Memorandum

Date: November 10, 2006

To: Becky Shortland, Gray’s Reef Reserve

Cc: Laurie Fowler

From: Charlie Maffitt

Subject: Use of tracers to determine movement and dispersal of water-borne pollutants

Question:
Are there tracers which can be used to determine whether pollutants from the Altamaha River are being carried out to Gray’s Reef? If so, how are these monitored/detected?

This memorandum will attempt to briefly discuss current trends in technology with regard to use of tracers in water as a means of identifying and tracking pollutant and nutrient dispersal from a river’s mouth into the open ocean. Specifically it will seek to provide the managers of offshore reefs with evidence that pollutants do in fact travel widely in the ocean and that the water quality of rivers affects the water quality of the oceans they drain into and the health of oceanic ecosystems.

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Among the many environmental impacts of water-borne pollution in rivers and streams is the effect that these pollutants and nutrients have on coral reefs and the complex and sensitive ecosystems they host. Pollutants, sediment, and even nutrients such as Nitrogen and Phosphorous (found commonly from fertilizer runoff) can all have negative effects on the health of reefs. Coral reef systems are highly oligotrophic and potentially vulnerable to changes resulting from nutrient enrichment. Even trace amount of nitrogen and phosphorous can have devastating effects on the health of coral. According to ReefRelief.org, Dr. Peter Bell of the University of Queensland and Dr. Brian Lapointe of the Harbor Branch Oceanographic Institution independently determined exactly the same limit for acceptable nutrient concentrations\(^1\): Biologically available nitrogen (nitrate plus ammonia) needs to be below 1.0 micromole per liter (less than 14 parts per billion), and biologically available phosphorus (orthophosphate plus dissolved organic phosphorus) needs to be below 0.1 micromole per liter (less than 3 parts per billion). These levels are lower than previously predicted, and are almost undetectable in coastal waters, underscoring the potential harm to reefs from nutrient loads in rivers.

The world’s most famous reef is no exception: In 2002, the Queensland Australia government commissioned an independent study to review scientific evidence linking land use, water quality, and reef degradation in the Great Barrier Reef. The results of that study, entitled *A Report on the Study of Land Based Pollutants and Their Impacts on Water Quality in and adjacent to the Great Barrier Reef*, confirmed the negative impacts of land-based pollution on the reef. Among their conclusions, they noted that “Impacts on offshore areas of the reef are not fully understood, but the health of offshore regions is linked to that of inshore areas, estuaries, and rivers”, and that “by the time widespread effects are obvious, the system would be almost irreparably damaged.” The findings of the study led directly to the Commonwealth’s creation of a Reef Water Quality Protection Plan which seeks specifically to “protect the reef from land-based sources of pollution” by reducing the diffuse and point sources of pollution which enter streams and rivers on the mainland by means of sustainable practices and better land use decision-making.

Given that the effects of land-based pollution on the health of reefs offshore are cause for concern, identifying the source of the pollutants is a necessary first step in rectifying the situation. However, tracing the source of pollution in open waters can be difficult because of the amount of dilution that occurs once rivers empty into the ocean. For example, fluorescent dyes such as Fluorescein, Uranine, and Rhodamine WT are often used in municipal sewer systems and waterways, and can be used to trace the movement of groundwater over large areas. These dyes, however, are extremely difficult to detect in large bodies of water such as bays and harbors, not to mention the ocean. As such, they are not considered to be good candidates for tracing water dispersion and movement in coastal areas.

The use of radioactive isotopes as tracers in water overcomes the dilution problem because the isotopes are so easily detected in trace amounts. For example, in 1989, Swiss scientists used traces of Tritium accidentally discharged in a pulse by an isotope processing plant in northern Switzerland to observe the movement of the contaminant through a sewage treatment plant, rivers, and various wells and aquifers. Similarly, researchers at Oregon State University used measurements of Chromium-51 to track the plume of the Columbia River some 350 kilometers to sea. The radioactive signature was added to the river by nuclear reactors in Hanford, Washington, and it allowed researchers to study rates of transport and mixing of the river water at sea, and to identify the river’s plume in the presence of other sources of fresh water. However, in both of these experiments, the radioactive isotope was already present due to industry pollution and not as a result of deliberate introduction.
Deliberate introduction of radioactive isotopes for use as a tracer in large bodies of water is performed from time to time, but can be costly and involve legal constraints. For example, the state of California prohibits deliberate introduction of radioactive tracers into the environment unless “there is shown to be a substantial public interest in the information intended to be obtained by the study” and “that the study will be performed by persons or agencies competent to handle and use the radioactive material safely and with due regard for potential effects on public health.” In other words, while legal for research, the deliberate introduction of radioactive material into the environment is not to be taken lightly and can be difficult and time-consuming for which to obtain approval. In addition, the cost to obtain the radioactive material itself may be prohibitive.

The most recent development in field tracer studies has been the use of Sulphur Hexafluoride (SF6), an inert synthetic gas which is detectable in very trace amounts and can be tracked in large bodies of water. It is non-reactive, inexpensive, and offers an extremely low detection limit. It has allowed for the creation of very accurate studies of water transport and mixing in areas over 100km2 over two weeks.

In a recent series of experiments, researchers from Columbia University in New York introduced SF6 by bubbling less than 1 mol (available for roughly $15) into various tidal estuaries feeding into New York Harbor, including the Hudson River, then traced the mixing and dispersion of that water over 7-13 days. The SF6 levels were measured at various locations around the harbor by a boat using a gas chromatograph equipped with an electron capture detector (GC-ECD), with samples taken every day. The results of the experiment allowed them not only to track the mixing of waters within the harbor, but also to see where the waters from the various creeks and rivers actually were ending up and in what quantities.

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6 California Health and Safety Code 11470.
Fig 1. Series of daily average SF6 tracer measurements in New York Harbor over 8 days in July 2002. Injection point is shown by yellow arrows.

Fig. 2 Schematic diagram of a fully automated high-resolution SF6 sampler.
Woods Hole Oceanographic Institute has also employed SF6 as a tracer of water mixing and movement in the deep sea. A large amount (175 kg) of SF6 was injected into the water over nine days, then ten months later samples were taken throughout the water column to determine the level of mixing and dispersal, both vertically and laterally. Despite covering an area of over 500,000 square nautical miles, only 55%-60% of the tracer was found, suggesting higher than expected lateral movement.  


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Given the success of the recent deployments of SF6 as tracer in ocean waters, as well the fact that it is both cheaper and less harmful to the environment than radioactive tracers, I suggest that a field tracer study using SF6 could very easily be used to document the fate of the Altamaha’s waters and the pollutants and nutrients they carry into the ocean with them. Such an experiment could very well provide much-needed evidence documenting the impact of land-based pollution on offshore ecosystems such as reefs, and might in fact be a good research experiment for future practicum semesters or ecology students.

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