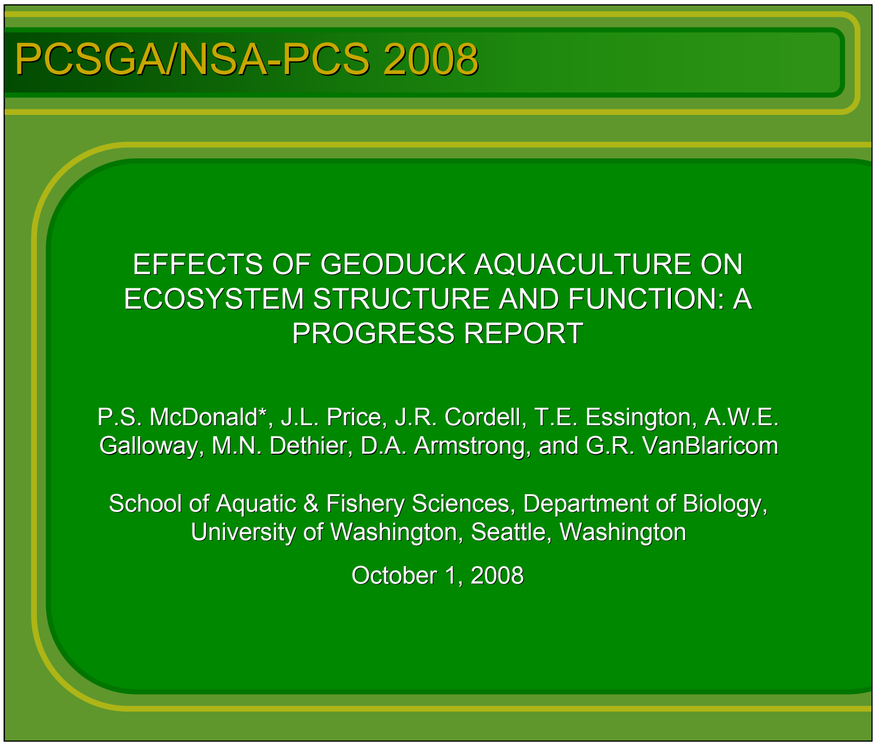
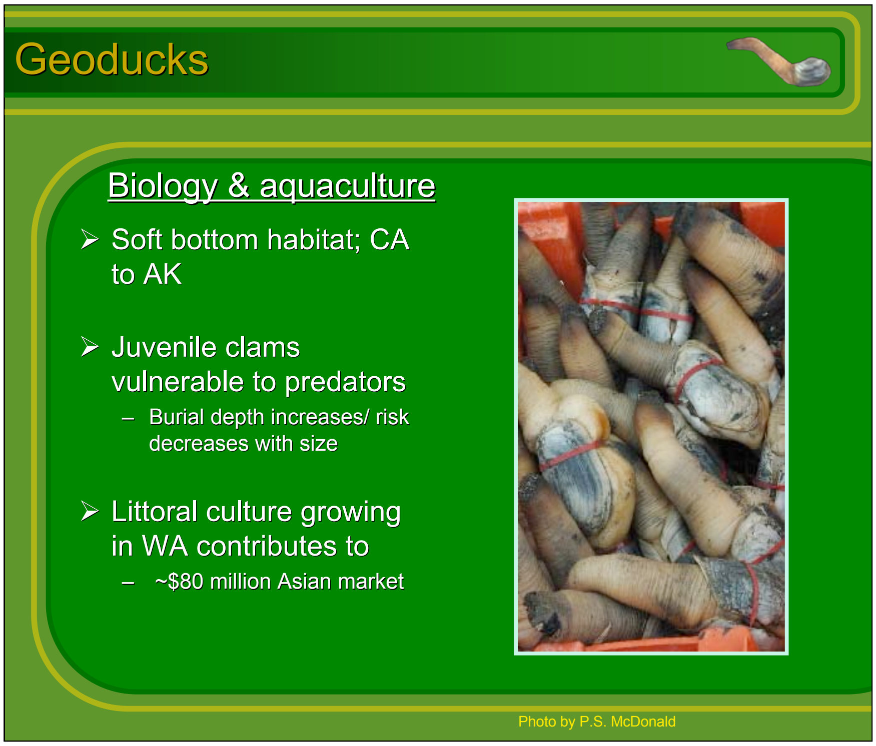


-Good Afternoon.

-Today I'll provide you with an overview of our work to date investigating the ecosystem effects of intertidal geoduck aquaculture in Puget Sound

-I must also acknowledge my co-authors: Jenny Price, Jeff Cordell, Tim Essington, Aaron Galloway, Megan Dethier, David Armstrong, and Glenn VanBlaricom.

-Let me begin by introducing our study subject.

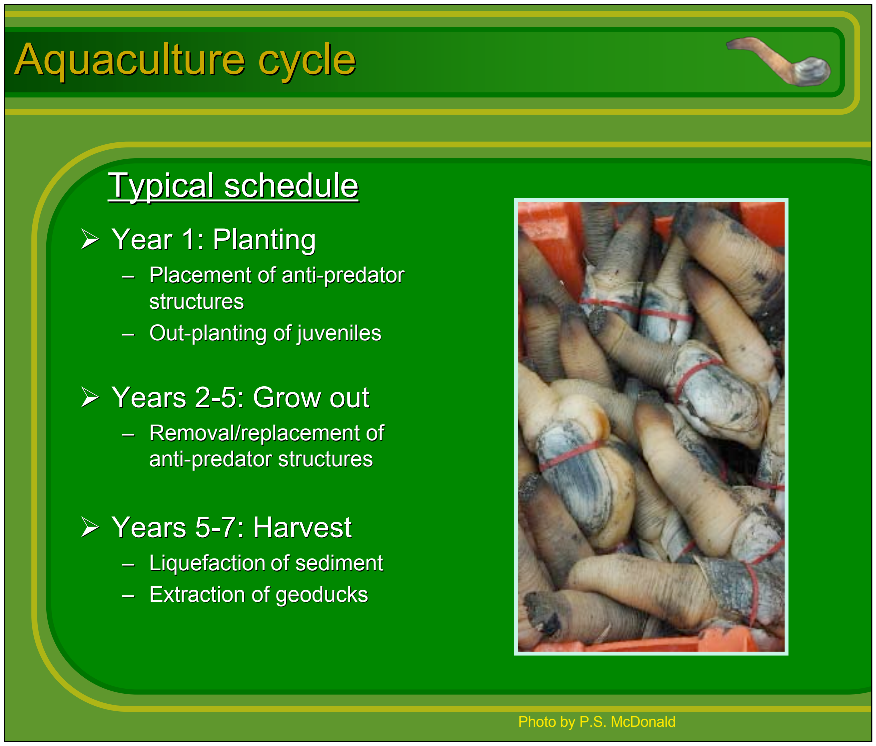


•The Pacific geoduck, *Panopea abrupta,* occurs in low intertidal and subtidal soft substrates from California to Alaska.

•This large, hiatellid clam is long-lived and natural predation on adults is low.

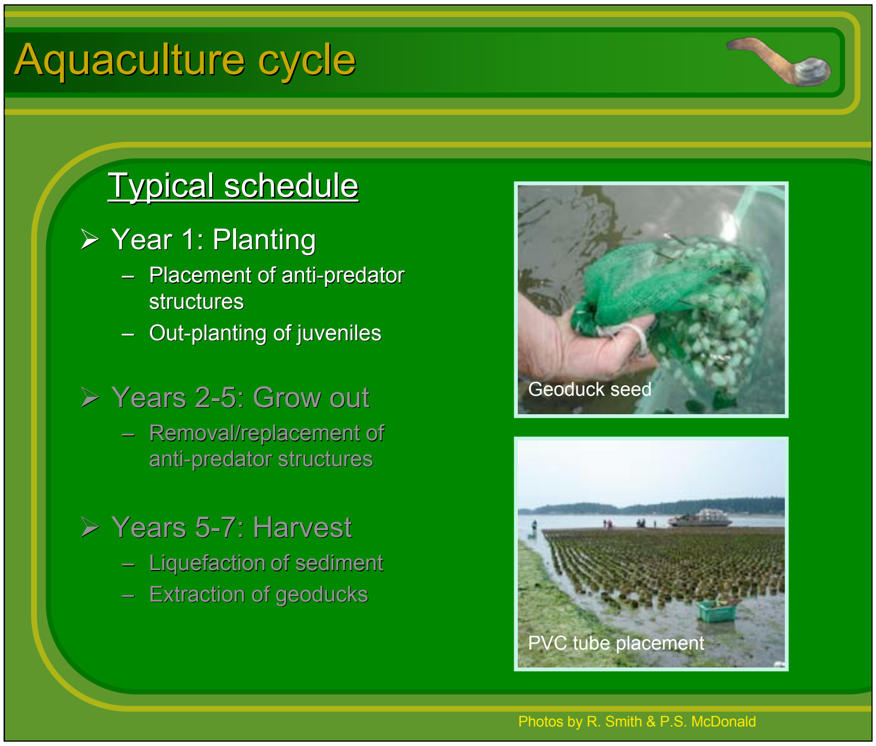
•However, juvenile clams are vulnerable because they can't bury deep enough to avoid predators.

•In recent years, harvest of wild geoduck has been augmented by intertidal (or littoral) culture of hatchery reared seed clams.



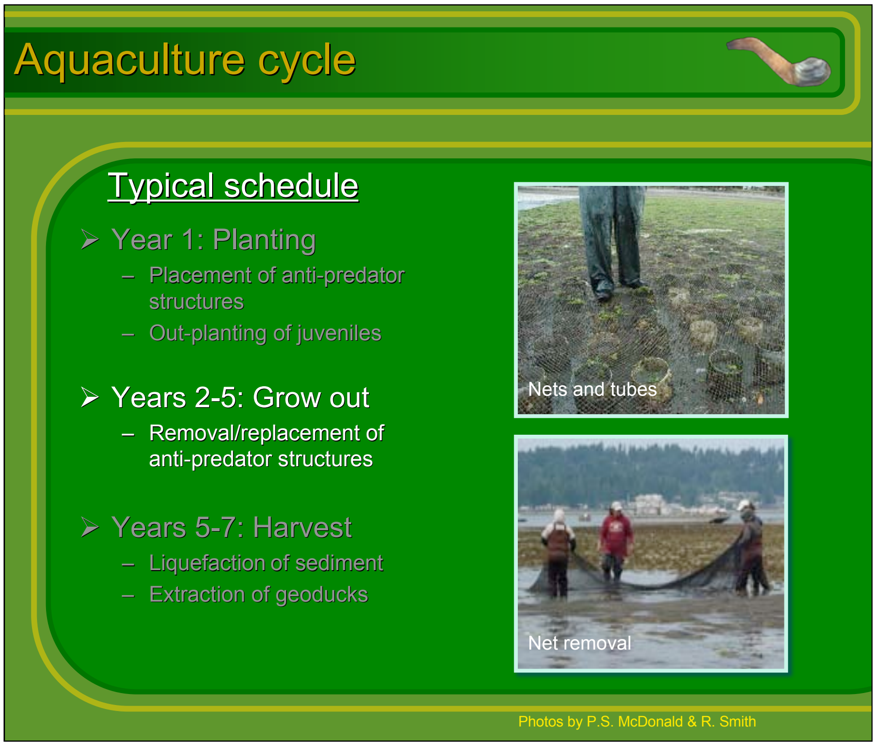
•Although each grower may modify and adapt their techniques to optimize yield, a generalized 5-7 year culture cycle might look something like this.

•I want to step through these generalized phases now since our project attempts to address ecological concerns in each phase.



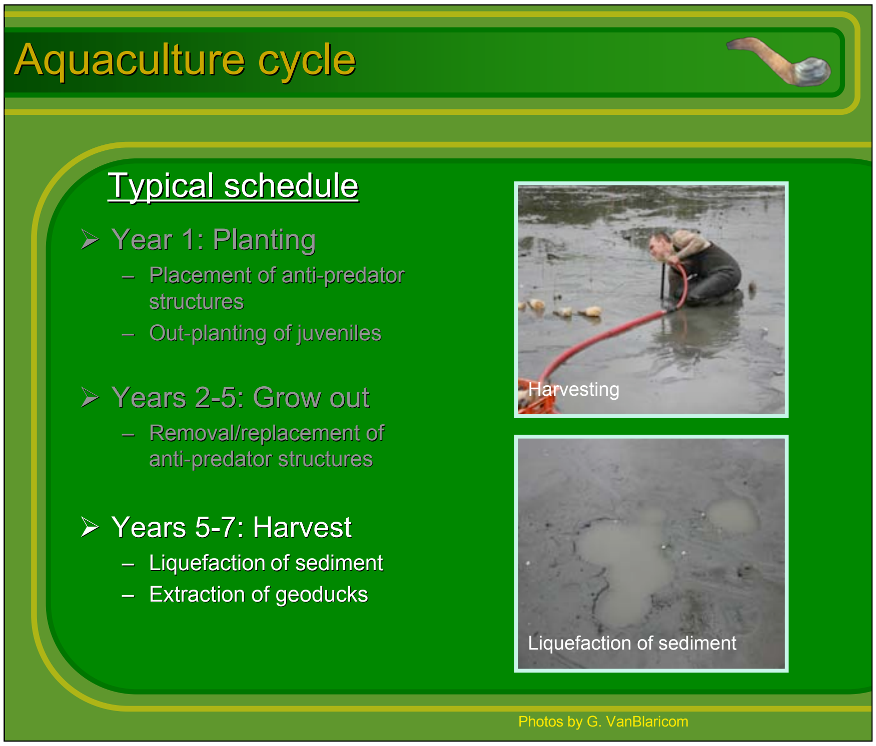
•In year 1 of the culture cycle, seed clams are planted along with the placement of anti-predator structures, including PVC tubes and netting.

•Obviously, the addition of structures and a high-density of filter-feeding clams represents at least a modification of the ecosystem.



•During the grow-out phase, in years 2-5, the nets and tubes are eventually removed.

•Again, the system has been modified by a change in surface structure and the continued growth of the high-density clams.



•The clams typically reach market size and are suitable for harvest in years 5-7.

•Geoduck are extracted from the sediment using a jet of water, which causes liquefaction of the sediment around the clam's body, allowing them to be removed easily.

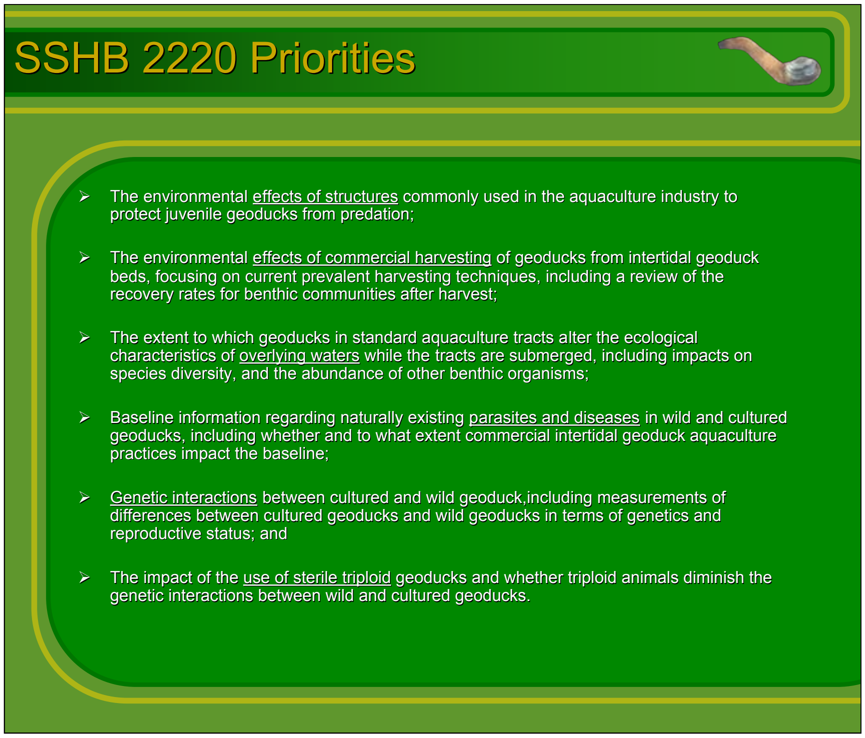
•Harvest represents the final modification to the ecosystem since liquefaction may affect nutrient release, sediment characteristics and the infaunal community.

•A Sea Grant funded literature review and aquaculture workshop revealed the dearth of peer-reviewed information concerning the ecological effects of large-scale geoduck aquaculture.

•As I'm sure many of you are aware, this lack of scientific data has caused concern about potential effects.

•and these concerns have put the industry at odds with upland property owners and conservationists.

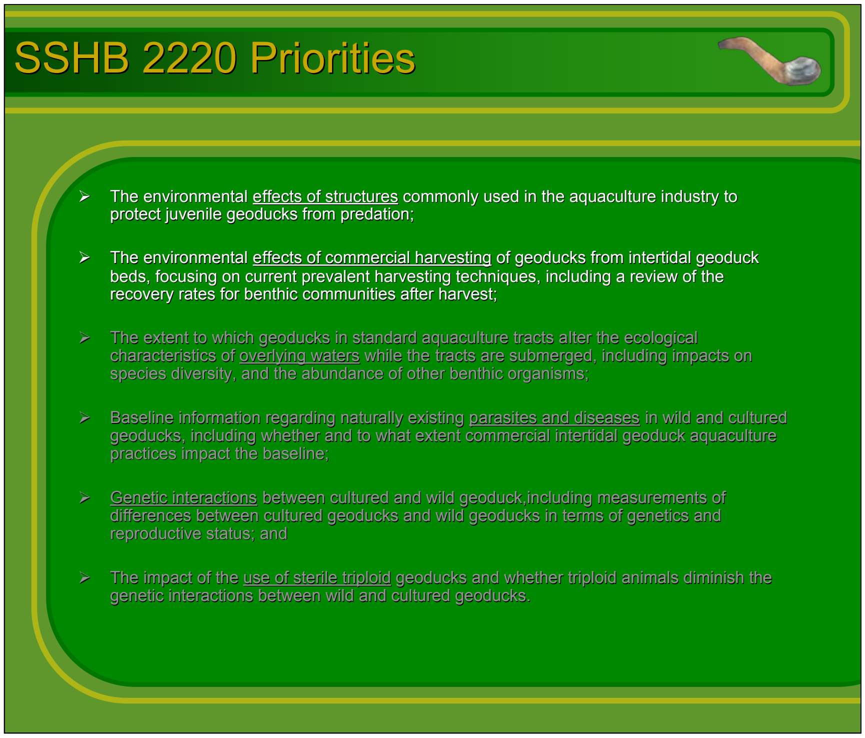
•Thus our research group seeks to provide data on the ecological effects of geoduck aquaculture that can inform resource management decisions.



•In response to requests by stakeholders, the 2007 WA State Legislature adopted HB 2220, in part to provide funding for research.

•As part of the house bill, WA Sea Grant was directed to commission a series of scientific studies that examine the possible effects of current aquaculture techniques on the natural environment of Puget Sound.

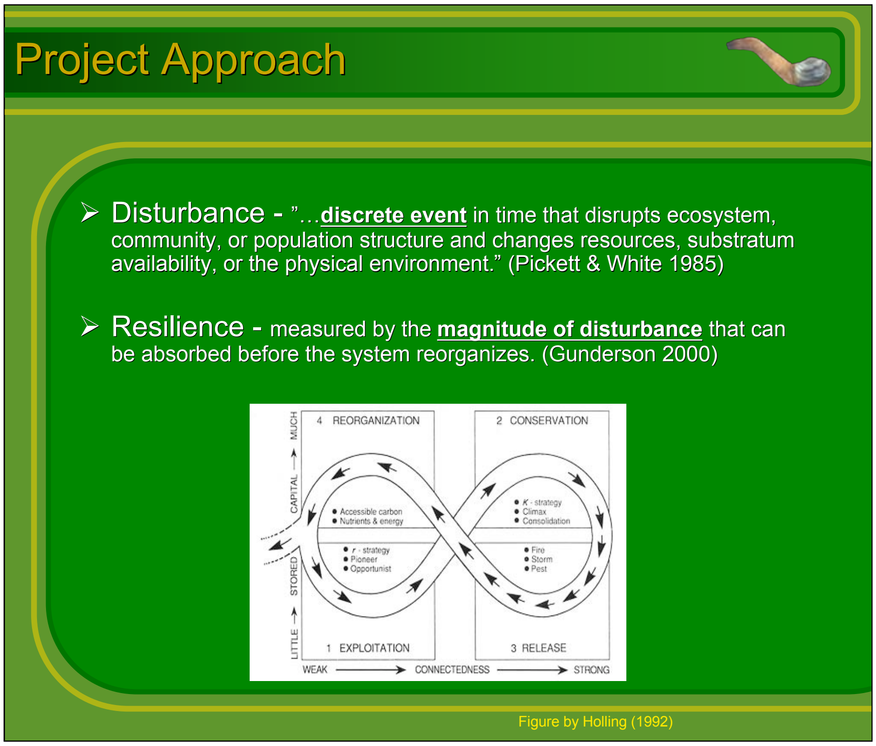
•In particular, the bill prioritized research on the effects of aquaculture structures and harvesting techniques, effects on overlying waters, parasites and diseases, Genetic interactions, and the effects of using sterile triploids.



•Our group received funding to address the first two priorities.

•1) The environmental effects of structures used to protect juvenile geoducks and

•2) the environmental effects of commercial harvesting focusing on current prevalent techniques.



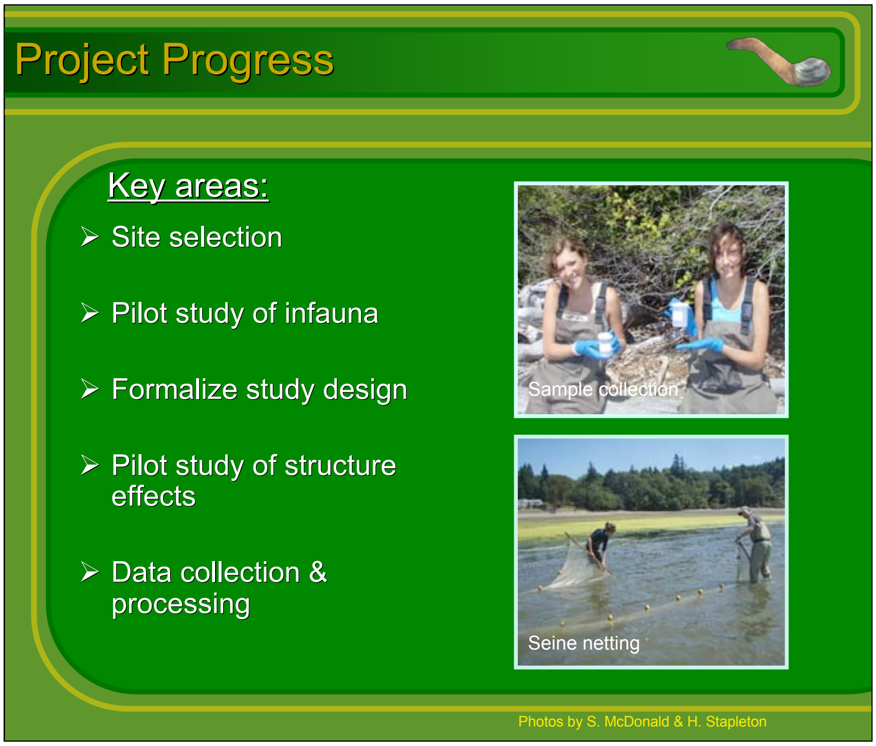
•An explicit part of our approach is compare geoduck aquaculture to other aquaculture techniques and natural levels of disturbance.

•We then track responses to disturbance and subsequent rates of recovery to ascertain ecosystem resiliency

•We use Pickett and White's definition that a disturbance is a relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substratum availability, or the physical environment.

•While resilience is the ability of a system to resist a change in state and can be measured by the magnitude of disturbance that can be absorbed before the system reorganizes.

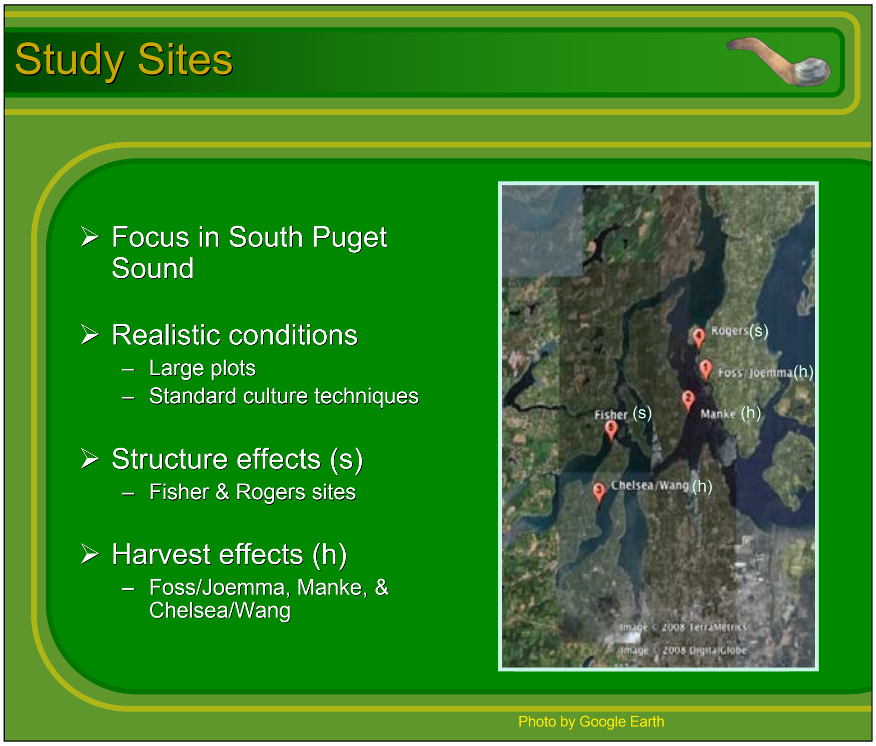
•In the 4-box model developed by Holling, systems can go through cycles of different states. The disturbances we're interested in occur here in box #3 and resilience considers how hard the system must be pushed to send it into box #4, the reorganization phase.



•Our research program has only been underway for a few months so I don't have a lot of results to share with you

•However, I would like to tell you about the progress we've made thus far in 5 key areas, including:

•site selection, a pilot study of infauna abundance, formalizing the study design, a pilot study of structure effects on mobile fauna, and continued data collection and processing.



•In terms of study site selection, we worked closely with a number of growers to find a core group of sites for initial sampling.

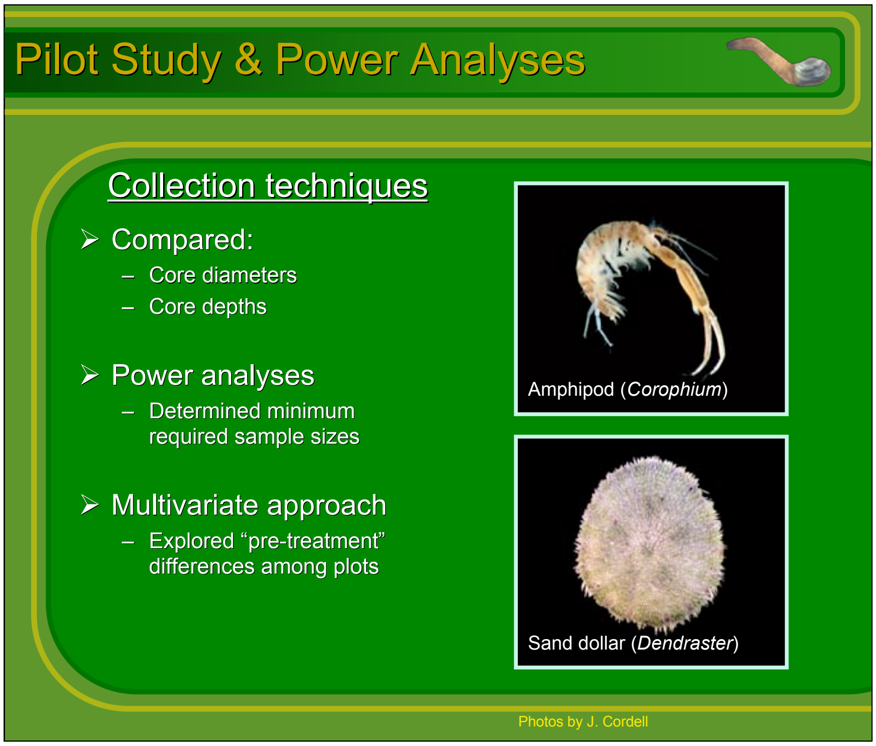
•This included site visits to areas across Puget Sound, although after consultation with Sea Grant and assessment of budget constraints, we're currently focusing on South Puget Sound.

•We also chose sites to maximize consistency of physical conditions and similarity of culture techniques.

•Since addressing scale effects is important, all of the plots are at least 2500 sq. meters (or nearly 27,000 sq feet).

•We're investigating the effects of aquaculture structures at the Fisher site in Totten Inlet and the Rogers site in Case Inlet.

•Harvest effects will be investigated at the Foss/Joemma and Manke sites in Case Inlet and the Chelsea/Wang site in Eld Inlet.



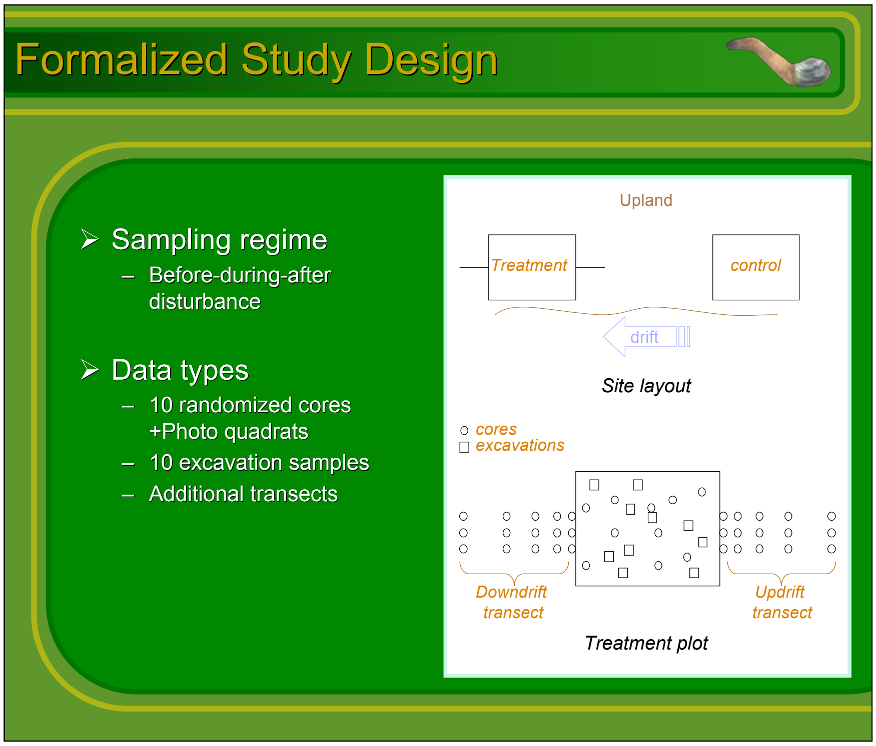
•Our initial sampling focused on a pilot study of infauna at these sites.

•The objective of this preliminary work was to test collection methods, including identifying the most suitable core diameter and depth.

•We also conducted power analyses to determine the minimum required sample size to detect differences in the abundance of important taxa.

•In addition to traditional power analyses, we've used multivariate techniques to explore differences in infaunal communities in our pre-treatment samples.

•Overall these preliminary efforts have been useful for streamlining sample collection and processing and have greatly improved our efficiency.



•As part of this first field season, we've also formalized our study design.

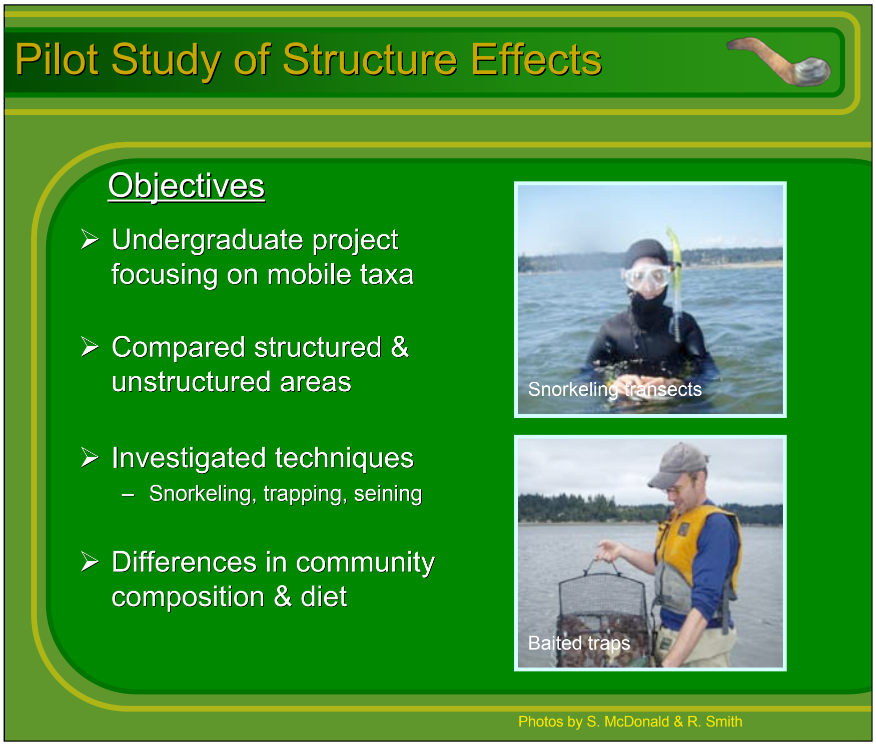
•Our sampling regime consists of samples taken before, during, and after the disturbance, whether that be addition of structure during planting, removal of structure for grow-out, or extraction of geoducks during harvesting.

•At each site, our large treatment and control plots are separated by up to several hundred meters.

•During each sampling period, we collect 10 randomized cores and photo quadrats within each plot that will eventually be used to determine plot-wide responses to disturbance. The cores are used for small infaunal invertebrates, while the photo quadrats provide information on % cover of vegetation and debris and burrow density.

•Additionally, 10 randomized excavation samples are used to sample large scarce invertebrates.

•To determine whether effects are limited to plots, transects of additional core samples are also collected at standardized distances from each plot. When possible these transects have been established updrift and downdrift of the treatment plots.



•Sea Grant encourages student participation in funded projects and we've been fortunate to work with many talented students thus far.

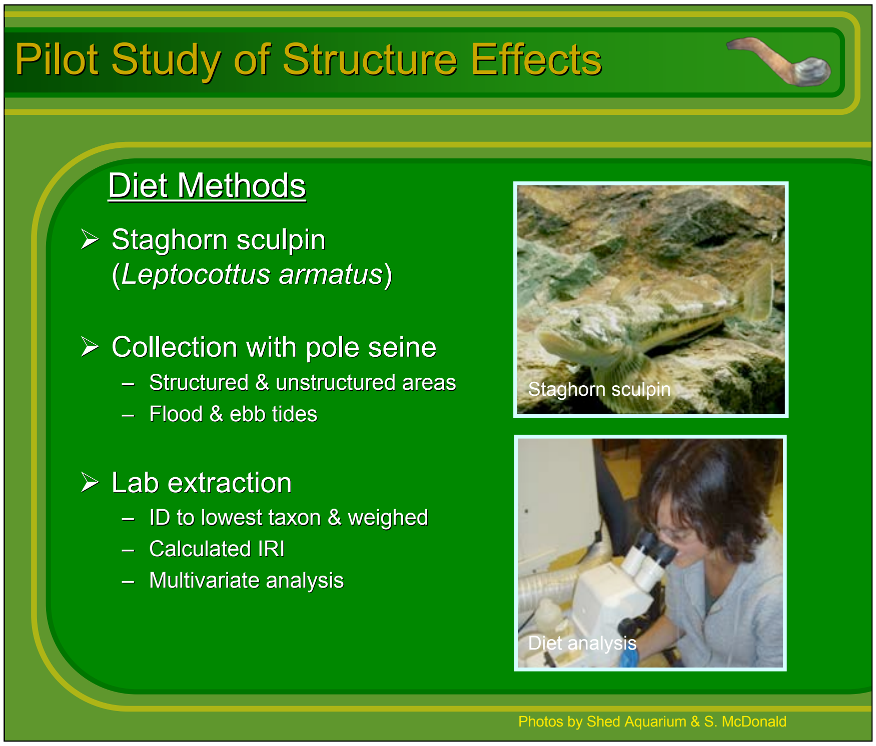
•In fact, as part of our first field season, we had an undergraduate, Rachel Smith, complete a pilot study investigating the effects of aquaculture structures on mobile taxa. Rachel was funded through the Research Experience for Undergraduates program at Shannon Point Marine Center.

•The pilot study compared communities of mobile organisms in plots with geoduck aquaculture structures to nearby areas containing no aboveground structure.

•and one of the objectives of the study was to evaluate the suitability of various sampling techniques, including snorkeling, trapping, and seining, for our larger project.

•In addition to comparing densities and relative abundance of important organisms, Rachel also conducted a fish diet study.

•I'd like to tell you about some of her work now but please bear in mind that these are pilot data from one study site and we are continuing to explore these patterns.



•Staghorn sculpin, Leptocottus armatus, were used as a model subject for the pilot diet study because they are abundant predators.

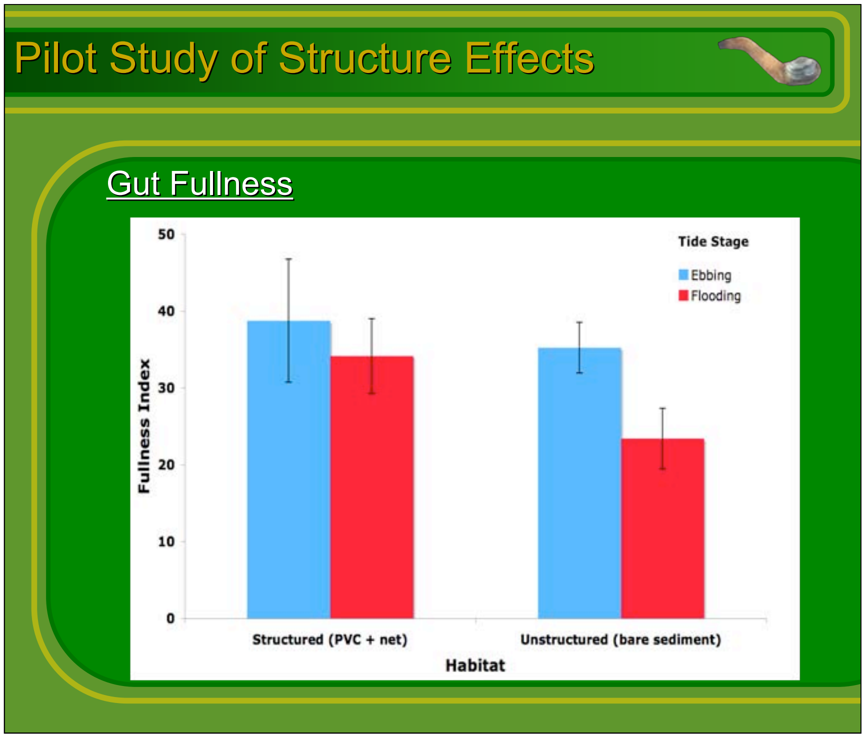
•Fish were collected using a pole seine on plots containing aquaculture structures and plots with no aboveground structure.

•and collections were made on both flooding and ebbing tides to capture evidence of feeding within the plots.

•In the lab, gut content was extracted, identified to the lowest taxonomic level, and weighed

•Rachel then calculated a simple index of relative importance based on weight, volume, and frequency of occurrence.

•and these results were analyzed with multivariate statistics.

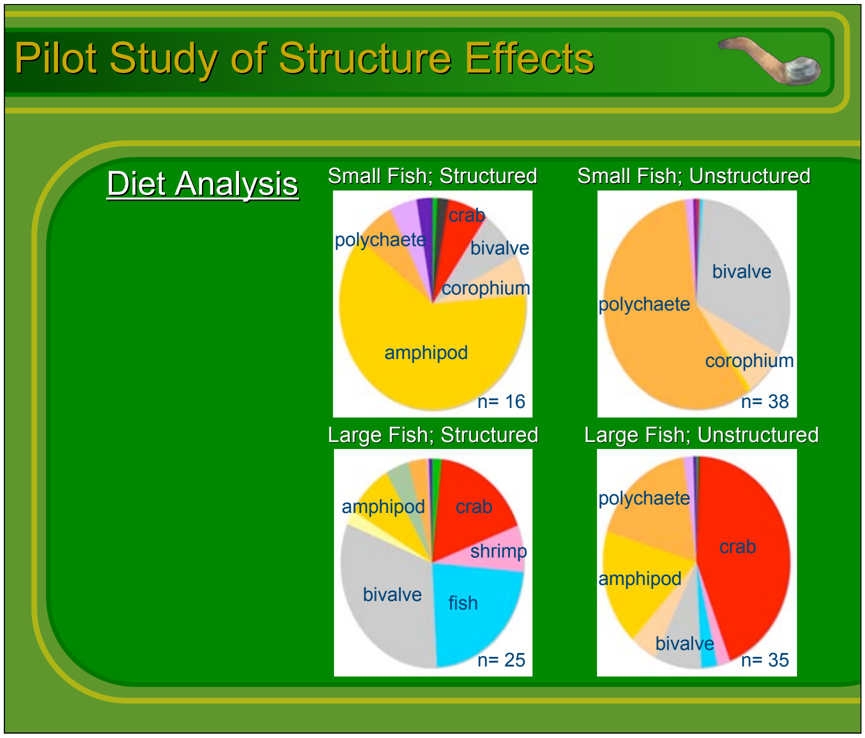


•Now I'd like to show you some of the results from this pilot study.

•This first figure depicts gut fullness, or gut content weight standardized by the size of the sculpin, on a plot containing geoduck aquaculture structures and an unstructured plot of bare sediment.

•Again, collections were made on both ebbing tide in blue and flooding tide in red. As you can see, guts of sculpin captured as they moved out of littoral plots were more full than those entering plots on flooding tides.

•This suggests that these sculpin are making intertidal forays to feed.



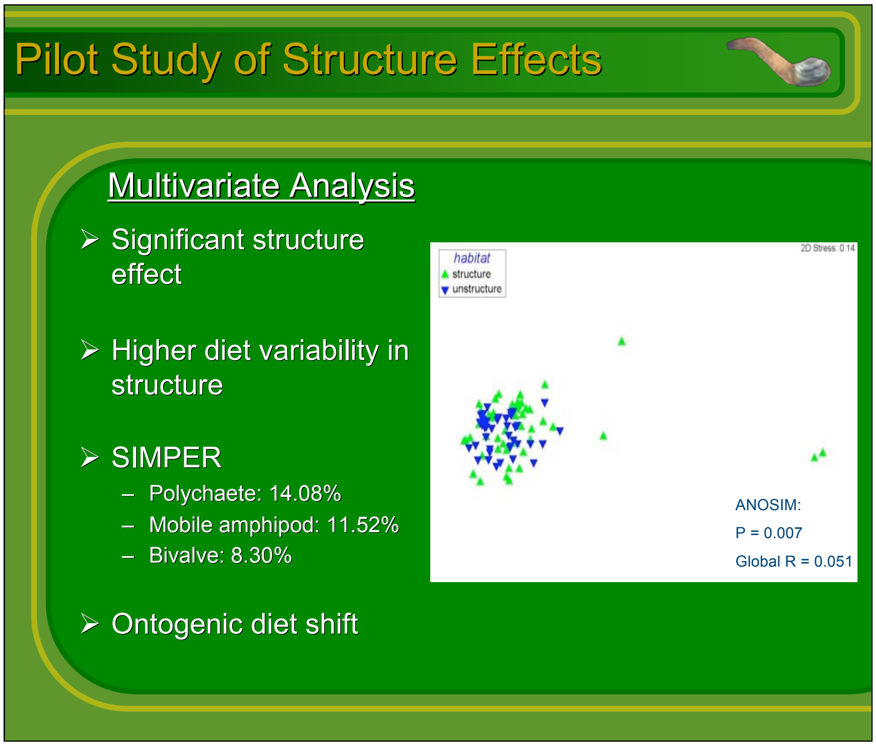
•These pie charts show the contribution of various prey categories to the diets of small and large staghorn sculpin in plots containing geoduck aquaculture structures and plots with no aboveground structure.

•Qualitatively, we can see differences in diet with sculpin size and habitat structure.

•For small sculpin, in particular, diets differ dramatically, with mobile amphipods making up the majority of the diet in areas with aquaculture structures and polychaetes making up the majority of the diet in unstructured areas.

•In general, sculpin diet in the structured plot is more diverse than in the unstructured plot.

•Moreover. larger sculpin have more diverse diets than small sculpin, possibly because their larger mouth gape allows them to take advantage of a wider range of prey resources.



•Our multivariate analysis detected a significant effect of habitat structure in the diets of staghorn sculpin.

•This is primarily seen in the ordination graph to the right as higher diet variability of sculpin foraging on the structured plot (green triangles) as compared to the unstructured plot (blue triangles).

•Using SIMPER software, we see the primary difference in diet can be attributed to the polychaete, mobile amphipod, and bivalve categories.

•Primarily, more mobile amphipods were consumed in the plot with aquaculture structures and more polychaetes and bivalves were consumed in the plot without aquaculture structures.

•Not surprisingly, we also saw evidence of ontogenic diet shifts with increasing sculpin size.

•As the project moves forward, lessons learned from Rachel's pilot study will be used in other efforts addressing the effects of aquaculture structures on the community composition of mobile taxa.

•Moreover, we'll use this information to investigate how differences in diet may be reflected in individual growth rates for mobile taxa.

•We will also continue to collect data on infauna and epifauna as planting and harvest occur and we'll track recovery using the methods I've described.

•In collaboration with our colleagues at the University of Maryland, We will relate patterns in biotic communities to changes observed in sediment characteristics and nutrients.

•Eventually we hope to expand the study across Puget Sound to incorporate conditions and practices used throughout the region.

•At this time I'd like to make a little plug for assistance.

•In order to address our research questions, we need the cooperation of property owners and industry stakeholders.

•Not surprisingly, finding appropriate sites is challenging since we require that plots be large, discrete, and adjacent to suitable unfarmed control sites

•So if you'd like to participate please contact me. We'd really appreciate the help.

•I'd like to close by acknowledging once again the funding source for this project - WA State legislature and WA Sea Grant

•The work would not be possible without the continued cooperation of growers, property owners and other folks involved in the issue. In particular, I'd like to thank Brian Phipps, Kent Kingman, Tom Bloomfield, John Lenz, Steve Bloomfield and Jeff Fisher.

•I also have to thank our team of volunteers and technicians that have been instrumental in sample collection and processing

•At this time, I'd be happy to take any questions.

•Thank you.