habitat

Lewin (1986), Young (1987)

Supply Side Ecology

- Space will not be occupied unless propagules get to it
- Processes causing variation in arrival of recruits
  - Production of larvae
    - Fertilization
  - Dispersal
    - Transport, period of dispersal, mortality
  - Oceanographic conditions
  - Larval mortality
  - Larval behaviour
  - Settlement

Larval Habitat Selection

- Much of early motivation for studying recruitment
- Directed towards settlement
- Main Issues
  - Do larvae actively select habitat?
  - If so, how?
- Alternatives to Active Selection
  - Passive
    - Hydrodynamic dispersal and sorting
    - Larvae and substrate have related characteristics (eg Stickiness)

Larval Habitat Selection

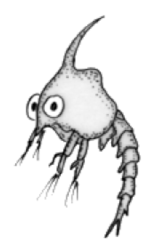
- 3 Stages of Settlement
  - Stage 1 - Getting to/staying in vicinity of suitable habitat
  - Stage 2 - Getting to the bottom
  - Stage 3 - Staying on the bottom
- Active processes could be useful in all these stages

Conclusions

- Many life histories amongst invertebrates
  - Though there are trends, these are not rules
- Though direct development is more evolutionary evolved, many advantages to pelagic development
- Cannot infer recruitment from settlement
  - Modified by post-settlement mortality
- Larval arrival/retention often influenced by larval behaviour
- Interactions between benthic recruitment and water column processes in the field are poorly known

Larval Habitat Selection – Stage 1

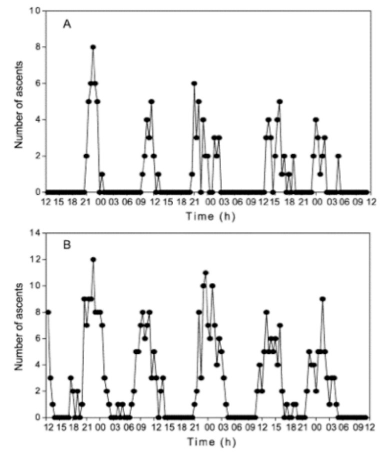
- Stage One
  - Ample evidence for active behaviours that keeps larval benthos in general area
- Blue Crabs – *Callinectes sapidus*
  - Adults live in upper estuaries
  - Larvae live in the water column on the open continental shelf
  - No adults live on the continental shelf
  - How does this happen?



Forward et al., 2002; Tankersley et al., 2003; Goodrich et al., 1989

Larval Habitat Selection – Stage 1

- Larvae hatch in estuary and are advected offshore
  - Late stage females migrate to mouth of estuaries
  - Spawn at peak high tide, just when starts to ebb
    - Larvae taken out to sea – rapid transport to feeding grounds
  - Why?
    - **More food available in coastal waters!**

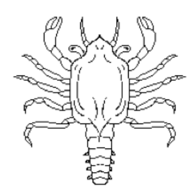


Forward & Cohen, 2003

Forward et al., 2002; Forward & Cohen, 2003; Tankersley et al., 2003; Goodrich et al., 1989

Larval Habitat Selection – Stage 1

- Larvae return to estuaries after 1-2 months
  - Reverse vertical migration
    - Up in the day down at night
    - Phototaxis & Geotaxis
  - On shore transport
    - Day time on-shore winds drive the larvae back into the estuary
  - Storm surges
    - Megalopes accumulate near surface waters in fall – transported in shore by storms/hurricanes at this time of year



Forward et al., 2002; Tankersley et al., 2003; Goodrich et al., 1989; Little & Epifiano, 1991

Larval Habitat Selection – Stage 1

- Once near mouth of estuary
  - Flood Tide Transport
  - Leap-Frog up the estuary

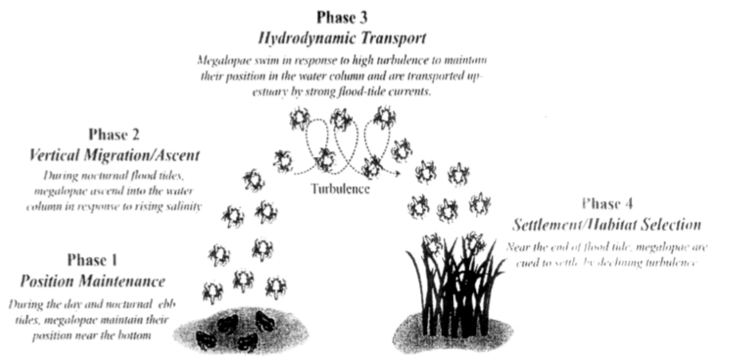


Fig. 1. *Callinectes sapidus*. Conceptual model of flood-tide transport and settlement of megalopae in estuaries (modified from Forward and Tankersley 2001; Forward et al. 2002b)

Forward et al., 2002

Larval Habitat Selection – Stages 2&3

- Getting to the bottom & staying on the bottom
- Factors implicated
  - Specific microbial populations
  - Cement from adults
  - Specific chemicals
  - Grain size itself
  - Chemical gradients from disturbed sediments = avoidance
  - Water borne polypeptides – oyster larvae
- Sensing Mechanisms
  - Tactile – larvae feel rather than smell
  - Chemotaxis (for specific polypeptides (oysters))

Larval Habitat Selection – Stages 2&3

- Conclusions from Lab Studies
  - In still water, active selection can occur on small spatial scales (mm-20cm)
  - Swimming & crawling
- BUT – is this true in the field?
  - Larger spatial scales – 10m – km??
  - Water flows??
  - Swimming speeds??
  - Size??
  - Sinking rates??
- No studies have adequately shown upstream transport of larvae past their swimming speeds
  - Still active debate!