OMB Approval No. 0648-0384
Expiration Date: 3/31/2013

Project Final Report

A. Grant Number: NA11NMF4570218

B. Amount of Grant: $179,053 to Virginia Institute of Marine Science over 2 years (plus extension). This year's budget was $88,795.

C. Project Title: Population Decline and Restoration of Soft-Shell Clams in Chesapeake Bay: Role of Predation, Habitat, Disease, and Environmental Factors

D. Grantee: Virginia Institute of Marine Science

E. Award Period: 07/01/2011 - 06/30/2014 (including no-cost extension)

F. Period Covered by this Report: 07/01/2011 - 06/30/2014

G. Summary of Progress and Expenditures to Date:

l. Work Accomplishments: (as related to project objectives and schedule for completion)

a. Brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant

Faculty, staff, and students from the Virginia Institute of Marine Science (VIMS), along with collaboration from Anson Hines and staff at the Smithsonian Environmental Research Center (SERC), have researched the causes of the decline in soft-shell clam, *Mya arenaria*, populations in Chesapeake Bay. A suction-sampling survey of *Mya arenaria* and other bivalves in the upper and lower Chesapeake Bay continued this year through the spring of 2014. In addition, caging studies were conducted with *Mya arenaria* in different habitat types (mud, sand, seagrass, and shell hash) in the York River and various predation studies were conducted in Maryland. In the upper Bay, we also conducted a survey using escalator dredging, with the help of local watermen. We examined any *M. arenaria* and *T. plebeius* collected for the presence of the disease *Perkinsus chesapeaki*.

Sampling Methods: Soft-shell clam Survey

- In a quantitative sampling effort, we surveyed soft-shell clams in various habitat types in three replicate MD (Eastern Bay, Chester River, and Rhode River - the western shore, from Sandy Point south to Rhode River) and three replicate VA (York River, Mobjack Bay, Lynnhaven Bay) tributaries of Chesapeake Bay.
- We examined current and past prevalence of the disease *Perkinsus chesapeaki*, from sites that have been used previously by the Cooperative Oxford Lab (with assistance from Chris Dungan, MD DNR), as well as current prevalence in newly established sites from which we determined *P. chesapeaki* disease prevalence.
- In the Maryland portion of Chesapeake Bay in spring and fall 2013, in conjunction with the Maryland Waterman's Association, 772 clams (531 *T. plebeius*, 241 *M.arenaria*) were collected from the eastern and western shore sites of Maryland and assayed for the presence and intensity of *Perkinsus chesapeaki*. Clams were collected via hydraulic escalator dredge with the help of a waterman, Captain David Baxter.

- All *T. plebeius* and *M. arenaria* were counted, and when available, approximately 30 clams of each species were randomly retained, from each site, and assayed for disease. Clam densities at each site were determined by dredge length and time. The shell length of all assayed clams were measured to the nearest mm. Dissolved oxygen, salinity, and temperature were also recorded at each station using a YSI.
- In three subestuaries of the Lower Chesapeake Bay (Lynnhaven River System, York River, Mobjack Bay), bivalves were collected in November 2011, April 2012, July 2012, October 2012, April 2013, and July 2013; we used 4 sites within each subestuary; we had 3 replicate samples from each site.
- Sites were chosen haphazardly from sites of known substrate composition, resulting in a relatively equal number of sites with shell hash, oyster shell, and vegetated substrate.
- At each site, we measured temperature, salinity, and dissolved oxygen using a YSI. The same procedures were used in MD and VA.
- Bivalves were collected using a suction sampler, which collects samples of 0.11 m^2 area and 40 cm depth, and starting in March 2012 we also took cores of 0.008 m^2 area and 10 cm depth.
- Samples were sieved through 3-mm mesh (suction samples) or 500-µm mesh (core samples) and frozen for the lower Bay VIMS samples. Upper Bay SERC suction samples were sieved through 1-mm mesh, and no subcore was taken.
- In the laboratory, for VIMS samples, all *M. arenaria* and *T. plebeius* in the 3-mm samples were measured to the nearest 0.1 mm, dried in a drying oven for 48 hours at 60 ^{o}C, ashed in a combustible oven, and the ash-free dry weight was calculated as a measure of biomass. For the SERC samples, 1-mm samples were measured to nearest 0.1-mm, and there was no ashing.
- Some of the 500-µm samples were lost in freezer failures but the remainder will be sorted under a microscope and any bivalves will be identified to species and counted.
- Starting in spring of 2012 in VA, we quantified blue crab abundance at each site using 6 replicate 20 m tows of a modified crab scrape. All blue crabs were measured to the nearest 0.1 mm. In addition, any fish caught in tows were identified, measured to the nearest 1 mm and released. In MD, tows were conducted in the spring, summer, and fall with a 16' wide otter trawl for seven minutes, for approximately 500 meters. Two tows were conducted at each of 17 sampling sites. All blue crabs and fish were measured to the nearest 1-mm and released.
- Starting in spring of 2012 in VA, we counted the number of ray pits present within 1 m to either side of a 50-m transect as a proxy of cownose ray (*Rhinoptera bonasus*) abundance.
- The relationship between *M. arenaria* and *T. plebeius* biomass, environmental variables, and predator abundance were examined using generalized linear models (GLMs) and generalized additive models (GAMs).
- Similar survey sampling using suctions and ray-pit counts were conducted in Maryland using a 50-m transect, searching 1-m to either side, at each of the seventeen sites.
- In the Maryland sites, we worked with the MD Watermen's Association to quantify clam densities in opportunistic locations by riding along with watermen and quantifying their catch from clam dredging, a quantitative measure, as they fished for *M. arenaria.*
- We have completed the disease processing for *M. arenaria* and *T. plebeius* collected in Maryland. We dissected 1098 *T. plebeius* and 444 *M. arenaria* for disease analysis.

Results: Soft-shell clam survey Suction sampling – Virginia (Figs 1-3 at end of report)

- All surveys (fall 2011, spring/summer/fall 2012, and spring/summer 2013) have been completed for the lower Bay.
- In November 2011, bivalve species richness was significantly greater in Mobjack Bay and the Lynnhaven River System than in the York River. However, only shell hash

habitats were sampled in the York River in 2011, whereas the other two rivers had more substrate types available that were sampled.

- Two individuals of *M. arenaria* were found in fall 2011, so *M. arenaria* comparisons among habitats were not possible.
- *T. plebeius* were found in all Virginia rivers sampled, and *T. plebeius* biomass was significantly greater in seagrass habitats than in shell hash habitats. This trend may be driven by the presence of larger *T. plebeius* in seagrass habitats, though this trend was not significant.
- In Virginia, *M. arenaria* biomass was significantly lower in summer, during the predation period, than in spring for both 2012 and 2013.
- *M. arenaria* were found at extremely low densities in the Lower Chesapeake Bay. The survey captured 2 *M. arenaria* in fall of 2011, 62 *M. arenaria* in the spring of 2012 (nearly all of which were in the York River), 5 *M. arenaria* in spring of 2013 (all in the York River), 0 *M. arenaria* in the fall of 2012, 5 *M. arenaria* in the spring of 2013 and 4 new recruits in summer 2013 (in Pleasure House Creek, Lynnhaven).
- Generalized linear models (GLMs) were used to analyze spring and summer 2013 *T. plebeius* biomass (AFDW data) and generalized additive models (GAMs) were also used.
- *M. arenaria* density overall (Figs 1 & 2): *M. arenaria* density was significantly greater in the York River than in other lower Bay tributaries (Fig. 1), and density was slightly greater in the spring of both years (Fig. 2; marginally significant $p = 0.07$). Year was not significant in the GLM, likely because of many zeroes in the data set, and GAMs were used for this reason. GAMs identified a significant effect of year, with a significant decrease in *M. arenaria* density in 2013. There was no effect of predator abundance, predator size, or characteristics of substrate on *M. arenaria* density.
- *T. plebeius* density overall (Figs 1 & 3): *T. plebeius* density increased over time. *T. plebeius* densities were significantly greater in seagrass, and significantly less in gravel habitats (Fig. 3). GAMs identified a significant positive relationship between *T. plebeius* density and substrate volume. There was no effect of predator abundance or predator size on *T. plebeius* density.
- *M. arenaria* biomass overall: *M. arenaria* biomass peaked in the spring and declined through the summer and fall, when predators were most abundant. *M. arenaria* biomass was greatest in spring 2012 at the mouth of the York River (43.3 g/m^2), and significance of season and river in the linear model was largely driven by the population of *M. arenaria* that occupied the mouth of the York River in the spring of 2012. GAMs did not identify a significant effect of predator abundance, predator size, or substrate volume on *M. arenaria* biomass.
- *T. plebeius* biomass overall: *T. plebeius* biomass was not a function of year or season, but biomass appeared to increase throughout the sampling period. *T. plebeius* biomass was positively correlated with the presence of seagrass. GAMs identified a marginally significant positive relationship between substrate volume (volume of any substrate retained on 3-mm mesh) and *T. plebeius* biomass, but predator abundance and size were not significant predictors of *T. plebeius* biomass.
- In summary, the study period encompassed two fairly mild years (in terms of temperature and storm activity) that exhibited marked differences in *M. arenaria* population size. *M. arenaria* were abundant in 2012 and nearly absent in 2013. *M. arenaria* exhibited seasonal trends in biomass that reflected the active feeding season of many Chesapeake Bay predators, and even though the study did not capture a significant effect of predator size or abundance, it is likely that predators played a role in the decline of *M. arenaria* biomass and density through the summer and fall each year. *T. plebeius* biomass and density did not exhibit seasonal trends but appeared to increase throughout the duration of the study. *T. plebeius* biomass and density appeared to be a function of characteristics of habitat, including the presence of seagrass and the volume of substrate.

Results: Soft-shell clam survey using escalator clam dredge – Maryland (Figs 4-6 at end of report)

- Spring 2013 clam densities, for both species (359 total in spring with 200 *T. plebeius* and 159 *M. arenaria*), experienced a marginal increase from their season lows in the fall of 2012, and neither species experienced an increase anywhere near the magnitude that occurred in the spring of 2012.
- Eastern and Western shore clam densities, in the spring of 2013, were similar to each other, unlike the density differences seen in the spring of 2012.
- Between the spring and fall 2013 samplings (413 total in the fall with 331 *T. plebeius* and 82 *M. arenaria*), *T. plebeius* densities increased at all but two sites. *M. arenaria* densities decreased from spring to fall at all but one site.
- Disease prevalence among *T. plebeius* assayed in the spring of 2013 was similar to that seen in the fall 2012 clams. More than half of the sites sampled in the fall of 2013 had infection rates of 100%, only one site had a lower rate that its spring counterpart. Despite the increase in infection, disease intensity in the fall of 2013 seemed nearly equal to that of the spring 2013 samples.
- Spring 2013 disease prevalence among *M. arenaria* was also similar to fall 2012 levels. Infection prevalence was near 100% in the fall of 2013 for the few sites where *M. arenaria* could reliably be obtained. Spring of 2013 disease intensity was lower than the fall of 2012, similar to the trend seen in the spring of 2012 and fall of 2011. With the exception of one station, disease intensities were all higher in the fall of 2013 than in the spring of 2013.
- One of the Maryland sites (Western shore) could not be sampled in spring 2012 for the dredging portion of the study because of the collaborating waterman's schedule.
- In general, clam densities at Eastern and Western shore sites, in the spring of 2012, were higher than fall 2011 densities. Spring 2012 densities declined through the summer of 2012 and fall 2012 densities were the lowest recorded for both species. Clam densities at Eastern shore sites were higher than at Western shore sites. *T. plebeius* densities were approximately 5x higher at Eastern shore sites, *M. arenaria* were approximately 10x higher at Eastern shore sites.
- *Perkinsus chesapeaki* infection reached a maximum of 70% in the fall of 2011. One site had an 83% infection rate in the spring of 2012, but the majority of the sites sampled showed no infection, likely due to a good recruitment over the winter, low water temperatures, and low salinity. Two sampling sites had 100% infection in the summer of 2012, and several others, where clams were available, had infection rates greater than 50%. Almost half of the sites where clams were collected in the fall of 2012 had infection rates of 100%. The lowest infection rate was 48%.
- Infection intensities, using the Mackin Scale (0 = no infection through 5 = heavy infection), were "light", less than 2, at all sampling sites across all sampling periods, with the exception of one site in the fall of 2011 that was greater than 2.
- Recruitment appeared to increase in 2013, though it was not as high as the 2012 recruitment. These lower numbers could be because the sampling was conducted slightly later in spring 2013 than spring 2012, and predation may have already had an effect on populations. Disease seems low in the new recruits and low overall in 2013.
- The overall pattern is variation in spring recruitment strength followed by high summer mortality associated with predators, fishing, and moderate disease intensity. Notably, mortality occurred prior to the large storms that hit the Chesapeake Bay in 2012.
- Juvenile *M. arenaria* were collected from Indian Field Creek, York River, VA, in April 2013 and analyzed for *Perkinsus chesapeaki* in July 2013. Hypnospores were present in two individuals as a very light infection.

Results: Comparison of SERC and Maryland DNR soft-shell clam surveys using escalator clam dredge - Maryland

- We obtained soft-shell clam data from Maryland DNR for density, *Perkinsus* prevalence, and *Perkinsus* intensity during 2001-2008 and compared it with 2011-2013 data collected during the present study.
- *M. arenaria* and *T. plebeius* density were similar to the period 2006-2008 and below the 2001-2008 average.
- *Perkinsus* prevalence in fall samples was usually between 60-100% for both *M. arenaria* and *T. plebeius* and showed no trend.
- Mean *Perkinsus* intensity in fall samples varied from 0.5 to 3 on the Mackin scale and showed no trend.
- The limited available long-term data indicated that both *M. arenaria* density and fishery landings in Maryland declined by >99% from 1962 to 2013.
- There was little difference in the density of *T. plebeius* from 2001-2013. However, there was a strong decreasing trend and an 85% decline when the three-year average from 2001-2003 was compared with 2011-2013.

Sampling Methods: Soft-shell clam field caging study & lab experiments – Virginia

The following experiment was completed in the York River in summers 2012, 2013, and 2014:

- Four to six replicate cages, caging controls, stockades, and uncaged plots were placed in seagrass, sand, shell hash, and mud habitats in the York River to examine predation by blue crabs and cownose rays on soft clams.
- Cages were 0.5 x 0.5 m and were constructed of 13 mm mesh with PVC frames. Cages were sunk into the sediment approximately 10 cm.
- Stockades were constructed by placing 8 10-ft PVC poles around the plot at 25 cm intervals. Stockades exclude cownose rays, while allowing crab and fish predation.
- Healthy soft-shell clams (*M. arenaria)* were marked with permanent marker and planted at densities of 12 clams per each 0.25 m^2 plot.
- A cage was placed over all planted clams to allow them to acclimate to field conditions for 24 hours.
- After five to seven days, the plots were collected using a suction sampler and sieved across a 3-mm mesh sampler, and the remaining bivalves were counted as well as any broken shells. Count data was converted to proportional mortality per day to account for any differences in experimental duration among plots.
- Data was analyzed using Akaike's Information Criterion (AIC), which allows for the comparison of multiple working hypotheses. Location, habitat type (i.e. substrate quantity and quality), sediment grain size, and predator (i.e. caging) are all hypothesized to have an effect on soft-shell clam survival.
- We examined environmental effects (temperature, salinity) by comparing survival of clams in experiments in 3 replicate sites each in MD and VA (which differ in environmental characteristics) and in targeted replicated lab experiments examining clam survival with a fully crossed design with 24 replicates in each of two temperatures (22 ^{o}C and 30 ^{o}C) and two salinities (5 psu, 20 psu).

Results: Soft-shell clam field predation and caging experiments – Virginia

- In 2012, high mortality rates were observed for *M. arenaria* in partial cages, stockades, and uncaged plots as compared to caged controls. This indicates that crabs are the major predators of soft-shell clams in this system. There was a significant interaction effect driven by the stockade treatment in sand, suggesting that stockades decrease clam mortality in sand. This may be evidence for ray predation in sand.
- Caging experiments in VA in June 2013 experienced nearly 100% mortality in all treatments over a period of 5 days, preventing any further analysis of the effects of habitat or specific predators on clam mortality.

- Caging was completed in late May 2014 in the York and Mobjack Rivers and analyses are underway.

Results: Soft-shell clam survey Temperature and salinity laboratory experiment – Virginia

- The experiment was completed with a summer Governor's School intern and GK-12 students involved in the NSF GK-12 PERFECT program in the summer and fall of 2013.
- Clams were exposed to extreme temperatures (22°C and exceeding 30°C) and salinities (below 5 psu and 20 psu) for two weeks.
- There was a significant interaction between the effect of salinity and temperature on clam mortality, such that extreme mortality occurred when high temperatures and low salinities occurred together.
- When high temperatures or low salinities occurred alone, mortality was similar to the control (~ 20 psu, ~ 22°C).
- There was no effect of extreme salinity or temperature on clam growth rates over the two-week period.

Sampling Methods: Soft-shell clam field caging study – Maryland

- A summer-intern experiment was completed in the Rhode River in summer 2012.
- Five 0.25 m^2 experimental plots, each containing five small *M. arenaria* (35-45 mm) and five *T. plebeius* (50-75 mm) were placed in a mud/sand habitat in Canning house Bay, in the Rhode River, MD.
- Clams were lightly buried in the sediment and covered with a 0.5-m x 0.5-m cage constructed of 13-mm mesh for 24-hours, to allow for acclimation.
- After 24-hrs, cages were removed and exposed to predation for an additional 24-hours.
- Experimental plots were sampled with a suction sampler through 1-mm mesh 48-hours after initial deployment.
- Six controls were deployed at the same time. Two caged controls with clams, two caged controls without clams, and two un-caged controls without clams. Caged controls remained covered for the entire experiment.

Results: Soft-shell clam caging study – Maryland

- Predation on clams was significantly higher in un-caged plots as compared to caged plots.

Sampling Methods: Bare-bottom mesocosm predation study with blue crabs – Maryland

- A summer-intern experiment was completed at SERC's wetlab facility in summer 2012.
- Ten replicates of 15 clams, five small *M. arenaria* (30-40 mm), five large *M. arenaria* (45-55 mm), and five *T. plebeius* were placed in a bare bottom 1.89 m^2 mesocosm to determine if blue crabs have a prey or size preference.
- Clams were allowed to acclimate to bare tanks for 24 hours while adult blue crabs were concurrently starved.
- Adult crabs were added to the mesocosms, allowed to feed for 12 hours, and remaining clams enumerated after 12 hours.
- Three controls, with no crab added, were also conducted for 12 hours.

Results: Bare-bottom mesocosm predation study with blue crabs – Maryland

- When readily and easily available (in bare-bottom tank), adult blue crabs did not exhibit a preference in clam species or size.

Sampling Methods: Clam burial mesocosm predation study with blue crabs – Maryland

- A summer-intern experiment was completed at SERC's wetlab facility in summer 2012.
- Ten replicates of 15 clams, five small *M. arenaria* (35-40 mm), five large *M. arenaria* (45-55 mm), and five *T. plebeius* (55-65 mm) were placed into two of three sand-filled 0.2 m^3 bins which then nested into the floor of a 1.89 m^2 mesocosm and were covered

with an additional 0.1 m of sand to determine to determine prey preferences and consumption rates of adult blue crabs on burrowing clams.

- Clams were lightly buried in two of three sand-filled 0.2 m^3 bins and allowed to acclimate for 24 hours while adult blue crabs were concurrently starved for 24 hours.
- Crabs were added to the mesocosms and allowed to feed for 24 hours. To discourage the crabs from associating a bin edge with food, one randomly chosen sand-filled bin received no clams.
- After 24 hours, crabs were removed and remaining clams enumerated.
- Four controls, with no crab added, were also conducted for 24 hours.

Results: Clam burial mesocosm predation study with blue crabs – Maryland

- Adult blue crabs displayed no preference in species or size of clams eaten.
- Adult blue crabs consumed significantly fewer buried clams than unburied clams.

b. Summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or unusual developments that may lead to deviation of research directions or delay of progress toward achieving project objectives.

Work has been completed on this project, aside from some ongoing analyses. As of July 2014, six seasons of the soft-shell clam sampling are complete and caging is complete for the York River and mesocosm experiments are completed. We are also in the process of compiling long-term data sets for predators of *M. arenaria*, namely blue crabs and cownose rays. The work did not deviated from our original objectives although we extended the grant into summer 2014.

2. Applications:

Outputs and management outcomes achieved.

a. Outputs

i. New fundamental or applied knowledge: None yet
ii. Scientific publications:

Hernandez Cordero, A.L., R.D. Seitz. 2014. Structured habitat provides a refuge from blue crab, *Callinectes sapidus*, predation for the bay scallop, *Argopecten irradians concentricus* (Say 1822). Journal of Experimental Marine Biology and Ecology 460:100-108.

Long, W.C, R.D. Seitz, B.J. Brylawski, R.N. Lipcius. 2014. Individual, Population, and Ecosystem Effects of Hypoxia on a Dominant Benthic Bivalve in Chesapeake Bay. Ecological Monographs 84(2): 303-327.

R.D. Seitz, Wennhage, H., U. Bergstrom, R.N. Lipcius, and T. Ysebert. Value of coastal habitats for exploited species: II. Coastal habitat use by commercial species. *online 2013*. ICES Journal of Marine Science 71(3): 648-665.

Sturdivant, S.K., R. D. Seitz, and R.J. Diaz. 2013. Effects of seasonal hypoxia on macrobenthic production and function in the Rappahannock River, VA, USA. Marine Ecology Progress Series 490: 53–68.

Ralph, R., R.D. Seitz, B. Orth, R.N. Lipcius. 2013. Population-wide association between

vegetated habitats and juvenile blue crab density in Chesapeake Bay. Marine Ecology Progress Series 488: 51–63.

Hernandez-Cordero, L.A., R.D. Seitz, R.N. Lipcius, C.M. Bovery, D.M. Schulte. 2012. Habitat Affects Survival of Translocated Bay Scallops, *Argopecten irradians concentricus* (Say 1822), in Lower Chesapeake Bay. Estuaries and Coasts 35: 1340–1345.

Seitz, R.D. 2011. Gradient effects on structuring of soft-bottom infauna: *Macoma balthica* and predation, recruitment and food availability. Journal of Experimental Marine Biology and Ecology: 409: 114–122.

Seitz, R.D., K.E. Knick, M. Westphal. 2011. Diet Selectivity of Juvenile Blue Crabs (*Callinectes sapidus*) in Chesapeake Bay. Integrative and Comparative Biology 51(4): 598-607.

Bradley, C.D., R.D. Seitz, and K.E. Knick. Classification of benthic communities and trophic structure at altered shorelines in a depauperate estuary. *In review.* Marine Biology.

Lipcius, R.N., R.P. Burke, S.J. Schreiber, D.M. Schulte, R.D. Seitz, and J. Shen. Synergy of the historical record, metapopulation dynamics, and disease resistance in native oyster restoration. *In review*. Marine Ecology Progress Series.

Hines, A.H., and M.R. Goodison. Final report for Rapid Response Funds to assess clam populations post Hurricane Irene and Tropical Storm Lee. Submitted to Maryland Sea Grant.

Seitz, R.D. S. Aguilera, M.A. Wood, and R.N. Lipcius. Production and Zonation on Rip-Rap Shorelines: the New Rocky Intertidal of the Mid-Atlantic Coast. *Submitted to Estuarine, Coastal and Shelf Science*.

iii. Patents: None

New methods and technology

- Escalator dredging was used as a quantitative sampling method, whereas previously this methodology has been used primarily as a collection methodology for watermen.

iv. New or advanced tools (e.g. models, biomarkers): None yet

Workshops

A NOAA press event was organized in Gloucester Point, VA, in November 2011. We presented the goals, methods, and results of our project in a poster presentation for managers, scientists, and reporters.

In January 2012, a similar press event was organized in Edgewater, MD, where the poster was again presented to managers, scientists, and reporters.

<u>Presentations:</u>

<u>2014:</u>

Glaspie, C.N. and Seitz, R.D. The role of predation in the decline of a dominant clam, *Mya arenaria*, in Chesapeake Bay, VA, USA. Oral presentation, Australian Marine Sciences Association Meeting, Canberra, Australia, July.

Gomez, E, and Seitz, R.D. Impacts of Shoreline Modification on Benthic and Predatory Communities in Subestuaries of the Chesapeake Bay, USA. Benthic Ecology Meeting, Jacksonville, FL. March.

Karp, M, Seitz, R.D. Quantifying species composition and zonation patterns on riprap, York River, Chesapeake Bay. Benthic Ecology Meeting, Jacksonville, FL. March.

Seitz, R.D., Knick, K.E., Davenport, T., Jackson, N. Living shoreline impacts on near-shore benthic communities in upper and lower Chesapeake Bay. National Shellfish Association Meeting. Jacksonville, FL. March.

Glaspie, C.N. and Seitz, R.D. "Seasonal trends in razor and soft-shell clam biomass in Lower Chesapeake Bay: Effects of temperature, salinity, and predation." Oral presentation, Benthic Ecology Meeting, Jacksonville, FL, March.

Ogburn, M.B., Goodison, M., Roberts, P.M., Seitz, R., Hines, A.H. 2014. Evaluating the roles of predation, habitat, disease, and environmental effects on the decline of softshell clams in upper Chesapeake Bay. National Shellfisheries Association Annual Meeting, Jacksonville, Florida, March.

2013:

Seitz, Rochelle D. , Håkan Wennhage , Ulf Bergström, Romuald N. Lipcius, Tom Ysebaert. 2013. Coastal habitat use by commercially and ecologically important species. International Council for Exploration of the Seas Annual Science Conference. Reykejvic, Iceland, September.

Seitz, Rochelle D., Kathleen E. Knick, Theresa M. Davenport. 2013. Anthropogenic stressors affect benthic community structure: Upland usage and shoreline development. Coastal and Estuarine Research Federation Meeting. San Diego, CA, November.

Seitz, R. D., D. M. Dauer, and R. J. Llansó. 2013. Anthropogenic effects on long-term patterns of benthic species richness and functional diversity in Chesapeake Bay. Benthic Ecology Meeting, Savannah, GA, March

Knick, K., T. Davenport, R. Seitz. 2013. Replacing bulkhead with living shoreline: impacts on near-shore benthic communities in the Corsica River, Chesapeake Bay. Benthic Ecology Meeting, Savannah, GA, March

Glaspie, C. N., and R. D. Seitz. 2013. Habitat-mediated predation on soft-shell clams in the York River, VA, Benthic Ecology Meeting, Savannah, GA, March

Glaspie, C. N., and R. D. Seitz. 2013. Predator-driven shifts in soft-shell clam distribution. Atlantic Estuarine Research Society meeting, Williamsburg, VA, April

Llansó, R.J., D. M. Dauer, R.D. Seitz, M.F. Lane, and J. Dew-Baxter. 2013. Restoration and degradation trajectories of the benthic communities of Chesapeake Bay: Inter-decadal changes in abundance and species diversity and composition. Atlantic Estuarine Research Society meeting, Williamsburg, VA, April

2012:

Seitz, R.D., K.E. Knick, A.S. Lawless, C.M. Bradley. 2012. Effects of shoreline stabilization structures on living resources in estuaries: changes in abundance, biomass, and diversity of benthic invertebrates and their predators. Restore America's Estuaries Meeting, Tampa, Florida, October.

Seitz, R.D., K.E. Knick, A.S. Lawless, C.M. Bradley. 2012. Mechanisms Determining Patterns in Fish and Crabs Associated with Development in Chesapeake Bay: Bottom-up Control. American Fisheries Society Annual Meeting. St. Paul, Minnesota, August.

Kornis, M.S., D.L. Breitburg, R.D. Seitz, J. Upoff, D. Bilkovic, et al. 2012. Relating community composition, abundance, growth, and condition of aquatic macrofauna to watershed landuse and shoreline alteration in Chesapeake Bay. American Fisheries Society Annual Meeting. St. Paul, Minnesota, August.

Glaspie, C. N. and Seitz, R. D. "The effects of habitat complexity and predation on bivalve distribution and abundance." Oral presentation, Virginia Institute of Marine Science Biological Sciences Departmental Seminar; May, 2012.

Rochelle D. Seitz, Anson H. Hines. Population decline and restoration of soft-shell clams in Chesapeake Bay: Role of predation, habitat, disease, & environmental factors. National Shellfisheries Association meeting, Seattle, WA, March 2012.

Glaspie, C. N. and Seitz, R. D. "The effects of habitat complexity on bivalve diversity in three

Chesapeake Bay tributaries." Poster presentation, Benthic Ecology Meeting, Norfolk, VA, March, 2012.

Rochelle D. Seitz, Kathleen E. Knick, Theresa M. Davenport. Multiple stressors and benthic community structure: anthropogenic effects in Chesapeake Bay. Benthic Ecology Meeting, Norfolk, VA, March 2012.

Theresa M. Davenport, Rochelle D. Seitz, Kathleen E. Knick. Impacts of Shoreline Development on Benthic Infaunal Prey and Near-Shore Predator Community Structure in Chesapeake Bay. Benthic Ecology Meeting, Norfolk, VA, March 2012.

Margaret Luebs. A Comparison of Predation on Soft-Shell Clams (*Mya arenaria*) and Stout Razor Clams (*Tagelus plebeius*). Intern presentation, SERC, August 2012.

2011:

Seitz, R.D., A.H. Hines, and C. Dungan. 2011. Population Decline and Restoration of Soft-Shell Clams in Chesapeake Bay: Role of Predation, Habitat, Disease, and Environmental Factors. NOAA Press event, Gloucester Point, VA. November, 2011.

Glaspie, C. N. and Seitz, R. D. "Bivalve predator-prey interactions in the Chesapeake Bay and implications for management." Oral presentation, Virginia Institute of Marine Science Biological Sciences Departmental Seminar; April, 2011.

Seitz, R.D., K.E. Knick, and R.N. Lipcius. 2011. Threshold resource density for crabs in nursery habitats. National Shellfisheries Association Meeting (BCARC Session), Baltimore, MD, March.

Seitz, R.D., S. Aguilera, C. Bovery, and R. Lipcius. 2011. Rip-rap shorelines: the new rocky intertidal of the southeast. Benthic Ecology Meeting, Mobile, AL, March.

Davenport, T.M. and R.D. Seitz; 2011. Impacts of Shoreline Development on Benthic Infaunal Prey and Near-Shore Predator Community Structure in Chesapeake Bay, U.S.A. Benthic Ecology Meeting, Mobile, AL, March.

Bradley, C., and R.D. Seitz. 2011. Bottom-up Control in the Patuxent River, Maryland: Impacts of Shoreline Hardening on Infaunal Communities and their Predators. Benthic Ecology Meeting, Mobile, AL, March.

Outreach activities/products (e.g. website, newsletter articles):

- One VIMS graduate student has developed a research project related to *Mya arenaria* population dynamics and is heavily involved in this project.
- Each summer, an NSF-funded REU student and/or a Governor's School student has developed projects or been involved with projects concerning soft-shell clam populations.

b. Management outcomes - I. Management application or adoption of:

i. New fundamental or applied knowledge: None yet
ii. New or improved skills: None yet
iii. Information from publications, workshops, presentations, outreach products: None yet
iv. New or improved methods or technology: None yet
v. New or advanced tools: None yet

c. Management outcomes - II. Societal condition improved due to management action resulting from output; examples:

i. Improved water quality: None yet
ii. Lower frequency of harmful algal blooms: None yet
iii. Reduced hypoxic zone area: None yet
iv. Improved sustainability of fisheries: None yet

d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal):

- Partnership established with the Maryland Watermen's Association to work with local watermen for escalator dredge sampling.

3. Expenditures:
   a. Describe expenditures scheduled for this period.

This period was an extension of the original grant. This grant deadline was extended to provide funding for additional summer caging experiments and mesocosm experiments in 2014. We planned to spend the money on caging supplies, transportation, vessel usage, and salary.

b. Describe actual expenditures this period.

Approximately 10% of the VIMS budget was available during this extension period and was spent. The majority of the funding for the period's budget was spent on salary, travel, supplies for the mesocosm experiments, and the summer caging experiments. All of the funding for the Smithsonian subcontract was dispersed to them, which has been spent according to budgeted amounts.

c. Explain special problems that led to differences between scheduled and actual expenditures, etc.

Budget was spent according to grant extension commitments.

Prepared By: Signature of Principal Investigator; Date: 06-30-2014

NOAA COP Annual Progress Report Form

7/16/2007

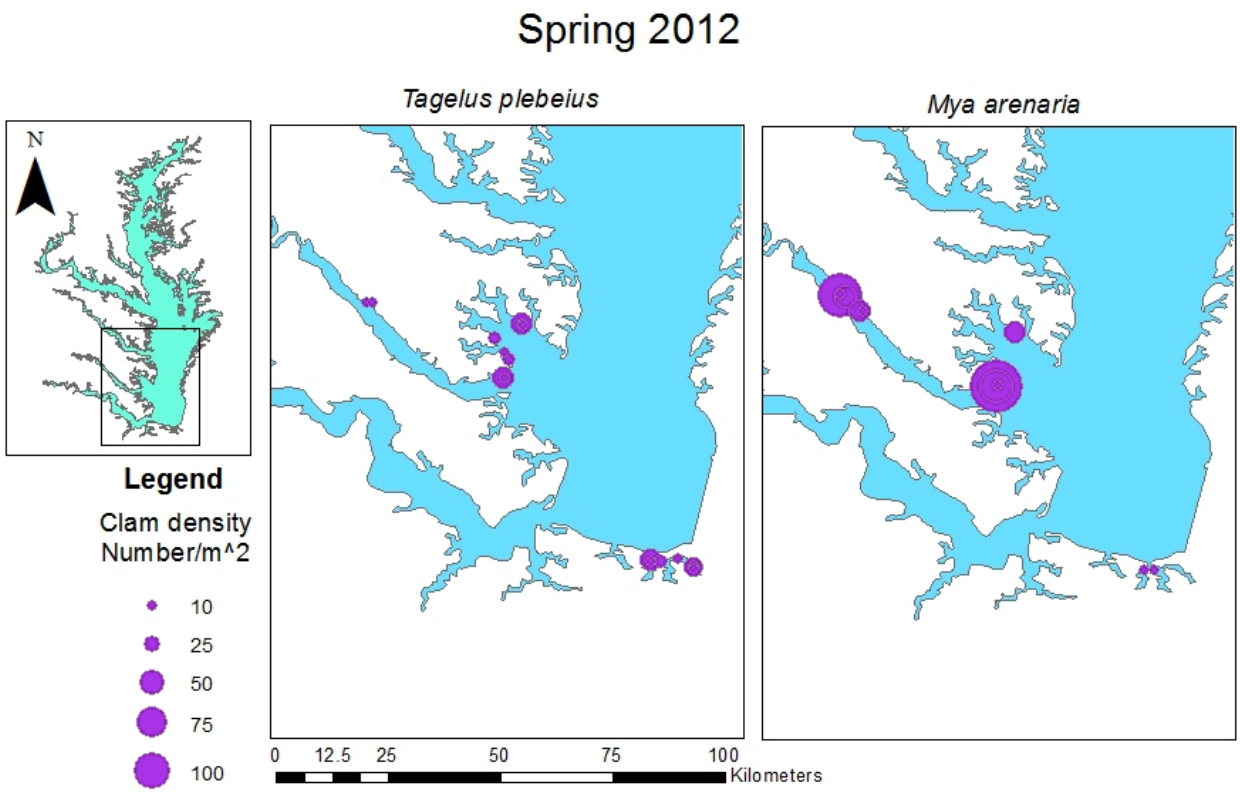

Figure 1. Mean density (clams m^{-2}) of *Tagelus plebeius* (left panel) and *Mya arenaria* (right panel) in lower Chesapeake Bay sampling sites in spring 2012.

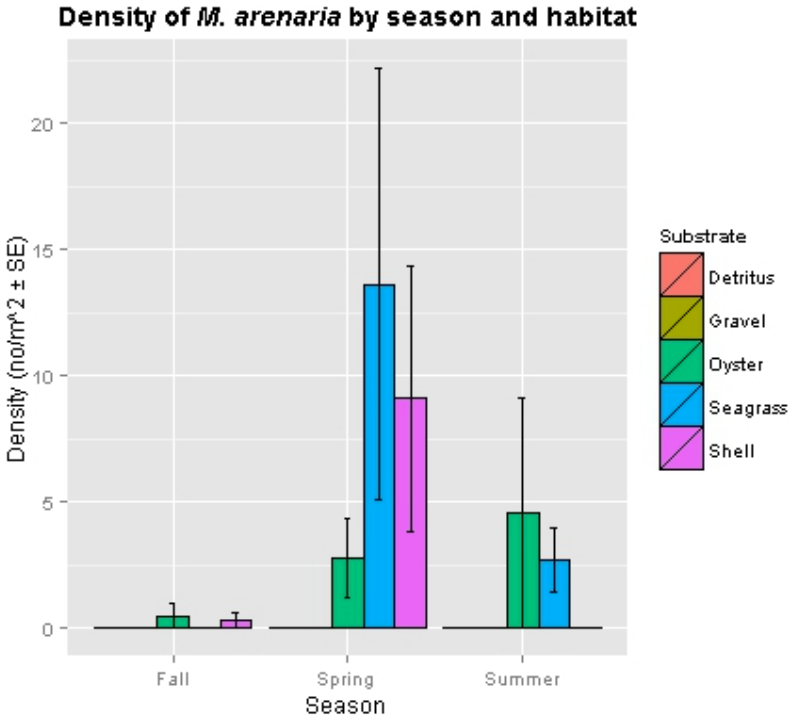

Figure 2. Mean density (clams m^{-2}) of *Mya arenaria* by season and habitat in lower Chesapeake Bay sampling sites (averaged over two years for each season).

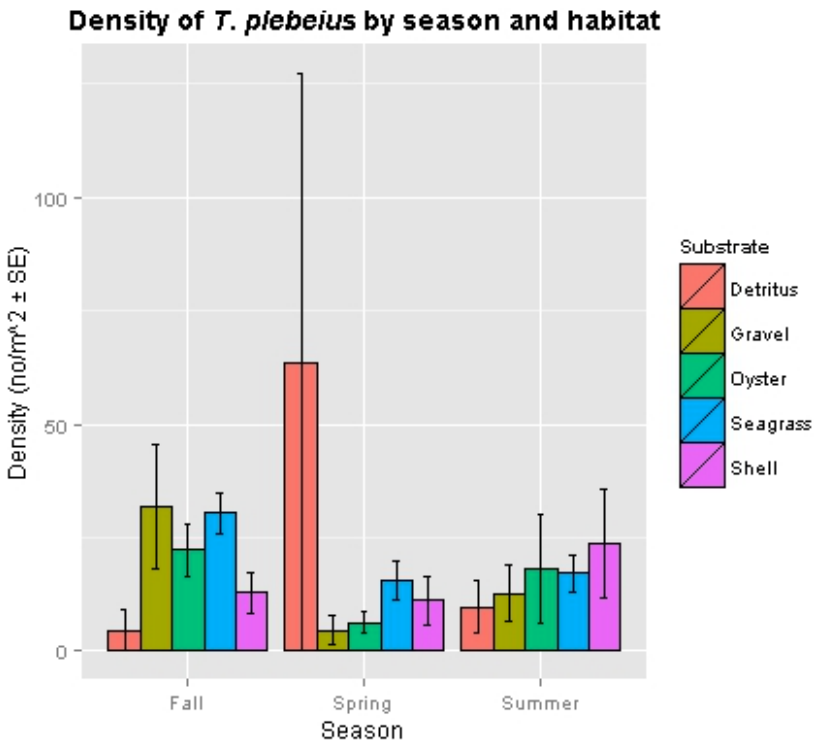

Figure 3. Mean density (clams m^{-2}) of *Tagelus plebeius* by season and habitat in lower Chesapeake Bay sampling sites (averaged over two years for each season).

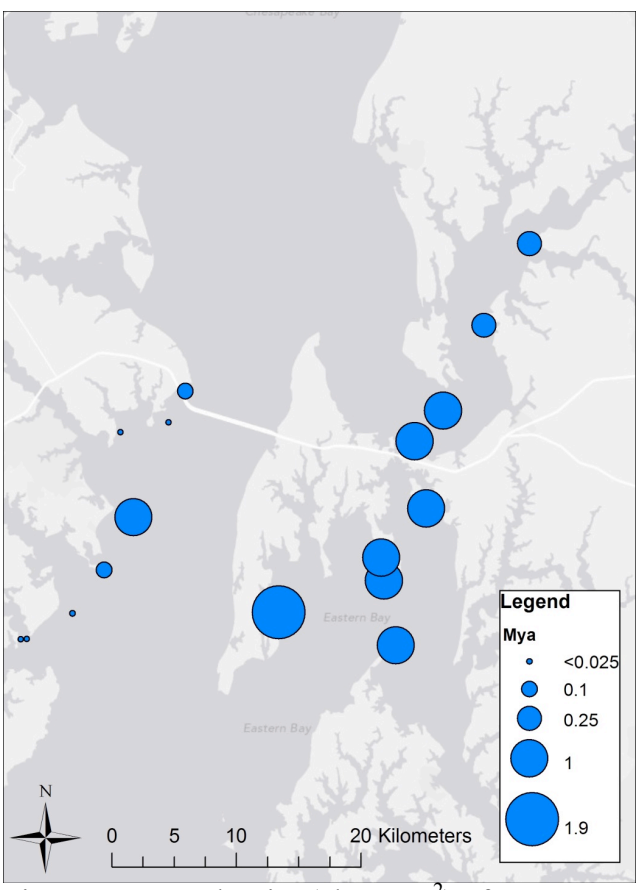

Figure 4. Mean density (clams m^{-2}) of *Mya arenaria* in upper Chesapeake Bay sampling sites. Site means were calculated by averaging across the six sample dates from 2011-2013.

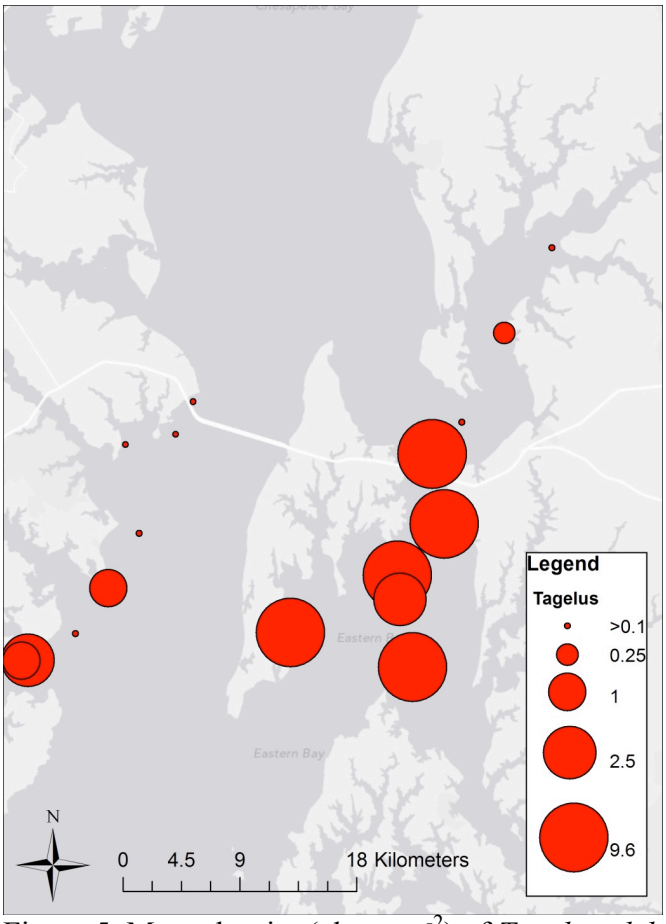

Figure 5. Mean density (clams m^{-2}) of *Tagelus plebius* in upper Chesapeake Bay sampling sites. Site means were calculated by averaging across the six sample dates from 2011-2013.

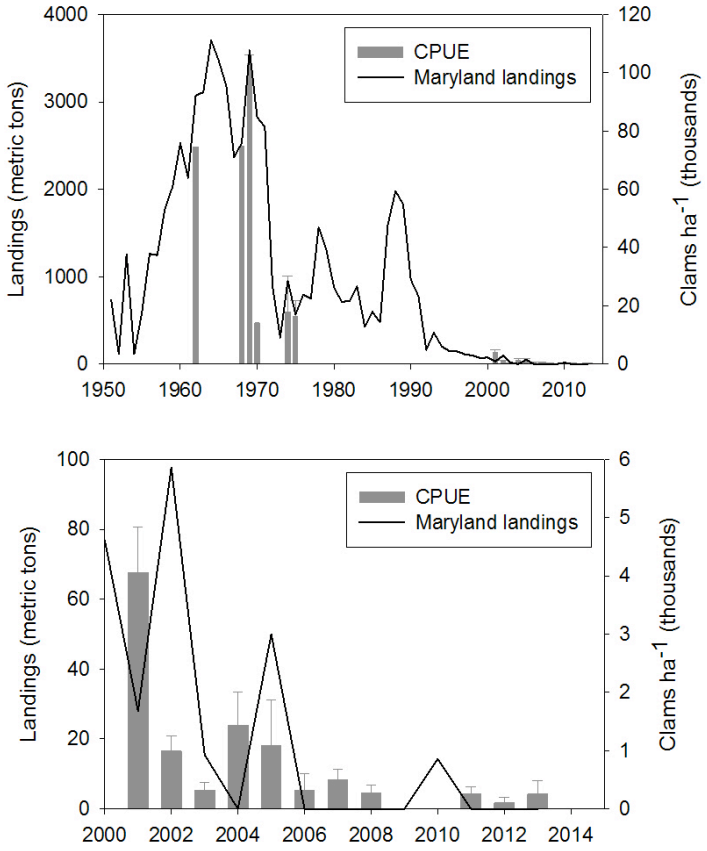

Figure 6. Long-term trend in fishery landings and fishery-independent catch per unit effort (CPUE) of *Mya arenaria* in Maryland for the periods 1950-2013 (top) and 2000-2013 (bottom). Landings data were obtained from the NMFS Commercial Landings Database. Historical CPUE data were adapted from Homer et al. (2011) for sites sampled in the present study. (Reference: Homer, M.L., C.F. Dungan, and M.L. Tarnowski. 2011. Assessment of Chesapeake Bay ommercial softshell clams *Mya arenaria* and *Tagelus plebeius* with emphasis on abundance and disease status. Commpletion Report to the NOAA CBO Fisheries Science Program).

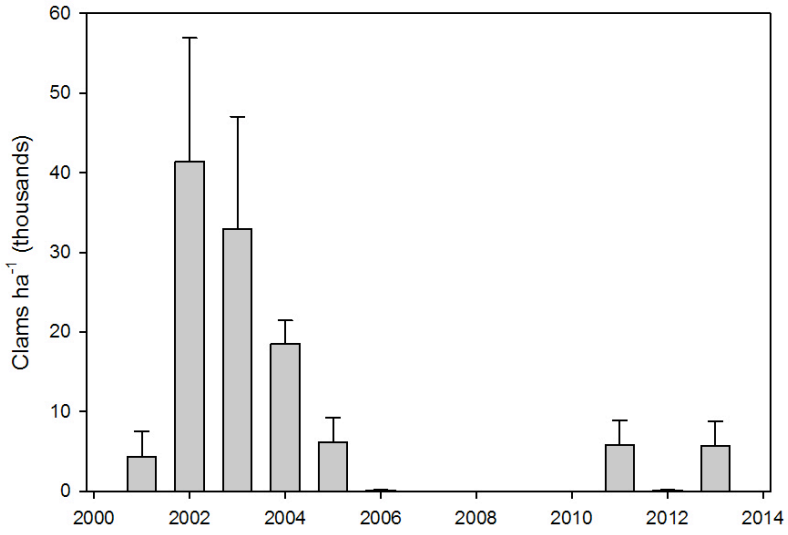

Figure 7. Trend in catch per unit effort (CPUE) of *Tagelus plebius* in upper Chesapeake Bay for the period 2000-2013. Data prior to 2011 are adapted from Homer et al. (2011) for sites sampled in the present study.