

## 2.11 Embeddable Sensors (SEN)

During this past year, the sensors research group made several significant advances including an up-scaled deployment of remote and embedded sensing in the environment, a portable flow cytometer for real-time aquatic algae analysis, and an extremely sensitive domoic acid assay. The environmental deployment project focused on the spectral analysis of wild plant species. The first phase was done at swamp Timothy. Similar hyperspectral analysis is planned to expand to aquatic sea plant in the future. In addition, the sensor group has also successfully developed the first flow-cytometer-based algae analysis portable system. It was shown that both counting and species differentiation can be achieved. Finally, the sensor group has also developed an extremely sensitive domoic acid assay. Domoic acid is an important molecule to monitor in marine algae since it is a toxin often generated by algal blooms that transfers through the food chain and causes sickness and mortality in marine mammals and seabirds.

### Remote and embedded sensing in environmental systems

A new sensor project focuses on up-scaling the CENS embedded sensing approaches in terrestrial and aquatic systems to larger spatial scales by integrating embedded and remote sensing techniques. More specifically, we are focusing on identifying and testing remote sensing methods and algorithms for detecting changes in the environment. This new project has been undertaken in the managed seasonal wetlands of Central California, which are the largest expanse of wetlands west of the Mississippi River. During 2009-10, progress on this project included developing and testing of a high-resolution image classification method for mapping key plant species in a wildland setting. Effectively, this is a large-scale version of the CENS imager-as-sensor approach. A major accomplishment was identifying a quantitative relationship between key wetland plant species' reflectance spectra and substrate conditions, such as moisture, texture and salinity (as summarized by the soil apparent electro-conductivity measurement).

In the upcoming year, this research will begin to examine methods to connect embedded and remote sensing in terrestrial and aquatic systems. The terrestrial component will continue to probe soil-water-salinity implications with respect to plant community structure. Specifically, we are beginning to exam hyperspectral reflectance as a tool for assessing plant water content. In a more novel approach, we have begun to explore the use of hyperspectral radiometry in aquatic systems. Specifically, we intend to examine reflectance/absorption spectra in the context of algae-related compounds (chlorophyll, dissolved organic matter), which have been examined by others, as well as other chemical constituents, such as nitrogen and phosphorous species.

### Portable algae micro flow cytometer

The main focus of the project is to develop a portable micro flow cytometer which is suitable for on-field monitoring of algae population. The overwhelming growth of microalgae, the microalgal bloom, has negative effects on marine ecosystems. However, the factors driving the selective proliferation of algae, especially the harmful species, are not well studied partially due to the time- and labor-intensive analysis methods. In this project, we build an algae micro flow cytometer which allows a time-efficient evaluation of the algae population, the portable size of which is suitable for on-field applications (Figure 9).

In our approach, a disposable microfluidic chip is used as the flow cell of the cytometer, the dimension of which can be optimized for different target species. Laser-induced-fluorescence and light extinction measurements are used to evaluate the algae properties including cell size, Chlorophyll- $\alpha$  fluorescence and physiological properties such as viability and enzyme activities by using biochemically specific dyes. Each algae cell is measured individually and several thousands of them can be measured in a short period of time to achieve a precise evaluation of the algae

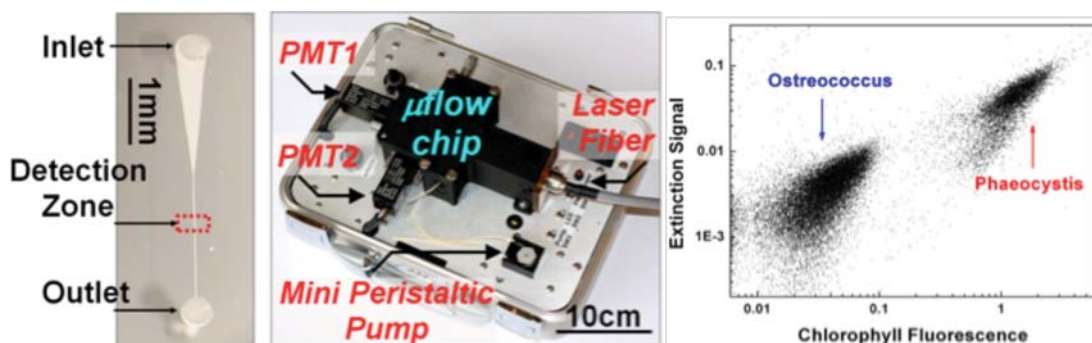


Figure 9. The “portable” algae micro flow cytometer system and a typical test result. Note that both the absolute count and algae differential can be done in the developed system.

population.

A prototype system (12" x 9" x 5") is built and successfully tested. It can be powered by the standard 110V AC or 5V DC sources. The test results are visualized on a laptop or a handheld computer. Evaluations of microalgae cell number counting, cell size and Chlorophyll- $\alpha$  fluorescence are successfully demonstrated. The measured information can be used to distinguish different algae species. The evaluation of physiological properties such as esterase activities (FDA staining) is also demonstrated.

#### **Electrochemical sensor for algae domoic acid detection**

An electrochemical sensor is developed for detection of Domoic Acid (DA). DA is a neurological marine toxin that is produced by different species of the algae *Pseudo-nitzschia* in the ocean. Since the DA is a small molecule with a molecular weight of 312 Da, a competitive immunoassay is used for its detection. In order to immobilize the DA in a repetitive and reliable format on the gold detection electrode, a mixed self assembled monolayer of thiol with both biotin and OH groups at the end is formed. Biotin is used to immobilize the DA-neuroavidin conjugate on the electrode surface and the OH group is used to block unspecific binding of the proteins to the gold surface. After immobilization of DA-neuroavidin, the anti DA antibody conjugated with HRP and the unknown concentration of DA is added to the electrode for the competition step. The free unknown DA molecules compete with the immobilized DA on the surface for binding to the antibody. After enough incubation time and wash the substrate is added and the signal is read.

The detection limit of our sensor is 1 pg/ml of DA in the buffer which is 10 times better than the commercially available ELISA kits for detection. Another advantage of the sensor compared with the other available techniques for detection is the small volume of sample that is used for detection which is only 2  $\mu$ l. This advantage will allow marine biologists to study the toxin produced by a smaller number of algae compared with the minimum of 100 cells required by the ELISA kits.