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Project PI: Carolyn Friedman
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I. INTRODUCTION

Shellfish aquaculture in the United States is based on both native species (e.g. hard clams and eastern oysters) and species that were introduced into culture after the turn of the last century. These include most of the bivalves cultured on the US west coast and Canada (e.g. Pacific oysters and Manila clams). At that time, neither regulatory agencies nor industry considered the threat that hitchhiking organisms and diseases posed. The resulting introductions of invasive species and exotic diseases created a number of persistent problems that still have not been solved. Current industry practices regarding the use of introduced species are highly regulated, but concerns persist regarding potential negative environmental impacts associated with the introduction of exotic species. The culture of native species is frequently recommended to reduce or avoid harmful interactions among cultured exotics and wild species (e.g Naylor et al, 2001). This strategy does not, however, preclude epidemiological and genetic impacts on native populations of conspecifics. Diseases naturally present at low densities in wild populations can achieve epidemic status in culture (e.g. White spot syndrome of penaeid shrimp, Dorf *et al.* 2005), and natural genetic structure can be disrupted via interbreeding between wild and cultured genotypes, potentially jeopardizing wild populations by decreasing their adaptive potential (Allendorf *et al.* 2001, Lynch 1991).

Shellfish aquaculture is an important component of rural economies on the US west coast with 2007 revenues in excess of $113 million. As an industry that produces a supply of healthful shellfish for humans and both receives and provides sustained ecosystem services though intensive growout of suspension-feeding bivalves, shellfish growers are in need of research to develop and implement ecologically and environmentally progressive practices. At the same time, it is increasingly clear that the continued growth of shellfish aquaculture (Fig. 1) requires access to larger areas of the intertidal, raising concerns over the cumulative effects of culture operations on intertidal and nearshore environments. The culture of native species such as geoduck clams creates potential for adverse interactions with wild conspecifics.

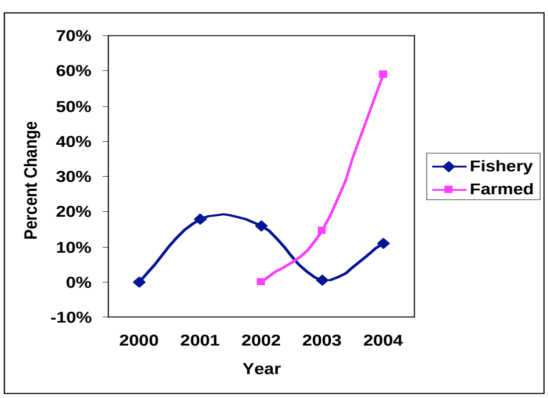

Fig. 1. Percent change in WA geoduck landings vs aquaculture production (Jonathan King, Northern Economics, Anchorage AK, personal communication).

Wild geoduck clams (*Panopea abrupta*, Conrad 1849) comprise a large proportion of Puget Sound biomass and, like other suspension feeders, provide vital ecosystem services as both primary consumers of phytoplankton and biodepositors (Newell, 2004). A Washington State commercial geoduck fishery, initiated in 1970, provides significant economic benefits; the potential for geoduck culture was recognized over 100 years ago (Hemphill, 1881), but was forestalled until development of sufficient economic demand and technical expertise in the mid 1990s (Beattie, 1992). Currently, geoduck aquaculture in Washington State (Fig. 1) is developing in close proximity to wild geoduck aggregations, though lack of a reliable seed supply and available habitat for growout has so far limited the industry's expansion.

The State of Washington is both the geographic center of the range of wild geoduck populations, and at the forefront of geoduck aquaculture. It is imperative to assess the potential effects of geoduck aquaculture on wild geoduck populations in Washington. The ongoing evolution of the geoduck aquaculture industry presents a unique and timely opportunity to evaluate, and potentially to mitigate negative effects of cultured-wild interactions in geoduck clams.

Geoducks are the target of the most economically important clam fishery in North America (Hoffmann, *et al.*, 2000). In addition to a robust demand from Asia, domestic demand for geoduck is increasing, but the capture fishery cannot satisfy demand in an ecologically sustainable fashion. In addition, on a return-per-acre basis geoducks are the western region's most valuable cultured shellfish species. Hence the intense interest in geoduck aquaculture and the predictions for continued rapid growth (Fig. 1). Cultured geoducks currently represent only about 16% of the 5.2 million pounds of Washington State geoduck. However, given current conditions, cultured geoduck production in Washington is projected to reach approximately 40% of Washington's wild geoduck harvest by 2010 (Jonathan King, Northern Economics, Anchorage, personal communication). That proportion is likely to increase even further as management of the wild fishery in Washington is expected to reduce spawning biomass per recruit to 40% of the unfished level (Bradbury and Tagart, 2000). Sustainable geoduck aquaculture may result in a reduction of fishing pressure on wild stocks, thus preserving natural habitat and genetic and ecological diversity.

Although only approximately 120 acres in Washington are currently devoted to geoduck production, established and startup growers are actively searching for intertidal ground to expand geoduck culture. In Washington State, approximately 30% of tidelands are in the public domain and managed by the Washington Department of Natural Resources (WDNR). WDNR has recently initiated leases of public tidelands for geoduck farming. Because they are the source of broodstock and genetic variability as well as an important provider of ecosystem services such as bentho-pelagic coupling and filtration, wild geoduck populations must be protected from disease, genetic perturbation and unsustainable fishing pressure.

Responsible management of present and future aquaculture so as to avoid negative interactions with wild geoduck populations requires an improved understanding of the disease dynamics in those populations. What are the spatial and temporal patterns of disease in wild populations, and how might they be altered by exchanges of pathogens with cultured populations?

II. METHODOLOGY

Objectives

1) To characterize endosymbiotic, commensal, and parasitic organisms associated with wild geoduck clams in three wild populations (n=60 each) in Summer and Winter.
2) To provide baseline information on the health status and disease prevalence in wild populations prior to possible perturbation from intensive geoduck culture.

Methods

When the Washington Sea Grant Geoduck Program RFP came out, funding was to be released in January 2008. We planned our project accordingly, with a Winter sample to be taken in Jan-Feb 08, and a Summer sample to be taken in August 08.

Characterizations and analyses were to have been initiated on the Winter 2008 samples in early Summer 2008. Due to delays in funding, we were unable to complete the planned Winter sample, so our disease characterizations and analyses are on hold. Winter 2008 samples were to be provided by Washington Depts. Natural Resources (Totten Inlet) and Fish and Wildlife (Thorndyke Bay), and by the Jamestown S'Klallam Tribe (Freshwater Bay); we have tentative (pending sufficient funding in these agencies) agreements with the same agencies for Winter 2009 sampling.

In each collection period we will target populations in south Puget Sound (Totten Inlet), Hood Canal (Thorndyke Bay), and the Juan de Fuca Strait (Freshwater Bay). For the August 2008 collection, sixty animals were measured (length and weight) and 3-5 mm cross sections were removed that contain siphon, ctenidia, labial palps, mantle, heart, digestive organs, and gonads. Because geoducks are of large size, for each individual a minimum of three histological cassettes was collected and processed to ensure sufficient coverage of somatic tissues. During dissections, small pieces of foot, digestive gland, and gill tissues were also excised and stored in 95% ethanol and archived for future diagnostic and genetic work within the collected populations. Any gross lesions were recorded and pieces of observed lesions were removed for histological processing or other standard pathology/microbiological methods (e.g. molecular characterization). Samples were preserved in Davidson's solution for 24 hr, and then stored in 70% ethanol until processed for routine paraffin histology and stained with hematoxylin and eosin. For each individual, three slides containing all sampled tissues will be examined for the presence of disease organisms. Parasite and disease prevalences will be calculated within and among sampling locales and seasons.

III. RESEARCH ACTIVITIES

1. SITE SELECTION

Three sampling sites reflecting the geographic range of geoduck clam culture within the State have been selected (Table 3). Sampling of wild populations, using SCUBA was conducted in July and August 2008, in partnership with Washington Department of Natural Resources (Totten Inlet), Washington Department of Fish and Wildlife (Thorndyke Bay) and Lower Elwha Klallam Tribe (Freshwater Bay).

Site Name	Location	Site Description
Strait of Juan de Fuca	Freshwater Bay	Northern site (A)
Hood Canal	Thorndyke Bay	Middle site (B)
Puget Sound	Totten Inlet	Southern site ©

Map of sample sites (see table above). Source: soundwaves.usgs.gov/2005/01/ uget-soundLG.jpg

2. FIELD ACTIVITIES

Date	Location	Activities
July 30 2008	Totten Inlet: 47.10.107 Lat by 122.57.395 Long	64 geoducks were collected and sent to UW
July 31 2008	Thorndyke Bay	55 geoducks were collected and sent to UW*
August 7 2008	Freshwater Bay	60 geoducks were collected and sent to UW

*The pump broke and a second trip resulted in an additional 2 clams collected for a total of 55 for this site for Summer 2008.

3. LABORATORY WORK
For the Summer 2008 collections, 55-64 animals per site were measured (length and weight) and 3-5 mm cross sections were removed that contain siphon, ctenidia, labial palps, mantle, heart, digestive organs, and gonads. Because geoducks are of large size, for each individual a minimum of three histological cassettes was collected and processed to ensure sufficient coverage of somatic tissues. During dissections, small pieces of foot, digestive gland, and gill tissues were also excised and stored in 95% ethanol and archived for future diagnostic and genetic work within the collected populations. Any gross lesions were recorded and pieces of observed lesions were removed for histological processing or other standard pathology/microbiological methods (e.g. molecular characterization).

IV. RESULTS TO DATE

Our Summer 2008 samples have been processed, slide mounted, and stained. The slides are in the process of being screened, but much of the characterization and analyses will not occur until Summer 2009 due to the sampling delay described above.

For all gross abnormalities, an extra cassette was taken. Gross abnormalities include for Totten Inlet clams: one with a pustule and one with a discolored mantle; For Freshwater Bay and Thorndyke Bay: no abnormalities noted.

V. OUTREACH

We presented our proposed research and complementary research in an oral presentation titled: ENDOSYMBIOTIC, COMMENSAL, AND PARASITIC ORGANISMS ASSOCIATED WITH WILD GEODUCK CLAMS (*Panopea abrupta*). Authors included Santa Cruz, A, Vadopalas, B and Friedman, CS in October 2008 at the Pacific Coast Shellfish Growers Association joint conference with the Pacific Coast Section of the National Shellfisheries Association in Chelan, WA.

VI. DISCUSSION

Given that samples have are just beginning to be examined we will discuss our findings in a later report.

Adequate baseline information on the presence of absence of particular parasites and pathogens is crucial for the management of both wild and cultured stocks because it allows us to identify both potentially problematic pathogens and the locales in which they occur. As an example, along the west coast of North America a bacterial disease of abalone, withering syndrome, has produced catastrophic losses of native abalone and has also reduced revenue in abalone farms (Haaker *et al.* 1992, Moore *et al.* 2000, Friedman & Finley 2003). One of the key factors in delaying identification of this abalone pathogen was a lack of baseline disease data (Haaker *et al.* 1992, Friedman *et al.* 1993, 2000). In Australia, a recently observed (December 2005 to present) herpes-like virus has caused severe losses of wild abalones, and a lack of baseline health information has made it difficult to determine whether the pathogen emerged from native stocks or was introduced (Friedman, pers. obs.). Similar deficiencies in background information have been observed in many marine species (Harvell *et al.* 1999). Our project will advance our knowledge of geoduck health in Washington state.

VII. REFERENCES

Burreson, E.M., Stokes, N.A., Friedman, C.S., 2000. Increased Virulence in an Introduced Pathogen: *Haplosporidium nelsoni* (MSX) in the Eastern Oyster Crassostrea virginica. Jounal of Aquatic Animal Health 12, 1-8.

Friedman, C. S., Roberts, W., Kismohandaka, G. and Kedrick, R.P. 1993. Transmissibility of a coccidian parasite of abalone, *Haliotis* spp. *J. Shellfish Res.* 12:201-205.

Friedman, C. S., Andree, K.B., Beauchamp, K.A., Moore, J.D., Robbins, T.T., Shields, J.D., Hedrick, R.L. 2000. '*Candidatus Xenohaliotis californiensis*', a newly described pathogen of abalone, *Haliotis spp*., along the west coast of North America. *Int. J. Syst. Evol. Microbiol.* 50:847-855.

Friedman, C. S. and Finley, C.A. 2003. Evidence for an anthropogenic introduction of "*Candidatus* Xenohaliotis califoriensis", the etiologic agent of Withering Syndrome, into northern California abalone populations via conservation efforts. *Can. J. Fish. Aquat. Sci.* 60:1424-1431.

Haaker, P. L., Richards, D.V., Friedman, C.S., Davis, G.E., Parker, D.O., and Togstad, H. 1992. Mass mortality and withering syndrome in black abalone, *Haliotis cracherodii* in California. *In S.A. Shephard, M.J. Tegner, and S.A. Guzman del Proo, eds. Abalone of the World.* Oxford: Blackwell Scientific:214-224.

Harvell, C.D., Kim, K., Burkholder, J.M. Colwell, R.R., Epstein, P.R., Grimes, D.J., Hofmann, E.E., Lipp, E.K., Osterhaus, A.D.M.E, Overstreet, R.M., Porter, J.W., Smith, G.W., and Vasta, G.R. 1999. Review: Marine ecology - Emerging marine diseases - Climate links and anthropogenic factors *Science* 285: 1505-1510.

Moore, J.D., Robbins, T.T., and Friedman, C.S. 2000. Withering syndrome in farmed red abalone, Haliotis rufescens: Thermal induction and association with a gastrointestinal Rickettsiales-like procaryote. *Journal of Aquatic Animal Health* 12:26-34.

Naylor, R.L., Williams, S.L., Strong, D.R. 2001. Aquaculture-a gateway for exotic species. *Science* 294 (5547):1655-1656.