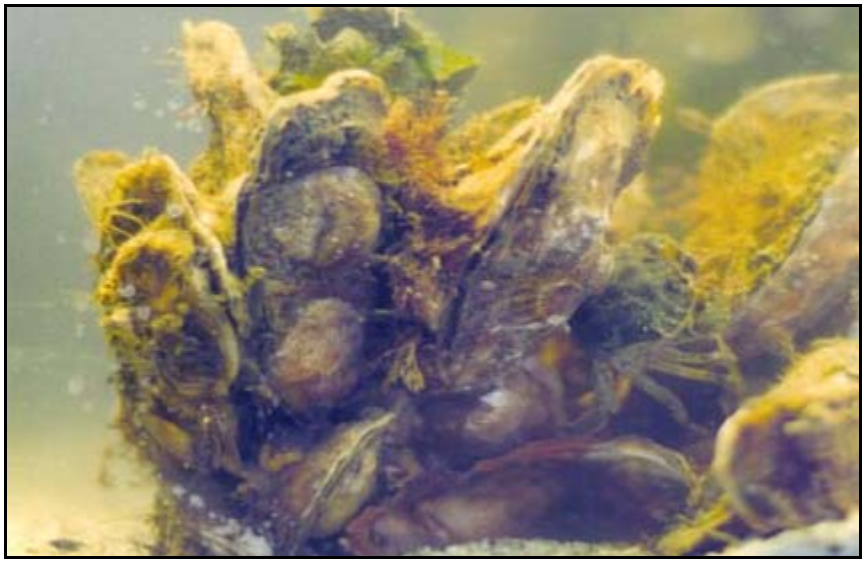
Evaluating Progress in Determining Potential Risks and Benefits of Introducing Diploid *Crassostrea ariakensis* to Chesapeake Bay



August 6, 2006

Prepared by the Chesapeake Bay Program's
Scientific and Technical Advisory Committee

STAC Publication 06-002

About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program on measures to restore and protect the Chesapeake Bay. As an advisory committee, STAC reports periodically to the Implementation Committee and annually to the Executive Council. Since it's creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical conferences and workshops, and (5) service by STAC members on CBP subcommittees and workgroups. In addition, STAC has the mechanisms in place that will allow STAC to hold meetings, workshops, and reviews in rapid response to CBP subcommittee and workgroup requests for scientific and technical input. This will allow STAC to provide the CBP subcommittees and workgroups with information and support needed as specific issues arise while working towards meeting the goals outlined in the *Chesapeake 2000* agreement. STAC also acts proactively to bring the most recent scientific information to the Bay Program and its partners. For additional information about STAC, please visit the STAC website at www.chesapeake.org/stac.

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Cover photo of *C. virginica* provided by the Chesapeake Bay Program.

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Evaluating Progress in Determining Potential Risks and Benefits of Introducing Diploid *Crassostrea ariakensis* to Chesapeake Bay

August 6, 2006

A STAC report prepared by Denise Breitburg and Jonathan Kramer

STAC Publication 06-002

INTRODUCTION

More than two years have passed since the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) workshop *Identifying and Prioritizing Research Required to Evaluate Ecological Risks and Benefits of Introducing Diploid Crassostrea ariakensis to Restore Oysters to Chesapeake Bay*. This workshop identified research priorities the scientific community determined were important to address in order to substantially reduce uncertainty in predicting risks and benefits of an introduction of diploid *C. ariakensis* to Chesapeake Bay. Since that time, the Maryland General Assembly has required that the STAC recommendations be substantially completed before the Maryland Department of Natural Resources (MD-DNR) can move forward with a plan to introduce diploid *C. ariakensis* to Chesapeake Bay.

Both the research recommendations and the estimate of time required to conduct adequate research described in the STAC report were originally generated by the scientific research community. The membership of STAC determined that is important to ascertain whether the scientific community considers the research conducted to date is adequate to predict the risks and benefits of an introduction of diploid *C. ariakensis* to Chesapeake Bay with a high level of certainty. The need to follow up the workshop recommendations with a survey such as this was determined soon after the release of the original STAC report.

In March 2006, a letter asking for participation in the survey (Appendix I) was sent to all researchers that the NOAA Chesapeake Bay Office (NCBO) and MD-DNR identified as recipients of funding to conduct research related to risks or benefits of an introduction of *C. ariakensis* (Appendix II). The letter listed the high and medium research priorities identified by the STAC workshop, and asked researchers to make a subjective determination of their progress in addressing those priorities. Full responses to the survey are included in the accompanying spreadsheet.

Only research priorities identified in the original STAC workshop report were considered. Thus economics, social sciences, and risk analysis were omitted from the survey. The contribution of all of these fields is vitally important to the decision-making process, and research in all has been conducted in support of the EIS. However, no specific recommendations were made on these topics at the workshop because few experts in these fields were in attendance. Modeling was also de-emphasized in the analysis of the survey because the question of whether data required for the models had been generated was deemed to be more critical than a determination of whether models had been constructed.

SUMMARY OF RESULTS

We received responses from all of the researchers involved in laboratory or field studies listed in Appendix I. Responses are summarized in Table 1, and full responses are included in the accompanying spreadsheet. Our summary below focuses primarily on

data generating studies. Modeling is critical to the EIS process, but is dependent on data used to construct and parameterize them. The code and structure of models has been completed in some cases, and these tools can be used and validated once the data from complementary studies becomes available. In synthesizing responses to the researcher survey, we relied solely on the responses of participating researchers. We did not alter the responses of researchers except, in a few cases, to improve the match between the research priority and the research study described by assigning the response to a different research priority.

Survey Results

Survey results indicate that:

- Only one of the 22 high-moderate priority research questions identified by the STAC workshop has been adequately addressed.
- Currently funded research on most of the 22 research questions will not be completed until late 2007 or summer 2008. Although we did not pose the question to researchers, final analysis and reporting of research results typically takes an additional 6 months.
- Few studies explicitly address the influence of genotypic variation, including variation due to differences among source populations of *C. ariakensis*, on the risks or benefits of introduction *C. ariakensis*.
- Few current studies explicitly address the effects of the physical and biological environment outside Chesapeake Bay in order to assess risks and benefits of *C. ariakensis* in other estuaries.
- Only a single limited study is explicitly examining the benefits of disease-tolerant strains of *C. virginica* relative to *C. ariakensis.*

Only a small percent of the individual research projects, and one of the high-moderate priority research questions identified in the STAC workshop was rated by researchers conducting the work as ≥90% completed as of May 2006. Ninety percent of the necessary research has been performed to assess the stability and reproduction potential of triploid *C. ariakensis*. On average, researchers report that projects have generated 45-72% of the information required to address the other 21 priority questions.

Research addressing several of the priority research questions is still in its early stages. In particular, very little is known yet about differences in reproductive rates and processes between *C. ariakensis* and *C. virginica,* the potential for reproduction interference, or whether *C. ariakensis* will affect disease transmission or prevalence in *C. virginica* and other bivalves (questions question 3B, 4B, 4C, 4F and 4H). Long term mesocosm studies intended to generate a wide range of ecological and biological data will not be completed for another two years. In addition, three questions rated as "moderate" priority have not been addressed by any funded studies.

One area in which considerable uncertainty remains is in understanding the genetic variation and taxonomic status of *C. ariakensis.* One researcher pointed out the need to develop a reliable means to differentiate among the many species of Asian oysters that

co-exist with *C. ariakensis* to reduce the potential for the introduction of multiple species other than *C. ariakensis*.

It is also important to note that some of the high priority research topics are addressed only tangentially by the studies that are currently funded. For example, workshop participants determined that it was important to understand the relative timing of reproduction of *C. virginica* and *C. ariakensis*. Simultaneous spawning increases the potential for reproductive interference, and earlier spawning by *C. ariakensis* could increase the likelihood of negative competitive effects on native oysters. Although important information on this topic will be generated by an ongoing mesocosm study, the study is not specifically directed at fully addressing this question. The oysters are being raised at only a single temperature and salinity regime, and only Chesapeake Bay *C. virginica* are being used. Thus the study provides no information about temporal overlap in reproduction in other areas of Chesapeake Bay or in other estuaries.

Other Systems and Other Options

One conclusion of the STAC workshop was that *C. ariakensis* would spread to other systems if it became established in Chesapeake Bay. Although many of the studies included in the survey could contribute to estimating risks and benefits of *C. ariakensis* outside Chesapeake Bay, the estimate of the percent of needed data that would be generated by currently funded studies was typically lower for non-Chesapeake systems than for the Chesapeake. We are aware of the fact that there are several studies of *C. ariakensis* being conducted outside of Chesapeake Bay. However, these studies address a small fraction of the U.S. estuaries or estuarine habitats.

CONCLUSIONS

The December 2003 STAC workshop recommended a 5-year timeline for funded research to adequately assess the potential risks and benefits of introducing diploid *C. ariakensis* to Chesapeake Bay. The need for a 5-year study period is still strongly supported by the research progress and time needed for completion of currently funded studies reported in responses to this survey. The current completion dates are largely determined by funding constraints. Not all meaningful and valuable data will be in hand at the end of 2008. There are some clear gaps identified in this survey that would require additional funding. However, by late 2008 currently funded studies will be completed, and results of those studies will be substantially analyzed and available to the EIS process.

Table 1. Summary of Responses

Research Questions and Topics	Priority from STAC Report	Percent of Currently Funded Research Completed as of May 2006 (range reflects estimates of multiple studies)	Percent of Research Needed for Topic Completed at End of Study; Anticipated Completion Date	Inclusion of Potential for Important Phenotypic and Genotypic Variation in Research Design	Research Relevancy to Systems other than Chesapeake Bay
CAN SELF-SUSTAINING POPULATIONS OF *C. ARIAKENSIS* BE ESTABLISHED IN CHESAPEAKE BAY					
1. Disease Susceptibility					
1A. What is the susceptibility of *C. ariakensis* to *Bonamia* sp. pathogens that could be present in Chesapeake Bay and other estuaries? (experiments)	Essential	25-80% for targeted studies; 10% for long-term rearing in mesocosms	50-100% of needed information by Aug. 2008	1 of 4 studies	Yes
1B. What is the potential for vertical transmission of Herpes viruses? (experiments)	High	25-70%	50-85% by Dec. 2007	Yes	Yes
1C. What is the susceptibility of *C. ariakensis* to *Perkinsus* sp. pathogens other than *P. marinus*? (experiments)	Moderate	25-70% for targeted studies; 10% for long-term rearing in mesocosms	50-85% by Aug. 2008	2 of 4 studies	Yes

Research Questions and Topics	Priority from STAC Report	Percent of Currently Funded Research Completed as of May 2006 (range reflects estimates of multiple studies)	Percent of Research Needed for Topic Completed at End of Study; Anticipated Completion Date	Inclusion of Potential for Important Phenotypic and Genotypic Variation in Research Design	Research Relevancy to Systems other than Chesapeake Bay
2. Research Methods					
2A. How will the use of triploid *C. ariakensis* in experiments affect the accuracy of predictions about diploids? (experiments)	High	20-50%	50-80% by Dec. 2007	1 of 2 studies	Yes
2B. What is the stability and reproductive potential of triploid *C. ariakensis*? (experiments)	Moderate	90%	Completed	Yes	Yes
3. Biological and Ecological Considerations					
3A. Is there genetic variation among *C. ariakensis* stocks from Asia related to important physiological and ecological traits that will affect the risks and benefits associated with introducing it to the Chesapeake Bay? (sampling and experiments)	High	50-70%	85-100% by March 2008	Yes	Yes
3B. What are the growth, survival and feeding responses of *C. ariakensis* versus *C. virginica* under a range of conditions in Chesapeake Bay? (experiments)	High	15-100%	50-100% by Aug. 2008	1 of 4 studies	Yes
3C. What are the vital reproductive rates and processes (, e.g., gametogenesis, spawning, fecundity, sex change) of *C. ariakensis v. C. virginica* under East Coast environmental conditions? (experiments)	High	0-10%	10-75% by Aug. 2008	No	Yes

Research Questions and Topics	Priority from STAC Report	Percent of Currently Funded Research Completed as of May 2006 (range reflects estimates of multiple studies)	Percent of Research Needed for Topic Completed at End of Study; Anticipated Completion Date	Inclusion of Potential for Important Phenotypic and Genotypic Variation in Research Design	Research Relevancy to Systems other than Chesapeake Bay
3D. Do physiological and behavioral characteristics of *C. ariakensis* and *C. virginica* larvae differ in ways that would affect larval survival and dispersal? (experiments and model)	High	40% experiments; 85% model	Experiments: 0% of needed data by Aug. 2006; model: 100% complete by June 2006.	No	Yes
3E. What are the settlement cues and substrate preferences of *C. ariakensis*? (experiments)	High	80%	100% by Nov. 2006	Some	Yes
3F. Population models to predict abundance and spread of *C. ariakensis* in Chesapeake Bay	High	20%	25% with full use of currently available data	Some	Model structure applicable but would presumably need to be reparameter-ized for other systems.

Research Questions and Topics	Priority from STAC Report	Percent of Currently Funded Research Completed as of May 2006 (range reflects estimates of multiple studies)	Percent of Research Needed for Topic Completed at End of Study; Anticipated Completion Date	Inclusion of Potential for Important Phenotypic and Genotypic Variation in Research Design	Research Relevancy to Systems other than Chesapeake Bay
3G. Is there a difference in mortality rates of juvenile *C. ariakensis* and *C. virginica* in responses to dissolved oxygen concentrations , sedimentation and predation? (experiments)	High	80-100%	100% by Aug. 2007	No	Yes
RISKS TO *C. VIRGINICA* AND OTHER BIVALVES					
4A. Is there genetic variation among *C. ariakensis* stocks from Asia related to important physiological and ecological traits that will affect the risks associated with introducing it to the Chesapeake Bay? (sampling and experiments)	Combined with question 3A (3A originally referred to benefits, and 4A referred to risks).				
4B. Are their habitat/strain combinations that would yield population growth and coexistence of both *C. ariakensis* and *C. virginica*? (model)	High	80-90% (data)	Unsure; current projects complete by Fall 2007	Some	Some

Research Questions and Topics	Priority from STAC Report	Percent of Currently Funded Research Completed as of May 2006 (range reflects estimates of multiple studies)	Percent of Research Needed for Topic Completed at End of Study; Anticipated Completion Date	Inclusion of Potential for Important Phenotypic and Genotypic Variation in Research Design	Research Relevancy to Systems other than Chesapeake Bay
4C. Will *C. ariakensis* increase disease transmission and prevalence in *C. virginica* and other bivalves?	High	0-50% for targeted studies; 10-85% for mesocosm experiments and field deployments	10-75% for targeted studies by Dec. 2007	Some in 2 of 6 studies	Some
4D. Will *C. ariakensis* reduce disease transmission or prevalence *C. virginica* and other bivalves? (experiments)	Moderate	0-50% for targeted studies; 10-85% for mesocosm experiments and field deployments	10-75% by Aug. 2008	Some in 1 of 6 studies	Yes
4E. Models of disease dynamics	Moderate	**No funded research on this topic.**			

Research Questions and Topics	Priority from STAC Report	Percent of Currently Funded Research Completed as of May 2006 (range reflects estimates of multiple studies)	Percent of Research Needed for Topic Completed at End of Study; Anticipated Completion Date	Inclusion of Potential for Important Phenotypic and Genotypic Variation in Research Design	Research Relevancy to Systems other than Chesapeake Bay
4F. What is the risk posed to *C. virginica* by cross-species fertilization? (experiments or models)	High	25%	50% by Nov. 2006	Only Oregon *C. ariakensis* tested	Only systems with 20 ppt salinity
4G. What are the likely extent, magnitude and outcome of competition for space and food between *C. ariakensis* and *C. virginica*? (experiments; data generated should be added to models)	High	10-85%	25-75% by Aug. 2008	Some in 1 of 3 studies	Yes
4H. What is the timing of reproduction of *C. ariakensis* relative to that of *C. virginica*? (experiments)	High	10%	75% by Aug. 2008	No	Some
4I. What is the likely effect of *C. ariakensis* on predation on *C. virginica?* (models and/or experiments)	Moderate	**No funded research on this topic.** (Newell response more applicable to different question.)			
RISKS AND BENEFITS TO ECOSYSTEM FUNCTIONS AND SERVICES					
5A. What will the growth form(s) of *C. ariakensis* be in Chesapeake Bay **and** what are the consequences of those growth forms to other organisms? Will the growth form of *C. ariakensis* provide the habitat value formerly provided by *C. virginica*? (experiments)	High	10-85% for field and laboratory experiments (model 90%)	30-75% by Aug. 2008 (model 100%)	Some in 1 of 5 studies	Some

Research Questions and Topics	Priority from STAC Report	Percent of Currently Funded Research Completed as of May 2006 (range reflects estimates of multiple studies)	Percent of Research Needed for Topic Completed at End of Study; Anticipated Completion Date	Inclusion of Potential for Important Phenotypic and Genotypic Variation in Research Design	Research Relevancy to Systems other than Chesapeake Bay
5B. How will *C. ariakensis* affect the abundance of oyster predators and competitors? (experiments and models)	Moderate	5%	25% by Dec. 2007	No	Only high salinity intertidal marsh habitat
5C. Will *C. ariakensis* affect biogeochemical cycling or plankton composition differently than *C. virginica?* (experiments)	Moderate	**No funded research on this topic.**			
HUMAN HEALTH AND HEALTH-REALTED RISKS TO FISHERY					
6A. Will *C. ariakensis* accumulate human pathogens or *E. coli* to a greater degree than *C. virginica?*	Essential	0-65%	50-100% by Dec. 2007	Some in 2 of 5 studies	Yes
OTHER OPTIONS					
7A. Is there a greater likelihood of successful restoration using 'Oregon' or other strains of *C. ariakensis* than using wild- or disease tolerant strains of *C. virginica*?	High	5%	25% by Dec. 2007	No	Only high salinity intertidal marsh habitat

Appendix I

Letter Sent to Researchers

Chesapeake Bay Program
SCIENTIFIC AND TECHNICAL ADVISORY COMMITTEE
645 Contees Wharf Road, P.O. Box 28, Edgewater, MD 21037
Phone: (410)798-1283 Fax: (410)798-0816
www.chesapeake.org/stac

Dear Colleague,

We are asking for a few minutes of your time to complete an important evaluation.

Two years have passed since the STAC workshop *Identifying and Prioritizing Research Required to Evaluate Ecological Risks and Benefits of Introducing Diploid Crassostrea ariakensis to Restore Oysters to Chesapeake Bay* identified research priorities the scientific community determined were important to address in order to substantially reduce uncertainty in predicting risks and benefits of an introduction of diploid *C. ariakensis* to Chesapeake Bay. Since that time, the Maryland General Assembly has required that the STAC recommendations be substantially completed before MD-DNR can move forward with a plan to introduce diploid *C. ariakensis* to Chesapeake Bay. The EIS panel has been charged with judging the adequacy of the research relative to the STAC and NRC report recommendations.

Both the research recommendations and the estimate of time required to conduct adequate research described in the STAC report were originally generated by the scientific research community. STAC, therefore, considers it critical to determine whether the scientific community considers the research conducted to date is adequate to predict the risks and benefits of an introduction of diploid *C. ariakensis* to Chesapeake Bay with a high level of certainty. The need to follow up the workshop recommendations with a survey such as this was determined soon after the release of the STAC report.

The importance of conducting this evaluation now is heightened by the possibility that the EIS panel will make recommendations on research conducted over a much shorter time frame than that originally recommended in either the STAC or NRC reports. It is possible that the these reports overestimated the time required to conduct research given the large infusion of research funding that has become available. STAC considers it important, however, that the research community that took the leadership in identifying and prioritizing research needs also have the opportunity to evaluate research progress relative to those needs.

PLEASE help us gather the information needed to conduct this evaluation by completing the attached survey and returning it to Melissa Fagan (faganm@si.edu) no later than March 15. Answer all questions about each of your active, completed, or impending research projects, and feel free to add any additional comments you consider important. If you have any questions about the questions or survey process, please feel free to contact Denise Breitburg at breitburgd@si.edu or 443-482-2308.

Thank you in advance for your help in this important task.

Sincerely,
Denise Breitburg
Jonathan Kramer
(for STAC)

STAC C. ARIAKENSIS RESEARCH SURVEY

SCOPE

Researchers Included

This survey is being sent all researchers we were able to identify that are conducting field studies, laboratory research or modeling related to the Research Priority areas identified in the original STAC research report. Our intention is to be inclusive. A listing of PIs and projects is attached in a separate document. This list was provided by NCBO and MD-DNR. If you know of any omissions, please notify us (through Melissa Fagan Faganm@si.edu) and feel free to pass on the survey.

Topics Included

This survey is limited to topics examined in detail at the STAC workshop. Although social and economic concerns are important to consider, we did not have a sufficient representation by those disciplines at the STAC workshop to adequately identify and prioritize research needs in those areas. Similarly, although the need for formal risk assessment was discussed, no specific recommendations on the scope or methodology of a risk assessment were identified. Finally, the workshop scope and goals did not include development of specific recommendations on research required to determine how to best utilize native oysters (wild or disease-tolerant strains) for restoration, the likelihood of successful restoration using native oysters, or strategies and techniques to improve disease tolerance of native oysters.

DIRECTIONS

Simply add your answers to this document, and send the completed survey as an email attachment to Melissa Fagan at CRC (faganm@si.edu). She will compile the information for STAC. Use your name and ariakensis survey (e.g., Mann ariakensis survey) in the subject line of the email to help Melissa track responses.

Questions should be answered by the lead PI of each project, or, in the case of complex projects, the appropriate co-PI can take responsibility for each project component. It is important to be as comprehensive as possible and include all relevant research (funded or not). It is also important to avoid double counting progress of projects, thus giving the impression that we are closer to completion than is true. If a research project addresses >1 priority topic, please complete a separate form for each appropriate topic. Do not limit yourself to a single topic. Some research projects address several topics, and some research topics are addressed by several projects.

Please direct any questions about the interpretation of questions or information required to Denise Breitburg (breitburgd@si.edu or 443-482-2308).

We thank you for your help in this important effort.

Denise Breitburg and Jonathan Kramer

Questions (Provide separate answers for EACH research priority addressed (question 1, below), and separate answers for data-generating studies (i.e., field or lab research programs) vs. data synthesis and prediction studies (i.e., modeling or statistical analysis of existing results).

1) **PI name.** Name of person completing survey.

2) **Research priority addressed.** Select number and letter from list at end of survey.

3) **Title(s) of relevant project(s).** Please list all projects addressing this particular research priority that are completed, in progress, or funded but not yet started)

4) **Are these projects (a) data-generating studies (i.e., field or lab research programs) or (b) data synthesis and prediction studies (i.e., modeling or statistical analysis of existing results)**

5) **For the priority identified in #3, to what degree has your research project(s) provided information required to quantify the risks or benefits of introducing diploid *C. ariakensis* .** Please provide a numerical response that quantifies progress **as of March 1, 2006, recognizing the** scope of issues that need to be addressed for this priority. Your answer should not reflect a judgment of the importance of addressing this research topic, but rather an assessment of progress to date. **Please record your answer as a percentage (0-100%):**

6) **If the answer to #4 is <100%, answer the following:**
   a. **When your research project(s) is completed, to what degree will the information generated quantify the risks or benefits of introducing diploid *C. ariakensis* described by the selected Research Priority** Assume that approved 2nd and subsequent years of projects will be funded as planned. Please provide a numerical response recognizing the scope of issues that need to be addressed for this priority. **Please record your answer as a percentage (0-100%):**

   b. **What is the anticipated end date of funded research projects considered in your answer to 6a?** Base this end date on a realistic assessment of completion that includes funding delays, delays due to logistical constraints, and a report 3 months after the project end - - not on the current official end date of the grant.

7) **To what extent does your research include the potential for important phenotypic and genotypic variation in *C. ariakensis* and *C. virginica* in its design?** List appropriate category: (1) Not at all, (2) some genetic or phenotypic variation in *C. ariakensis* is included, (3) some genetic or phenotypic variation in *C. virginica* is included, (4) some genetic or phenotypic variation in *both species* is included, (5) research has extensively considered genetic *and* phenotypic variation in *both species.*

8) **Research relevancy to systems other than Chesapeake Bay.** Some research results are independent of site, while others are site dependent because of differences in physical and biotic environments. The STAC report recommended that risks outside Chesapeake Bay be evaluated because of scientific consensus that *C. ariakensis* will invade other systems if a self-sustaining population is established in Chesapeake Bay.

   a. **Is your research relevant to systems other than Chesapeake Bay?**

   b. **If your answer to 8a is yes, to which systems is it relevant?**

   c. **If your answer to 8a is yes, how thoroughly (i.e., what percent of needed information will it generate) will your research meet research needs for identified research priority for the system(s) identified under 8b.**

9) **Additional comments.** Please add any additional comments you might have. These may be included verbatim in the STAC report, or may be summarized, depending on the nature of the comments.

Table 1. Summary of Research Recommendations
Please enter number listed for each question/topic in survey question #2.

Research Questions and Topics	**Priority From STAC Report**
CAN SELF-SUSTAINING POPULATIONS OF *C. ARIAKENSIS* BE ESTABLISHED IN CHESAPEAKE BAY	
1. Disease Susceptibility	
1A. What is the susceptibility of *C. ariakensis* to *Bonamia* spp. pathogens that could be present in Chesapeake Bay and other estuaries? (experiments)	Essential
1B. What is the potential for vertical transmission of Herpes viruses? (experiments)	High
1C. What is the susceptibility of *C. ariakensis* to *Perkinsus* sp. pathogens other than *P. marinus*? (experiments)	Moderate
2. Research Methods	
2A. How will the use of triploid *C. ariakensis* in experiments affect the accuracy of predictions about diploids? (experiments)	High
2B. What is the stability and reproductive potential of triploid *C. ariakensis*? (experiments)	Moderate
3. Biological and Ecological Considerations	
3A. Is there genetic variation among *C. ariakensis* stocks from Asia related to important physiological and ecological traits that will affect the benefits associated with introducing it to the Chesapeake Bay? (sampling and experiments)	High
3B. What are the growth, survival and feeding responses of *C. ariakensis* versus *C. virginica* under a range of conditions in Chesapeake Bay? (experiments)	High
3C. What are the vital reproductive rates and processes (, e.g., gametogenesis, spawning, fecundity, sex change) of *C. ariakensis v. C. virginica* under East Coast environmental conditions? (experiments)	High
3D. Do physiological and behavioral characteristics of *C. ariakensis* and *C. virginica* larvae differ in ways that would affect larval survival and dispersal? (experiments and model)	High
3E. What are the settlement cues and substrate preferences of *C. ariakensis*? (experiments)	High
3F. Population models to predict abundance and spread of *C. ariakensis* in Chesapeake Bay	High
3G. Is there a difference in mortality rates of juvenile *C. ariakensis* and *C. virginica* in responses to dissolved oxygen concentrations , sedimentation and predation? (experiments)	High

Research Questions and Topics	Priority From STAC Report
RISKS TO *C. VIRGINICA* AND OTHER BIVALVES	
4A. Is there genetic variation among *C. ariakensis* stocks from Asia related to important physiological and ecological traits that will affect the risks associated with introducing it to the Chesapeake Bay? (sampling and experiments)	
4B. Are their habitat/strain combinations that would yield population growth and coexistence of both *C. ariakensis* and *C. virginica*? (model)	
4C. Will *C. ariakensis* increase disease transmission and prevalence in *C. virginica* and other bivalves? (experiments)	High
4D. Will *C. ariakensis* reduce disease transmission or prevalence *C. virginica* and other bivalves? (experiments)	Moderate
4E. Models of disease dynamics	Moderate
4F. What is the risk posed to *C. virginica* by cross-species fertilization? (experiments or models)	High
4G. What are the likely extent, magnitude and outcome of competition for space and food between *C. ariakensis* and *C. virginica*? (experiments; data generated should be added to models)	High
4H. What is the timing of reproduction of *C. ariakensis* relative to that of *C. virginica*? (experiments)	High
4I. What is the likely effect of *C. ariakensis* on predation on *C. virginica?* (models and/or experiments)	Moderate
RISKS AND BENEFITS TO ECOSYSTEM FUNCTIONS AND SERVICES	
5A. What will the growth form(s) of *C. ariakensis* be in Chesapeake Bay **and** what are the consequences of those growth forms to other organisms? Will the growth form of *C. ariakensis* provide the habitat value formerly provided by *C. virginica*? (experiments)	High
5B. How will *C. ariakensis* affect the abundance of oyster predators and competitors? (experiments and models)	Moderate
5C. Will *C. ariakensis* affect biogeochemical cycling or plankton composition differently than *C. virginica?* (experiments)	Moderate
HUMAN HEALTH AND HEALTH-REALTED RISKS TO FISHERY	
6A. Will *C. ariakensis* accumulate human pathogens or *E. coli* to a greater degree than *C. virginica?*	Essential

Research Questions and Topics	**Priority From STAC Report**
OTHER OPTIONS	
7A. Is there a greater likelihood of successful restoration using 'Oregon' or other strains of *C. ariakensis* than using wild- or disease tolerant strains of *C. virginica*?	
OTHER RESEARCH TOPICS (please list)	

Appendix II

List of Researchers and Funded Projects Provided by the NOAA Chesapeake Bay Office and Maryland Department of Natural Resources

Understanding *C. ariakensis* within its native range: taxonomy, pathogens, and ecology
Investigator: Year 1: Drs. Mark Luckenbach (VIMS),
Year 2: Drs. Mark Luckenbach (VIMS), Kennedy Paynter (UMD), Junda Lin (Florida Institute of Technology), Huayong Que (Chinese Institute of Oceanography), and Chris Richardson (University of Wales)

Genetic and ecological structure of oyster estuaries in China and factors affecting success of *Crassostrea ariakensis*
Investigators: Ximing Guo (Rutgers HSRL), Aimin Wang (Hainan University), Guofan Zhang (Institute of Oceanology Chinese Academy of Sciences), Haiyan Wang (Institute of Oceanology Chinese Academy of Sciences)

Analysis of genetic variation in *Crassostrea ariakensis*: Evaluation of germplasm resources for broodstock development
Investigators: Kimberly S. Reece, Standish K. Allen Jr.

Assessing levels of genetic variation within and among native populations and hatchery stocks of the Suminoe oyster *Crassostrea ariakensis* using a suite of molecular markers
Investigators: Jan Cordes and Kimberly Reece

Genetic and ecological structure of oyster estuaries in China and factors affecting success of *Crassostrea ariakensis*
Investigators: Ximing Guo (Rutgers HSRL), Aimin Wang (Hainan University), Guofan Zhang (Institute of Oceanology Chinese Academy of Sciences), Haiyan Wang (Institute of Oceanology Chinese Academy of Sciences)

Evaluation of gametogenesis and spawning cues for diploid *C. ariakensis* for estimation of environmental risk and establishment of diploid brood stock populations
Investigators: Drs. Don Meritt (UMCES) and Stan Allen (VIMS)

Fertilization interference between *Crassostrea ariakensis* and *C. virginica*
Investigators: David Bushek (Rutgers HSRL), Ximing Guo (Rutgers HSRL), Greg DeBrosse (Rutgers HSRL)

Spawning interactions between *Crassostrea ariakensis* and *Crassostrea virginica*, Does the Proposed Introduction of a New Species Pose a Recruitment Threat to Native Oysters?
Investigators**:** Drs. Donald Meritt and Stan Allen

Behavioral responses of *Crassostrea ariakensis* and *Crassostrea virginica* larvae to environmental change under spatially realistic conditions
Investigators: Roger Newell (UMCES Horn Point Lab), Victor Kennedy (UMCES Horn Point Lab), Joan Manuel (UMCES Horn Point Lab).

Behavior and substrate selection in *C. ariakensis* pediveliger larvae in response to variation in environmental condition.
Investigators: Mario Tamburri (UMCES CBL), Mark Luckenbach (VIMS), Denise Breitburg (SERC)

Competitive interactions between *Crassostrea virginica* and *C. ariakensis*
Investigators: Mark Luckenbach, Gene Burreson

Oyster growth rate and population biology studies (A Population Model for the Oyster *C. ariakensis)*
Investigators: Drs. Roger Mann and Juliana Harding

Assessing the potential for natural predators (messohaline) to control the spread of the Suminoe oyster, *Crassostrea ariakensis*
Investigators: Roger Newell, Victor Kennedy (UMD Horn Point Lab)

Will predation mortality differ for larvae of native and non-native oysters?
Investigators: Denise Breitburg (Smithsonian Environmental Research Center) Co-PIs: Richard Fulford (Smithsonian Environmental Research Center)
Mark Luckenbach (Virginia Institute of Marine Sciences) Roger I. E. Newell (University of MD Center for Environmental Science- Horn Point Laboratory)

Predation by polyhaline invertebrate predators on young non-native oysters, *Crassostrea ariakensis*, in Chesapeake Bay
Investigators: Victor Kennedy (UMCES Horn Point Lab), Roger Newell (UMCES Horn Point Lab)

Environmental Tolerance Studies on *Crassostrea ariakensis*
Investigators: Dr. Yonathan Zohar, Jennifer Carroll and John Stubblefield

Sensitivity to Hypoxia – Comparison of *Crassostrea ariakensis and Crassostrea virginica*
Investigators: Drs. Mark Matche and Cindy Driscoll (MD DNR / Oxford Lab)

Oxygen tolerance of native and non-native oysters
Investigator: Kennedy Paynter

Comparative post-settlement growth and survival in the Suminoe oyster *Crassostrea ariakensis* exposed to intertidal emersion
Investigators: Mark Luckenbach (VIMS), Peter Kingsley-Smith (VIMS)

Comparison of characteristics of the native oyster, *C. virginica,* and the Asian oyster, *C. ariakensis,* in the discharge area of a nuclear power plant in the Chesapeake Bay
Investigator: Richard Mclean (MD DNR) and George Abbe (Morgan State University)

Competitive interactions between eastern and suminoe oyster from diploid larval settlement through to development of reefs and the assessment of the habitat value of such reefs
Investigators: Drs. Roger Newell (UMCES), Mark Luckenbach (VIMS), Denise Breitburg (SERC), and Chris Dungan (MD DNR Oxford Lab)

Long-term mesocosm studies of competitive interactions between diploid *Crassostrea virginica* and *C. ariakensis*
Investigators: Roger Newell (UMCES Horn Point Lab), Denise Breitburg (SERC), Mark Luckenbach (VIMS), Chris Dungan (MD DNR Oxford Lab)

Characterizing performance of the Suminoe oyster, *Crassostrea ariakensis,* in Maryland waters
Investigator: Kennedy Paynter

Comparative performance of triploid *Crassostrea ariakensis* and *C. virginica* in bottom habitats in Virginia and Maryland
Investigators: Mark W. Luckenbach (VIMS) Co-PIs: Standish K. Allen, Jr. (VIMS), Peter Kingsley-Smith (VIMS), Kennedy Paynter (UMCES), and Donald Meritt (UMCES)

Caged *Crassostrea ariakensis* deployment in Chesapeake Bay: Growth, disease, *Polydora* infestation, and mortality in 3 and 4 year old non-native oysters
Investigator: Kennedy Paynter, University of Maryland, College Park

Potential pathogens of *Crassostrea ariakensis* in its native range in China and in established populations in Washington, USA
Investigators: Eugene M. Burreson, Standish K. Allen Jr., Kimberly S. Reece

A histological investigation of oyster parasites and pathology in three Chinese estuaries containing varying mixtures of coexisting oyster species including *Crassostrea ariakensis*
Investigators: David Bushek (Rutgers HSRL), Susan Ford (Rutgers HSRL), and Ximing Guo (Rutgers HSRL). Note: This is a companion project to **EIS Project 25 --- "Genetic and ecological structure of oyster estuaries in China and factors affecting success of *Crassostrea ariakensis*"** (FY 2004, NOAA award NA04NMF4570424)

***Research and Development Studies on* Crassostrea ariakensis**
Investigators: Drs. Yonathan Zohar, Gerardo 2 and Feng Chen

Susceptibility of *Crassostrea ariakensis* to the oyster pathogen *Bonamia ostreae* and to *Bonamia* sp. recently discovered in *C. ariakensis* in North Carolina
Investigators: Eugene Burreson (VIMS), Ryan Carnegie (VIMS), Corinne Audemard (VIMS), Charles Peterson (UNC IMS)

Susceptibility of *Crassostrea ariakensis* to *Bonamia* species: potential for increased disease transmission between oyster species
Investigators: Gerardo Vasta and Jose Robledo

Potential for *Crassostrea ariakensis* to serve as a vector for exotic pathogens in Chesapeake Bay
Investigators: Kimberly Reece (VIMS), Ryan Carnegie (VIMS), Eugene Burreson (VIMS), Chris Dungan (MD DNR Oxford Lab)

The use of non-native oysters in the restoration of Chesapeake Bay oyster populations and the potential threats posed by harmful algae
Investigators: Patricia M. Glibert, Donald Meritt, and Diane K. Stoecker

Evaluation of *Crassostrea ariakensis* as a potential sink or reservoir for pathogens of humans and shellfish
Investigators: Gerardo Vasta and Eric Schott (COMB), Denise Breitburg, and Anson Hines (SERC)

Comparison of Microbiological Characteristics of *Crassostrea virginica* and *Crassostrea ariakensis*
Investigators: Drs. Howard Kator and Kimberly Reece

Does *C. ariakensis* accumulate more microbial pathogens than *C. virginica* increasing the pathogenic risk for human consumption?
Investigator: Carys L. Mitchelmore

Comparison of bacteria uptake and depuration rates between the Suminoe oyster *Crassostrea ariakensis* and the American oyster *Crassostrea virginica*
Investigators: Jeff Govoni and James Morris

Environmental tolerance-dependent competition between adult *Crassostrea ariakensis* and *C. virginica* in recovering and retaining waterborne disease agents in relation to water salinity
Investigators: Thaddeus Graczyk (Johns Hopkins University, Bloomburg School of Public Health)

The potential for using triploid *Crassostrea virginica* for on bottom culture in Chesapeake Bay
Investigators: Melissa Southworth (VIMS), Co-PIs: Roger Mann (VIMS), A. Thomas Leggett Jr. (CBF) and AJ Erskine (Bevans Oyster Company & Cowart Seafood Corporation)

Non-native oyster trials for aquaculture
Investigator: Mike Marshall & Jonathan Grabowski

Comparative economic evaluation of triploid *C. ariakensis* and triploid disease-resistant *C. virginica*: Companion trial to 2005 VSC deployment
Investigators: Standish K. Allen, Jr., Ph.D. Co-PIs: Karen Hudson and Bob Fisher

Biosecurity and comparative field trials of triploid *Crassostrea ariakensis* with *C. virginica*
Investigators: Standish K. Allen Jr., Kimberly S. Reece, Eugene M. Burreson

Biological material support for studies on *Crassostrea ariakensis*
Investigator: Stan Allen (VIMS)

Supply and Management of Oyster Harvests in the Chesapeake Bay: An examination of historical factors and their implications for introduction of non-native oysters and targeted alternatives
Investigator: Robert Wieland, Main Street Economics

Modeling dispersal of *Crassostrea ariakensis* oyster larvae in Chesapeake Bay
Investigators: Drs. Elizabeth North, Raleigh Hood, Ming Li, and Tom Gross

Evaluating Ecosystem Effects of Oyster Restoration in Chesapeake Bay
Investigators: Carl F. Cerco and Mark R. Noel (USACE, ERDC)

Ecological Risk Assessment (ERA) in support of a programmatic Environmental Impact Statement (EIS) to evaluate alternative approaches to increasing oyster populations into the Chesapeake Bay
Investigators: Dr. Mary Christman (UMD), Jon Volstad (Versar)

Economic Component of an Environmental Impact Statement for Proposed Introduction of the oyster species, *Crassostrea ariakensis*, into the tidal waters of Maryland and Virginia to re-establish a naturalized, reproducing, and self-sustaining population of oysters.
Investigators: Drs. Doug Lipton (UMD), Jim Kirkley and Tom Murray (VIMS)

Cultural Analysis for EIS on Oyster Restoration Alternatives
Investigators: Dr. Michael Paolisso