United States Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)

NOAA

Report to the Chairman, Committee on Appropriations, U.S. Senate

June 2007

NOAA Chesapeake Bay Office

Chesapeake Bay Oyster and Blue Crab Restoration

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report responds to a request in the Senate Appropriations Committee Report, FY2007:

> *Chesapeake Bay Oyster and Blue Crab Restoration*—The Committee provides $5,000,000 to research methods of restoring blue crabs, and $6,000,000 for oyster restoration, in the Chesapeake Bay. The Committee directs NOAA to provide a comprehensive report on the progress made to date and strategic plans for the future of these efforts, including performance benchmarks and plans for financial self sufficiency.

This report discusses progress in programs to research and restore native oysters and blue crabs in the Chesapeake Bay, and details plans and developments for the programs for 2007 and beyond. The report also discusses plans and potential for economic self-sufficiency for oyster and blue crab research and restoration in the Bay.

Oysters are important to the Bay for both commercial and ecological reasons. Bay oyster revenue from landings in recent years (2000-2005) averaged $3.2 million, representing an average of 957,000 pounds. By contrast, in the early 1950s, landings ranged from nearly 30,000,000 pounds to more than 40,000,000 pounds. Oysters provide significant ecological services to the Bay, including providing food and habitat to other Bay species and filtering water—each oyster can filter up to up to five liters of water per hour. In 2005, the Bay's oyster biomass was 1.487 billion grams, far short of the *Chesapeake 2000* Agreement commitment to raise the population ten-fold from the 1994 level of 1.59 billion grams by 2010.

The Bay's commercial blue crab harvest in recent years (2003-2005) averaged $58 million, and the blue crab fishery is the most economically significant fishery in the Bay. Landings by recreational crabbers and money spent by fishers on crabbing activities further add to the blue crab's economic impact in the region. However, the blue crab spawning stock has fallen by 85 percent since 1990, a decline that, if not stopped, may lead to the irreversible collapse of the blue crab population in the Bay.

Both the oyster and crab fisheries are state-managed activities. While NOAA's role is primarily advisory and through provision and control of the Federal funding discussed in this report, if properly focused on both management and technical initiatives, this role has the potential to help the states to develop sustainable fisheries and a healthier Bay. Although the results to date have been modest, NOAA plans to continue providing strong leadership to help ensure its efforts in this area have the greatest possible impact.

The NOAA Chesapeake Bay Office (NCBO) has supported *oyster restoration* in Maryland and Virginia since 1999. Maryland restoration projects are implemented by the Oyster Recovery Partnership (ORP). The program has achieved gains in the production and deployment of juvenile oysters (spat), improved scientific knowledge, and engaged watermen in restoration activities. Much of the focus has been on planting oysters in managed reserves where, under the current program design, oysters can be harvested once they are larger than market size, depending on disease condition. Other oyster restoration projects are accomplished in sanctuaries and unmanaged areas. The ORP also pays oystermen for removing diseased beds and depositing these oysters

elsewhere in the Bay. Between 1999 and 2006, a total of $11.6 million in federal funding supported the Partnership's work. To date, the program has enhanced over 600 acres of oysters; projects have planted a total of 265 million spat on shell in sanctuary sites, 478 million spat on shell in managed reserves, and 210 million spat on shell in unmanaged, open areas. Reflecting an evolving focus, the program's 2006 workplan devotes about 45 percent of planting effort to sanctuaries, 45 percent to managed reserves, and less than 10 percent to unmanaged areas. The ORP's choice of restoration strategies reflects goals of both long-term oyster restoration and short-term harvests. The NOAA Chesapeake Bay Office is improving the oversight and design of restoration projects to enhance the likelihood of sustained improvements in oyster stocks in the Maryland portion of the Bay.

From 2004 through 2006, NOAA awarded a total of $8 million to the Virginia Institute of Marine Science (VIMS) to support oyster restoration activities in Virginia. These activities have enhanced about 1,000 acres in Virginia. Although scientists are still in the process of fully implementing and measuring the results of the Great Wicomico River project, the project as a whole has not achieved a marked increase in the native oyster population. VIMS is using NOAA funds to encourage private industry to develop hatchery-based production capacity. Although private hatcheries in Virginia are still unable to meet the demands of large-scale restoration, they are providing a means to increase overall oyster production capacity and a way to engage the private sector as a partner in the restoration effort. There are indications that this approach may promote sustainability of stocks by providing economic incentives for watermen to manage harvests in order to maximize the reproductive capability of their stocks.

The lack of a standardized tracking system for restoration efforts has contributed to the difficulty of measuring the progress of oyster restoration projects. Some organizations have tracked spat planted, while others have tracked acres "restored" (i.e., enhanced). Because no single database currently exists to track restoration projects in the entire Chesapeake Bay, NCBO is working with grantees and other partners to establish a standard set of performance-based metrics, as well as project-specific success criteria to evaluate the success of individual project sites.

NCBO also funds *blue crab research and stock enhancement studies* as part of its partnership role in the Chesapeake Bay Program. From 2002 to 2006, a total of $12 million has supported this research through the Blue Crab Advanced Research Consortium (BCARC), a formal partnership of Federal and academic institutions. The BCARC has achieved significant developments in hatchery technology and techniques and has met its objectives of producing and releasing an increased number of juvenile blue crabs in the Chesapeake Bay. A total of 290,000 hatchery crabs have been released from 2002 through 2006, with greatly accelerating production and releases in 2006. However, the technology has not been implemented on a scale large enough to impact the blue crab population in the Chesapeake Bay. In addition to exploring stock-supplementation technologies, NOAA is using the science to examine management initiatives that the states could implement to ensure the crab-harvesting industry remains sustainable.

OYSTER RESTORATION

A. Background

Oysters play a pivotal role in the health of the Chesapeake Bay by filtering water and providing habitat, yet their current low numbers impede their ability to provide these functions. In addition, the oyster fishery, once a productive and vibrant part of the regional economy, is now struggling. NCBO funds native oyster restoration as part of its partnership role in the Chesapeake Bay Program. Specifically, NOAA supports efforts to achieve a commitment of the *Chesapeake 2000* Agreement: *"By 2010, achieve, at a minimum, a tenfold increase in native oysters in the Chesapeake Bay, based upon a 1994 baseline. By 2002, develop and implement a strategy to achieve this increase by using sanctuaries sufficient in size and distribution, aquaculture, continued disease research and disease-resistant management strategies, and other management approaches."* This goal is to be accomplished through the activities of multiple Federal, state, and other partners of the Chesapeake Bay Program.

Prior to the initiation of the specific funding (described below), NOAA principally funded oyster fishery studies (stock assessment and relevant research/management topics) through the Chesapeake Bay Stock Assessment Committee. Congressional appropriations to NOAA (which began in 1999) specifically address native oyster restoration activities in Maryland. A second budget line was added in 2002 for Virginia activities. The President's budget request for oyster restoration has been $850K annually since 2002 under the budget line for "Chesapeake Bay Oyster Restoration." Annual appropriations have exceeded this request, and the NOAA Chesapeake Bay Office has administered them for the overall benefit of oyster restoration in the Chesapeake Bay. The Maryland recipient for these appropriations, the Oyster Recovery Partnership (ORP), has remained the same each year since funding inception. Virginia funds went to the Virginia Oyster Reef Heritage Foundation in 2002 and 2003 and were designated for the Virginia Institute of Marine Science from 2004 to present (see Figure 1).

B. Progress to Date

1. Maryland Activities

NOAA funding for oyster restoration activities in Maryland has been directed both toward enhancing the ecological benefits of oysters to the Chesapeake Bay (because oysters provide habitat and filter water) and restoring the oyster fishery (which benefits local watermen and their communities). Annual funding for these efforts has increased over the years from $450K in FY99 to $4,000K in FY06.

While the Maryland activities supported by NOAA funding to ORP have not resulted in a marked gain toward the goal of a tenfold increase in the native oyster population, tangible and significant advances have been made:

- Vastly increased capacity and efficiency for production, handling, and deploying large amounts of oyster larvae and spat;

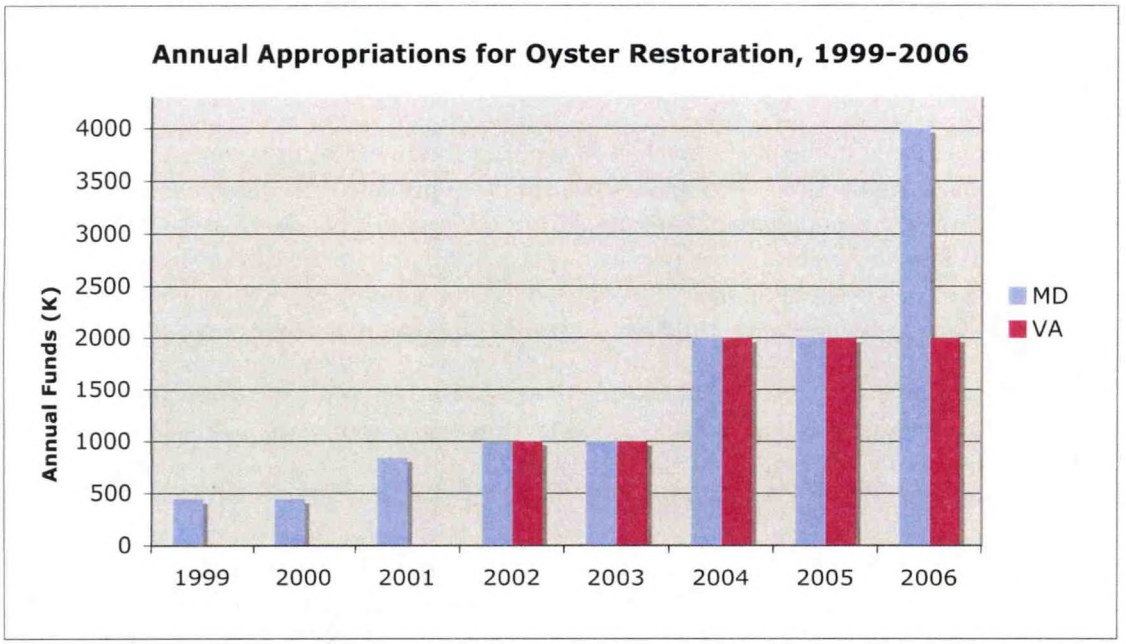

Figure 1. Annual appropriations to the NOAA Chesapeake Bay Office for native oyster restoration activities from 1999 to 2006.

- Improved scientific knowledge about what does and does not work, which in recent years has resulted in better projects demonstrating impressive growth and survival of local populations at some sanctuary sites; and
- Engaging watermen to show them a new way of doing business by actively working to cultivate oysters, which ultimately can be transitioned to a privately supported venture and alleviate industry pressures on state management and policy for oysters.

All of these elements are fundamental to success in the oyster restoration endeavor, and they were not previously in place. First, capacity is critical because the Chesapeake Bay is large and 99% of oyster populations and their habitats have been lost; without large-scale capacity to accomplish large-scale restoration there is little hope of having a measurable impact and thus little hope of attaining the ecological benefits necessary to restore the health of the Bay. Second, the science of oyster restoration is still in its infancy and the inherent variability of the natural environment makes progress slow–every year is different—but progress is being made. Third, the oyster resource and bottom habitats are managed by the state, which has a long history of management based upon harvest returns to the industry rather than ecological restoration. In many circles the shift to ecological objectives has occurred, but some policies and traditional practices remain (e.g., the state must obtain approval from county oyster commissions for any changes to bottom management, including designating a particular site as a sanctuary).

From 1999 through 2001, funding to the Oyster Recovery Partnership was utilized to test several different oyster restoration techniques. Tests conducted with disease-tolerant strains of oysters during this same period did not show significant improvement in survival rates over wild strains for two diseases, MSX and Dermo. The use of these strains has not been a major component of oyster

restoration in Maryland. Instead, efforts have focused on managing around disease by using the moderate- to low-salinity regions in the upper reaches of the Chesapeake Bay, as called for in the Maryland Oyster Roundtable Action Plan.

Funds provided to ORP through NOAA have been used to increase production capacity (e.g., shell handling, hatchery production, and other restoration infrastructure needs), implement on-the-ground restoration projects (including planting spat on shell and bar cleaning), and collect monitoring data. There has also been a significant increase in funding to support operation of a new state-of-the-art hatchery within the new Aquaculture and Restoration Ecology Laboratory (AREL) facility at the University of Maryland Center for Environmental Science's (UMCES) Horn Point Laboratory.

Results of these restoration projects have been mixed, with some sites having high survival rates and showing long-term persistence, and other sites succumbing to disease mortality – especially as a result of higher salinities during the 2002 drought year. The current strategy is to restore sites in moderate- to low-salinity areas that are not likely to suffer substantial disease mortality. Since 2000, the ORP has planted more than 900 million disease-free spat-on-shell oysters at more than 40 locations in Maryland (see Figure 2).

NCBO is collaborating with the Maryland Department of Natural Resources and Versar, Inc., to develop a new oyster stock assessment for the state, through which scientifically robust sampling methods will yield greatly improved estimates of oysters within Maryland waters. Importantly, this new stock assessment will allow progress toward oyster restoration goals to be more effectively tracked. NCBO has worked to improve the indicators by which native oyster restoration progress is reported by the Chesapeake Bay Program. Due to multiple partners being involved in oyster

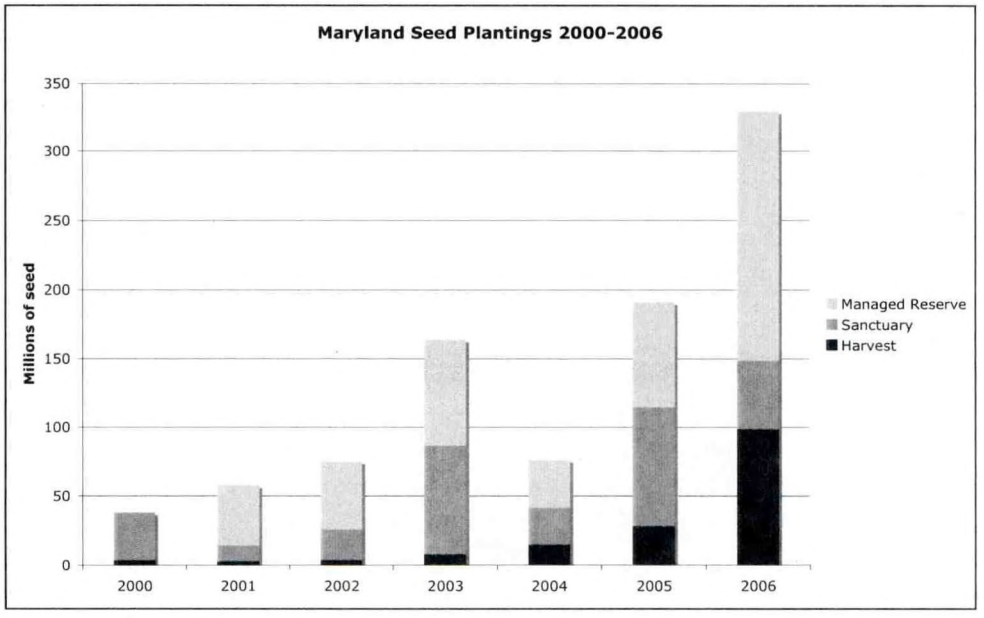

Figure 2. Millions of spat-on-shell oyster seed planted on managed reserves, sanctuaries, and harvest bars in Maryland from 2000 to present.

restoration within Maryland, difficulties in tracking total acreages planted exist because there is separate accounting for Army Corps funds for shell and NOAA funds for oyster seed awarded to ORP. NOAA is working with the Army Corps and other partners to resolve this data management challenge. NCBO has funded a project that will yield a combined database and will maintain this database in the future. For scale of reference, there have been well over 600 acres enhanced through a variety of techniques.

Beginning in 2001, the Oyster Recovery Partnership developed a new strategy known as "managed reserves." To establish a managed reserve, existing oysters are first removed by dredging to reduce the local disease reservoir, and are placed in other areas of the Bay where their effects are expected to be minimized. Known as "bar cleaning," this technique is currently under evaluation for its efficacy in reducing local disease levels and promoting greater oyster growth and survival. The area is then planted with clean shell and seeded with disease-free spat on shell produced by the UMCES Horn Point hatchery. After remaining closed for a period of time, managed reserves are opened for controlled harvest. Managed reserves are monitored for oyster size, density, and disease to inform management actions, better understand disease progression, and determine if harvest is appropriate. Additional bar cleaning may be conducted if there is an unacceptable increase in disease prevalence or intensity. The rationale behind the managed reserve strategy is that it results in a population of oysters larger than would be present on a harvest bar, since a portion of the oysters are allowed to grow beyond the 3-inch minimum harvest size before the managed reserve is opened for harvest. These larger animals, in turn, provide greater ecosystem services, such as habitat and water filtration. They also have greater reproductive capacity due to their larger size and the high densities of oysters present. This strategy began to show promise in 2004, when 4-inch oysters survived to harvest from managed reserves planted in 2001. Some observers believe that these oysters should remain in the water for an even longer time prior to harvest to maximize their ecological benefits and reproductive capabilities; however, the science on this issue is still unresolved.

The Maryland Department of Natural Resources designates sanctuaries as areas permanently closed to shellfish harvest. Sanctuary designation involves a lengthy public process, including consultation with local waterman groups and county oyster commissions. Harvest bars are also state-designated, and are areas open for harvest to all oyster license holders under the state's oyster fishery management regulations. According to the FY06 workplan submitted to NOAA by the Oyster Recovery Partnership, the ORP will continue to strive for an equal average year commitment to sanctuary and managed reserve sites, with less than a 10% resource commitment to open harvest bars. According to the ORP, this commitment to multiple restoration strategies allows for evaluation of different methodologies and consideration of various stakeholder interest groups. However, critics argue that the ORP's strategies do not maximize long-term restoration by allowing the majority of planted oysters to be harvested (and usually before the oysters reach full reproductive potential). NOAA plans to increase its oversight and direction in this area to help ensure that all partners are working toward long-term restoration.

2. Virginia Activities

Since 2002, NOAA has provided funds for oyster restoration in Virginia through its Chesapeake Bay Office and Office of Ocean and Coastal Resource Management, which provides Federal Coastal Zone Management (CZM) support to the Virginia Coastal Management Program. Annual accomplishments in terms of acres enhanced with these funds in combination with those of partner agencies are shown in Figure 3.

While the Virginia activities supported by NOAA funding to VIMS have also not achieved a marked gain toward the goal of a tenfold increase in the native oyster population, coordination by the NOAA Chesapeake Bay Office has brought about significant and tangible advances:

- Coordination of Federal and state agencies to fully implement and measure results of the Great Wicomico project;
- Improved scientific knowledge about what does and does not work, which in recent years has resulted in better projects demonstrating survival that may indicate the beginning of disease resistance in local populations at some sanctuary sites; and
- Engagement of private industry to meet the need for larvae and spat to accomplish large-scale restoration.

These recent advances are critical for Virginia oyster restoration. The Great Wicomico project is the first attempt to focus resources at a scale commensurate with the system so that project impacts can be accurately measured beyond background "noise" caused by variability in the natural environment. Completing this major test case will allow NOAA to evaluate the success and transferability of this subestuary focused approach for other parts of the Bay. Second, much has been learned about how to accomplish successful oyster restoration in the high salinity waters of Virginia. For example, it is now known that without repeated seeding or natural recruitment of oysters, created three-dimensional reefs will degrade from fouling organisms and boring sponges. This discovery has led to advances in thinking about local oyster populations as "sources" and "sinks" and realization that metapopulation science must be applied to consider oyster restoration from a landscape perspective of interacting local subpopulations. Also, scientists at VIMS believe they are now seeing evolution of disease tolerance in sanctuaries, a result that has required many years to develop through protection of sanctuary sites. Finally, the Virginia industry of small shellfish hatcheries, watermen, and oyster growers recently assisted by providing the needed larvae and spat to implement large-scale restoration.

Supported by NOAA CZM funds, oyster restoration activities in 2002 and 2003 were directed toward on-the-ground shell plantings in a number of tributaries, with a focus on the lower Rappahannock River. The deposit of shells in Virginia was intended to serve as a setting surface for spat produced naturally from existing wild oyster populations. The funds were used to purchase a combination of shell from oyster processing houses and shell dredged from historic deposits in the lower James River.

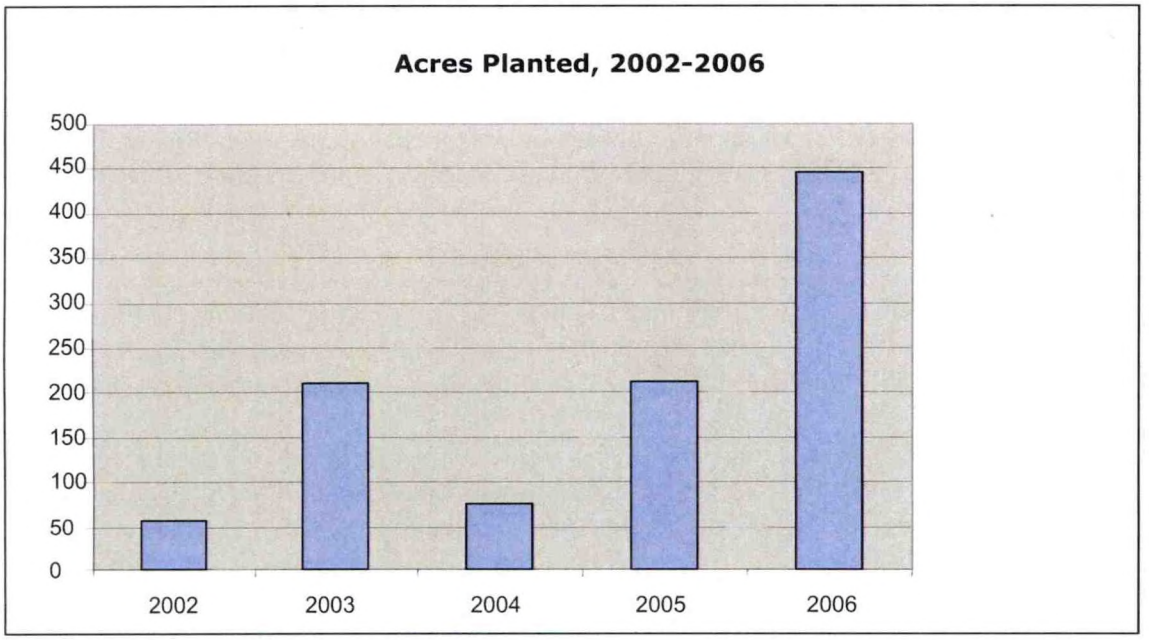

Figure 3. Acres enhanced by NOAA funding for oyster restoration activities in Virginia, 2002 to 2006.

Since FY04, the NOAA Chesapeake Bay Office has received $2M each year of congressionally directed appropriations for oyster restoration activities in Virginia. A portion of these funds (typically $500K each year) has been provided through the Virginia Institute of Marine Science (VIMS) to the Virginia Marine Resources Commission (VMRC) to support various shell-planting activities. The remainder is administered within VIMS to complement other Federal and state activities. These efforts have largely been, and remain, focused within the Great Wicomico River, a small trap-type estuary. These activities include work necessary to prove or disprove the hypothesis that deploying large numbers of oysters in a trap estuary could provide enough oysters to overcome the effects of disease, and eventually lead to a self-sustaining population. The Great Wicomico River project has used only a disease-resistant strain of native oyster called the Delaware Bay strain, or DEBY. Over the past three years, approximately 20 million DEBYs have been deployed in this small river system, and NOAA funds have supported VIMS researchers to monitor growth, disease, and recruitment rates of oysters deployed through this project. The DEBY oyster was selected not only for its disease resistance, but also because it can be tracked through genetic typing. In other words, we can track the progress of our efforts versus recruitment signals from the wild native strains already present in this river. In 2007, the goal is to produce 40 million DEBY spat on shell for placement in this system to get a better understanding of how many oysters are necessary to see large recruitment numbers, and essentially restore native oysters in this tributary. Once a successful model can be identified, lessons learned there can be transferred to other similar systems.

To increase collaboration and develop joint funding priorities among the various oyster restoration groups, the Virginia Interagency Oyster Team was formed in 2004. The agencies on this team include NOAA, the U.S. Army Corps of Engineers, Norfolk District (Corps), VMRC, VIMS, the Chesapeake Bay Foundation, and The Nature Conservancy. Targeted efforts within the last two

years have been focused in the Great Wicomico River to test the original hypothesis that smaller trap estuaries can be used as natural hatcheries for disease-resistant oysters. NOAA funds in 2004 and 2005 were initially targeted toward VIMS monitoring of Corps projects in the Great Wicomico River. However, the Corps has not been able to sustain the scale of projects necessary to test the hypothesis. To ensure the project continued in a timely manner, in 2005 and 2006, the Virginia Interagency Oyster Team developed and began implementing a strategy that will ensure annual inputs of millions of spat-on-shell oyster in the Great Wicomico River.

A major component of this strategy involves applying some of the NOAA funds to encourage private industry to develop hatchery-based production capacity by creating a market for disease-tolerant spat on shell for restoration and to increase production of healthy oysters on established leases. This work has just begun with a pilot project (described below), and it will take some time for the Virginia industry to reach self-sufficiency. Although private hatcheries in Virginia are still unable to meet the demands of large-scale restoration, they are providing a means to increase overall oyster production capacity and a way to engage the private sector as a partner in the restoration effort.

C. Strategic Plans for the Future

1. 2007 NOAA Oyster Restoration Activities

Pending review of proposals submitted to NOAA for FY07 funding, NOAA anticipates continuing to address the limitations of larvae and spat and engaging private industry in the restoration effort. In Maryland, the ORP is requesting funds to continue to support hatchery infrastructure and spat production at the UMCES Horn Point hatchery, and to engage watermen in the implementation of managed reserves. These reserves provide a form of controlled cultivation of shellfish, contrasting with Maryland's traditional wild public fishery. The managed reserve strategy began to yield initial results in 2004. NOAA will evaluate results from 2004 to 2007, and will release a report on that evaluation in 2008.

In Virginia, VIMS is requesting funds to work with private hatcheries and growers to produce larvae and set the larvae on shell for deployment on restoration sites. This pilot began in 2005 with one hatchery and three growers and is expanding in 2006 to include three hatcheries and six growers. It is slated to expand further in 2007, adding additional hatcheries and growers. This pilot provides a means for evaluating a new collaborative model for oyster restoration in Virginia, creating an economic incentive for private industry to produce the spat-on-shell oysters needed for public restoration efforts and for commercial production on leases—all of which increases long-term incentive for private funding and investment in the hatchery and production facilities which would support both restoration and commercial production. This has benefits for the oyster industry as well as restoring ecological services of a key Bay species. The pilot will yield results suitable for an evaluation that NOAA will conduct in 2008.

2. Long-term Planning for Oyster Restoration

Because Maryland and Virginia share jurisdiction of the Chesapeake Bay and oysters are a state-managed resource, NOAA support for oyster restoration is carried out within the context and constraints of state strategies and fishery regulations. NOAA works with the state regulatory agencies to coordinate as much as possible, but final decisionmaking authority for oyster management rests with the states. To date, restoration efforts have been designed to serve multiple goals, balancing economic and ecological benefits to serve the many partners and constituent groups involved. Uncertain funding from year to year has been a challenge for effective long-range planning.

In Virginia, NCBO staff participate in two efforts to inform long-term planning for more effective oyster restoration and management. One is the Blue Ribbon Oyster Panel, convened by the Virginia Marine Resources Commission and Virginia's Secretary of Natural Resources to develop a new statewide plan guiding oyster management. A similar panel was convened in the early 1990s; however, its recommendations are largely outdated. The Commonwealth has largely managed its oyster resources on a case-by-case basis, with no comprehensive goals or strategies clearly outlined. This Blue Ribbon Panel report, expected in summer 2007, will contain very specific and comprehensive recommendations for oyster management, including input from state management agencies, Federal partners, nonprofit groups, and industry. The report will address the need for a clear definition of what constitutes an oyster sanctuary within state waters and increased enforcement and penalties for watermen operating in closed areas.

The second oyster management effort in Virginia is the Virginia Oyster Heritage Program. This group re-formed in January 2007 at the request of the Virginia Marine Resources Commission to develop a river-specific oyster management plan for the Rappahannock River. The Rappahannock River provides a good case study in developing a river-specific oyster management plan because private industry, state, and Federal (NCBO) funds have all been used to restore portions of the oyster bottom and all entities have a representative on this group. A final plan is expected in summer 2007. The final report will contain detailed recommendations for rotational harvest areas, sanctuaries, and increased enforcement. The group is also discussing "harvest triggers," monitoring and assessment information that would set appropriate levels to open or close harvest in areas. Results from this effort can be applied to other major rivers and their subestuaries throughout the Chesapeake Bay.

In addition, NOAA is co-funding a Bay-wide oyster evaluation project along with the Keith Campbell Foundation for the Environment and the U.S. Fish & Wildlife Service. Support in the form of project management and facilitation services is also being provided by the Chesapeake Research Consortium and Maryland Sea Grant. This project includes a team of scientists and data analysts compiling data from past efforts to better understand lessons learned over the past decade of restoration activities. A report from this group is due in late 2007 (see Appendix A).

Key factors that affect the ability to implement large-scale oyster restoration include:

- Limited capacity for hatchery production of oyster larvae
- Limited capacity for settlement of oyster larvae to produce spat-on-shell
- Existing and continued habitat degradation

- Limited substrate availability
- Poor water quality
- Disease (continuing need for disease research, including development of disease-tolerant strains)
- Regulation, management, and enforcement

NOAA is working with multiple partners in both states to address challenges to oyster restoration. State and Federal agencies are tackling additional challenges in areas such as water quality. Expansion and development of new hatchery capacity are helping to significantly increase the scale and impact of restoration efforts. In addition, agency and partner coordination through the ORP in Maryland and Virginia Interagency Oyster Team in Virginia is improving the focus and effectiveness of both existing and new strategies.

One area of potential promise is the transition from a wild public fishery to private cultivation in both states to satisfy the demand for harvest. Worldwide, in all cases where past overexploitation resulted in depleted oyster stocks, reinvigoration of the commercial industry and alleviation of harvest pressure on wild populations has been achieved through a shift from the wild fishery to aquaculture cultivation. To explore the potential for this complementary approach, NOAA has provided funding to the state Sea Grant programs to explore oyster aquaculture as part of this transition. Some of the current activities in each state have also been devised to move in that direction, particularly the Managed Reserve strategy in Maryland and the pilot project to obtain hatchery larvae and spat from private hatcheries and growers in Virginia. NOAA is exploring the potential, feasibility, and appropriate Federal role in oyster aquaculture development and science in the Chesapeake Bay.

D. Performance Benchmarks

The NOAA Chesapeake Bay Office is responsible for reporting the status and accomplishments of its native oyster restoration program annually to NOAA and biennially to Congress. In addition, NOAA and the Corps are jointly responsible for reporting the status, accomplishments, and following year's work plan for all Federally funded oyster restoration to the Federal Agencies Committee of the Chesapeake Bay Program. Current NOAA and Chesapeake Bay Program reporting for oyster restoration is largely limited to spat planted (see Figure 2) and acres enhanced (see Figure 3).

A Bay-wide definition of "restoration" or "restored" has not been agreed to by all Bay Program partners, including necessary rigorous quantification or evaluation of performance-based success for oyster restoration. A more informative suite of performance measures and indicators is needed to provide a clearer picture of both implementation activities and outcomes of oyster restoration efforts.

To address the need for better performance measures and accountability, NCBO is working in FY07 with grantees and other partners to establish a standard set of performance-based metrics, as well as project-specific success criteria to evaluate the success of individual project sites. These metrics may cover a variety of factors such as oyster population status (oyster abundance, biomass, density, distribution, size, survival, recruitment, disease), physical/chemical conditions (substrate

characterization, water quality—especially dissolved oxygen, sedimentation rates, hydrodynamics), ecological benefits (fish species diversity, abundance of key taxa, diversity of benthic infaunal and epifaunal communities), and economic benefits (harvested amounts, dockside value, number of watermen benefiting).

During the process of developing performance measures and indicators, those being used in other oyster restoration programs domestically and internationally will be investigated for possible application to the Chesapeake Bay. NOAA will work with grantees to ensure that program monitoring provides appropriate data at the necessary frequency and duration for sampling and reporting to ensure reliable performance measurement. Appropriate sampling designs will be devised for sites that are not monitored in a given year.

E. Financial Self-sufficiency

The critical ecosystem functions that oysters provide—especially habitat creation and water filtration—are now widely recognized as a primary impetus for rebuilding wild oyster populations. The Chesapeake Bay's oyster populations are biologically self-sustaining at the present time, but at extremely low levels of abundance. Substantial increases are needed before we can expect the species to naturally sustain abundant populations adequate to provide the desired ecosystem benefits.

Restoration necessarily involves the repair of damage and replacement of losses to oyster habitat that have occurred over time. Suitable oyster habitat is estimated at a few percent of the original acreages, as a result of more than a century of habitat destruction from fishing gear and burial from excessive sedimentation released by land use practices. Oyster populations are also estimated to be just a few percent of their historic abundance. Reversing these downward trends is a long-term prospect, which we believe will be accelerated by a large-scale effort to rehabilitate habitat and restock oysters.

NOAA funding has been instrumental in testing restoration methods and developing the logistical capabilities to accomplish large-scale oyster restoration in the Chesapeake Bay. Significant progress has been made in expanding the capacity to accomplish this work. While these research and infrastructure developments will contribute to oyster restoration efforts in the future, they have not significantly impacted the Bay's oyster population or allowed the oyster fishery to be financially self-sustaining at the present time.

NOAA recognizes the importance of economic analysis, and in FY05 the NOAA Chesapeake Bay Office funded a project examining the net economic benefits of publicly funded oyster restoration and management efforts. The study focuses on Maryland's state-sponsored oyster fishery repletion program, as well as the Federally funded managed reserve strategy being implemented by ORP with NOAA and Army Corps funds. A final report from this economic study is expected by May 2008.

In both Maryland and Virginia, the public oyster fishery based upon harvest off of public grounds has not been self-sustaining for many years. The fishery has relied on human intervention by means of moving substrate (reshelling), planting seed (restocking), or abandoning areas altogether due to disease. In most cases, the value of the fishery revenue generated off of these grounds has not been

sufficient to make the state managed programs self-sustaining. All of the current restoration plans call for excluding large portions of the currently productive oyster grounds from harvest, in the hopes of establishing valuable habitat, disease-resistant oysters, and broodstock that might spawn and replenish other areas. However, this approach, by design, precludes an economic return since there is no revenue generated without any harvest.

New collaborative efforts in both states point to a potential avenue for economic self-sufficiency through private sector involvement. The managed reserve strategy being tested in Maryland yielded harvest size oysters for the first time in 2004. Economic data are being evaluated as they become available. In Virginia, the effort to produce healthy oysters and native triploid oysters for use on existing commercial leases in Virginia provides incentive for the private sector to put more commercial leases back into production which will help move part of the program toward economic self sufficiency. Both states are actively reevaluating their regulations for use of public bay bottom, including restrictions on aquaculture and availability of high-quality leased grounds. All of these changes signal tremendous potential for increased private oyster cultivation through aquaculture in the future, which will yield both economic and ecological returns.

Chesapeake Bay native oyster restoration efforts have successfully put in place substantial infrastructure elements necessary to either continue publicly supported oyster restoration on public grounds or allow private entities to utilize the same approaches to grow oysters for eventual economic return. In Maryland, there is a large-scale UMCES operated facility, and there are efforts in the early phases to explore bringing additional smaller facilities on line. In Virginia, there is small-scale existing infrastructure involving private hatchery and setting facilities, augmented by logistical and technical support from VIMS. How these public investments translate into private-sector or market-based opportunities remains to be seen.

See Appendix A for additional information on related efforts to address native oyster restoration in the Chesapeake Bay.

II. BLUE CRAB RESEARCH AND STOCK ENHANCEMENT

A. Background

The NOAA Chesapeake Bay Office funds blue crab research and stock enhancement studies as part of its partnership role in the Chesapeake Bay Program. Specifically, NOAA supports efforts to achieve a commitment of the Chesapeake 2000 Agreement:

"By 2001, establish harvest targets for the blue crab fishery and begin implementing complementary state fisheries management strategies Baywide. Manage the blue crab fishery to restore a healthy spawning biomass, size and age structure."

NOAA began specifically addressing blue crab activities in 2002. The program has continued to receive increased funding support in years since. The University of Maryland Biotechnology Institute—Center of Marine Biotechnology is the identified principal investigator and lead scientific organization for the Blue Crab Advanced Research Consortium (BCARC), which manages the research activities.

B. Progress to Date

From the 2006 Blue Crab Advisory Report completed by scientists around the Chesapeake Bay region and coordinated by NOAA, analysis of long-term fishery-independent surveys conducted in the Chesapeake Bay (Bay-wide winter dredge survey, Virginia and Maryland

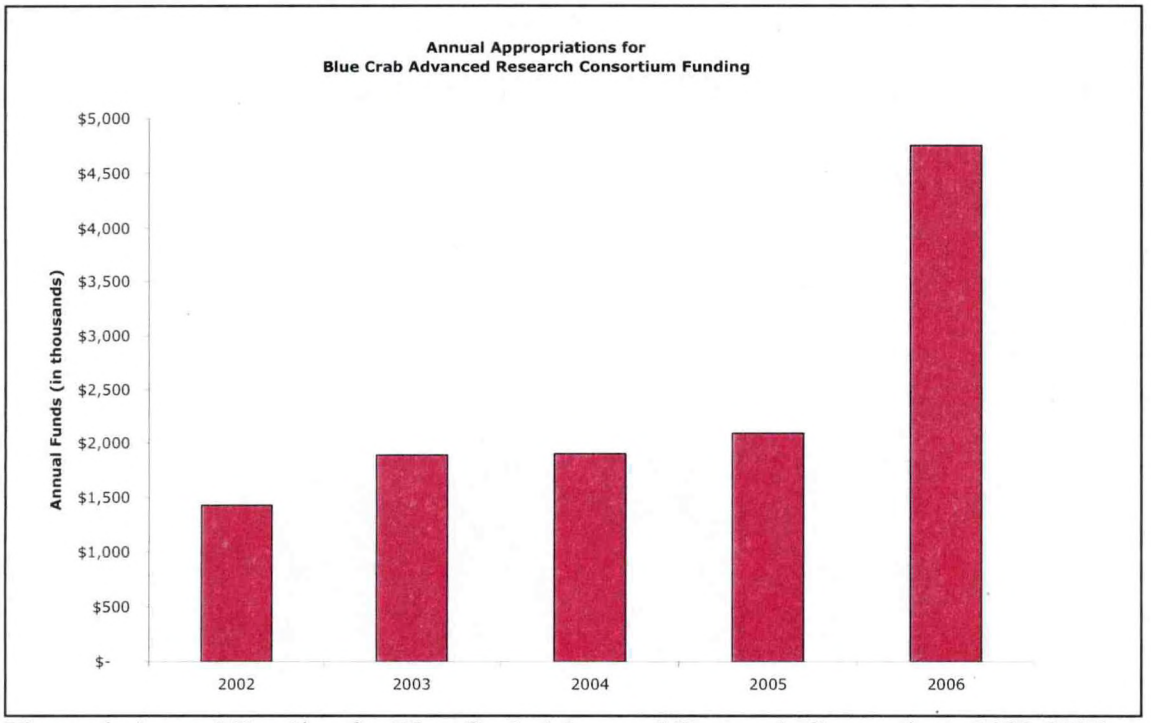

Figure 4: Annual Funding for Blue Crab Advanced Research Consortium, 2002-2006.

trawl surveys, Calvert Cliffs peeler pot survey) indicate that overall abundance of blue crabs in 2005 remained stable but low. Three of four surveys estimated female spawning stock biomass as average; however, the Virginia trawl survey indicates abundance of mature female crabs remained below average for the ninth consecutive year (and for 12 of the past 14 years). The dredge survey measures abundance during the dormant winter period, and all female crabs 60mm and greater will potentially enter the spawning stock during the following season. Therefore, an estimate of 'potential spawning stock biomass' including all females 60mm and larger is considered to be the most appropriate measure of abundance and was used for the 2006 Advisory Report.

A new stock assessment completed and reviewed in 2005 updated the management control rule that defines threshold for abundance (overfished) and exploitation (overfishing). The current status of the stock was compared to thresholds and targets defined by this control rule. Stock abundance in 2005 was greater than the overfished threshold. Exploitation, defined as the proportion of the legal-sized crabs available at the beginning of the year that were harvested, has decreased in recent years. In 2005, harvest was lower than the target level for the first time since 1997. However, low abundance, combined with an extended period of high exploitation rates, indicated a stock condition that warrants concern for the ninth consecutive year.

Since its inception in 2002, the BCARC program has approached the challenge of restoring the Chesapeake blue crab population in a systematic and scientifically sound manner. BCARC has: (1) investigated the concerns resulting from a depressed population level of blue crab in the Chesapeake Bay and the Gulf of Mexico, (2) solicited the opinions and wisdom of international experts working on similar fisheries problems, (3) developed a comprehensive plan targeting enhancement of the Chesapeake blue crab breeding stock, and (4) implemented the program in logical and quantifiable steps of increasing magnitude.

For the fifth consecutive year, BCARC has met its stated objectives of producing and releasing more juvenile blue crabs in the Chesapeake Bay, monitoring their survival and performance, implementing complementary research programs that augment the biological understanding of crabs and the Bay ecosystem, and developing stakeholder partnerships. BCARC has adhered to an externally reviewed enhancement program and the preplanned implementation of research programs designed to provide additional technology and safeguards. The program has become an international model for stock enhancement, as evidenced by invitations to present at national and international conferences (e.g., conference keynote at the International Conference of Stock Enhancement and Ocean Ranching) and requests for advice and collaboration from Federal agencies involved in restocking and stock assessment initiatives (Gulf States Marine Fisheries Commission, NOAA-NMFS, Alaska Sea Grant, private initiatives, etc).

Work accomplished by BCARC has received commendation from noted blue crab experts around the world:

> "The 2005 assessment [see Appendix 2] was found to involve significant improvements over the previous 1997 assessment document in all areas that were reviewed. Biological properties critical to an appropriate and valid assessment include the estimates of natural mortality, crab growth, and recruitment. Significant changes and improvements in all areas have been made and in many cases, published."

—Malcolm Hadden, University of Tasmania, Australia (from the international, independent peer review on the 2005 Blue Crab Stock Assessment)

"[The] BCARC Project has high potential to become the first U.S. success story in marine stock enhancement."
—Kenneth Leber, Mote Marine Laboratory

BCARC consists of formal partnerships between the University of Maryland Biotechnology Institute—Center of Marine Biotechnology (COMB), Smithsonian Environmental Research Center (SERC), Virginia Institute of Marine Science (VIMS), North Carolina State University (NCSU), and the University of Southern Mississippi (USM). A condensed description of BCARC progress is provided below for each of the major objectives of the program.

1. Hatchery/Nursery Technology and Juvenile Production

During 2006, there was considerable success in obtaining egg masses (sponges) in broodstock females, both during and outside of the natural spawning season. This was accomplished by carefully manipulating environmental conditions in different groups of animals to induce spawning at the desired time. As illustrated in Figure 5, sponges were obtained on a monthly basis from February through November (10 of 12 months).

The use of state-of-the-art hatchery facilities (including pathogen-free artificial seawater, recirculating filtration systems, and enriched food chain technology) has enabled the development of critical benchmark technologies:

- The entire life cycle of the crab has been closed in captivity for the first time;
- Out-of-season spawning has been established allowing for off-season production; and
- Captive hatching and rearing technologies have been developed and optimized.

BCARC technology has reached a point where survival of newly hatched crabs (zoeae) to the megalopa stage (earliest juvenile stage, measuring about 2 mm), once an insurmountable obstacle that restricted crab culture, is no longer a rate-limiting step. Indeed, BCARC produced nearly 3,250,000 megalopae in 2006, with the survival rate from zoeae stocking to megalopae harvest averaging more than 34%.

In 2006, BCARC reached record production levels of release-size juveniles (about 20 mm). The collective expertise of consortium scientists, in combination with the specialized facilities available through the state (COMB and Maryland Department of Natural Resources) have enabled the nursery technology for releasable blue crabs to progress rapidly, from essentially 0% survival prior to the Consortium's 2002 inception to 15% (from megalopa to juvenile stage) in 2006. Survival of similar stage animals in the wild is estimated at only a fraction of this number. The technology has evolved to a stand-alone process that has been patented by several BCARC scientists (USPTO # 6,584,935; issued July 1, 2003). This technology has enabled the production of more than 570,000 juvenile crabs since 2002, including nearly half the total number—307,500—in 2006. Moreover, since 2002, more than 290,000 of the hatchery-raised crabs have been tagged and released. The BCARC production from the hatchery has supplied field releases and experimental animals, in annually increasing numbers, to all consortium partners during the course of this project.

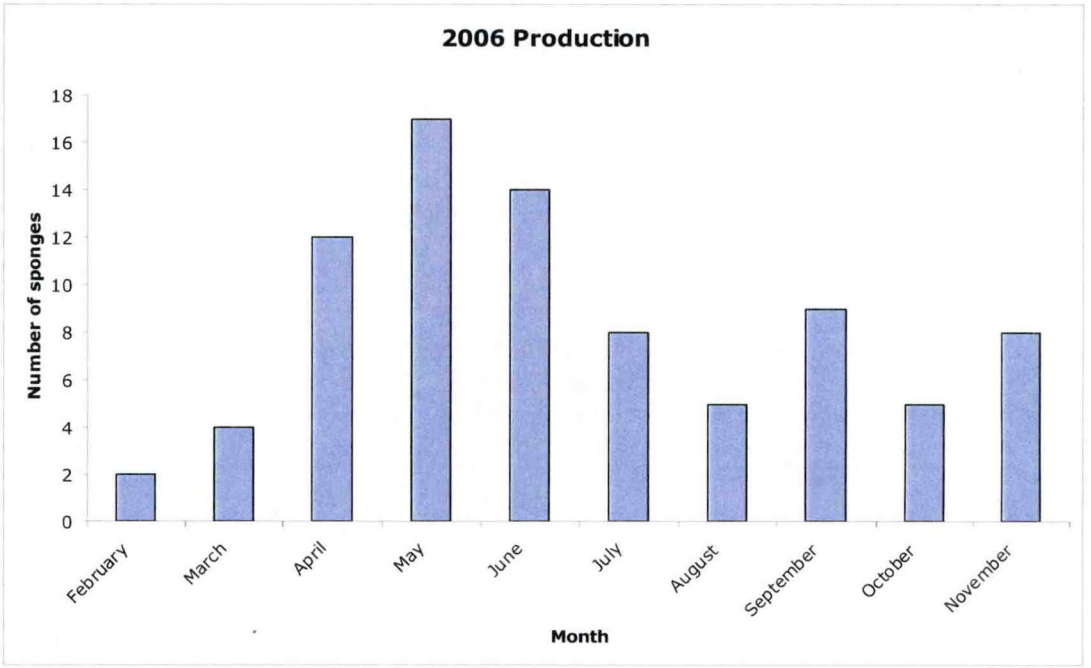

Figure 5. Egg mass (sponge) production in adult female broodstock during 2006. Peak production occurred during April-June (natural spawning season); however, considerable production was induced in early spring and throughout the fall.

2. Field Releases of Blue Crab Juveniles in the Chesapeake Bay

Consortium scientists have gone to considerable effort to maximize the survival and productivity of the released crabs. This effort has entailed a series of carefully designed studies and long-term monitoring efforts in the upper and lower Bay. These studies were intended to establish such critical factors as optimum size for release, optimum time of year for release, most effective stocking density (carrying capacity), suitable release habitat (i.e., a habitat suitability index), and the overall effects of local enhancement efforts.

Over the past five years (2002-2006), 39 batches totaling about 175,000 hatchery-reared juvenile crabs were tagged and released into nursery habitats of the upper Chesapeake Bay. Batches of 1,000 to 14,300 juveniles were released into small coves (0.2-6 hectares) and monitored for survival and growth to maturity. The hatchery crabs enhanced local subpopulations by an average of 146%, more than doubling wild populations, with survivorship to maturity averaging 12%. Production from these releases averaged 380 mature crabs per hectare, which is more than double the levels of production reported for intensive pond culture for the closely related blue swimmer crab in China.

3. Field Studies

a. *Maryland*

Upper Bay field biologists at SERC completed releases of 14 batches totaling about 74,000 hatchery-reared 20 mm juvenile blue crabs during spring-fall 2006 into small (0.2-1 hectare) coves of the Rhode and South Rivers. The number of crabs released in 2006 was more than double the amount released in any previous year (see Figure 6), illustrating significant progress toward increasing the scale of releases.

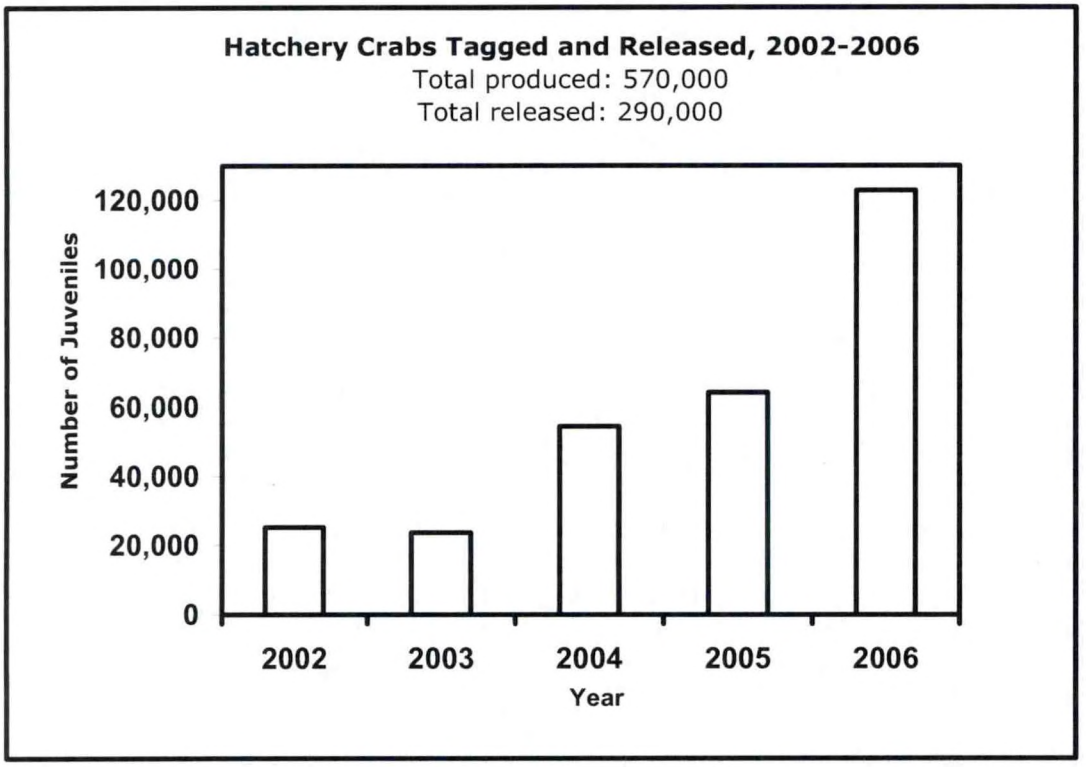

Figure 6: The number of hatchery crabs tagged and released into studied nursery areas around the Chesapeake Bay during 2002-2006.

b. *Virginia*

Field releases of hatchery crabs in 2006 have also been implemented in the lower Bay (York and James Rivers), with a total number of 49,000 juveniles released. In the lower Bay, efforts were undertaken in 2006 to release and monitor smaller juveniles (5-15 mm). This release strategy is intended to make use of the lower Bay's more plentiful seagrass beds (prime juvenile crab nursery habitat) and maximize hatchery yields by eliminating tank mortalities due to late-stage cannibalism in the 15- to 20-mm size class.

In total, experimental enhancement of blue crabs in 2006 ranged from 213 to 394% of wild populations (i.e., doubling to quadrupling wild stocks) in the coves—the highest levels observed since the releases began in 2002.

Most importantly, BCARC field studies have demonstrated that hatchery juveniles reached maturity (4-5 inches) in as few as three months after release (five months post-hatching), mated in the field, and migrated to the spawning grounds, thus indicating released crabs may contribute to the spawning stock in their first year. This research further suggests that hatchery releases have the potential for rapid input to blue crab population growth.

4. Research Programs

In addition to the hatchery production and tag-and-release studies in the Bay, a focused effort is underway to improve the understanding of blue crab biology, gather management-related data, and identify potential threats to the fishery. The BCARC has established basic science research programs in several areas. Progress in each area is described below.

a. *Endocrine Research Related to Molting and Reproduction*

Experiments have been conducted to isolate the genes, proteins, and hormones involved in vital life processes such as molting, growth, and reproduction. At present, the work is centered on bursicon, a hormone involved in the shell hardening (molting) process, and vitellogenin, an egg protein essential for reproduction. In each case, researchers expect that their studies will not only provide a greater understanding of crab biology, but will also enable improvements in the hatchery process and lead to more cost-effective production (such as synchronized molting and improved egg quality, hatching, and survival). The discovery of bursicon, which is involved in regulating the length of the shell-hardening process, may also have ramifications for dramatic improvements in commercial soft-shell crab operations.

b. *Disease Research in the Chesapeake Bay and Gulf of Mexico*

As the production and release of juvenile blue crabs has increased, so has the need for stringent screening of the released animals and the release habitats. In response to this need, BCARC has established a partnership with the NOAA-NCCOS lab at Oxford (Cooperative Oxford Lab; COL) to monitor blue crab diseases in hatchery broodstock, juveniles, and grow-out facilities. A full-time assistant professor position has been established (paid one half by COMB and one-half by NOAA-COL). In addition to capitalizing on the complementary expertise, facilities, and instrumentation available at each institute, this partnership leverages additional funds to support research faculty at COMB. Through this position, an application of a DNA-based disease-detection assay (PCR) to hundreds of crabs in the Bay and hatchery has been initiated.

Crustacean disease research is a primary interest in the Gulf of Mexico and a foremost expertise of the University of Southern Mississippi. The Mississippi and Chesapeake partners work collaboratively on this shared interest. One important finding (by researchers in Mississippi) that is pertinent to both regions is that blue crabs not only carry white spot virus (a prominent shrimp pathogen in the Gulf and along the Atlantic Coast), but that the virus can kill crabs. The implications of this finding in terms of recent drops in crab populations must still be evaluated. Ironically, Hurricane Katrina appears to have lessened the incidence of disease (white spot virus, *Hematodinium*) and pathogens (*Loxothylacus texanus*, *Ameson michaelis*) in the Gulf of Mexico. Recent research in the Gulf has thus been redirected to identifying the presumed environmental basis for these disease and pathogen declines.

c. *DNA-based Tagging Methodologies*

In 2006, DNA from 288 Chesapeake Bay blue crabs (from samples collected in 2005) was examined and compared to DNA from more than 50 hatchery crabs in a blind experiment. The data suggest that the wild blue crab population is highly diverse in terms of genetic composition. A methodology was developed using the DNA information to distinguish the wild crabs from the hatchery-developed crabs. In testing this methodology, minimal examples of false positives and false negatives—where the source of the crab was mistakenly identified—were noted. In short, the results indicate that a valid DNA-based tagging technology is now available.

d. *Blue Crab Genetics in the Chesapeake Bay and Gulf of Mexico*

In addition to the DNA-based tagging technology being tested, a broader study of blue crab genetics has been under way for several years, and has been reported in multiple publications. The implementation of a Bay-wide restocking program will necessitate careful consideration of (and protection of) the gene pool of wild Chesapeake stocks. As noted above, BCARC studies have provided ample data on the natural stocks and identified several factors that must be taken into account during restocking. Comparative studies in the Gulf of Mexico (by University of Southern Mississippi) have provided relevant additional data on gene distribution among wild populations. Such data is critical for fisheries management in the Gulf and Chesapeake regions.

One tool in the BCARC genetic research has been mating studies. To determine whether potential genetic isolation might exist between Atlantic coast and Gulf of Mexico blue crabs, Chesapeake scientists received 12 juvenile male crabs from the Gulf of Mexico partners. These were grown to maturity (> 110 mm) and paired with Bay females undergoing their prepubertal molt. The first four pairings resulted in cannibalism of the females, but the remaining six pairings resulted in successful insemination. BCARC researchers will repeat these cross-population matings in 2007 with the goal of obtaining successful broods in the laboratory and analyzing genetic exchange (a critical component of restocking and fisheries management).

This genetics work is part of a larger, comprehensive BCARC study that led to a 2004 University of Southern Mississippi Ph.D. dissertation ("Population Genetics of the Blue Crab in the Gulf of Mexico") and a 2004 Towson University M.Sc. thesis ("Multiple paternity in the blue crab, *Callinectes sapidus*, assessed with microsatellite markers"), and that will culminate in a University of Maryland Ph.D. dissertation entitled "Population Genetics of Blue Crab (*Callinectes sapidus*) in the Atlantic Coast and Gulf of Mexico." The information in these texts, which was previously unavailable, will bolster the BCARC's restocking strategies and provide much-needed data on the Chesapeake and Gulf of Mexico stocks to fisheries managers and policymakers.

In summary, the BCARC continues with a well-coordinated, academic-stakeholder partnership that is moving steadily toward the successful implementation of large-scale Bay-wide restocking of blue crabs. Crab mass-production technology has been developed, and up-scaling efforts are under way. The restocking effort will target increasing breeding stocks in the Bay, and tools to quantify the program's success are now available. Considerable effort will be required to scale-up the BCARC mass production technology, and a coordinated effort between academic partners and stakeholders is imperative. Additional basic research programs to address scientific understanding in understudied areas of blue crab biology, including ecosystem impacts, have already been established by BCARC partners in the Mississippi, North Carolina, Virginia, and Maryland. Such a

comprehensive program lays the foundation for the long-term health and management of this critical fishery in the mid-Atlantic and Gulf of Mexico regions.

C. Strategic Plans for the Future

By continuing to coordinate management activities, fund competitive science and research projects and support stock enhancement and hatchery technologies, NOAA will continue addressing the needs of the blue crab population, the potential for stock enhancement, and research on the biology of the Bay's most valuable species.

Scaling up from existing small-scale protocols is not a straight-forward and linear process. The current results from the hatchery technology and juvenile production are impressive and strongly suggest that planned BCARC increases in production are feasible and attainable in the near future.

Consortium partners are continuing to work to optimize the culture technology, in terms of both survival rates and cost effectiveness. The BCARC has established a partnership with the Maryland Department of Natural Resources, enabling consortium scientists and the Maryland Watermen's Association to renovate a state facility formerly used as an oyster hatchery for use in blue crab post-larval nursery production. In addition to facility use (formalized in a state-sanctioned memorandum of understanding), the state has contributed in-kind personnel, utility costs and upgrades, and building operating expenses. Alternative grow-out technologies, such as pond grow-out methodologies, have also been explored by the BCARC partners in North Carolina and Mississippi with some early success. Personnel exchanges have led to technology sharing with the University of Southern Mississippi and refined techniques for seed crab culture in the Gulf of Mexico.

In addition to the hatchery production, increasing the size and spatial scale of the field releases of juvenile crabs will be a crucial next step in the assessment. Chesapeake Bay watermen are and will continue to locate and monitor the released crabs, as part of the ongoing BCARC effort to implement and optimize release strategies.

DNA tagging data suggest that the wild blue crab population is highly diverse in terms of genetic composition. For more effective fisheries management policies, further studies are needed to address how the crabs maintain such a high level of genetic diversity with an apparent decreasing population.

D. Performance Benchmarks

The NOAA Chesapeake Bay Office is responsible for reporting the status and accomplishments of all its living resource programs biennially to Congress. In addition, NOAA, BCARC, and the state jurisdictions are responsible for sustainable management of the Bay's living resources. Although the states have management jurisdiction in Bay waters, NOAA and BCARC provide scientific information so that state managers can make informed decisions. Indicators have been developed by the Chesapeake Bay Program partners to assist management of the Bay-wide blue crab stock at sustainable levels. The current BCARC program and other on-going research support the Bay-wide management goal of doubling the size of the blue crab spawning stock.

A Bay-wide goal was adopted to reduce harvest pressure on blue crabs and to double the size of the blue crab spawning stock from the 1997-1999 average level. Harvest pressure, measured by an exploitation fraction, had risen not only near but well above the safe side of the overfishing threshold through the late 1990s. Initially adopted in 2001, Bay jurisdictions agreed to implement measures to reduce harvest pressure by 15% by 2003. By reducing harvest pressure, the stock would be expected to return to more sustainable levels of abundance. Management measures were adopted throughout the Bay by 2003. Data for 2005 showed that for the first time since the targets and thresholds were adopted, the exploitation rate was achieved. This represents real progress in controlling harvest pressure on crabs. While it appears that harvest pressure has fallen, the blue crab stock, or actual number of crabs, remains below the long-term average as measured by fishery-independent surveys—in particular the winter dredge survey, which samples ~1,500 stations throughout the Bay. NOAA will continue to work with the BCARC as well as state agencies to ensure that the monitoring and analysis work provides the data and information needed to sustainably manage the blue crab resource. BCARC will continue to track benchmarks discussed previously under "Progress to Date" and illustrated in Figures 5 and 6.

E. Financial Self-sufficiency

BCARC addresses the 85% decline in the blue crab spawning stock that, if not stopped, may lead to the irreversible collapse of the blue crab population in the Bay. The program provides policymakers with the facts and data to facilitate science-based management for the blue crab fishery, and develops strategies to replenish the blue crab spawning stock. As such, the program entails public investment in designing strategies that will preserve a critical ecological resource in the Chesapeake Bay and a major industry in the mid-Atlantic region. The continuing goal for the blue crab fishery is to develop a sustainable fishery that will protect the crab resource and provide the greatest and most stable social and economic returns to the public.

In light of the development of successful hatchery technology and techniques, BCARC plans to establish several large-scale blue crab hatcheries and up to 20 blue crab nurseries around the Chesapeake Bay. In partnership with state agencies such as Maryland Department of Natural Resources, this "scaling up" would increase production to several million juvenile crabs annually. It is envisioned that such large-scale production facilities will be operated by watermen trained by the BCARC program and supported by non-Federal resources, including state (both Maryland and Virginia), industry, and foundation funding. This will lead to a gradual reduction in the relative Federal investment in these components of the program, and will allow partners to develop both additional fishery products and additional solutions to restore coastal resources.

As indicated, in the short five years of Federal funding, the blue crab program has made major strides in demonstrating the feasibility of using hatchery-produced juvenile blue crabs to enhance its declining spawning stock in the Bay. However, BCARC research to date is based on localized upper and lower Bay studies. Additional research is necessary to evaluate the potential for much larger scale hatchery production of blue crab juveniles and further validation of the approach. Ultimately, BCARC will be able to assess whether blue crab stock enhancement is viable in the Chesapeake Bay and whether continued public funding is necessary to sustain or enhance the population.

At the same time, the patented technologies developed by BCARC have potential applications to commercial aquaculture for blue crabs and other species. While there is no detailed plan to generate private revenue from such technology at this time, growing interest could lead to the sale of such applications to investors. This could reduce the public burden for technology development and potentially lead to additional privately supported research.

See Appendix B for additional information on related efforts to address blue crab research and stock enhancement in the Chesapeake Bay.

APPENDIX A: Related Efforts for Native Oyster Restoration

Oyster Environmental Impact Statement **Expected Draft EIS: 2007**

An Environmental Impact Statement (EIS) is currently under preparation by the Army Corps of Engineers, the State of Maryland, and the Commonwealth of Virginia, to examine the risks and benefits of introducing a non-native, Asian oyster species to the Chesapeake Bay. The EIS is also evaluating eight identified alternatives, including native oyster restoration and aquaculture. Cooperating agencies on the EIS are the Environmental Protection Agency, Fish and Wildlife Service, and NOAA. NOAA is currently conducting a three-year research program to support the high priority scientific information needs of the EIS. Projects will continue through the end of 2007, and in a few cases into early 2008. The EIS Lead Agencies plan to release a Draft EIS in 2007. A public review period will follow release of the draft EIS, leading to a final EIS at a later date to be determined.

Oyster Evaluation Project **Expected Completion: Late 2007**

NOAA, the Campbell Foundation for the Environment, and the U.S. Fish and Wildlife Service are cosponsoring this project, which will provide a retrospective scientific analysis and synthesis of oyster restoration activities and "lessons learned" from 1990 to present in the Chesapeake Bay. After more than a decade of applied research and implementation aimed at oyster restoration in the Chesapeake Bay, it is crucial that a comprehensive review be conducted. The ORP and VIMS are also providing support for this project in their FY06 Cooperative Agreement awards for NOAA oyster funding. The project began in May 2006 and is expected to conclude in late 2007. This effort will provide a summary of restoration projects and results, placed in context with the specific management objectives that have driven the restoration effort. This synthesis will serve as a foundation for formulating more efficient and effective restoration practices for the future. The project will also dovetail with the oyster EIS currently under development.

Virginia Blue Ribbon Oyster Panel **Expected Completion: July 2007**

The Blue Ribbon Oyster Panel was convened in summer 2006 by the Secretary of Natural Resources and Commissioner of the Virginia Marine Resources Commission. This Panel builds on work done by the previous 1992-93 Blue Ribbon Panel. That original Panel responded to what was a new low in oyster harvests in Virginia by establishing a series of sanctuary reefs and a 'no net loss' policy for oyster harvests in state waters. The current Panel's mission is to develop a new statewide oyster management plan with overarching guidelines for the state's repletion program. Monthly meetings bring together representatives from industry, research, management, and restoration agencies. The Panel is expected to ask for a substantial increase in state funding for oyster restoration and management activities. A final report is expected in July 2007.

Virginia Oyster Heritage Program **Ongoing Annual Effort**

In December 2006, VMRC directed the Virginia Oyster Heritage Program (VOHP) to reconvene and develop a management strategy for oyster resources in the Rappahannock River. NOAA had previously (2002-2003) funded VOHP for several restoration projects in the Rappahannock River after oyster resources were significantly depleted by harvest and disease pressures in the late 1990s. NOAA funds were divided between projects in harvest and sanctuary areas. For the past several years, watermen have annually argued at each December VMRC hearing that these sanctuary areas should be open for harvest because they are on public bottom and many of the harvest areas have since been depleted. This annual debate is frustrating for all parties, and VMRC requested that the VOHP bring together members from industry, research, state and Federal management, and nonprofit organizations to develop a strategic plan for the Rappahannock tributary. This group is working toward identifying a series of rotational harvest areas in the Rappahannock, along with enlarging current sanctuary areas that would remain permanently closed and possibly a refuge for large, older oysters in this system. These tributary-specific plans will set benchmarks for restoration, harvest, and management for each system. Although the first priority for the group was to focus on the Rappahannock River, other Virginia river systems will be addressed subsequently. Each plan will be reviewed every three years to ensure it is meeting the established criteria.

Economic Analysis Project **Expected Completion: Early 2008**

This project is conducting an economic analysis of native and non-native alternatives to support the EIS. The project is funded through NOAA's Non-native Oyster Research Program via an award to Main Street Economics for the project entitled "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." The project will end in January 2008, and the final report will be delivered to NOAA within 90 days of completion. The project objectives are to determine harvest and production costs in the oyster fishery and to gather general cost information on publicly funded restoration and management efforts to obtain comparisons of net economic benefits of the various EIS alternatives including native oyster restoration and aquaculture. This project will provide crucial information to evaluate the potential for "financial self sufficiency" of oyster restoration and cultivation efforts.

Oyster Aquaculture Planning Project **Expected Completion: Late 2007**

NOAA's national Aquaculture Program seeks to enable the expansion of environmentally beneficial aquaculture production of marine species to reduce impacts on wild stocks, reduce seafood trade deficits, and provide a consistent supply of high-quality seafood as a healthy food option for the American public. NOAA has initiated a project to identify how Federal resources could be leveraged to increase oyster aquaculture production for both restoration and commercial production in the Chesapeake Bay region. As part of this planning process, NOAA collaborated with NOAA's National Sea Grant Program in FY06 to award a grant to the Maryland Sea Grant Program. Through this grant, Sea Grant extension agents from both Maryland and Virginia will lead a community effort to develop a plan identifying opportunities and evaluating prospects for Federal investment to promote financially self-sustaining oyster aquaculture production.

Benthic Mapping and Habitat Characterization **Ongoing**

In recent years, funding in Maryland has been directed to bottom mapping, habitat characterization, and hydrographic survey efforts that are being conducted in partnership between NOAA and ORP through shared staff and the use of NOAA's R/V *Bay Commitment* and R/V *In Situ*. The NOAA Chesapeake Bay Office's Habitat Characterization and Mapping Program is an extension of one of NOAA's traditional roles as provider of nautical charting surveys. The Habitat Characterization and Mapping Program works to identify the physical components of benthic habitat in targeted areas to support the improved site selection of oyster restoration activities. The research vessels R/V *Bay Commitment* and the R/V *In Situ* have been configured to acquire bathymetry, side scan sonar, and seafloor stratigraphy data to support these site assessments. Acoustic classifications are derived from this data and then verified with video, profiling cameras, divers, and sediment sampling. The combined acoustic and physical data are organized into a GIS mapping system.

APPENDIX B: Related Efforts for Blue Crab Research and Stock Enhancement

Blue Crab Advisory Report **Annually in May**

The NOAA Chesapeake Bay Stock Assessment Committee, which includes scientists and fishery managers from around the Bay, develops annual reports on the status of the blue crab resource. This annual report provides important technical information in a concise manner to regional fishery managers so that they may make informed decisions in regards to adopted targets and thresholds for the resource.

Blue Crab Stock Assessment **Completed: November 2005**

The first Bay-wide assessment for blue crab was undertaken in 1995 and completed in 1997. This assessment concluded that the stock was fully exploited at average levels of abundance. In 2001, biomass and exploitation thresholds and exploitation target reference points were adopted by regional management agencies, and a full Bay-wide assessment was initiated in 2003. This assessment was completed and internationally reviewed in 2005 and adopted by management agencies in 2006. The data and information provided through the BCARC in the blue crab assessment represented substantial advances in the knowledge of the resource that increase the chance of maintaining a sustainable blue crab fishery.

Monitoring Programs **Ongoing through 2007**

Numerous monitoring programs are conducted on an annual basis that provide required information for science and management of the blue crab resource. The VIMS Trawl Survey, Maryland Summer Trawl Survey, and Bay-wide winter dredge survey provide relative abundance estimates of juvenile and adult blue crabs. These monitoring programs are an integral component of the management process.