

ENHANCING OCEANOGRAPHIC SCIENCE – DEVELOPING THE INTERFACE BETWEEN SCIENCE AND SOCIETY⁺

Peter R. Betzer
Dean, College of Marine Science
University of South Florida

ABSTRACT

Although here are a host of important societal problems that are related to the oceans most oceanographers are only peripherally involved with marine commerce, emergency management agencies, water management boards, water supply groups, fisheries industries, environmental protection/restoration projects, aquaculture and tourism. From my experience the aforementioned groups would benefit greatly from scientific advice and, further, they are in a position to help generate permanent funding that I contend is critical to advancing oceanographic science. While the collaboration between these groups and oceanographic scientists could evolve in many directions, it is clear that the Commission on Ocean Policy can initiate the interaction. Specifically, they could call for the creation of an advisory council made up of oceanographers and representatives of prospective user groups that would be asked to consider the particular problems that oceanographers could become involved in addressing. Initiating a regular dialogue between scientists and interested user groups would I believe help the involved user groups and eventually lead to legislative initiatives that bring new, recurring state resources to our field.

1. The Situation in Ocean Sciences

It is clear from my three decades of experience with the federal agencies that support ocean science (NSF, ONR, NOAA, NASA, USGS, DOE and USGS) that federal funding for ocean sciences is inadequate to support many excellent scientific proposals and while there are a number of important multi-institutional initiatives underway – GLOBEC, RIDGE, CLIVAR and JGOFS – our field suffers from the fact that federal funding cannot, and does not, provide **continuity i.e. once a research program is completed federal funding ceases**. Certainly there are occasional cases where selected federal programs – i.e. University National Oceanographic Laboratory Systems (UNOLS) - have been funded for decades but even here the waxing and waning of federal support is substantial enough that there have been years where research vessels had to be taken out of service and experienced professionals released. As I see it the fundamental challenge facing the ocean sciences community is to expand recurring state funding for our field. Clearly with the current demands on federal resources it will be extremely difficult to substantially increase federal support for ocean programs and, even if we succeeded, enhanced federal funding cannot generate

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continuity. My hypothesis is that there is an excellent chance for our field to establish productive scientific and financial linkages with commercial, civic, state management and industry groups. Initially the funding these groups provided ocean scientists would support specific research initiatives requested by the user group such as current, tide and wind data that are provided by Physical Oceanographic Real Time Systems for marine commerce in Charleston, Galveston, Narragansett and Tampa Bays. The significant difference between generating funding from the commercial sector and the federal sector is that most CEO's and/or Directors of commercial groups have considerable influence with state legislators. In short, if so motivated, industry leaders could lead an effort to generate recurring state support for oceanographic groups. This latter action item is a critical challenge that is a key to strengthening our field.

2. Potential Important Linkages With Ocean Science

There are a number of important commercial, regulatory, industry and management groups that could benefit greatly from the active involvement of ocean scientists. A short list of potential user groups is included in Table 1:

TABLE 1
Potential user groups for Ocean Science

- a. Marine Shipping and Commerce – oil releases in ports, winds, tides and currents, introduction of non-indigenous species
- b. Oil and Gas Companies – pipeline leaks
- c. Emergency Management Groups – prediction of severe storm paths and the timing, location and extent of coastal flooding
- d. Water Management Districts – pollution, salt water intrusion
- e. Water Supply Groups – water purity
- f. Aquaculture Industry – harmful algal blooms, water quality
- g. Resort/Tourist Industry – state of health of beaches, erosion
- h. Fishing Industry – larval fish dispersal, oceanic fronts

The fundamental point is that there are a number of potentially important interfaces between oceanographic science and marine commerce, marine resources, emergency management and the tourist industry that can, indeed should, be developed. I would underscore what I believe is a pivotal point for our field – If oceanographic science can develop meaningful linkages with a number of the “user” groups cited above, our field will have gathered some powerful allies who can mount focused campaigns with state legislators that generate recurring support.

3. A Technological Approach to the Commercial Interface

There are a number of new sensor systems and technologies that have been developed recently including: 1) an underwater mass spectrometer; 2) a long path

length spectrophotometer; and 3) a dual-laser imaging system all of which will provide significant new insights into oceanic processes. In addition to a number of general oceanographic applications, these powerful new systems have particular significance to: 1) understanding chemical and biological dynamics in the coastal ocean; 2) building a set of observational systems/networks that are fundamental to oceanographic science; and 3) addressing the needs of our potential commercial industrial and regulatory partners (Table 1). It should be noted that there are some excellent examples of individuals or small groups that have developed a linkage with marine commerce and used that linkage, to advance oceanographic science (i.e. the Physical Oceanographic Real Time System in Tampa Bay).

There are three new Sensor Systems of Particular Relevance to Ocean Science and the Proposed User Groups listed in Table 1.

a. Underwater Mass Spectrometer

A versatile, real-time sensing system for low molecular weight organic compounds and gases in seawater has been developed (Short et al., 2001) and applied to tracking a dilute plume of dimethyl sulfide in Tampa Bay.

This powerful new, in situ, analytical system could also be used to: 1) detect leaks in underwater pipe lines for the oil and gas industry; 2) monitor water supplies for chemical solvents; 3) track chemical plumes in salt and fresh water systems; 4) carry out surveys in Port/Harbors; and 5) monitor sewage systems for organic solvents.

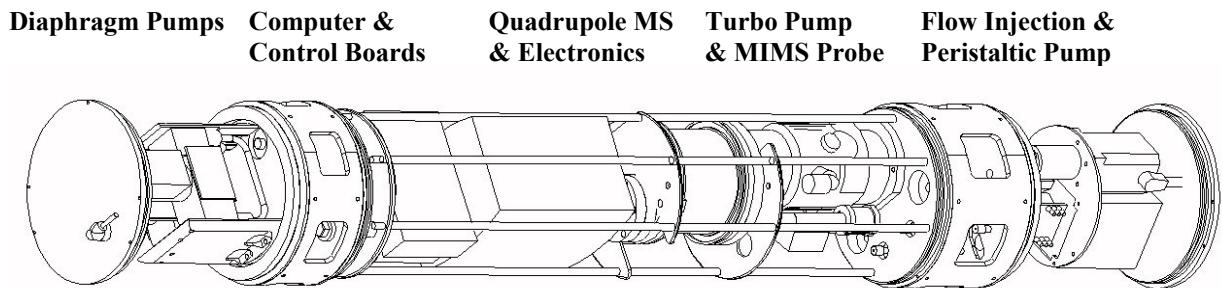


Figure 1. Schematic of the three-pressure-vessel system for the underwater membrane-introduction quadrupole mass filter system.

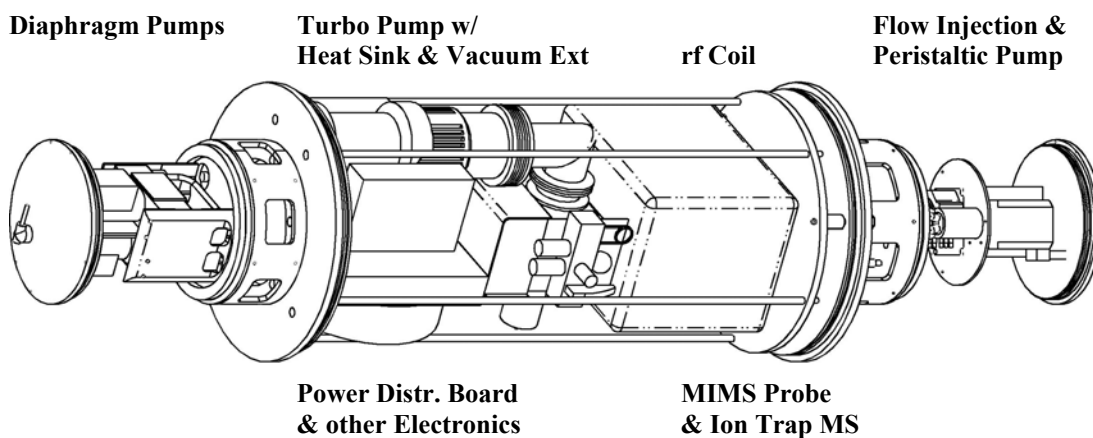


Figure 2. Schematic of the three-pressure-vessel system for the underwater membrane-introduction ion trap mass spectrometer system. The first and third vessels are identical to those used on the quadrupole mass filter system.

Figure 3. Field data from the underwater ion trap mass spectrometer while mounted inside a remotely operated underwater vehicle (ROVEX). The trace shown is for mass-to-charge (m/z) 91, the primary diagnostic ion for toluene. Peaks represent in-situ analyses of water in the Bayboro Harbor (St. Petersburg, FL) as compared to charcoal-filtered (clean) water. Analyses indicate higher volatile organic compound (VOC) concentrations in the boat channel as compared to outside the channel. The source of VOCs is presumably motorboat exhaust.

Appendix I provides technical details related to the underwater mass spectrometer system and its recent evolution.

b. Long Path Length Spectrophotometer

A second system that will almost certainly revolutionize the measurement of trace metals and nutrients in both sea water and fresh water systems is a long path length spectrophotometer (Waterbury et al., 1997; Yao et al., 1998; Yao and Byrne, 1999; Byrne et al, 2000; Byrne et al., 2000). This compact system (Fig. 4) provides a means of carrying out *in situ* measurements for trace constituents like dissolved iron and nitrogen species that are extremely reactive biologically and are normally present in extremely small concentrations (Table 2). Basically this fundamental breakthrough has opened up a host of new analyses all of which can be made *in situ* with extremely small sample sizes (~0.1ml) without using an expensive research vessel or subjecting the sample to contamination during processing on a research vessel (Fig. 5). This system is small enough that it could also be deployed in underground fresh water wells where it could continuously monitor the surrounding chemical environment for several months. The system could also be used to continuously monitor city/municipal water supplies, the quality of bottled water and provide data on ground water and fresh water run off. Appendix II provides a set of scientific publications that detail the capability of this chemical analysis system.

TABLE 2

Long Pathlength Absorbance Spectroscopy (Pathlength 4.5 meters)

<u>Analyte</u>	<u>Detection Limit</u> ⁺	<u>Reference</u>
Fe(II)	0.2 nanomolar	Waterbury et al. (1997)
Fe(III)	0.2 nanomolar	Waterbury et al. (1997)
Cu(II)	0.4 nanomolar	Callahan et al. (submitted)
NO ₂ -	0.5 nanomolar	Yao et al. (1998)
NO ₃ -	1.5 nanomolar	Yao et al. (1998)
Cr(VI)	0.2 nanomolar	Yao et al. (1999)
Mo(VI)	0.4 nanomolar	Yao et al. (1999)
HS-	2.5 nanomolar	Byrne et al. (2000)
Quinine Sulfate	0.06 nanomolar	Byrne et al. (2000)
Chlorophyll-a	0.03 nanomolar	Byrne et al. (2000)*

*Obtained using LPAS system in fluorescence mode

⁺ Nanomolar = 10^{-9} moles/liter

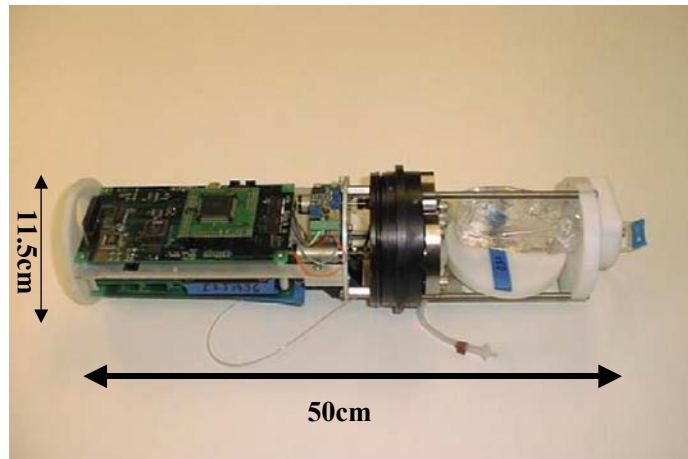


Figure 4. Long path length spectrophotometric analysis system without pressure vessel

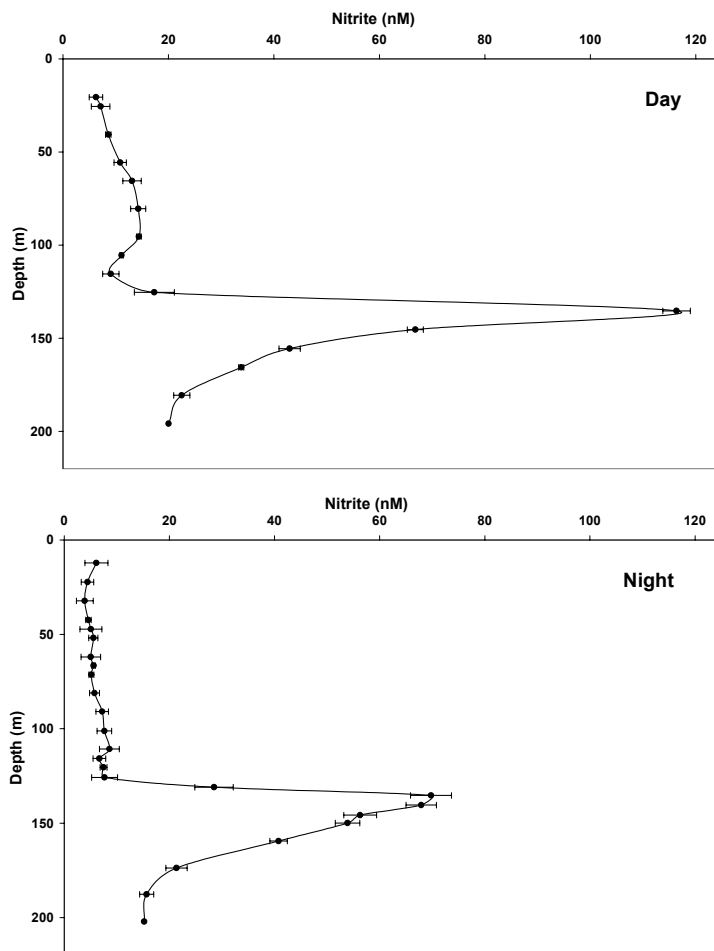


Figure 5. Daytime (upper graph) and nighttime (lower graph) profiles for nitrite (NO_2^-) in nanomolar concentrations (10^{-9} moles/liter). Error bars show full range of five measurements over 20 seconds.

c. Dual Laser Imaging system

A third system that has greatly expanded our ability to image microscopic biological organisms in aqueous environments utilizes high speed digital line scan cameras and two orthogonal, 3 milliwatt lasers (Samson et al., 2001). The system can define water-borne particulates down to 12 micrometer diameter and the images it produces are so crisp that in many cases a biologist can speciate the specimen (Fig. 6). Also the images of fragile organisms such as jellyfish make it apparent that there is little if any turbulence associated with this system (Fig. 7 and 8). In addition to the obvious important oceanographic applications, there are a number of important societal needs. For example, water supplies need to be regularly tested for organisms such as cryptosporidium because they can, and have infected municipal water supplies (i.e. Milwaukee, Wis.) with disastrous effects (MacKenzie et al., 1994). In addition to the need for real time monitoring of water supplies, there is the challenge of defining the types of non-indigenous organisms that are being released in U.S. coastal waters/ports by marine commerce. The rapid destruction of the calico scallop industry off Florida's and Georgia's east coast was linked to a protozoan parasite from the eastern Atlantic Ocean that almost certainly originated from the bilge water of a commercial vessel (Moyer et al., 1993 and Moyer et al., 1995). The fundamental point is that recent advances in optical imaging technology that are being used almost exclusively by oceanographers have important uses in other arenas. Further, the application of these technologies will likely provide our field with a powerful group of advocates who are capable of generating increased state, and corporate, support. Appendix III provides detailed technical specifications for this Imaging System as well as some representative images of microscopic planktonic assemblages from the Gulf of Mexico.

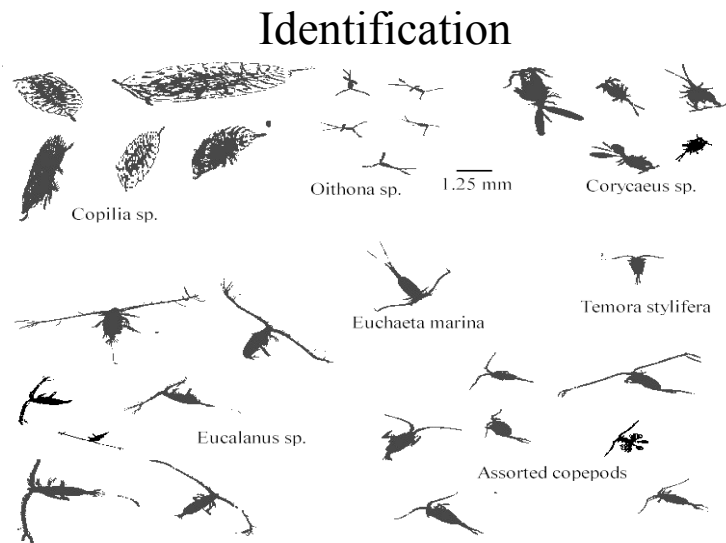


Figure 6 Zooplankton images from Gulf of Mexico made with dual laser line scan camera system.

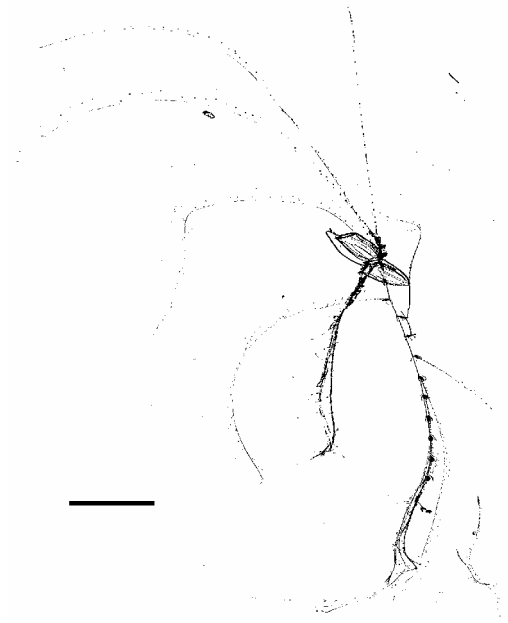


Figure 7 Large siphonophore imaged at 60 meters depth in offshore waters of the Gulf of Mexico using the 2048 pixel camera of dual laser, line-scan camera system. Scale bar represents 1 cm. These organisms are broken up by plankton nets.



Figure 8 Fragile organisms (three jellyfish and a siphonophore), captured using line-scan camera system.

5. Recommendation to Commission for Ocean Policy

This is a critical period for oceanographic science and our field needs to develop productive working relationships with the oil and gas industry, with the marine shipping industry, with water supply groups, with environmental agencies, with emergency management agencies and with major sea ports. While the mode of operation and traditions of these diverse groups might differ from those of academic scientists, there is little question that all could benefit from collaborating with ocean scientists and I think it is fitting that the Commission on Ocean Policy initiate this process. It is important to note that I am not asking oceanographers to focus solely on applied problems. **Rather, I am suggesting that if our field demonstrates its value to commercial, civic, industrial and state groups, we will almost certainly develop powerful allies who will subsequently push legislative funding initiatives in our behalf.** Recurring state funding can have a tremendous impact on the course of oceanographic science and this is exactly what is needed to advance our field. In short, securing recurring state funding should be an important priority for our field and a small working group representing the previously cited sectors (Table 1) and Oceanographic scientists should be appointed to develop a framework for collaborative action. For many years oceanographers could have set up joint projects that built a productive interface with other groups and expanded state support for our science. After decades of limited interchange, it is time to initiate a dialogue between scientists and commercial/civic/management/industry sectors that will, I believe, help propel oceanography forward.

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