A Pollution Map *Worth Ten Thousand Words*

By **Edie Widder**, CEO and Senior Scientist Ocean Research & Conservation Association.

NUTRIENT POLLUTION is one of the world's most widespread environmental challenges. Nitrogen and phosphorus enter lakes, streams, rivers and coastal ecosystems as point source and non-point-source (NPS) pollution. Sources include: 1) excess nutrients carried off fertilized crops and urban lawns and gardens by rain, snow melt, irrigation and wind, 2) animal waste carried off farms and feed lots, 3) leaky septic systems, 4) sewage as treated and untreated outfalls and distributed biosolids, 5) irrigation systems that use reclaimed water recovered from wastewater treatment plants, 6) polluted groundwater and 7) excess airborne nitrogen resulting from the burning of fossil fuels.

Figure 2. Based on nutrient analysis of sediment samples, a pollution gradient map is generated as a graphic overlay on an ArcGIS map. In this map, total nitrogen concentrations measured in parts per million are color coded with red showing highest and blue lowest concentrations. The map makes it easy to spot problems, such as the buildup of nitrogen in the residential lined finger canals, as well as locations like that circled at top left, where "best practices" for lawn maintenance are having a positive impact.

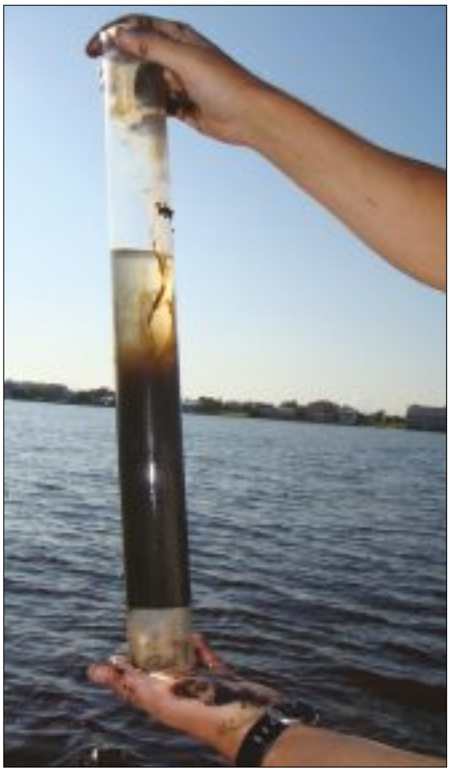

Figure 1. A sediment sample can be collected with corer, as seen here, or a grab. In either case only the top 5 cm are used for analysis in order to focus on recent deposition of bioavailable nutrients.

In freshwaters, phosphorus (P) is the primary nutrient that is in shortest supply, while in marine and estuarine environments nitrogen (N) is the most important nutrient that limits the growth of photosynthetic organisms. When these once limiting nutrients are supplied in excess, algae blooms occur. Some of these algae produce toxins that lead to shellfish poisonings, fish kills, mass mortality of marine mammals, contamination of drinking water supplies and, in the case of aerosolized toxins, respiratory and neurological human health impacts. Non-toxic blooms also have serious impacts as they block sunlight leading to the loss of seagrass, kelp beds and coral reefs and they produce "dead zones" – regions where the decomposition of dead algae consumes oxygen to such a degree that animal life suffocates and dies. The size and number of dead zones in the world's oceans have been growing at an alarming rate over the past 50 years, contributing significantly to the decline of coastal ecosystems.

The imbalance of N and P cycles around the world is having major socio-economic impacts and is a problem of growing global concern. Better nutrient management has been called for and goals have been set such as "20:20 by 2020", which refers to a 20% improvement in nutrient use efficiency by the year 2020 leading to an annual saving of around 20 million tonnes of nitrogen. It has been estimated that meeting this goal would lead to improvements in human health, biodiversity and climate worth approximately $170 billion per year.

Nutrient management requires nutrient monitoring. Monitoring assures use of the best available science in formulating management decisions and provides feedback to the public and policy makers as to whether management goals are being met. The vast majority of nutrient monitoring is accomplished by collecting water samples by hand for processing in a laboratory. Unfortunately, this approach is of limited value in multifaceted aquatic ecosystems, such as coastal zone environments, where changes may occur over very short space and time scales; distinguishing natural variation from human-induced variation requires measurements with a high degree of spatial and temporal resolution. The solution suggested most often to meet this challenge is real-time monitoring (RTM). RTM has excellent temporal resolution, but the costs of these systems, plus the logistical challenges of deploying and maintaining complex sensors in situ, often limits their spatial resolution.

As a compromise between the poor temporal and spatial resolution of hand sampling and the excellent temporal, but often budget-induced poor spatial resolution of RTM, our organization has developed a sediment-focused pollution mapping solution. Instead of providing the snapshot in time that a hand sample represents, sediment samples provide a time-integrated sample, and can be used to locate pollution sinks – the places where nutrients accumulate in the sediment of a given body of water. Because sediments have a natural affinity for nutrients, and because contaminants often have a much longer residence time in the sediments than the water, the best indicator of local water pollution problems often lies on the bottom.

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Figure 3. High School students collecting sediment samples in the Indian River Lagoon.

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Figure 4. Students being trained in how to process sediment samples.

Sediment sampling is low tech (Figure 1) and relatively low cost. Sediment samples can be tested for phosphorus, which is generally measured as Total Phosphorus (TP) or Orthophosphate (PO_4), as well as any or all of the various forms of nitrogen present, such as Nitrate (NO_3), Nitrite (NO_2), Ammonia (NH_4), Inorganic Nitrogen (NIORG), Organic Nitrogen (ORGN), Total Kjeldahl Nitrogen ($TKN=NH_4+ORGN$) and Total Nitrogen ($TN=NO_3+NO_2+NH_4+ORGN$). Locating hotspots of nutrient accumulation can provide valuable indicators of where nutrients are entering water ways and where they are accumulating and creating reservoirs of nutrient pollution that can be reintroduced into the water column by storm activity and boat traffic. Localizing hotspots also provides critical data needed to select optimum locations for expensive RTM systems.

Recognizing that a picture is worth ten thousand words, rather than simply providing policy makers and the public with numerical data on the concentrations of nutrients found in sediments, we have been using pollution maps like that shown in Figure 2. This map displays total nitrogen in parts per million with high nitrogen shown in red and low nitrogen in blue. Just like a weather map this picture provides a synoptic, highly visual representation of a spatially complex data set that is easily understood by laymen. This particular map reveals high buildup of nitrogen in the finger canals in this community located on the Indian River Lagoon along the east coast of Florida. Because finger canals are channels that were dug in order to create additional waterfront lots, many canals are lined by homes with highly fertilized lawns that slope to the water's edge.

Pollution maps not only reveal problems they can also reveal solutions. For example, the two canals circled at the top left in Figure 2 exhibit low nitrogen, despite impinging directly on a golf course. This golf course is owned by a country club that uses "best practices" for lawn maintenance, employing a low dose liquid organic fertilizer and bagging all lawn clippings instead of allowing them to enter the lagoon. When this map was shown to the local city commission, it lead to the implementation of the first fertilizer ordinance instituted along the Indian River Lagoon. Many other communities have since followed suit, limiting the application of fertilizers in an effort to abate the algae blooms that are beginning to plague these waters.

Pollution maps such as this represent a valuable, visual conservation tool that can transform our ability to inform and educate communities about the condition of their local aquatic ecosystems. Because of the simplicity of the data collection involved, we have found that stakeholders can be enlisted to help collect the samples. Whenever possible we work with local students and citizen scientists to generate these maps in order to further raise community awareness and provide valuable hands-on experience with science (Figures 3 & 4). Too often there is a disconnect between science and action, because gathering and publishing sound science data is a meticulous and time consuming process, while policy decisions are made under deadlines and amid controversy. By getting community stakeholders working directly with scientists, we can not only solve the immediate problems at hand, but ensure good policy decisions by developing an informed constituency dedicated to improved outcomes.

It has been said that "water is the Oil of the 21st Century ...the precious commodity that determines the wealth of nations" (Fortune Magazine May 2000), however, unlike oil, water has no substitute. Water is absolutely essential for all life as we know it and protecting the health of our aquatic ecosystems is critical to our continued existence on the planet. We need to find cost-effective ways to monitor and maintain them so that they can continue to provide the services on which we depend. Making pollution visible through the use of sediment pollution maps is a means toward that end.

Dr. Edie Widder
CEO and Senior Scientist
Ocean Research
& Conservation Association
www.teamorca.org

ORCA
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