Deploying Dissolved Oxygen Sensors On Crab Pots for Ocean Observations

Researchers Partner With Fishermen to Use Auto-Reporting Bottom-Positioned Sensors for Ocean Research

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Over the past decade, regional ocean observing systems have been established along nearly the entirety of the U.S. coastlines, forming a major component of the national Integrated Ocean Observing System (IOOS). Observations from these systems provide information to support decision making by governmental agencies and commercial enterprises, such as shipping and fishing.

A major challenge facing any observing system is achieving cost-effective spatial and temporal coverage for resolving the physical, biological and chemical processes that occur in the coastal ocean, with timescales ranging from less than a day to decades and spatial scales from a kilometer to coastwide. Observational buoys are too few, and ship-based towed platforms can only cover a small area of the ocean for a limited amount of time. AUVs, such as gliders, combine some aspects of ship-based and moored platforms; however, in the coastal ocean the operational costs remain relatively high.

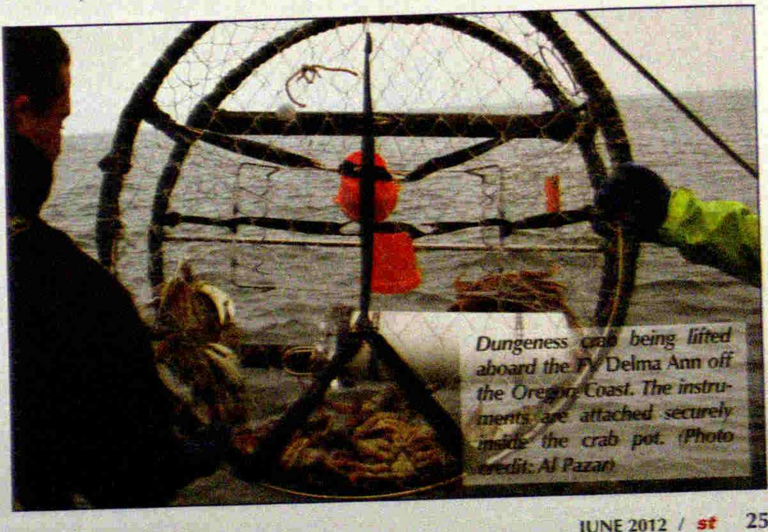
One strategy for increasing coastal ocean observations is collaborating with fishermen to use their vessels and their gear as sensor platforms. A few programs have developed to take advantage of this natural collaboration to achieve a greater density of observations. Since 2001, the eMOLT (Environmental Monitors on Lobster Traps) project has been collaborating with lobster fishermen in the Gulf of Maine, deploying temperature sensors and recently adding surface drifters and bottom current measurements using a new inclinometer device.

The Dungeness crab fishery along the U.S. West Coast offers a similar opportunity for collaboration. Off Oregon for example, the Dungeness crab season runs from December 1 through August 14 (although the fishing tapers off rapidly over the first few months). During the crab season, more than 350 vessels deploy up to 500 crab pots, steel traps about 1 meter in diameter that rest on the seafloor and attract crab, with bait. Each pot is a potential platform for scientific observations.

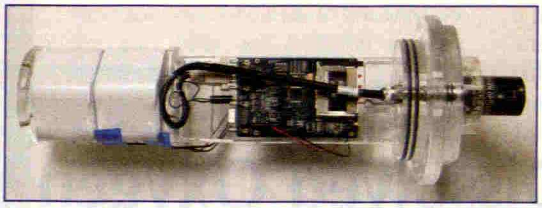
Oregon Fishermen in Observational Research

In 2005, the authors began collaborating with commercial Dungeness crab fishermen on the central Oregon coast and deployed temperature sensors on fishermen's gear. The project began with one fisherman out of Newport, Oregon, deploying 20 crab pots with sensors. The project has expanded each year and now has 15 participating fishermen from Port Orford, Oregon, to Quinault, Washington, deploying 80 temperature sensors in their crab pots and on their surface floats (the surface to bottom temperature difference can be used as a proxy for bulk stratification).

Pots are deployed in water depths ranging from 2 to 50 meters, and the location is typically repeated year to year. Temperature is measured using Onset Computer Corp.'s (Bourne, Massachusetts) TidBit temperature loggers, and measurements are recorded every 10 minutes and averaged into hourly values. The fishermen log the GPS time and position and water depth from the ship's echosounder at each deployment and recovery. Fishermen also record catch data per recovery.



Dungeness crab being lifted aboard the F/V Delma Ann off the Oregon Coast. The instruments are attached securely inside the crab pot. (Photo credit: Al Pazar)



The instruments used for this project consisted of a sensor, data logger and batteries. (Photo credit: J. Childress)

In 2009, the authors expanded their collaboration with commercial crab fishermen to include observations of near-bottom dissolved oxygen, using a sensor designed in-house. The dissolved oxygen instrument packages were designed with the specific goals of making high-quality measurements of benthic dissolved oxygen and having a low overall cost per unit so that an array of instruments can be deployed for concurrent monitoring of dissolved oxygen at higher spatial resolution than present.

Dissolved Oxygen

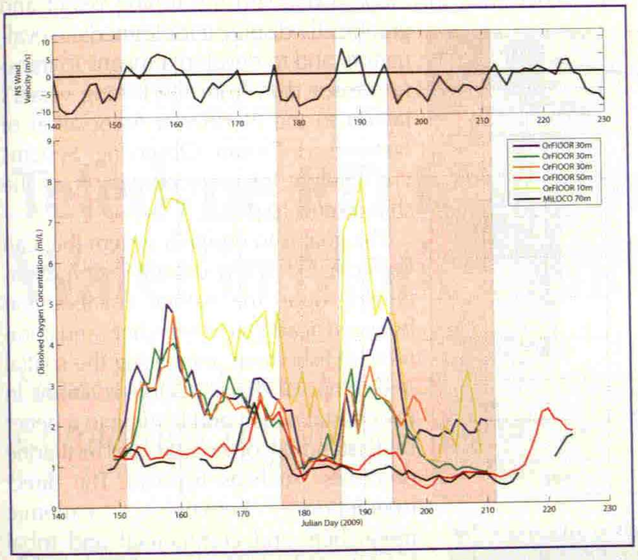
Dissolved oxygen has been identified by the IOOS as a core variable because it is directly related to the health of coastal and estuarine ecosystems. Dissolved oxygen concentrations strongly affect community abundance and structure, and below a minimum level (hypoxia), aquatic animals that cannot escape to more oxygen-rich regions will die. The development of hypoxia affects estuaries and the coastal ocean in a variety of regions, leading to mass mortality events and extreme changes in ecosystems, so understanding the underlying processes are very important. Dissolved oxygen concentrations are controlled by a combination of physical and biological processes, such as vertical mixing and respiration, and as a result vary on a range of time and space scales, pushing the limits of existing observational capabilities.

In recent years, the variability of dissolved oxygen and development of hypoxia over the inner shelf has become a major focus along the coasts of Oregon and Washington. In the summer of 2002, an episode of hypoxia led to widespread die-offs in commercially important species. At that time, the occurrence of hypoxia along the open coast, in the relatively shallow (inshore of the 50-meter isobath) water was unprecedented. However, since then, hypoxia over the inner shelf has developed every year, although the extent, duration and severity vary considerably.

Dissolved oxygen is directly related to the process of ocean acidification, and proxies for ocean pH levels (Aragonite saturation state) have been developed based on temperature and dissolved oxygen. Maps have been created along the entire U.S. West Coast, although considerable interpolation is applied given the large spacing of the measurements. The observations from the crab pot collaboration will serve to increase the observations available to evaluate acidification in the coastal ocean.

Sensor Deployment

Dissolved oxygen sensors that also measure temperature were deployed on five crab pots at five locations along the central Oregon coast from May 28 to August 11, 2009. Locations were chosen to capture cross-shelf and alongshore



Day average dissolved oxygen concentrations from five sensors deployed in the summer of 2009.

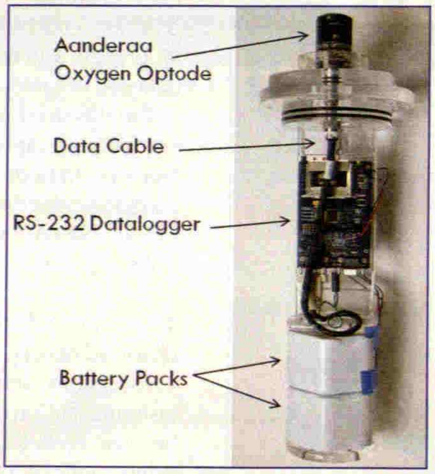
changes in dissolved oxygen concentrations in a region with consistently recurring hypoxic conditions. These locations were also consistent with the cooperating fisherman's normal fishing grounds to minimize inconvenience to his work.

The instruments, measuring 13 centimeters by 13 centimeters by 53 centimeters, were deployed inside the crab pots using stainless steel worm clamps to secure them to the steel frames. Sampling commenced once the units were powered on using a magnetic reed switch operated by the vessel master or crew and ceased when the units were turned off or the batteries became depleted.

The dissolved oxygen units are comprised of four primary components: an Aanderaa Data Instruments AS's (Bergen, Norway) 3835 dissolved oxygen and temperature sensor that communicates data via RS232 serial protocol, an RS232 data logger, battery packs and an underwater pressure case. Although the sensor also measures temperature, it will be referred to as the dissolved oxygen unit. This setup is rated to 300 meters, which is the same depth rating as the Aanderaa dissolved oxygen sensor.

To record serial data from the sensor, the Acumen Instruments Corp. (Ames, Iowa) DataBridge SDR2 was used because of its ability to log serial data to flash media while using minimal power. Data are saved in text documents (extension .dat) and can easily be read and analyzed in Microsoft Excel or MATLAB.

The battery packs used to power the sensor and data logger are purchased from the Sexton Co. (Salem, Oregon) and provide 20,500 milliampere-hours at 10.5 volts. The packs are made from seven D-cell alkaline batteries and a protection circuit to safeguard the batteries and equipment should a malfunction occur. The batteries are shrink-wrapped into a cylinder, with six cells around and one in the middle. These battery packs can then be stacked and fit inside a 4-inch-inner-diameter waterproof PVC pipe casing designed by the Sexton Co. A machined acrylic endcap mounts on the front with a double O-ring seal and allows the researchers and fishermen to look inside the unit, confirming that the equipment is operational and that there are no leaks. The sensor is mounted into the endcap and is protected by a stainless steel guard to prevent against mechanical damage. A magnetic thumbscrew is used to power the unit on and off by way of a magnetic reed switch inside the pressure case.



Schematic view of a dissolved oxygen unit. The instrument was designed and manufactured with the Sexton Co. and is shown without the PVC pressure case. (Photo credit: J. Childress)

Results

The dissolved oxygen sensors sampled on 10-minute intervals subsequently averaged to hourly values. Sensors were calibrated before and after deployment. The dissolved oxygen observations compared favorably with the moored measurements and showed a wide range of variability on short temporal and spatial scales. The researchers avoided potential biases in dissolved oxygen measurements by having the fishermen maintain a single deployment location, rather than following the most productive fishing grounds. Likewise, flushing times for a crab pot are much shorter (less than 10 seconds) than the response time of the dissolved oxygen sensor (approximately 25 seconds).

The dissolved oxygen observations for the 2009 field season showed a range of variability, primarily related to changes in the coastal winds and upwelling. Generally, shallower depths had higher dissolved oxygen concentrations, but values in shallow water could collapse to extremely low—hypoxic—values when the winds were to the south (upwelling-favorable) for extended periods of time. The dissolved oxygen measurements on crab pots compared well to nearby observations from a more traditional mooring.

Next Steps

Sensors were deployed again in 2011 and are tentatively scheduled to take additional samplings this summer. One planned improvement is to add a real-time reporting capability to the commercially deployed sensors, making the data immediately available to fishermen in their vessels and the ocean research community.

Expanding the collaboration with commercial Dungeness crab fishermen in Oregon is proposed, measuring dissolved oxygen and temperature in estuaries and the coastal ocean. Specifically, the plan is to add the ability to automatically download data to a laptop onboard the fishing vessel and graphically display it for immediate evaluation, and to develop a means to transfer sensor data from the fishing vessel's laptop to the Northwest Association of Networked Ocean Observing Systems via wireless Internet connection as the ship returns to port.

The goal is to design a system that can be recreated in any coastal region, capitalizing upon the natural collaboration between academic researchers and commercial fishermen, increasing the spatial and temporal density of observations in the coastal ocean and leading to a better understanding of coastal and estuarine processes, such as hypoxia. The direct interaction between academic researchers and commercial and tribal fishermen has already resulted in a greater exchange of information.

Previous efforts have shed new light on the extent and scale of dissolved oxygen variability in the coastal ocean, and the next steps will offer a direct benefit to the fishermen in terms of near-real-time data relevant to the fishery.

Acknowledgments

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Jeremy L. Childress, designer and project manager for the Sexton Co., studied marine biology at Millersville University. For graduate school, he studied marine resource management at Oregon State University and researched crab pots as platforms of opportunity for ocean observation. Childress also serves as chair for the Marine Technology Society's Oregon section.