1. Introduction
   1. Within Ostreidae, Crassostreinae are broadcast spawners and Lophinae and Ostreinae are brooders
   2. History of exploitation has already imperiled *Ostrea*
   3. *C. gigas* may be preventing *O. lurida* comeback in Puget Sound (Trimble et al. 2009)
   4. Ideal *O. lurida* habitat is currently buried beneath 10-15’ of new sediment (Trimble pers. comm.)
2. Reproductive Strategy
   1. Paired gonad with profusely branching tubules in connective tissue beneath mantle. 2 genital canals and 2 gonoducts, one on each side of body. Sperm and ova are discharged into gonoduct then through the urinogenital cleft to the suprabranchial chamber where they are entrained in the respiratory current from the gill cilia. Release of gametes from follicles is achieved via muscle contractions in gonoduct, but actual movement of gametes is affected by cilia in gonoduct and genital canal. (Galtsoff 1938)
      1. Females: ovulation, rhythmic adductor contractions, closing and opening of mantle. Eggs pass through gills to be expelled, except in *Ostrea* spp. where they remain in the pallial chamber
      2. Males: sperm from testis through spermiduct, urogenital cleft and into suprabranchial chamber where the water current bears them to the cloaca and they are washed away. Depends solely on cilia and respiratory current.
   2. *C. virginica*: 10-50 million eggs per female at ~50 um diameter; spawn when water T 20C; grow well in warm brackish water, waters from rivers and estuaries rich in nutrients (Matthiessen 2001)
   3. *Crassostrea* (Thompson et al. TEO)
      1. Gonochoric/dioecious alternate hermaphrodite, protandric with sex being more or less size-dependent
      2. Stresses skews sex ratio towards male
      3. Germinal epithelium proliferation and gamete development through spring with spawning in late spring/summer
      4. Stress, including disease, can cause shift in biochemical composition of tissues because of preferential use of certain energy stores
      5. Males spawn in response to phytoplankton, females in response to conspecific gametes, temperature for both
   4. *O*. *edulis*: fewer eggs, ~1 million and larger at 150 um diameter; spawn when water T at 15C; eggs extruded into mantle cavity and fertilized, incubated ~1 week; grow best subtidally in cooler saline waters and take 4-5 years to reach marketable size (Mathiesson 2001)
   5. *Ostrea* (Thompson et al. TEO)
      1. less reproductive output per gram body weight than Crassostrea
   6. *O. lurida* are protandrous then sequential hermaphrodites (Couch & Hassler 1989)
      1. Although gametes of both types can be found at same time (Hopkins 1936)
   7. Male *O. lurida* release sperm balls that disintegrate to spermatozoa. Conspecific sperm triggers spawning; called spermatozeugmata in *O. edulis*, sperm are not active until disassociate from spermatozeugmata cluster (Couch & Hassler 1989; O Foighil 1989)
   8. Fertilized eggs develop 10-12 days in *O. lurida* and then release 250-300,000 larvae which are veligers for 11-16 days (Couch & Hassler 1989)
      1. From 25 broods of *O. lurida* average of 214,642 larvae. The number of larvae in females varies with female size and nutrient reserves. Gestation lasts ~10 days (similar to *O. edulis*) (Hopkins 1936)
3. Evolutionary History
   1. water allows planktonic larvae because there is no desiccation, buoyancy, suspended food (Strathmann 1990)
   2. Lower O2 diffusion constant in water and higher viscosity could limit potential of parental protection, favoring planktonic stage (Strathmann 1990)
   3. Shedding of female gametes is advantageous in marine environment because water is wet and opportunity for multiple fertilizers (Strathmann 1990)
      1. Dilution of gametes could be a problem, but some solutions include congenic sperm as ovulation cue and brooding spermatophores (frequently single parternity)
   4. Pleisiomorphic condition of oysters is a combination of trans-ctenidial ovulation, broadcast spawning, and planktotrophic development. Brooding is a derived trait and evolved once in the common ancestor of Lophinae and Ostreinae and was retained in descendents. *Ostrea chilensis* is the only species to lose obligate feeding planktonic larvae (derived) (Ó Foighil & Taylor 2000)
   5. In comparison of 4 brooding oysters and 3 broadcast spawners, the larviparous have a wider range of life history and genetic values indicating a possible opportunity to evolve in more ecological conditions. For example, oviparous are found onshore only whereas larviparous species are found offshore and onshore. Higher genetic diversity in oviparous. There is a broader range of evolutionary patterns in larviparous. (Buroker 1985)
   6. Hypothesis that brooders are smaller adults does not have firm ground. Possible hypotheses include: 1. Allometry of gamete production and brooding (larger organisms produce too many eggs to brood), 2. Variability of recruitment with less parental care, 3. Increased dispersal with less care. No one hypothesis covers all cases where smaller adults are brooders. (Strathmann & Strathmann 1982)
   7. Nonbrooding larger adult size usually means greater: age at maturation, longevity, fecundity, bouts of reproduction (Strathmann 1990)
   8. Brooding may occur so that larvae are not released until they are able to actively swim up and avoid being smothered by silt (Hopkins 1936)
   9. *Crassostrea* adults have an extremely wide range of thermal and salinity tolerances, although rate of change of T matters and there are physiological limits (Shumway in TEO)
   10. *Ostrea lurida* in Puget Sound historical distribution: tidelands and flats between mean high and low tides (Steele 1957)
4. What does a changing climate look like for the intertidal?
   1. Oysters are exposed mostly to surface waters – these are the waters that will warm and acidify the most
   2. Upwellings of undersaturated waters – shoaling
   3. Sea level rise – may benefit ostrea over crassostrea
5. Future Climate: Oyster Response
   1. Enhanced protection of larvae in Ostrea, may get them past critical vulnerable stage
   2. More larvae produced by crassostrea, may have more genetic variability and thus potential to adapt
   3. Cultivated *C. gigas* inside and outside lagoon – mortalities in the autumn and winter and spring linked to temperature changes in water mass (Chavez-Villaiba 2010)
   4. *O. lurida* are sensitive to heat and cold and vulnerable to overexploitation in PS because the waters are not warm enough for sets each year (Mathiesson 2001)
   5. high summer mortality of *C. gigas* even in native habitat; in PS Willapa is getting warmer and there have not been recent good sets (Trimble pers. comm.)
   6. *O. lurida* are sensitive to high and low temperature (Couch & Hassler 1989)
   7. Larval and juvenile *O. lurida* grew significantly less at pCO2 970 ppm compared to 380 ppm (Hettinger et al. 2010)
   8. A number of diseases associated with global warming
      1. *Perkinsus marinus* (Dermo): pathogenic to *C. virginica* not *ariakensis*; trophozoites overwhelm phagocytic activity of hemocytes (Alavi et al. 2009)
      2. *Bonamia ostreae*: parasite plays active role in incorporation into hemocyte and may inhibit hemocyte esterases and ROS production (Morga et al. 2009)
   9. Other stressors decrease bactericidal response in *C. gigas* (Gagnaire et al. 2007)
6. Conclusion
   1. Exploitation of stocks