MOMS: BODEGA MARINE LABORATORY'S
METEOROLOGICAL AND OCEANOGRAPHIC MONITORING SYSTEM

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Abstract

The Bodega Marine Laboratory (BML) is implementing a local data management system, which includes an array of sophisticated data-acquisition sensors that make up its Meteorological and Oceanographic Monitoring System (MOMS). Meteorological and marine sensors placed on Bodega Marine Reserve, aboard the Laboratory's research vessel, in open ocean and Bodega Harbor will measure a variety of environmental factors including: wind speed and direction, relative humidity, air temperature, insolation, barometric pressure, wave and tidal height, and water temperature and salinity. The majority of these sensors will be linked by cable to a BML-based recorder and to a statistical computer and monitor (SCM) specifically designed for this application. Remote data loggers for the terrestrial and harbor stations will be downloaded using a tape reader. Data from MOMS will be accessible via modem. The National Weather Service will access data every three hours. Researchers at Scripps Institution of Oceanography and other institutions will also have access to the data. When complete, the BML data management system will integrate information generated from MOMS, scientific research, the BML Library, and the Laboratory's synoptic collection.

INTRODUCTION

Minicomputers, microcomputers and environmental monitors are changing the way scientists approach field investigations. Fixed and portable monitors are now capable of continuously sampling, displaying and storing large quantities of environmental data that were traditionally collected in labor intensive manners. Access to real-time data gives researchers the information necessary to modify field sampling strategies in response to changing environmental conditions. Data stored in electronic format can rapidly be queried, manipulated and correlated with other variables, while telecommunication capabilities will facilitate data exchange among institutions. A computerized
data management system is one means of providing a complete picture of the information available about a site. The Bodega Marine Laboratory (BML) is implementing a local data management system, a major component of which is an array of sophisticated data-acquisition sensors that make up its Meteorological and Oceanographic Monitoring System (MOMS).

**BODEGA MARINE LABORATORY—DESCRIPTION AND RESEARCH**

The Bodega Marine Laboratory (BML) is an organized research unit of the University of California (UC) administered by the Davis campus. Located 80 km north of San Francisco, California, on the Sonoma County coast, the Laboratory buildings are situated on the 132 ha Bodega Marine Reserve, one of 27 reserves in the UC Natural Reserve System. While the reserve includes only the area above mean high tide, the area extending 300 m offshore has been designated the Bodega Marine Life Refuge by the State Legislature, effectively increasing the size of Bodega Marine Reserve. The Laboratory also leases 36 ha of mud- and sandflats in Bodega Harbor.

The Laboratory offers access to a diverse array of coastal habitats. Intertidal habitats include exposed and semi-protected sandy beaches, salt marshes, estuaries and rocky intertidal shoreline. Terrestrial habitats include sand dunes, dune-strand areas, coastal prairie, freshwater marshes and a small riparian woodland. Elevation changes from sea level to 58 m on the property and to 12 m depth subtidally. Except for the sandy beach in Horseshoe Cove, the ocean-frontage features a steep cliff plunging to a rocky shoreline. The San Andreas Fault runs along the eastern portion of the reserve causing obvious topographic and vegetative changes. The non-ocean facing portion of the property is bordered by state and county parks and by Bodega Harbor, which has extensive mudflats and sandflats. Marinas within the Harbor provide good float and piling habitats. The town of Bodega Bay is a tiny fishing community that supports a moderate tourist industry while surrounding areas are coastal grasslands grazed by livestock.

The climate in Bodega Bay is characterized as “cool and wet” during winter (mean temperature of the coldest month is 6°C) and “cool and dry (but foggy)” in summer (mean temperature of the warmest month is 18°C). Northwestern winds predominate and are usually quite strong in spring months. Winter storms come from the south with strong winds, heavy seas and rainfall. Over 90% of the annual rainfall (79 cm/yr) falls between the months of October and April. During the summer months, the coast experiences heavy fog cover more than 50% of the time. Fog usually dissipates in late morning and returns in late afternoon.

**Bodega Head** is subjected to continual intense wave action. Average daily wave height is approximately 2.5 m although during periods of heavy winter storms heights of 5-10 m are not uncommon. Strong coastal upwelling produces consistent seawater
temperatures in the range of 9-13°C. High winds, heavy seas and strong coastal upwelling make the local waters extremely turbid and dangerous. Eight fishermen died in local storms in one recent 12 month period. "Sneaker waves", averaging 6.5 m in height, frequently hit the coast and enter the harbor. These unpredictable waves are responsible for numerous deaths and boat capsizeings each year.

Documented research has been conducted in Bodega Bay since the early 1930's when S.F. Light brought students to the area from UC Berkeley. The first Laboratory building was constructed in 1964 with a grant from the National Science Foundation (NSF). Organized year-round research and teaching has been conducted on-site since that time. There are two types of research activities at BML—laboratory-based investigations and field-related studies that take advantage of the reserve and surrounding habitats. Fourteen scientists, 21 graduate students and 40 technicians and staff are in residence at the laboratory full-time. Several scientists from the National Marine Fisheries Service (NMFS) also share BML facilities on a routine basis. In addition, 17 scientists and 24 graduate students active research programs at the facility. BML also hosts numerous visiting scholars who come to the facility for varying lengths of time from throughout the United States and the world.

The laboratory supports research in the fields of aquaculture and fisheries, biochemistry, biophysics, botany, cell biology, ecology, entomology, marine geology, marine toxicology, physiology and zoology. Samples of current research include: nutritional biochemistry of marine fish and invertebrates; endocrinology and physiology of marine crustaceans and molluscs; population genetics of marine fish, invertebrates and coastal flora; reproductive physiology of marine shrimp; toxicity of bleached kraft mill effluent on marine organisms; and cellular biology with emphasis on the role of water in cell structure. Field studies include: community organization of insect herbivores; ecology and floral visitation behavior of bees; physical factors affecting intertidal organisms; structure of wintering shorebird populations; effects of bird and fish predation on intertidal organisms; ecology of monkey-faced eels; and effects of soil nitrogen, protein and toxic chemical concentrations of Lupinus arboreus on insect populations.

METEOROLOGICAL AND OCEANOGRAPHIC MONITORING SYSTEM (MOMS)

To complement the basic research conducted at BML certain baseline data about local environmental conditions are an asset to researchers. This information is also valuable to local fishermen and boaters. Certain weather parameters have been recorded at the site since the 1960's. These data are acquired by manual means—each morning (except weekends, holidays, vacations or sick leaves) a technician reads a thermometer, checks a barometer and measures sea water temperature. This methodology has provided general information about environmental trends but cannot tell a researcher what
a specific variable was at a given time on a specific date. Oceanographic conditions have been similarly sampled. A buoy outside the entrance to Bodega Harbor records sea and air temperature. Researchers or fishermen who need information about sea conditions, wave height, wind speed, etc. call the local U.S. Coast Guard (USCG) station in Bodega Bay. The person answering the telephone looks out the window and gives the caller an idea about local weather conditions. Since the Coast Guard station is in a protected harbor behind a breakwater, estimates of wave height and activity are seldom accurate.

In an effort to provide continuous and reliable environmental data BML is installing a Meteorological and Oceanographic Monitoring System (MOMS). The purpose of the system is to collect and organize data about ambient weather and oceanic conditions that are commonly used by more than one investigator. These data will be immediately available through a computer terminal or stored in electronic format for later use. Three years of effort by SEADATA Corporation (now part of Pacer Systems) has produced an automated system that will record data from a variety of land-, sea- and vessel-based sensors. The three basic components of the system are fixed and mobile land-based weather stations, a moored subtidal ocean monitoring system, and a variety of sensors aboard the Laboratory's research vessel. Three NSF grants and one grant from the National Oceanic and Atmospheric Administration (NOAA) funded the system’s hardware.

The fixed weather station, mounted on a 10 m tower on the BML roof, measures wind speed and direction, solar radiation (global sun and sky radiation), barometric pressure, relative humidity and temperature (Table 1). Data are sampled every 0.25 to 1 second. Two micro-climate stations will be located elsewhere on the reserve and two portable micro-climate stations will be carried to different sites (depending on need) by interested researchers. Data recorded at specific sites can then be compared to fixed-station data in order to better understand the reserve's numerous microclimates.

**TABLE 1. WEATHER MONITORING STATION.**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SENSOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind speed and direction</td>
<td>R.M. Young Wind Monitor (Model 05103)</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>Li-Cor Pyranometer Sensor</td>
</tr>
<tr>
<td></td>
<td>(Model LI-2005B)</td>
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<tr>
<td>Barometric pressure</td>
<td>YSI Barometric Pressure Transducer</td>
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<tr>
<td></td>
<td>(Model 2014)</td>
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<tr>
<td>Relative humidity and</td>
<td>Vaisala Humidity and Temperature</td>
</tr>
<tr>
<td>temperature</td>
<td>Probes (Model HMP IIIA)</td>
</tr>
</tbody>
</table>

The main oceanographic station sits on a 6 ton subtidal concrete and steel mooring at the mouth of Horseshoe Cove at a depth of 12 m. This mooring, supplied by NMFS, is actually composed of several weights once used to hold anti-submarine nets in place
across San Francisco Bay in World War II. The USCG assisted the Laboratory in constructing, transporting and deploying the mooring. The USCG Cutter BLACKHAW, with the assistance of BML's vessel, the SUSAN K, deployed the mooring on one of the foggiest days of the summer of 1986. Heavy seas and dense fog caused the mooring to be placed at an angle in the wrong place. Teams of BML divers later moved the 6 ton mooring, with the aid of many float bags, to its proper location near the opening of Horseshoe Cove.

Subtidal sensors attached to the mooring measure tide and wave height. Additional sensors, located at BML seawater intake, sample seawater salinity and temperature at intervals of 0.25 to 1 second. (Table 2). In addition to subtidal monitors in Horseshoe Cove, a remote data logger located in Bodega Harbor measures harbor tidal height. Over 350 m of heavy iron chain was laid on the ocean floor to serve as an anchor for the cable carrying data from the instrumentation to the BML-based computer and monitor. BML divers located and marked a path for the cable along the ocean floor. The SUSAN K hoisted 10 m sections of the chain overboard to divers who shackled sections in place along the ocean floor. The ends of the chain were bolted to the fixed mooring and to concrete slabs around the Laboratory's seawater intake system. The cable, which will carry signals from instruments to computers, has not yet been deployed. Selecting a cable capable of withstanding tremendous wave action was a challenge in itself. The cable consists of copper wires shrouded in plastic, surrounded by electrical tape, encased in plastic, surrounded by two rows of steel cable, and finally wrapped in plastic several mm thick. The cable is expected to have a life span of 5 years in the intertidal zone. The cable will be bolted to the chain by BML divers and connected to instruments in the coming months.

**TABLE 2. OCEANOGRAPHIC MONITORING STATION.**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SENSOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tide and wave height</td>
<td>Paroscientific Pressure Transducer</td>
</tr>
<tr>
<td>Seawater salinity</td>
<td>Seabird Conductivity Meter</td>
</tr>
<tr>
<td>Seawater temperature</td>
<td>Thermisters</td>
</tr>
</tbody>
</table>

Sensors are not yet in place aboard the laboratory's research vessel. Proposed equipment will measure: wind speed and direction; sea surface temperature; luminous intensity; barometric pressure; and conductivity and temperature with depth. Additional equipment will include a color video echo sounder, acoustic doppler current profiler and a plotter-Loran C interface. This instrumentation will be used to perform monthly transects on fixed stations or to gather data for specific research projects.

Sensors on the fixed weather and oceanographic stations are hardwired to the laboratory and are received by IBM- and IBM-compatible PCs, recorders and a statistical computer and monitor (SCM) designed specifically for BML by SEADATA. (The
oceanographic SCM was delivered the last week of September 1987.) Data are downloaded into the laboratory's PDP-11 minicomputer, IBM- and IBM-compatible microcomputers and are stored on floppy disks and magnetic tapes. Data from remote and mobile sensors are downloaded by a tape reader and added to the system. Data are stored in coded format and can be accessed and manipulated with a number of commercially available software packages. In the future, the backlog of meteorological data collected over the past 23 years will be manually added to the database. All computers and monitors associated with the system are connected to uninterruptable power supplies to guard against power failures (a common problem at our remote location during winter storms). BML has two diesel generators to provide emergency power when the electricity fails.

The information logged and stored by the MOMS system will be available to BML researchers directly and to outside users via a modem. The National Weather Service (NWS) will access the data every 3 hours to update marine and coastal forecasts for fishermen and boaters. Investigators at Scripps Institution of Oceanography (SIO) will access the system for a variety of Coastal Ocean Dynamics Experiment (CODE) related projects. NWS and SIO are sharing in the maintenance costs of the telecommunication hardware. The Laboratory has no immediate plans to charge fees for access to or information provided from the system. A description of the system and data sets will be filed with the National Environmental Data Referral Service (NEDRES) to make its existence known to other researchers.

**BML DATA MANAGEMENT SYSTEM**

The MOMS instrumentation is one source of data feeding into BML's broad-based data management system. Although still in the development stage, this system will be composed of four additional types of information. First are data generated from lab- and reserve-based research and monthly research cruises on fixed transects. Second are bibliographic data from BML's library. Third are specimens in BML's synoptic and herbarium collections. Lastly is information contained within a geographic information system (GIS), a specialized data management system used to store and retrieve cartographic data. Maps of the terrestrial and mudflat portions of the reserve are currently being digitized as the first step in creating the GIS. Intertidal areas will be digitized at some future date.

When fully implemented, the BML data management system will reduce the time researchers spend locating, compiling and synthesizing data, thereby increasing the time available to them to analyze and test hypotheses. Automation of this information allows high speed transmission of data, making it available to other locations and permitting comparisons which would be very costly in a different format. The data management system, centralising all known information about local habitats and organisms, will foster new research at BML since researchers will have a wealth of environmental data,
biological inventories, and research at their fingertips. These data, accumulated by thousands of scientists over a span of time, will provide new researchers with the background information necessary to formulate and answer new questions about our unique environments.

BIBLIOGRAPHY


