<u>Living Resources</u>

Protection and restoration of living resources is at the center of the *Chesapeake 2000* agreement. Achieving the challenging goals require that the scientific community identify critical gaps in our understanding of living resources clearly articulate the research needed to enable informed management choices. These choices will span a wide range- from protection and conservation of some species and habitats to biological and ecological "engineering" designed to restore other species including the habitat, and ecological function. Inherent within this goal is the recognition that research efforts should lead to better management and new strategies for monitoring progress over short and long-term time scales.

Oyster Restoration

<u>Priority needs</u>

1. Develop understanding of the ecology of oyster reefs and beds to facilitate restoration and appropriate valuation.
2. Conduct the research required to evaluate potential risks and benefits of introducing a non-native oyster to Chesapeake Bay.
3. Advance husbandry technologies and management strategies in support of commercial fishery.

<u>Background</u>

Returning a sustainable, ecologically, and economically viable oyster population to Chesapeake Bay has been a commitment of federal and state governments and has enlisted researchers across the Bay community and beyond. This effort has now reached an important juncture as plans for large-scale restoration strategies are being developed. Recently, the proposed use of non-native oysters, especially *Crassostrea ariakensis*, has been advanced as a potential means to restore economic value as well as ecological function. That proposal has added further complication to an already daunting suite of issues and critical needs for research. As the Bay community contemplates major efforts in ecological engineering using either native or non-native oysters, there are a number of research priorities to be addressed.

The most critical, overarching research need that would be responsive to *C2K* requirements is the development of methodologies to successfully restore native oyster populations to Chesapeake Bay across a range of salinity regimes. Although large sums of money have been expended on placing shell and spat in Chesapeake Bay and its tributaries, only a small fraction of those funds have been devoted to systematic research designed to test and improve methods for oyster restoration. An experimental approach for testing restoration methods is critical because it will provide the greatest chance of success in future restoration efforts, while also providing scientifically defensible information on whether success is possible. Measures of success will depend on the goal of restoration efforts, which include provision of habitat, improving water quality, and sustaining a fishery. Both STAC and the National Sea Grant Program convened workshops within the past year that helped identify research questions relevant to native and non-native oyster management decisions. Another significant policy step is the agreement between Maryland, Virginia and the Federal government to conduct an Environmental Impact Study (EIS) on the proposed *C. ariakensis* introduction. The EIS was initiated in late 2003 and will apply new research findings in a decision- making framework. It is probable that the EIS will identify additional research needs as well. As a result of these activities, significant levels of new funding are becoming available for oyster research, although much of that funding is targeted to the evaluation of *C. ariakensis* and a limited number of other topics.

<u>Recommendations</u>

1) Reef Construction and Engineering: It is critical to develop a better understanding of how to site and construct oyster reefs to maximize recruitment, growth, and survival of oysters and associated communities. This requires an experimental approach to test restoration methodology, clearly defined measures of success appropriate for goals of particular restoration projects, and sufficient monitoring to determine relative success of restoration and control sites. Improved restoration methodology will require examining the relationship between engineering issues (reef design, construction, seeding methods, and type of seed to use) and oyster population dynamics, disease prevalence and intensity, and reef function.

Development and testing disease-tolerant strains is critical, as is field-testing and modeling of the potential for outplanting of disease-tolerant strains to improve disease resistance in wild populations. The U.S. Army Corps of Engineers plans to conduct large-scale restoration projects in Virginia involving both reef construction and stock enhancement using selectively bred strains of the native oyster. Such initiatives (e.g., proposed for the Great Wicomico River, Virginia) represent important opportunities to conduct tributary-scale experiments to assess gene flow and rates of transfer of disease resistance to wild populations of oysters. A strong research and monitoring component should be supported and incorporated into these large-scale restoration activities.

Restoration research should also consider the potential contribution of non-engineering approaches to oyster restoration through the management of natural populations, including no-take zones for remnant oyster beds, which can serve as sources of seed. It is important to improve understanding of how to restore the ecological, as well as fishery value of oyster reefs, including knowledge of how spatial patterns of beds promote restoration or enhance interactions among restored oyster beds. Routine monitoring of restored beds is needed and expanded use of remote sensing technologies for monitoring shellfish habitat and ambient water quality near restoration sites is recommended. Mapping bottom conditions to distinguish sites with acceptable characteristics and sediment accumulation rates for restoration can contribute to the success of oyster restoration.

2) **Potential Risks and Benefits of Introducing *Crassostrea ariakensis* to Chesapeake Bay**. Both the 2004 STAC workshop report, and the 2003 NRC report describe research required to evaluate potential risks and benefits of introducing a non-native oyster to

Chesapeake Bay. An introduction of diploid animals to the Bay, either intentionally or as a result of reversion of triploids, will likely be irreversible. Furthermore, successful establishment of *C. ariakensis* within Chesapeake Bay will almost inevitably result in its spread to other Atlantic Coast estuaries. Research is required to evaluate the consequences of taking such a step. Weighing the benefits against the risks requires research and modeling on the potential for *C. ariakensis* to become established throughout a range of Bay habitats, as well as the risks it poses to other Bay organisms through direct and indirect interactions (including disease). Because the species most at risk from an introduction of *C. ariakensis* is likely to be the native oyster, *C. virginica*, the potential for native oyster restoration is an important factor in evaluating risk of a non-native oyster introduction.

3) **Oyster Husbandry and Management:** Hatcheries have the potential to play a significant role in oyster restoration, sustainable fisheries, and aquaculture, whether native or non-native oyster species are used. Improved technology for production as well as development of disease-tolerant strains is needed. Biotechnological explorations, including molecular manipulations at the gene level, for disease resistant strains is a high priority. Research is also needed to understand the linkages between restoration and the management of natural populations (fisheries management and recruitment, stock-specific genetics and disease resistance, mortality, and dispersal). Further, there is a need to develop understanding of cumulative effects of multiple anthropogenic and natural stressors on strategies to increase oyster populations in Chesapeake Bay. Of particular concern are improved understanding of harvests-disease interactions, and sustainable harvest levels. Finally, it is important to couple production of manipulated populations of native oysters with protected areas for grow out and seed source for disease-resistant strains; this might include exploring rack aquaculture and relocation to reduce exposures to salinity-dependent parasites.

4) **Ecological Value of Reef Ecosystems and Oyster Restoration:** Restoration of biogeochemical cycling, physical circulation, water clarity and associated species (planktonic, benthos, fish, SAV, etc.) in oyster reefs is critical. A better understanding of nutrient cycling on oyster reefs, as well as trophic and non-trophic species interactions, is needed to estimate ecosystem benefits of a restored oyster population. Such information should be used in statistical modeling, food web simulations, and the development and application of biophysical models, and will depend on continuing evaluation of reef impacts throughout the coming decade.

Additionally, there is an important need for better understanding of the socioeconomic impacts of large-scale oyster reef restoration efforts and oyster decline. Included are issues pertaining to balancing needs of conservation, traditional fisheries, aquaculture (including the potential of aquaculture to reduce harvest pressure), and the implications of multiple uses of habitat.

Exotic Species

Priority needs

1. Develop a fundamental understanding of the relationship between organism supply and invasion success.
2. Improve tracking of sources, establishment, and spread of exotic species.

Background

Chesapeake 2000 identifies Exotic Species as a priority area of concern, establishing a CBP Task Force in 2000 to rapidly advance knowledge and directed activities on the introduction and establishment of non-native species in the ecosystem. Invasions can (and presently do) undermine efforts to restore fisheries, preserve and restore critical habitats, and attain effective ecosystem management. The relationship between supply and establishment of invasives is poorly resolved, and there is an uneven picture of the extent and temporal pattern of invasions. Such gaps in information and understanding make it difficult to develop effective management and policy in this area.

Recommendations

1) **Sources, Supply, and Prevention of Invasive Organisms:** We need to develop a fundamental understanding of the relationship between organism supply and invasion success. A combination of laboratory experiments and field-based research can provide important insight and guide management decisions. CBP should support research, including agency partnering, on ballast tank cleansing processes to reduce introductions of ship ballast biota. Microscopic invaders (viruses, bacteria, plankton, and specific disease causing taxa) likely pose the greatest threat and hence their elimination should be a priority. For example, the recent and unexpected identification of an oyster parasite from the genus *Bonamia* in North Carolina waters underscores the significance of this issue, particularly in light of proposals to introduce into Chesapeake Bay a non-native oyster susceptible to this parasite. By the same token, the introduction of non-native oysters may also be a vector for the introduction of herpes-like viruses which could affect other related species. An assessment of this risk should be undertaken.

2) **Monitoring and Tracking Invasions:** A tracking system must be developed to detect new invasions and probable sources. Screening should be included in the current monitoring programs of the CBP, providing long-term records of organism sources and subsequent establishment.

3) **Bay Health and Invasion Susceptibility:** It is important to evaluate effects of environmental conditions on establishment and consequences of exotic species introductions to Chesapeake Bay. Environmental conditions influence colonization and spread of exotic species; in some cases, factors such as habitat degradation and overfishing can increase susceptibility of ecosystems to invasions. These interacting factors must be included in research programs addressing invasive species.

4) **Ecological and Economic Impact of Invasions:** Continued evaluation of introduced species' impacts on critical habitats and resources, as well as food web and ecosystem impacts should be a high priority. Proactive modeling of potential impacts by invasive

species can prepare resource managers to understand possible ecological or economic effects and for remedial actions before these species have a disruptive effect on the Bay.

Fisheries and Fish Management

Priority needs

1. Develop effective monitoring of distribution and abundance of fish resources, and distribution and quantity of harvest activities.
2. Advance knowledge of predator-prey relationships and species-habitat relationships to facilitate multi-species and ecosystem-based fisheries management.

Background

Ecosystem-based fisheries management incorporates knowledge of the interactions among exploited and non-exploited species, their habitats and stressors, to develop management plans. Success of this approach requires more than knowledge of individual species life histories and population dynamics. It remains critically important to conduct focused research on individual species such as the migratory fishes, now greatly reduced from historical levels in Chesapeake Bay and on iconic species such as the native oyster and blue crab to insure significant progress towards *Chesapeake 2000* goals. Several research, monitoring, and modeling approaches are recommended. The recently completed Fisheries Ecosystem Plan for Chesapeake Bay (*http://noaa.chesapeakebay.net/Fish’FEP_DRAFT.pdf*) will serve as a source document to identify needed research to support implementation of ecosystem-based fisheries management in the Bay.

Recommendations

1) **Monitoring and Assessing Fish Stocks:** Managing fisheries requires basic knowledge on stock size and trends in abundance. Spatial distributions of living resources and statistics on harvesting activities are needed for effective modeling, economic valuation, and management. Field experiments are required and analytical methods must be developed to estimate abundances of adult anadromous fishes upon their return to Chesapeake Bay to spawn. Conducting such research will assist in development of much-needed restoration targets for adult shads and river herrings. Further, monitoring will provide information on tributary-specific information on carrying capacity for young-of-the-year pre-recruits needed to judge restoration success. Monitoring and assessment of forage fish populations, especially Atlantic menhaden and bay anchovy, are important to provide information on these species needed in multispecies modeling. There is a need for assessment of declining American eel populations and evaluation of causes. Monitoring of fishes, especially striped bass, for disease and evaluation of its effects on stock productivity is an important need. Baywide surveys of fishes that were initiated recently (e.g. CHESFIMS and CHESMAP) are the monitoring tools that need support to provide assessment information for management.

2) **Multispecies and Trophic Analyses:** To meet mandates of *C2K*, we must increase knowledge of species interactions in food webs, especially predator-prey relationships.

Such relationships are the 'trophic underpinnings' that sustain production of fisheries resources and include lower trophic levels (e.g., plankton and benthos), which are major prey of fishes. Predator-prey models of key interactions, e.g., striped bass/menhaden and blue crab/fish, should be developed.

3) **Fish-Habitat Relationships:** Research is needed to increase understanding of habitat (SAV, wetlands, shallow bottom, deep, cool oxygenated waters, hypoxia, oceanic impacts on migratory taxa) in relation to spatial distributions of fish species; this includes estimating effects of habitat restoration on food web interactions and habitat use. The interaction between habitat pattern and extent on food web functioning and predator-prey relationships needs to be studied, analyzed, and modeled. It is important to achieve a better understanding of how spatial heterogeneity of habitat and harvesting activities can be applied to improve management through Marine Protected Areas and other forms of spatially-explicit management. Experiments to evaluate performance and effectiveness of spatial management techniques and to define essential fish habitat must be conducted to design effective and efficient ecosystem-based fisheries management. Information onthe role of location and habitat with respect to fishing and behavior of fishers is needed to develop social and economic databases and models that define harvesting behavior.

4) Stock Enhancements: Restoration and management approaches increasingly involve stock enhancement of native fishery species (e.g., oysters, shad, sturgeon, and most recently blue crab) as well as plants (SAV and emergent wetland plants). In addition to uncertainties of success in such ventures related to trophic, habitat, and environmental factors, there are important genetic considerations when hatchery produced animals or cultivars are used for fishery enhancement or population and habitat restoration. Research is required to quantify and minimize genetic risks such as inbreeding and bottlenecking of populations, while developing protocols that maximize the chances of management success.

5) **Fisheries Models for Prediction and Assessment:** The development of new, and improvements of existing, multispecies and ecosystem-based fisheries stock-assessment models are required. Support is required to develop and employ a suite of multispecies, living resource models to evaluate impacts of manipulating water quality, prey, and fishing pressure on living resources. Analyzing and modeling effects of climate variability or change and sea level rise on anadromous fish population dynamics and recovery potentials also are critical to understand and manage recoveries in these taxa. Blue crab deserves particular attention. Blue crab assessment models and targets ultimately should be developed in the context of multispecies management in Chesapeake Bay. The same is true for forage fishes, such as Atlantic menhaden, that is both fished and serves as a major prey of piscivorous fishes. Development of food-web models for Chesapeake Bay should be initiated leading to more realistic trophic network models and dynamic food-web simulation models (e.g., the ECOPATH and ECOSIM modeling now underway, as well as other modeling approaches). Additionally, incorporation of environmental and multiple stressor effects, e.g., water quality, disease, and harvesting, into multispecies and ecosystem-based stock-assessment models is needed. For effective

'buy-in' by resource harvesters, developing models that lead to better understanding of the socioeconomics of multispecies fisheries is critical.