Estuarine Processes Portfolio
SCIENCE TO SUPPORT ECOSYSTEM RESTORATION

The 2010 deadline to remove the Bay and the tidal portions of its tributaries from the list of impaired waters under the Clean Water Act, set by the federal courts and addressed in the *Chesapeake 2000* agreement, is rapidly approaching. As the pressure to clean up the Bay mounts, a sound scientific foundation for restoration becomes increasingly essential. Maryland Sea Grant plays a leadership role by funding cutting-edge science to support the sustainable use, conservation and restoration of the Chesapeake Bay.

Since the 1990s, researchers have identified specific ecosystem components that are diagnostic of the Bay's water quality and habitat conditions. Of particular concern are excessive inputs of nitrogen and phosphorus from sewage plant discharges, agricultural runoff and atmospheric deposition. The demise of underwater grass beds in the last several decades has also been linked to an overabundance of nutrients and decreased light available for photosynthesis.

Understanding these ecosystem processes in Maryland's coastal waters requires research that is integrative in its scope. Over the last five years, Maryland Sea Grant has invested over $1.3 million of core funding in 11 different studies to elucidate estuarine processes, and is committed to fund an additional $0.58 million for 4 studies during 2005 to 2007. Since its inception, Maryland Sea Grant has supported research in oxygen dynamics, eutrophication and underwater grass ecology. In the last five years, our research program has strengthened its emphasis on ecosystem function, food web interactions, water column dynamics, nutrient cycling and benthic systems, recognizing the role that research plays to fill information gaps that hamper restoration efforts. By honing our focus in this manner, we capitalize on our unique role in the Bay community. Our efforts have catalyzed a new generation of research, expanding our understanding of nutrient cycling and informing forecasting and modeling efforts aimed at the big picture of ecosystem function. An added emphasis on coastal technologies has helped spark innovative ways of synthesizing the new wealth of data from the Chesapeake watershed.

Understanding Ecological Complexity

Biogeochemistry: Nutrients. Beginning in 2000, Maryland Sea Grant supported researchers to investigate complex interactions among nutrient cycles (especially nitrogen and phosphorus) in the water column and the biota of the Bay ecosystem. Excess nutrients, especially nitrogen, lie at the heart of the watershed's ecological troubles, causing algal blooms that can reduce light penetration and lead to oxygen depletion. Understanding how nitrogen is transformed from its fixed form (available for algal growth) to nitrogen gas is crucial, because this process (denitrification) actually removes nitrogen from the estuary. Researchers Jeffrey Cornwell and Todd Kana at the UMCES Horn Point Laboratory (R/P-49 and earlier R/P-45) developed a rapid method for directly measuring nitrogen gas production. They found that the rate of nitrogen removal by denitrification used in Chesapeake Bay water quality models had been significantly underestimated.

The team, along with Chris Chick (a Maryland Sea Grant Research Fellow and alumnus of the Research Experience for Undergraduates program), will build upon this work in a current Sea Grant-funded study to investigate the role that microalgae in the sediment play in nutrient cycling and primary production. This research fills a critical gap in the understanding of shallow water processes in the Bay and should provide data necessary for enhancing predictive modeling of shallow water processes.

Biogeochemistry
IMPACTS: INFORMING SCIENCE AND ECOSYSTEM MANAGEMENT

Maryland Sea Grant and the researchers it supports have:

- Refined denitrification rate estimates for the Chesapeake Bay, a critical component of the Bay water quality model.
- Integrated their nutrient data with U.S. EPA marsh and watershed data to develop nutrient balances for the agriculturally dominated Choptank River.
- Worked with citizen groups from Talbot County, Maryland to tabulate data on Choptank water quality.
- Expanded their research into a larger National Science Foundation-funded Biocomplexity study.
- Undertaken a Sea Grant-funded research project on the role of oysters in nitrogen cycling.

Primary Production: Underwater Grasses. Nutrients like nitrogen and phosphorus are essential for the growth of submerged aquatic vegetation (SAV), which provide key habitat for much of the Bay's food web. But excess nutrients increase algal primary production, which often results in decreased light for underwater grass growth. Ecologists Michael Kemp and Laura Murray (R/P – 48), from the UMCES Horn Point Laboratory, speculated that the spatial distribution of these plants may affect their susceptibility to eutrophication stresses and nutrient cycling within underwater grass beds. Teaming up with Jeff Cornwell, their study integrated underwater grass ecology with sediment nutrient fluxes to explore how nutrient cycling patterns alter bed species composition and density in the beds.

They found that the middle of dense grass beds accumulates the fewest epiphytes (small plants that grow on the blades of underwater grasses and block light penetration) and ammonium concentrations decrease respectively as one moves inward from the outside, to the edge, then to the middle of dense beds. Building on these studies Maryland Sea Grant Research Fellow Rick Bartleson developed a model to show that variation in the abundance, cover and bed sizes influences how underwater grasses respond to external nutrient enrichment. In a separate study, Kemp and Murray also discovered that one common underwater grass species, *Ruppia maritima* (widgeon grass), enhances the survival of other grass species when they are transplanted into an existing *Ruppia* bed. These findings relate directly to the success of underwater grass restoration projects.

New Sea Grant Guide to UNDERWATER GRASSES

Submerged aquatic vegetation (or SAV) plays a key role in the ecology of coastal waters, and especially in the Chesapeake Bay. To help citizen volunteers, students, and others interested in learning more about these plants, Maryland Sea Grant has produced a new guide to underwater grasses in collaboration with the NOAA Chesapeake Bay Office, the Alliance for the Chesapeake Bay, and the Maryland Department of Natural Resources.

The 70-page guide, *Underwater Grasses in Chesapeake Bay & Mid-Atlantic Coastal Waters*, features color photographs of 16 SAV species, along with line drawings and helpful descriptions. The guide also includes ways to distinguish between similar plants, as well as additional information about floating aquatic vegetation and algae, including algal blooms that can impact underwater grasses. Especially useful is an identification key that leads the user through details of leaves, stems, and other characteristics toward the proper naming of the plant in hand.

Building on their nutrient cycling studies in underwater grass beds, Kemp, Murray and Cornwell, along with Maryland Sea Grant Research Fellow Jessica Davis, are currently studying how sediment quality and associated biogeochemical processes change with bed development. In its final year, this project found that different species of underwater grass have different rates of respiration, nitrification and denitrification, which suggest that species may differ in their ability to conserve, reuse and remove nitrogen from the Bay. These data also support Kemp and Murray's earlier studies that show significantly better plant survival when new plant shoots are planted into existing beds. This research deepens our understanding of the role played by underwater grasses to influence the nutrient cycling of the surrounding sediments and overlying water.

Underwater Grasses
IMPACTS: INFORMING SCIENCE AND ECOSYSTEM MANAGEMENT

Sea Grant and the researchers it supports have:

- Established protocols for effective restoration of multi-species underwater grass beds in Chesapeake Bay and other coastal ecosystems.
- Supported development of water clarity criteria and caps on nutrient and sediment loads to estuaries as part of Water Pollution Act of 1972.
- Provided data used as a basis for including submerged plants as part of the Chesapeake Bay water quality model used to assess alternative nutrient management scenarios.
- Collaborated with Chesapeake Bay Program Submerged Aquatic Vegetation (SAV) workgroup to incorporate research findings into an integrated Restoration Plan.
- Partnered with U.S. Army Corps of Engineers Waterways Experiment Station to support SAV restoration in the middle Bay.

Trophic Interactions: Linking Physics, Chemistry and Biology. An ecosystem-wide approach to estuarine processes means understanding interactions among organisms with each other and with the geochemical and physical factors in their environment. A better grasp of the complex dynamics associated with oyster reefs, for example, is necessary to structure efforts to restore the Chesapeake Bay's failing oyster fishery. Oysters also exert "top-down" control as they filter suspended particles from the water column and eject the undigested remains out "repackaged" as feces or pseudofeces that sink to the sediment surface. This helps to reduce turbidity so more light reaches the sediment surface. Recent research by Roger Newell (UMCES), along with Maryland Sea Grant Research Fellow Rebecca Holyoke, demonstrated that oysters also exert "bottom-up" control on phytoplankton by altering how nitrogen and phosphorus cycle within the sediments (R/P – 51). The "repackaged" nutrients deposited by oysters on the sediment are in a form available for burial, denitrification or benthic microalgae community growth, but less available for phytoplankton growth.

Detailing connections between benthic community composition and biogeochemical function is also essential to understanding the Bay as a complex ecosystem. Historically, studies of Chesapeake Bay biogeochemistry and the community of organisms living in the sediment (benthic infauna) have remained largely separate. Ecologist Roberta Marinelli at the UMCES Chesapeake Biological Laboratory and Maryland Sea Grant Research Fellow George Waldbusser recognize the importance of making a link between them. They are analyzing historical datasets to determine whether they provide sufficient information on both faunal abundances and biogeochemistry to link benthic community structure and function to sediment processes in a meaningful way (R/P- 55). Overall, they have found that the relationship between faunal data and sediment biogeochemistry for the Bay is poorly understood, revealing an important gap in our under-standing of benthic processes in the Chesapeake Bay.

External physical factors such as waves, wind and currents can alter the shape and health of underwater grass beds and oyster reefs. Oyster reefs, in turn, affect the growth of grass beds and alter their physical environment — forming breakwaters that change water clarity and flow patterns in the estuary. Recognizing the importance of such "coupling," researchers Raleigh Hood, Eva Marie Koch, Elizabeth North, Roger Newell and Larry Sanford, along with Maryland Sea Grant Research Fellow Shih-Nan Chen, are examining the physical-biological link between oyster reefs and underwater grass habitats (R/P – 57). They used man-made submerged and emergent breakwaters as surrogates for oyster reefs to assess whether these organisms modify their physical environment for mutual benefit. The research involves both a strong field component and comprehensive modeling effort. Results suggest that underwater grass habitat fares better with submerged breakwaters than with emerging structures.

Physical Fundamentals: Tools for Connecting the Dots

The complex physical properties of estuaries are fundamental to all processes, from nutrient cycling to the growth of underwater grasses to the complex interactions between oysters, crabs, and benthic invertebrates.

The optical properties of water, for example, are an essential driver of the Bay's primary productivity. Phytoplankton ecologist Charles Gallegos from the Smithsonian Environmental Research Center suspected that patterns of light absorption and scatter would vary systematically along the estuarine (salinity) gradient due to differences in phytoplankton, dissolved organics, and particulate matter (R/P-53). In cooperation with the Maryland Department of Natural Resources and the Environmental Protection Agency's Chesapeake Bay Program, both of whom collected additional samples at no charge, Gallegos developed optical water quality models that are specific to particular sites in the Bay. He showed that it is critical to use site-specific coefficients in optical models for management applications, such as determining habitat requirements for underwater grasses and setting water quality targets.

Wind, waves, tides and currents dynamically erode the Bay's bottom sediments, kicking up particles to the water column that limit its clarity. But a direct measurement of the "erodibility" of bottom sediment has proven difficult, limiting our ability to understand the effects of different wind or wave regimes. To address this knowledge gap, physical oceanographers Larry Sanford from the UMCES Horn Point Laboratory and Jerome Maa at the Virginia Institute of Marine Sciences developed methods to measure sediment shear stress (the force required to move sediment off the bottom of the Bay), eroded mass (the quantity of sediment stirred up), and erosion rates (R/P-52). Despite high spatial and temporal variability in their sites, they found that sediments close to the surface erode most readily, with the ability to resist erosion increasing rapidly with depth. Their results provide critical insight into what physical conditions might promote sediment resuspension and increased water column turbidity. Their data (critical shear stress and wave) have been used by other investigators and agencies, such as the Army Corp of Engineers, for Chesapeake Bay sediment modeling efforts.

Physical-Biological Coupling
IMPACTS: INFORMING SCIENCE AND ECOSYSTEM MANAGEMENT

Sea Grant and the researchers it supports have:

- Produced a model that will be available through the internet to managers, engineers and scientists that links physical water circulation (SHORECIRC) and wave (REFDIF) models to a biological model called SWOLS (Seagrass-Waves-Oyster-Seston-Light).
- Provided valuable information to local, state, and federal government concerning the construction of nearshore breakwaters.
- Suggested directions for improving the sediment monitoring activity of Chesapeake Bay Program based on observed information gaps.

Moving Forward: Catalyzing an Interdisciplinary Approach

An ecosystem-wide approach to a complex system like Chesapeake Bay calls out for interdisciplinary efforts, bringing scientists with expertise in such disciplines as physics, chemistry, oceanography, biology and mathematical modeling to the same table. Since 2000, Maryland Sea Grant's research program has moved squarely in this direction, funding interdisciplinary approaches to questions about how underwater grass beds function and relate to oyster reefs. This year two new studies on estuarine processes will take an interdisciplinary approach to inform restoration concerns. A study led by physical oceanographer Larry Sanford on the effect of waves, winds and tides on sediment erosion, resuspension and the resulting turbidity on the success of adjacent underwater grass beds combines extensive field work and modeling. This work is in partnership with the Maryland Geological Survey and in cooperation with Maryland Department of Natural Resources and the U.S. Geological Survey for use of their monitoring systems. In the interest of building a restoration-focused regional effort in the Mid-Atlantic and encouraging partnerships with other Sea Grant programs, Elizabeth North is leading a new multi-investigator, multi-institution study coupling physics and biology to understand transport processes of blue crab larvae in coastal waters.

As the Chesapeake watershed approaches the 2010 management deadline for improved water quality and healthy living resources, Maryland Sea Grant has proactively marshaled its resources to fund science that helps to explain this ecosystem in its complexity. An interconnected picture of how this estuary works is providing a critical scientific foundation as policy makers and managers work to develop an adaptive framework for restoration. Maryland Sea Grant will continue to have a unique role to play in building this foundation in the coming years.