COLLEGE OF SCIENCE DEPARTMENT OF INTEGRATIVE BIOLOGY

Sensitive barnacles:

Quantifying life history processes of *Pollicipes polymerus* to inform sustainable harvest management

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Introduction

Gooseneck barnacles, *Pollicipes* spp., are overharvested under insufficient and belated management in Spain, Portugal and British Columbia[1]. On the U.S. Pacific coast, harvesting of *Pollicipes polymerus* (Fig.1) is increasing. Sustainable management needs to be implemented before overharvesting occurs there as well.

I am investigating the life history of *P. polymerus* along the Oregon coast to inform sustainable harvest and the integration of **ecosystem based and socio-economic** management strategies. My study focuses on describing seasonal and regional variation in the **reproduction, growth, recruitment & abundance** of the species.

Study System

The nearshore waters of Oregon's Cape Perpetua and Cape Foulweather are both highly productive. Nonetheless, upwelling/downwelling dynamics at the two capes are such that Cape Perpetua - characterized by more frequent upwelling and a wider continental shelf[2] – exhibits higher nutrient availability, primary production, and larval retention.

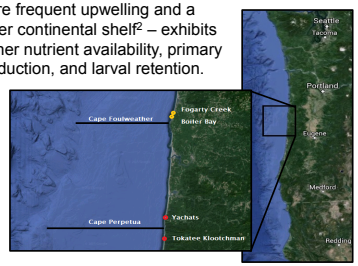

Figure 2: Study sites along Oregon coast. Black bars show width of continental shelf at Cape Foulweather (sites in yellow) and at Cape Perpetua (sites in red).

Methods

- Field and laboratory observations (since April 2015)
  - Bi-weekly and seasonal transect-quadrat surveys of *P. pollicipes* populations at four sites within Cape Perpetua and Cape Foulweather (Fig. 2, 3a).
  - Abundances estimated by quadrat photo analysis
  - Individuals collected for dried weight and brooding activity assessment (Fig. 3b).
- Field experiment simulating complete harvest to quantify population recovery rates (Fig. 7, initiated June 2013).
- "Harvestable size" considered ≥ 1g individual dried weight.

Questions

1. How do *Pollicipes* life history processes vary over time and space?
   A. Are spatial variations regional or site-specific? Do regional and seasonal variations match known near shore oceanographic patterns of primary productivity?
2. What is the recovery time of *P. polymerus* abundances after harvesting?

Figure 1: Gooseneck barnacles, *P. pollicipes*, in the field.

Hypotheses

1. Strong seasonal fluctuation in recruitment and reproduction patterns across all sites.

   Spatial variations of abundance, size, and seasonality correlate with regional variations of oceanographic patterns of productivity.
   a) Cape Perpetua sites have larger gooseneck populations with larger individuals and a higher rate of recruitment and reproduction.
2. Slow (>one year) recovery time after harvest.

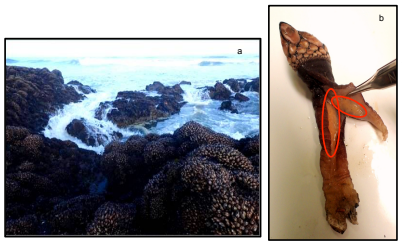

Figure 3: Field and laboratory methods. a) A low zone patch of highly abundant *Pollicipes* at Yachats, OR and b) an egg mass (circled in red) within the peduncle of a brooding gooseneck barnacle.

Results

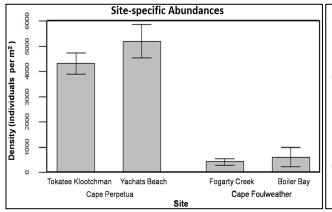

Figure 4: *P. polymerus* abundances of adults and juveniles (excludes recruits) at various sites in May 2015. Error bars indicate +/- 1 standard deviation.

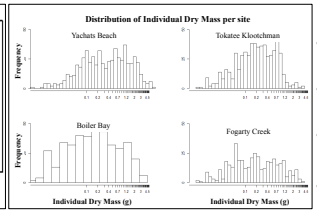

Fig 5: Distribution of individual dry weight of *P. polymerus* samples from each site; data is log transformed. May and July data combined since there was no significant difference in average dry weight between seasons.

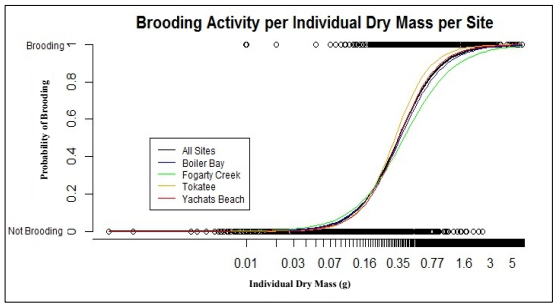

Figure 6: % of brooding *P. polymerus* in May and July per individual dry mass; data is log transformed. Significant site-specific trends of biomass-brooding relationship ($p \leq 0.0002$), displayed by trendlines.

- Adult abundances higher in Cape Perpetua sites ($p \leq 0.005$) (Fig4).
- Skewed weight distribution (Fig 5): recruits and juveniles dominate population.
- Preliminary analysis suggests that brooding doesn't vary during the months surveyed.
- Average dry mass about 0.3g larger at Yachats than all other sites($p \leq 1*10^{-5}$).
- After two years, abundances after simulated complete harvest are less than 20% of natural abundances (Fig7). No individuals have reached harvest size.
- Most recruitment has occurred around peduncles of adults. Harvest of adults removes recruits and juveniles as well.

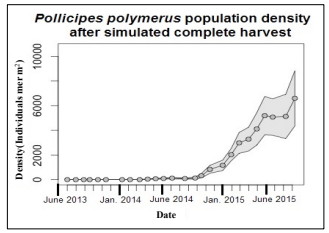

Fig 7: Abundances of P. polymerus in experimental patches after complete harvest in June 2013. Grey area indicate standard deviation.

Discussion

1. Cape-specific regional variation in abundance associated with higher oceanographic productivity in Cape Perpetua.

   Site-specific variation in dry weight distribution and brooding activity patterns. Potentially driven by site-specific conditions (wave action, desiccation exposure, nutrient availability, and species interactions)[3].
2. Harvest recovery is long-term: at least two years to re-establish abundances, longer before individuals are of harvest size.

Implications for Harvest Management

- Spatially-explicit design considering regional abundances and site-specific weight distributions.
  - Establish reference sites in high and low productivity regions to gauge harvest impacts and guide management decisions. Yachats serves as a harvesting maximum reference, exhibiting the highest abundances and average weights . Harvest rates along the Oregon coast should not exceed Yachats capacity for harvest.
  - Consider high productivity sites for integration into existing Marine Reserve design to protect healthy populations with high reproductive output and recruitment potential.
- Limit catch weight rather than individual size to prevent bycatch of recruits and juveniles attached to harvested individuals.
- Prevent overharvest by establishing protected areas within a site and/or allowing long-term recovery after harvest.

Literature Cited

1. Bald, J., A. Borja, and I. Muxika. 2006. A systems dynamic model for the management of the gooseneck barnacle (*Pollicipes pollicipes*) in the marine reserve of Gaztelugatxe (Northern Spain). Ecological Modeling 194(1-3): 306 - 315.
2. Menge, B.A., T.C. Gouhier, S.D. Hacker, F. Chan, and K.J. Nielsen. 2015. Are meta-ecosystems organized hierarchically? A model and test in rocky intertidal habitats. Ecological Monographs 85(2): 213-233.
3. Borja, Á., P. Liria, I. Muxika, and J. Bald. 2006. Relationships between wave exposure and biomass of the goose barnacle (*Pollicipes pollicipes*, Gmelin1790) in Gaztelugatxe Marine Reserve (Basque Country, northern Spain). Marine Science 63(4): 626-636.

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