Larval Ecology: MS 658. 3 credits. Roger Mann sole instructor.

The course is presented as twelve sections. The focus is on processes rather than a broad phylogenetic survey of all developmental types. The sections are as follows:

- Section 1. What are larvae anyway?
- Section 2. Developmental patterns and the evolution of the larval form.
- Section 3. Timing of spawning and the nature of spawning cues.
- Section 4. Limitations on the fertilization process and embryology.
- Section 5. Swimming, feeding and energetics in the larval size range.
- Section 6. Egg and larval size, and parental investment.
- Section 7. Dispersal of larval forms.
- Section 8. Mortality in the plankton.
- Section 9. Physical versus biological processes in inducing settlement and metamorphosis.
- Section 10. Early post metamorphic survival and recruitment to the reproductive population.
- Section 11. Larval biology at the extremes: Antarctic biology.
- Section 12. Larval biology at the extremes: Hydrothermal vents.

Section 1. What are larvae anyway?

- Broad contextual thoughts: The role of larval propagules for land and aquatic organisms may be either in dispersal and / or feeding?
- Why do larvae disperse? Is it to escape declining conditions and/or colonize new areas and/or increase range and/or increase genetic variability?
- What are the costs of dispersal? Mortality in plankton, loss to unsuitable habitat, reduced reproduction with over dispersal and/or offspring being less adaptive to local conditions.
- A counter argument: dispersal is a secondary (even accidental) product of planktonic feeding larval forms.
- The dispersal versus feeding issue begs the question: In the evolution of the larval form what is a primitive form?
- Historical context of larval studies: how did we get here?

Section 2. Developmental patterns and the evolution of the larval form

- Protostomes and Deuterostomes: early embryology and its use in taxonomy
- Evolution: the development of the planktonic ciliated form
- Planktotrophic larvae, egg size and the derived lecithotrophic form
- First records of the appearance of larval forms in the fossil record.
- Rates of evolution and developmental constraints.

Section 3. Timing of spawning and the nature of spawning cues

- Endogenous rhythm versus exogenous cues: the genetic component, arguments for long term hormonal control in marine species as an endogenous component
- Exogenous cues
    - Long time base approaching seasons
    - Short time base

    - Very short term
- The nature of the spawning events: never random, broadcast spawning prevalent
- Behavior and spawning: aggregate behavior
- Latitudinal variation in timing of spawning
- Match - mismatch in timing of spawning events
- Parental investment in reproduction.

Section 4. Limitations on the fertilization process and embryology

- Current models of the fertilization process.
- What are the roles in determining fertilization success of currents, turbulence, synchrony, pheromones (sometimes non species specific), and chemoattractants (sperm-egg interaction)?

Section 5. Swimming, feeding and energetics in the larval size range

- A review of the physical environment at the appropriate scale.
    - The Reynolds number environment at typical larval size.
    - Impact of viscosity on swimming and feeding: animal density, drag, sea water density.
    - Directed swimming in relation to form, differential drag and the center of gravity.
    - Non uniform propulsive forces and orientation to gravity.
- Passive / encounter (ciliated) versus directed capture feeding mechanisms
    - How do cilia work in feeding?
    - How are setae used as part of a mechanical system to capture particles?
    - How do directed capture feeders search and feed?
    - A minority case: mucous strings and nets (some anthozoa and polychaetes)
- Energetics: physical and biological factors that control larval duration in the water column.
    - Nutrition in the larval size range: DOM v particles of varying size ranges.
    - Quantitative information from culture on nutrition of larvae.
    - Measurement of “food” in situ and our deficiency in understanding larval dietary needs.
    - Use of multiple food resources by developing larvae: mouth size limitations.
    - Food patchiness: temporal, spatial, driving mechanisms.
    - How do larvae avoid starvation?
    - Measurement of feeding and assimilation rates, metabolic rates.
    - Energy metabolism and growth: the role of lipids, proteins and carbohydrates.
    - The transition from embryo to first feeding form in invertebrates: the importance of parental derived reserves.
    - The transition from embryo to first feeding form in fish : the yolk sac to feeding transition: energetic concerns and developments of digestive enzymes.

- The concept of critical feeding and "**P**oint of **N**o **R**eturn".
- Starvation sensitivity, developmental delay (searching windows and teleplanic larvae), recruitment delay.

Section 6. Egg and larval size, and parental investment

- Why planktotrophy and lecithotrophy but not a continuum?
- Past lecithotrophy to the emergence of functional juveniles.
- Nurse eggs in gastropods.
- How does the primitive form argument affect our view of dispersal as the prime motive for larvae versus the opinion of dispersal as a secondary consequence of pelagic larvae?
- Thorsons rule and its re-evaluation.
- Species pairs, such as in the Teredinidae.
- The r-k continuum and the broad subject of "bet hedging"strategies.

Section 7. Dispersal of larval forms

- Dispersal methods.
- Dispersal, survival (and mortality) and supply in maintaining community structure.
- Larval behavior in response to oriented environmental stimuli.
- Invertebrates: larval swimming rates in relation to water movement.
- Invertebrates: free fall rates versus active swimming, controlled sinking, helical swimming and mechanics of change in vertical versus absolute swimming rate.
- Invertebrates: the roles of spines and appendages in swimming and sinking.
- Fish larval behavior.
- Active versus passive roles in dispersal.
- Physics interacting with behavior in larval retention or dispersal: examples of ontogenetic changes, selected tidal transport, fronts, internal waves, plant canopies, cues.
- Extenuating examples: teleplanic larvae and "giant" larvae in echinoderms.
- Byssal drifting: a pseudo larval dispersal situation.
- Small and large scale models of dispersal.

Section 8. Mortality in the plankton

- Fecundity: the wastage of eggs and loss to predation.
- Estimating larval mortality.
- Who are the predators?
- Avoiding predation.

Section 9. Physical versus biological processes in inducing settlement and metamorphosis

- Settlement:
    - Role of behavior, gregariousness, selected microbial films or substrate types.
    - Microscale environmental selection accompanying settlement: crawling.
    - Nonsense cues for benthic organisms.

    - Passive versus active aggregation in benthic organisms: possible hydrodynamic determination versus genetic kin recognition.
    - What constitutes a good selection of a settlement site?
- Metamorphosis:
    - Physical “cues”, boundary layers, topography and eddies versus chemical “cues”: are the two exclusive, complementary, or just functioning at different temporal and spatial scales?
    - Characterizing the cue in oscillatory wave flows.
    - Where are we settling (for benthic invertebrates): two dimensions in the hard substrate versus three in soft sediments.
    - Specificity and the need (or lack thereof) for specific cues.
    - Concentration gradients versus induction of oriented swimming in the absence of gradients.
    - The competency time window: impact on ability to find a substrate in a discontinuous or heterogeneous environment.
    - Spontaneous metamorphosis without cues.
    - Ability to delay of metamorphosis: extending the time window.
    - Extending the time window: teleplanic larvae (again).
    - Mortality resulting from lack of a settlement cue or substrate.
    - Cost and benefits of delaying metamorphosis (ecophenotypic plasticity).

Section 10. Early post metamorphic survival and recruitment to the reproductive population

- “Supply side ecology” : the lack of distinction between larval settlement rate and early post larval mortality rate.
- The differing roles of larval and post metamorphic forms, and evolution as a result of mosaic response across the life history stages to these varying selection pressures.

Sections 11 and 12. Larval Biology at the extremes (or Systems that challenge our current concepts…..)

- The benthos below the seasonal ice cover on the Antarctic shelf.
- The hydrothermal vent systems of mid ocean ridges.
- Both of these are the subjects of current and exciting work, and form a suitable conclusion to the course.