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Woods Hole Sea Grant: 2006-2008 Projects

Seasonal Changes in Groundwater Flow Into the Coastal Ocean

Fresh water from water tables under the land flows out into the coastal ocean from beneath the seabed, a flow known as submarine groundwater discharge (SGD). Researchers have found that such flow can have a very large impact on estuaries. Groundwater carries land-generated nitrogen compounds, plus contaminants and trace elements into coastal ocean waters, where they can be a serious problem. SGD can supply high concentrations of fertilizing nutrients that drastically alter coastal ocean ecosystems as the excess nitrogen promotes excessive algal growth that can choke out shellfish, create anoxic zones, and stimulate harmful algal blooms. SGD comes not only from fresh water flow, but also from seawater that circulates through the seabed, becomes nutrient-loaded, and returns to the ocean. Saline SGD may carry even more nitrogen than fresh water SGD, but scientists don't yet understand the process and forces behind saline SGD. Scientists measuring saline SGD have found contradictory results, and models that take into account all the coastal processes that can influence saline submarine groundwater discharge (SGD) – such as tides and seasonal recharge cycles, do not yet exist. In a two-year study, Ann Mulligan of the WHOI Marine Policy Center and Charles Harvey of MIT are testing an idea that will clarify the amount, timing, and effect of saline SGD in Waquoit Bay, Massachusetts, an estuary where both freshwater and saline discharges have been measured. They suggest that the major exchange of salt water between sea bottom sediment and seawater is seasonal, driven by the seasonally-varying changes in groundwater recharge and water table levels that are in turn driven by precipitation over land. Mulligan and Harvey will set up innovative wireless monitoring stations that to make near-continuous measurements for a year, using sensors that gather real-time data on the hydraulic pressure difference between the surface seawater and the subsurface aquifer, and on the flow and direction of saline groundwater seepage using piezometers. They will determine the amount of nutrients saline discharge contributes to the coastal waters, by measuring nitrogen compounds in saline water flowing into and out of the bay floor. As well, they are modeling saline SGD as driven by seasonal changes in the water table, using data provided by the US Geological Survey on the depth of the saltwater-freshwater interface, and taking into account precipitation and temperature across the year. With this study, they hope to document the role of seasonal groundwater recharge in forcing the flow of saline SGD and contributing to nitrogen loading in Waquoit Bay, providing information about the seasonal nitrogen influx to coastal managers.

Tracing the Paths of Water Flow through the Marsh Sediments

This work will use radon and stable isotopes of radium and nitrogen as tracers to understand some of the processes that occur in salt marshes and estuaries. Water flows into the coastal saltmarshes either from runoff, or as underground water flow (submarine groundwater discharge, or SGD), which can also involve saltwater circulation and re-emergence through bottom sediment. Either source can carry large amounts of nitrogen compounds and trace elements to the marsh with it, increasing nutrients in the water and contributing to eutrophication in estuaries. But the volumes and nitrogen inputs from GSDs are have been difficult to estimate with current methods. Building on previous work using radium isotopes to track Matthew Charette, of the Marine Chemistry and Geochemistry Department at WHOI, is using naturally occurring isotopes to estimate SGD fluxes and distinguish the sources of nitrogen inflow into two Massachusetts salt marsh estuaries that differ from each other in the major sources of freshwater inputs: Plum Island estuary, a highly developed area where surface runoff from rainfall is the main input, and the less-developed Pamet River estuary where groundwater is the primary input of fresh water. Radium isotopes can help identify where the SGD originated, Radon can be used to trace freshwater GSD as well as saltwater or brackish GSD, and stable isotopes of nitrogen in several nitrogen compounds can identify the nitrogen as being from natural sources or anthropogenic sources. Charette will sample total SGD (both freshwater and recycled seawater discharge) and nitrogen fluxes in both marshes in wet and dry seasons, collecting water samples from each marsh every hour for a complete tidal cycle, and analyze them for radium, radon, and nitrogen isotopes. The expectation is that seawater circulation through the salt marsh sediments will dominate at Plum Island, while freshwater SGD will be more important at Pamet. The work aims to demonstrate that radium isotopes and radon can be used to quantify multiple groundwater sources to the marsh, that such isotopic traders plus nitrogen isotopes can be used to evaluate the importance of differing nutrient inputs to the systems, and how GSD and runoff sources and their associated nutrient inputs change with the seasons.

Investigating How Disturbing Seafloor Sediments Affects the Exchange of Heavy Metals Between Sediments and Seawater

Sewage discharge from Boston, emptied into Boston Harbor for most of Boston's history, has been diverted to a remote discharge site in Massachusetts Bay since late 2000. The long history of discharge led to elevated levels of heavy metals (silver, copper, lead, and also iron and manganese) in Boston Harbor sediments, where they have been a source of concern. William Martin of WHOI's Marine Chemistry and Geochemistry Department, and Michael Bothner of USGS, continue their study of the harbor's sediments. They are seeking to understand both the fate of human-introduced metals already in the sediments, and the likely effect of new sewage input at the remote Mass. Bay site. Previous work showed that heavy metals in sediment may be released to the seawater, and this project focuses on resuspension of bottom sediments as a factor in that exchange, and will quantify how sediment resuspension on the seafloor at both sites affects the exchange of heavy metals between the sediments and the seawater. Taking sediment samples from both sites, they will subject them to erosion in a specially designed changer, then analyze changes in overlying water. Comparing results of this study with previously determined measurements of solute fluxes across the seawater-sediment boundary, Martin and Bothner intend to put together a complete view of the cycling of heavy metals in sediments of the bay and harbor. A goal of the work is "to create a database and theoretical framework needed to project the effects of anthropogenic metal inputs into Massachusetts Bay," as the sewage outfall continues to be introduced to the area.

Excess Nitrogen Entering a Coastal System from Vehicle Exhaust

Nitrogen pollution of coastal waters is a large environmental problem, not least because the sources of nitrogen are varied and diffuse. Fertilizers used on fields or home lawns, wastewater treatment or septic tank discharge, effluent from livestock operations, all contribute to the excess. Nitrogen compounds carried to the coast by streams, runoff, or groundwater cause eutrophication, "dead zones", and degradation of coastal habitats. Atmospheric nitrogen deposition onto land, so-called 'dry deposition,' is another large source of nitrogen input to the coast, one that is difficult to measure. In a continuation of Sea Grant-funded work, researchers Robert Howarth and Roxanne Marino (both of Cornell University) and Eric Davidson (Woods Hole Research Center) think that the deposition of nitrogen from vehicle exhaust in urban or seasonally populous areas has been underestimated in past studies. Previous work by these researchers showed high rates of nitrogen deposition near heavily-traveled roadways. This project continues their study of this problem. Howarth, Marino, and Davidson will quantify nitrogen deposition along Cape Cod roadways using three measurements: bulk nitrogen deposition (the nitrogen found in sample buckets, comprising the N in rainfall plus the N from aerial deposition into the buckets during the collection time); "throughfall" (material falling through the tree canopy, which includes the N in rainfall plus nitrogen compounds deposited on the leaves from dry sources and washed off in the rain); and estimates of the dry deposition based on calculations of N gas concentration in the air. Another objective is to measure nitrate in the soil water along gradients away from roads, and relate vehicle volume to estimated amounts of nitrogen that flows downstream into coastal lagoons in the area. Focusing on two of their previous study sites: the watershed leading from a heavily-used highway to a large estuary (Rte 28 to Waquoit Bay), and the watershed from a seasonally high-use roadway to a shallow coastal pond (Woods Hole Rd. to Oyster Pond); as well as other sites in areas where there is a field-to-forest transition without a roadway nearby, to verify the results due to vehicle traffic. The investigators state that this research will help demonstrate how nitrogen deposition from vehicle traffic contributes to nitrogen loads in coastal ecosystems, help alert coastal communities to the problem, and the results may contribute to policy development in areas of vehicle emissions regulation in coastal states.

Enlisting the Help of Frequently-passing Ships to Investigate Plankton Populations

Nantucket Sound, which lies between Cape Cod and the islands of Nantucket and Martha's Vineyard, and Waquoit Bay, a coastal estuarine embayment that connects to the Sound, have different temperature regimes, and the Sound is cooler than the Bay, but both are growing measurably warmer. Biologist Scott Gallager, physical oceanographers Richard Limeburner and Robert Beardsley, and computer scientist Andrew Maffei, all of WHOI, are conducting a long-term study of the plankton in these coastal waters, comprising several separate studies, to determine how the planktonic plants and animals (including larval fish) respond to changing climate regimes, and possibly allow predictions of what may happen to fish stocks in Nantucket Sound, an area of multiple uses including recreational and commercial fishing. Their objectives are to build and install new remote monitoring instruments on ferries that cross Nantucket Sound and on moorings in Waquoit Bay. The instruments will take measurements of physical water conditions and chemical properties, as well as plankton diversity and abundance (via image-recognition instrumentation); and use telemetry to transit data to shore. The researchers will integrate the real-time data into an existing model of the two bodies of water, to answer questions about the kinds and seasonal changes of plankton and the physical conditions that govern them. In particular, with this study the researchers want to know whether temperature differences between the two water bodies are reflected in different plankton communities.. Further, they want to assess whether warmer water in the Bay produces a connected sequence of blooms, in which early spring warmth promotes growth of predatory jellyfish plankton, thereby reducing other animal plankton that would normally eat the phytoplankton (plants), eventually leading to too much plant growth and, ultimately, summertime anoxic conditions in Waquoit Bay. If this is so, they reason, future continued warming in Nantucket Sound may produce the same conditions, which could lead to anoxia in this more-open water. Seasonal changes in plankton diversity, said Gallager, are a reflection of nutrient input, light, and temperature, coupled with biological processes including predator–prey interactions, growth, and reproduction. This project will supply baseline information about the coastal region that will fill a lack of data on real-time physical and biological properties and dynamics in this heavily-used coastal area.

How Does Fresh Water Flowing into an Estuary Affect Storage and Release of Nitrogen?

Coastal waterways and marshes are subject to increasing levels of nitrogen pollution that promotes eutrophication. Marshes are also subject to varying inflows of fresh water from seasonal precipitation and changes in flow to the creeks supplying marshes. Although marshes are thought to be among the most important sites of nitrogen cycling in estuaries, few studies have examined how freshwater inputs affect that cycling of nitrogen compounds between the water and the underlying sediments and marshes. Expanding on their previous work that examined changes in nitrogen release from subtidal sediments in response to salinity, Anne Giblin and Charles Hopkinson of the Marine Biological Laboratory in Woods Hole are studying how changing salinity alters nitrogen exchanges between the inter-tidal, vegetated marsh sediments and the water in the upper reaches of the estuary. Their hypothesis is that changing salinity in the marsh, due to changing freshwater input, changes the timing, amount, and form of nitrogen released from sediments into the water—which in turn can greatly change primary productivity and promote phytoplankton blooms. The project has three objectives. First: to determine how seasonal and annual variations in fresh water (from creeks) affect storage and release of nitrogen compounds from marshes. Second: to measure rates of nitrogen cycling, retention and loss through annual seasons. And third: to expand on their model of nitrogen cycling in brackish marshes, adding in the upper marsh region and couple the model with existing models of water flow, estuarine primary production and respiration. Over a seasonal cycle, they will examine water drainage at varying places in the marsh, and measure nitrogen transformations within sediments in places closer to or farther from tidal creeks, building a comprehensive view of salinity effects on nitrogen cycling in the upper marsh. Results of Giblin's and Hopkinson's study will improve understanding of controls on estuary productivity, and contribute to a larger model of the Plum Island Sound estuary, a site of a long term ecological study (LTER) funded by the National Science Foundation.

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