WRITTEN TESTIMONY OF

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HEARING ON
HARMFUL ALGAL BLOOMS: IMPACTS ON OUR NATIONAL WATERS
BEFORE THE
SUBCOMMITTEE ON OCEANS, ATMOSPHERE, FISHERIES, AND COAST GUARD
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
U.S. SENATE

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Mr. Chairman and members of the Subcommittee. Thank you for the opportunity to introduce myself: Ivory Engstrom, Director of Special Projects for McLane Research Laboratories (MRL), Inc. As Director of Special Projects for MRL, my job is to identify and commercialize promising technologies for wider use in the oceanographic and environmental monitoring communities, as well as to work with researchers and developers to enhance existing technologies and enable broad deployment of innovative sensing systems. While some of our traditional product line of samplers have already been used to collect and enumerate Harmful Algal Bloom (HAB) species[1], this testimony will focus on a couple of the newer biological sensing instruments that we manufacture for the identification and detection of HAB species and their toxins. I will also highlight some of the research that our users are performing with these new biosensors.

McLane Research Labs, Inc., East Falmouth, Massachusetts, was founded in 1983 to provide advanced time-series samplers and engineering design services to the international oceanographic community. MRL's product lines include a range of biogeochemical and physical oceanography sampling and profiling instruments for use in oceanographic research and environmental monitoring. MRL has grown steadily over its 35-year lifetime, and much of our growth can be attributed to the addition of new cutting-edge sensors and monitoring tools.

IMAGING FLOWCYTOBOT

Of particular relevance to this hearing are two of our technologies, both developed at outside institutions and licensed to MRL though the technology transfer process. The first technology is an instrument called the Imaging FlowCytobot, or IFCB. Developed at the Woods

[1] Pilskaln, C.H., Anderson, D.M., McGillicuddy, D.J., Keafer, B.A., Hayashi, K., Norton, K. Spatial and Temporal Variability of Alexandrium cyst fluxes in the Gulf of Maine: Relationship to seasonal particle export and resuspension. *Deep-Sea Research II*, Vol. 103, 2014 (40-54)

Hole Oceanographic Institution (WHOI), Woods Hole, Massachusetts, by Dr. Heidi Sosik and Dr. Robert Olson[2], the IFCB is designed to operate continually, 24 hours a day, 7 days a week. The IFCB is essentially an automated, underwater microscope and flow-cytometer with a laser-based, phytoplankton detection system. The instrument acquires images of cells in the water that are available for remote retrieval. Electronically transmitted to shore, these data are processed by performing automatic image recognition and quantification of microorganisms in the water, similar to the facial-recognition technology used in airports. Typically, these data are publicly available via the Internet using a WHOI-developed software package called the "IFCB Dashboard." Provision of immediate access to high-resolution information is critical when assessing the dynamic nature of HAB events.

Figure 1: Imaging FlowCytobot

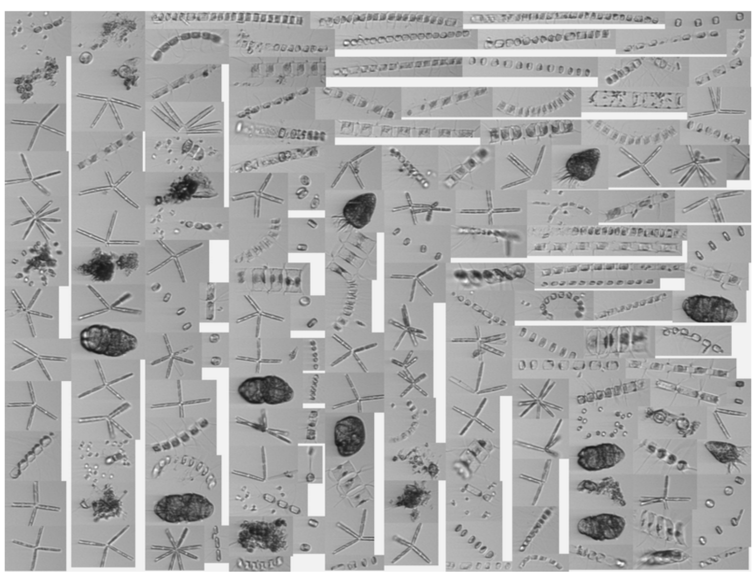

Figure 2: IFCB Dashboard Mosaic

[2] Olson, R.J., Sosik, H.M. A submersible imaging-in-flow instrument to analyze nano- and microplankton: Imaging FlowCytobot. *Limnol. Oceanogr.: Methods* 5, 2007 (195–203)

The IFCB was originally designed to study general phytoplankton (algal) ecology, but it has quickly established itself as an effective HAB monitoring tool. Because the IFCB detects and counts individual cells, it has the capacity to discover HAB species in low concentrations and enables researchers and resource managers to make informed decisions quickly based on the existing organisms in the water. Many HAB species can be identified by the imagery, although the toxicity of individual cells may be unknown, as there are toxic and non-toxic strains of some species. In general, the IFCB provides the early warning necessary for resource managers to implement management actions to quantify HABs and their associated toxins. As HAB toxins often accumulate in shellfish, the possible impacts on aquaculture production and seafood safety are serious and significant.

As an example of the manner in which this technology can assist the aquaculture industry, in the summer of 2017, MRL partnered with a local aquaculture farm, Ward Aquafarms, to perform a pilot study of the IFCB technology. The species of interest in this case was the dinoflagellate *Cochlodinium polykrikoides,* which causes larval and juvenile shellfish mortality. Upon deployment of the sensor on July 28, 2017, *C. polykrikoides* was instantly detected in the water. Dr. Daniel Ward, the owner of the aquafarm, was immediately notified by the MRL project team who were monitoring the IFCB dashboard and, as a result, juvenile shellfish in the affected nursery area were moved to an alternate grow site where the concentration of the HAB species was much lower. According to Dr. Ward, "*I checked the IFCB, and sure enough, there was C. polykrikoides at high densities, so we moved all of our seed oysters out into deeper water to get away from the bloom. If the IFCB wasn't deployed, I most likely wouldn't have known the bloom started, and most of the seed oysters in the nursery would have died*."[3] This pilot study confirmed that deployment of autonomous, in situ sensors such as IFCB can have significant benefits for aquaculture production and protection of valuable domestic sources of seafood. We look forward to continuing our IFCB testing in aquaculture applications and to the prospect of automating mitigation strategies at the grow site based on IFCB data interpretation.

The IFCB has been in development at WHOI for over 10 years, and, in that time, WHOI partners and early adopters have demonstrated the value of this sensor in shellfish management. Dr. Lisa Campbell of Texas A&M University, College Station, Texas, has been a user of the technology from its earliest incarnation, even before MRL's acquisition of the technology in 2012. Dr. Campbell has set up a monitoring system in Port Aransas, Texas, using IFCB from September 2007 through August 2017. In early February 2008, manual inspection of collected IFCB images revealed that, unexpectedly, the water contained cells of the toxin-producing dinoflagellate *Dinophysis*. Continuous monitoring by IFCB showed the formation of a *Dinophysis* bloom and its subsequent termination. Manual sampling of surface water near the intake of the IFCB was performed, confirming the presence of *Dinophysis*. These observations led to the first-ever closure and recall of oyster harvests due to Diarrhetic Shellfish Poisoning

[3] McLane Research Labs, "Imaging FlowCytobot Guides Operational Response for Aquaculture Farm" *Environment Coastal & Offshore*. September 2017: 48-51. Print

(DSP) in the United States. This closure and recall occurred shortly before the Rockport Oysterfest event in the Port Aransas region, an event typically attended by up to 30,000 people. Many people were prevented from consuming contaminated shellfish and thus avoided potentially serious health consequences.[4]

Since its commercialization in 2013, MRL has manufactured over 30 IFCB instruments that are in use on the East, West, and Gulf Coasts of the United States as well as in Japan, Finland, and Chile. Other orders are expected from Hong Kong, Singapore, Germany, and Sweden.

ENVIRONMENTAL SAMPLE PROCESSOR

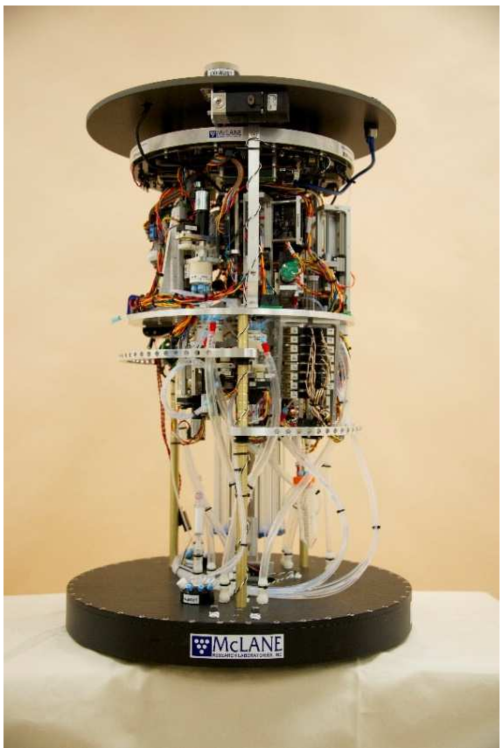

Figure 3: Environmental Sample Processor

The second MRL technology relevant to this hearing is the Environmental Sample Processor, or ESP.[5] It was developed at the Monterey Bay Aquarium Research Institute (MBARI) in Moss Landing, California, by Dr. Chris Scholin and his team at MBARI. This instrument – often called a "Microbiology Lab in a Can" – is about the size of a 55-gallon drum, and may be deployed in the water to collect microorganisms and perform genetic testing on the sample to determine whether certain species of interest are present and at what concentration. Not only is this instrument able to detect certain species in the water, it is also able to detect HAB toxins directly. Traditional methods of toxin detection have relied on testing shellfish tissue and do not necessarily characterize the actual amount of toxin in the water.

This biosensor is an extremely powerful tool providing information that would otherwise be difficult to obtain with traditional techniques. Typically, a water sample would need to be collected onsite using a small boat or research vessel, and then be brought back to the lab for analysis. The delay associated with traditional sampling methods means that stakeholders are less

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[4] Campbell, L., Olson R.J., Sosik, H.M., Abraham, A., Henrichs, D.W., Hyatt, C.J., Buskey, E.J. First Harmful *Dinophysis* (Dinophyceae, Dinohysiales) Bloom In The U.S. Is Revealed By Automated Imaging Flow Cytometry. *Journal of Phycology*. Vol. 46, Issue 1, 2010 (66-75)

[5] Greenfield, D.I., Marin III, R., Jensen, S., Massion, E., Roman, B., Feldman, J., Scholin, C.A. Application of environmental sample processor (ESP) methodology for quantifying *Pseudo-nitzschia australis* using ribosomal RNA-targeted probes in sandwich and fluorescent in situ hybridization formats. *Limnol. Oceanogr.: Methods* 4, 2006 (426–435)

equipped to make informed decisions in a timely manner, and weekly manual sampling may miss important trends or spikes in toxins or associated species.

ESPs are routinely deployed in the Pacific Northwest[6], the North Atlantic, and, most recently, the Great Lakes[7]. The ESP acts as both an early-warning system for HABs and a critical data source for inputs into predictive models. With more deployments occurring each year, HAB population models are being refined based on ESP data and observations from other marine sensors. These data are not only valuable to scientists and the public, but also to aquaculture stakeholders. Having the ability to detect harmful species at low concentrations before they become a problem can enable managers to implement countermeasures quickly, mitigating the harmful effects of HAB species on their stocks.

MRL development of ESP is ongoing and has enjoyed significant federal support from the National Oceanic and Atmospheric Administration's Prevention, Control and Mitigation of Harmful Algal Blooms (PCMHAB) program.[8] We were awarded a research grant to make improvements to the ESP system and to increase the sample carrying capacity of the instrument. As a result, the ESP received numerous mechanical and electrical improvements as well as a 50% increase in the number of available samples. In the spring of 2018, an initial test of the new and improved ESP was performed in collaboration with WHOI, under the leadership of Dr. Don Anderson (WHOI) and Dr. Mike Brosnahan (WHOI). The ESP was deployed alongside an Imaging FlowCytobot in a known HAB hotspot on Cape Cod.[9] In this particular case, we were monitoring for the presence of *Alexandrium catenella*, a toxic dinoflagellate. The study site was chosen within the Cape Cod National Seashore in anticipation of a recurring annual bloom that had previously been observed and was expected to form again in 2018. There were a number of technical challenges to overcome, but ultimately *Alexandrium catenella* were observed and detected by ESP in reasonable numbers and in general agreement with IFCB observations. In this case, only species detection was performed, but MRL continues to work on qualifying hardware and chemistry changes for toxin detection.

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[6] PSEMP Marine Waters Workgroup. 2014. Puget Sound marine waters: 2013 overview. S. K. Moore, K. Stark, J. Bos, P. Williams, J. Newton and K. Dzinbal (Eds). URL: http://www.psp.wa.gov/downloads/psemp/PSmarinewaters_2013_overview.pdf

[7] Mikulski, C., Ritzenthaler, A., Ruberg, S., Davis, T., Doucette, G. Development of an Immunoassay for Autonomous, Subsurface Detection of Particulate Microcystins in Lake Erie. USHAB 2015 Poster

[8] National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science, Prevention, Control and Mitigation of Harmful Algal Blooms (PCMHAB) Award no. NA11NOS4780022. Environmental Sample Processor (ESP) Development: Targeting Cost Reductions, Robustness and an Improved User Interface.

[9] Richlen, M.L., Erdner, D.L., McCauley, L.A.R., Libera, K., Anderson, D.M. Extensive genetic diversity and rapid population differentiation during blooms of *Alexandrium fundyense* (Dinophyceae) in an isolated salt pond on Cape Cod, MA, USA. *Ecology and Evolution*, Vol. 2, Issue 10, 2012 (2583-2594)

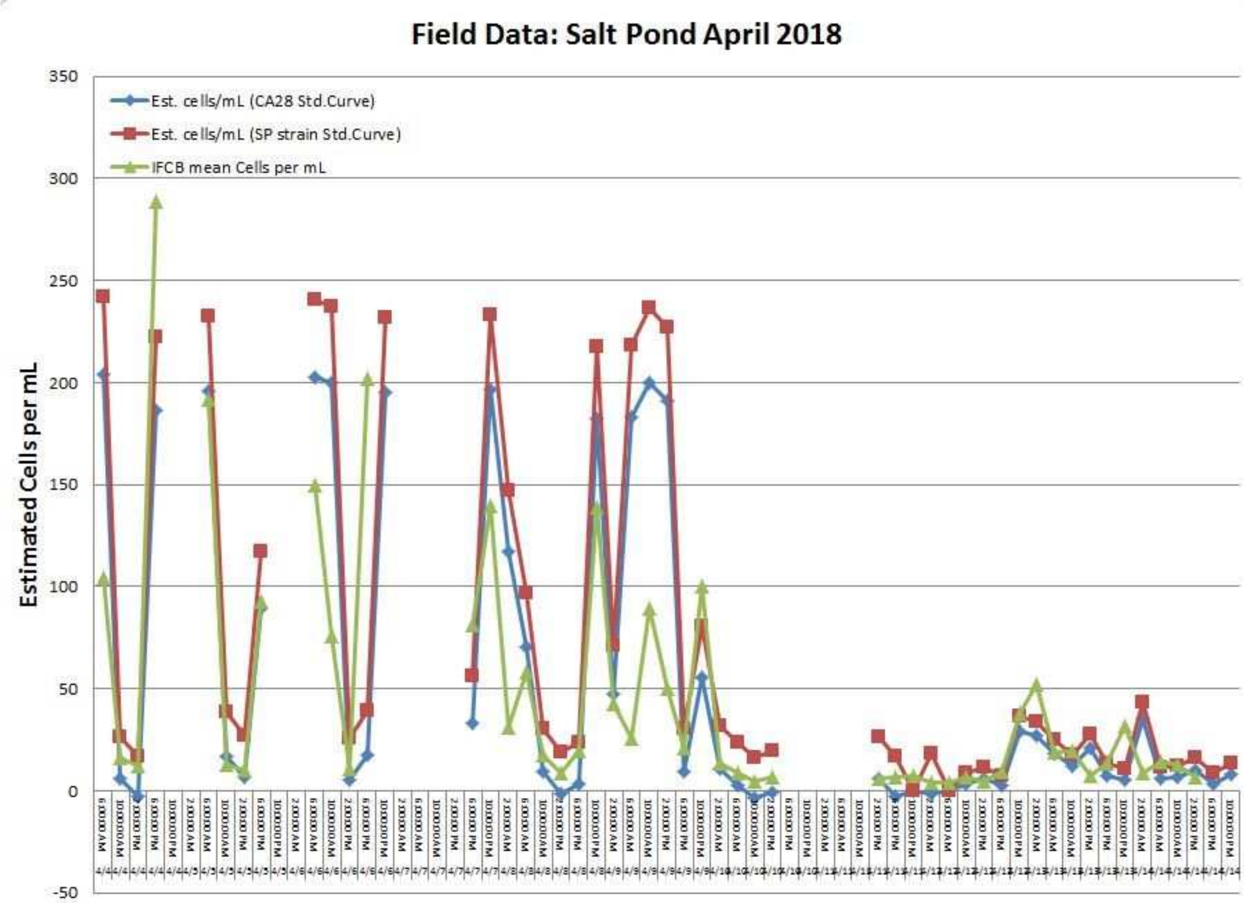

Figure 4: Preliminary Results from ESP/IFCB Study, (M. Brosnahan & T. Fougere, unpublished)

COLLABORATIVE DEVELOPMENT

Much of MRL's success is owed to our customers, who we view as partners. Our partners are the research scientists and technicians out in the field deploying these sensors and identifying the challenges associated with implementing such technologies and supporting information systems. We maintain very close relationships with our development partners as we continue to industrialize their designs and support them in creating new functionality, new detection protocols, and improved methods for data processing and visualization. In this way, our partnerships are highly collaborative. In the process of developing updates to hardware, software, and chemistry, we work together with the original developers to ensure that they are able to continue innovating on the platforms that MRL manufactures.

Indeed, it bears reiterating that the pioneering research is being done by our customers. We view our role as that of supporting our partners and providing high-quality instruments for their cutting-edge research. Our core expertise is in technology transfer and identification of new, innovative tools that may be beneficial to the research and monitoring communities. Against this background, we rely on the expertise of our partners and collaborators to guide our efforts and, ultimately, to provide an evidence-based strategic model that others may adopt.

INVESTMENT IN HAB SENSING TECHNOLOGY

There is a budding industry in development of tools for HAB monitoring. However, to my knowledge, there are currently few commercial offerings capable of providing near real-time biological data on HABs autonomously from remote locations. Experts such as Dr. Don Anderson of WHOI will attest that marine HABs appear to be increasing in severity and frequency, affecting nearly all coastal states. Additionally, all 50 states experience freshwater HAB events in one form or another. As these threats are increasing, there is a clear need for innovative instrumentation that provides valuable information for understanding, modeling, predicting, and finally mitigating the effects of HAB events.

HABs are a growing threat to our economy and our well-being, and as such, MRL has made significant investments in commercializing promising technologies for use as HAB early-warning systems. Bringing new technologies to market presents a number of challenges, both financial and technical. Initial costs are incurred not only during the technology transfer process itself, but also – and significantly – when launching a new product. The manufacture and support of these new products require increased resources, causing MRL to add new personnel and new capabilities. New products require documentation for assembly, testing, and user operation. Specialized equipment or expanded facilities may be required to manufacture these instruments. Production models must also be extensively tested before a product launch is enacted. In addition to jobs created at MRL, we are proud to employ other local companies in various supporting fields such as welding, machining, optics, electronics, and biotechnology.

We are only one of the many small businesses critical to supporting the research community. Other businesses are making similar investments in HAB monitoring and testing tools. Either by acquiring technology from independent labs or by developing instruments in-house, these businesses are important components of the "Blue Economy." MRL has been fortunate to build on the past successes of and investments in American ingenuity through our work in bringing technologies out of the lab and into the hands of new users.

RECOMMENDATIONS

Development of the biosensors described above would not have been possible without the support of government funding and private philanthropic contributions. It is my sincere hope that HAB-related funding will continue to be a priority. Competitive research programs such as NOAA's PCMHAB program, among others, offer a unique opportunity to push the limits of the current state of technology, and MRL is excited to continue our support of and involvement in various proposals and projects.

The deployment of new sensors and technology will create needs for supporting infrastructure and personnel to handle data products, interpret these products, and create notification systems to inform managers, stakeholders, and the public of potential HAB events. Not only are new information systems needed, but also deploying sensors on a large scale requires technicians, engineers, and scientists to service and maintain these sensors and information networks. New jobs will be created to address these demands, requiring skilled workers in varying disciplines.

The costs of maintaining a comprehensive network of sensors may be significant. However, in my view, the benefits far outweigh the costs. Consuming tainted seafood can result in serious human illness or death, leading to lost wages, lost workdays, and significant costs for medical treatment and *ex post* investigation.[10] HABs are not only toxic to humans, but also to other marine mammals, finfish, birds, dolphins, manatees, and sea turtles[11]. This has serious implications for recreation and tourism; recreational and commercial fishing; aquaculture production; and seafood safety. If the U.S. is to boost its domestic aquaculture output while maintaining the highest standards of seafood safety, we must consider how these tools can assist in enhancing protection efforts and HAB mitigation.

SUMMARY

In conclusion, there are various types of tools available to stakeholders for monitoring HAB species and bloom dynamics. In particular, both the ESP and the IFCB have a proven track record of success. The IFCB has demonstrated its value in our study at Ward Aquafarms, in Dr. Campbell's monitoring efforts on the Texas Gulf Coast, and in many other deployments and studies not mentioned in this testimony. The ESP continues to be used in the Great Lakes and on the East and West coasts, and is simultaneously undergoing further development and optimization at MRL and with our scientific partners. MRL has made significant investments in exploring these new technologies, and we would like to thank our partners for their enduring support and capacity for innovation.

Thank you, Mr. Chairman and members of the Subcommittee. It has been a pleasure to introduce MRL and some of our technologies. I hope that my testimony has been helpful in shining a light on just a couple of the tools available for HAB detection and monitoring, developed in cooperation with research teams in their studies of HABs. I welcome any questions that you or other members of the Subcommittee may have.

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[10] Hoagland, P., Anderson, D.M., Kaoru, Y., White, A.W. The Economic Effects of Harmful Algal Blooms in the United States: Estimates, Assessment Issues, and Information Needs. Estuaries, Vol. 25, No. 4b, 2002 (819-837)

[11] Corcoran, A., Dornback, M., Kirkpatrick, B., Jochens, A. A Primer on Gulf of Mexico Harmful Algal Blooms. October 2013. URL: http://gcoos.tamu.edu/documents/HabPrimer-10162013.pdf