

SOP 5 – Spatial Water-Quality Monitoring with LiCor PAR Instruments

Version 1.0 (August, 2007)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The Project Leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to Instructions for Recording Revisions in SOP 13.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

Introduction

This SOP describes the methods for spatial monitoring of underwater photosynthetically available radiation (PAR) throughout the NER coastal parks. At each park, 30 stations are occupied during a four-week late-summer index period. Depth profiles of PAR are measured using a LiCor LI-1400 console equipped with one underwater quantum sensor (LI-192SA) and one quantum sensor in air (LI-190SA “deck sensor”). The attenuation coefficient of downwelling PAR (K_d) is calculated from these data. Caruthers et al. (2001) provide a good primer on measuring the attenuation coefficient of PAR. We specify 2-pi sensors because they are robust and easier than 4-pi sensors to keep free of biofouling over long-term deployments. Although not relevant to this SOP, it makes practical sense to use the same sensor design for both spatial and continuous monitoring. Although 2-pi sensors theoretically measure downwelling rather than scalar irradiance (4-pi) the difference in attenuation coefficient measured with the different sensors is extremely small and negligible (Gallegos 1993, Moore and Goodman 1993, Moore et al. 1997).

Photosynthetic photon flux density (PPFD) is a highly erratic variable, so a certain degree of time averaging is necessary in order to smooth the data. This SOP calls for 15 second averaging of irradiance at each depth in the profile. It also calls for irradiance at depth to be reported as a percentage of the instantaneous irradiance in air. This latter step corrects for any error that would be introduced by changes in the incident solar irradiance over the period of time it takes to complete a full profile of the water column.

The purpose of this SOP is to standardize instrument programming, assembly, calibration, and use throughout the NER coastal parks. It provides step-by-step instructions as they pertain specifically to this monitoring protocol. It is outside the scope of this SOP to comprehensively review all of the information and methods that are required to operate these LiCor instruments and to make effective and accurate measurements. It is imperative that both field and laboratory personnel familiarize themselves with the LiCor LI-1400 Datalogger Instruction Manual and the LiCor Radiation Sensors Instruction Manual (for both the terrestrial and underwater type SA sensors). Although the LI-1400 has data logging capabilities, data are recorded manually in this protocol. The LI-1400 serves here as an easily programmable controller and display interface for the PAR sensors and performs some simple calculations and data averaging functions. It is possible to use the logging function as well, but the nature of the data from this SOP make manual logging more expedient.

Equipment requirements for this SOP include the following:

- LiCor LI-1400 data logger
- LiCor LI-192SA Underwater Quantum Sensors (2- π cosine-corrected)
- LiCor LI-190SA Terrestrial Quantum Sensors (it is recommended that this NOT be the sensor reserved for calibration purposes in the SOP on Continuous Monitoring with the YSI sonde)
- LiCor LI-2222UWB 10 m underwater cable
- LiCor LI-2003S mounting and leveling fixture for LI-190SA quantum sensor.
- LiCor LI-2009S lowering frame
- LiCor LI-1400 Data Logger Instruction Manual
- LiCor Radiation Sensors Instruction Manual: Terrestrial Type SA
- LiCor Radiation Sensors Instruction Manual: Underwater Type SA
- Personal computer with an RS232- compliant serial port (or USB to serial converter)
- RS232 cable (DTE to DTE with DE9 connectors)
- LiCor LI-1400-501 PC Communications Software
- AA-size alkaline batteries
- 7 oz “egg” or “bank” lead sinker

PAR Sensor Calibration

LiCor, Inc. recommends biennial factory calibration of its LI-192SA and LI-190SA quantum sensors. While more frequent factory calibration is recommended for sensors deployed by the NPS for continuous monitoring (see SOP on Continuous Water-Quality Monitoring with YSI Sonde), biennial calibration is sufficient for the discrete profiling described here. Should, however, the acrylic diffuser lens become scratched or the black paint (in the annular recess around the diffuser) peel or fade, then repair and recalibration is required. Both deck (LI-190SA) and underwater (LI-192SA) PAR sensors are factory calibrated in air. “Multipliers” are provided by LiCor that allow the electrical output for individual sensors to be converted into real values of PPFD (in units of $\mu\text{moles photons m}^{-2}\text{s}^{-1}$). For the underwater sensor, both “in air” and

“in water” multipliers are reported by LiCor. The latter accounts for immersion effects and is calculated from the “in air” value based upon an empirical relationship (“in water”=“in air”/ 1.32).

LiCor, Inc provides weatherproof calibration tags as part of their calibration services. For the deck sensor (190SA), this should be kept attached to the sensor’s cable. For the underwater sensor (192SA) this should be attached to the deck end of the underwater cable used for profiling. This provides a quick reference for checking that correct multipliers have been entered into the LI-1400.

LI-1400 Programming and Preparation

At the beginning of each field season, install four fresh C-size alkaline batteries according to the directions in the LI-1400 Data Logger Instruction Manual. These batteries are likely to last for the duration of the index period. The best approach to tracking battery charge is to activate the battery voltage channel and check it regularly. As a backup to manually checking the battery voltage, the LCD display on LI-1400 will blink on and off when the voltage drops to 4.0 V (the nominal full-charge voltage is 6.0 V). The unit will then shut off when the voltage falls to 3.8 V. Batteries should be replaced well before this occurs, with the goal of avoiding the need to replace batteries in the field.

Programming the LI-1400 can be done either directly using its membrane keypad, or indirectly by downloading programming instructions from a personal computer running LI-1400-501 PC Communications Software. The latter is significantly more intuitive and is described in the following steps.

- i. Launch the LI-1400-501 software and open a “NEW” programming document from the <File> menu
- ii. Highlight channel <I1> and select “light” as the sensor type
- iii. Fill in each of the fields as follows:
 - a. <Description> - enter the serial number for the underwater sensor (“UWQxxxx”)
 - b. <Channel Label> - enter “UW” (underwater photosynthetic photon flux density)
 - c. <Multiplier> - enter the “in water” multiplier from LiCor factory calibration certificate for the underwater sensor
 - d. <Average> - select 15 seconds
 - e. <Logging Options> - select “none”
- iv. Highlight channel <I2> and select “light” as the sensor type
- v. Fill in each of the fields as follows:
 - a. <Description> - enter the serial number for the deck sensor (“Qxxxxx”)
 - b. <Channel Label> - enter “Air”
 - c. <Multiplier> - enter the multiplier from LiCor factory calibration certificate for the deck sensor

- d. <Average> - select “15 sec”
 - e. <Logging Options> - select “none”
- vi. Highlight channel <VB BATT VOLTAGE> and select “Battery” as the <Sensor Type> and “none” as the <Logging Routine>.
- vii. Highlight channel <M1> and select “General” as the sensor type.
- viii. Fill in each of the subsequent fields as follows:
 - a. <Description> - enter “percent air”
 - b. <Channel Label> - enter “%A”
 - c. <Input Channel> - select “I1”
 - d. <Average> - select “15 sec”
 - e. <Math Function> - select “none”
 - f. <Channel Operation> – select “edit”
 - i. <Operator> - select “/”
 - ii. <Channel> - select “I2”
 - iii. <Function Type> – select “Poly”
 - iv. <Description> - leave blank
 - v. <Parameter a1> - enter 100
 - vi. leave remaining Parameters (a0 and a2-a5) set to 0
 - vii. select “OK”
 - g. <Logging Options> - select “none”
- ix. Select the <File> menu and save this program as “LiCor spatial survey setup”.
- x. Using the RS232 cable and serial ports, establish communication between the LI-1400 and PC (select “Connect” from the <Remote> menu).
- xi. Download the program to the logger (select “Send Setup” from the <Remote> menu).
- xii. Reset the time on the LI-1400 to local time (select “Set Time” from the <Remote> menu). For all anticipated use of this SOP, the time standard will be Eastern Daylight Savings Time.

- xiii. The LI-1400 is capable of simultaneously displaying the output from two different data channels. Follow guidance in the LI-1400 Datalogger Instruction Manual and adjust the display so that the first line is reporting output from the underwater sensor, and the second line is reporting the output from the math channel (which reports the percent of incident PAR reaching the depth of the underwater PAR sensor). If you have programmed the logger as described above, the display should look as follows (with “xxxxxx” replaced by actual values from the channels once the sensors are plugged in).

I1A xxxxxx UW

M1A xxxxxx %A

- xiv. The LI-1400 is now programmed for use.

Instrument Assembly

Attach the underwater 2 pi PAR sensor to the lowering frame in the “downwelling” (upward looking) position using the insulated screws and insulating washer provided by LiCor. These provide electrical insulation to help protect against galvanic corrosion of the aluminum lowering frame. Attach the underwater cable to the PAR sensor and lowering frame following guidance in the LiCor Radiation Sensor Instruction Manual.

Since no upwelling sensor is required for this SOP, the lowering frame will need to be balanced with weights to hang properly. Best performance and adjustability is achieved by adding approximately 210g of weight (approx 7.25 oz) in the “upwelling” sensor position. Lead “egg” or “bank” fishing sinkers work well for this purpose. This allows the lowering frame to hang properly with the least amount of weight. Additional weight can then be added to the bottom center ring as needed for different current conditions.

Attach a lowering rope to the top eye of the lowering frame. A low-stretch rope is required for this purpose. Quarter-inch double-braided polyester is preferred, but polypropylene ropes are also acceptable (they are also low stretch but much more difficult to tie). Nylon and natural fiber ropes are unacceptable. Tie in to the lowering harness using a bowline or anchor bend. Attach the underwater cable to the lowering rope at approximately 25 cm intervals along its entire length using black plastic electricians’ tape, making certain that there is slightly more slack in the cable than the rope. This will ensure that the rope is stressed rather than the cable. Using colored electricians tape, mark off depths on the lowering frame and lowering rope. Do not mark the underwater cable because your marks may migrate if the cable slips along the lowering rope. Make certain to reference all measurements against the depth of the diffuser on the PAR sensor. Depth increments should be 0.1 m for the first meter, 0.2 m for the second meter, and 0.5 m thereafter to a depth of 4 m. The rest of the cable is not needed and can be coiled and bundled with cable ties. Use an indelible marker to record the depths on the tape. Depth markings should be rechecked for accuracy at the beginning of each field season.

Install the LI-190SA terrestrial quantum sensor on the mounting and leveling fixture using the supplied Allen wrench and set screw. This deck cell will need to be placed in a location on the boat where it will not be shaded by personnel or equipment. This can be accomplished by either permanently attaching the mounting and leveling fixture to a high location on the boat (in which

case the 190SA is kept in the fixture only when conducting field work), or by using heavy duty Velcro® with pressure sensitive adhesive to create several mounting locations around the vessel.

Attach the end of the underwater cable to channel I1 on the LI-1400 via the BNC connector, and attach the deck sensor to channel I2. Channels are labeled on the back of the LI-1400: when looking from the front, the underwater connector should be plugged in at the left, and the deck sensor plugged in at the center.

Making Measurements

Light profiles should be measured within three hours of local apparent noon. This is a slight extension to the interval recommended by Carruthers et al. (2001), but it is possible to partially correct the attenuation coefficient for changes in solar angle due to refracted direct solar beam (McPherson and Miller 1993). Maximum zenith angles for this sampling window will be approximately 45°, and this would only be expected to generate a 0.8% increase in surface reflectance above that when the sun is directly overhead (Kirk 1994). Thus measuring PAR within 3 hours of local apparent noon will generate very good data without excessively shortening the field day.

At each station, a light profile is measured by suspending the lowering frame at a series of depths and recording the underwater irradiance as both a PPFD (channel I1) and a percentage of incident PAR (channel M1). The goal is to measure these values at six to eight depths within the photic zone. Readings should be spaced closer together near the surface where PAR attenuates the fastest. A good starting point for most parks in the NER will be to take readings at the following depths: 0.1 m, 0.2 m, 0.4 m, 0.8 m, 1.4 m, and 2.0 m. The deepest measurement should read below 5% on channel M1. Add additional depth readings up to 3.0 m until this is achieved or the bottom is reached. For very turbid and/or shallow stations, compress the six to eight readings into less depth. Do the opposite for stations with clear deep water. This task is accomplished as follows:

- i. Once on station, place the deck sensor in a position where it will not be shaded by any equipment or personnel.
- ii. Add sufficient weight to the bottom ring on the lowering frame so that it will hang vertically in any currents.
- iii. Working on the sunny side of the boat, suspend the lowering frame to the 0.1 m depth mark. Make sure that nothing is shading either of the sensors. Reposition the boat or yourself if water currents spin the lowering frame into a position that causes it to shade the underwater sensor.
- iv. Once at the proper depth, wait for a minimum of 15 seconds while the running average is updated. Pay the cable in and out as necessary to cancel out any motion of the vessel and maintain a constant depth. If the sensor is accidentally raised or lowered during this time, you must wait another full 15 seconds from the time when the correct depth was reestablished.
- v. Record the values displayed for channel I1 (PPFD units of $\mu\text{moles photons m}^{-2}\text{s}^{-1}$) and channel M1 (% of incident PAR).

- vi. Repeat this process at each of the remaining depths (e.g. 0.2 m, 0.4 m, 0.8 m, 1.4 m, and 2.0 m). If the bottom is reached before completing the above depth increments, lower the frame to the deepest possible whole increment marked on the rope and record the 15-sec averages from channels I1 and M1.
- vii. All of the above data must be recorded on the Spatial Survey Station Data Sheet (Appendix D) along with notations on the time (local), cloud cover ($\pm 25\%$), wind direction, wind speed and sea state (Beaufort Scale), and water depth. For wind direction, use 0° when Beaufort Force is zero and use 360° when wind direction is from the north. If adding or repeating depth readings at a station, log them in the sequence they were measured (not necessarily by increasing depth). If you choose to redo a reading, do NOT erase or write over the discarded value with the new one. Strike out and initial the suspect value, but do so in a way that maintains the legibility of the datum. It may still be used to help troubleshoot attenuation coefficients with poor correlation coefficients. Record the new datum in the next available free space.

A light profile must be measured at each of the spatial survey stations each time they are sampled. If the spatial sampling is conducted as designed, then 6 trend stations plus 6 random stations are occupied for each of four weekly survey cruises. Light profiles must also be measured at the continuous monitoring station to check the performance of the continuous PAR sensors and to provide data for a post-deployment calibration should it prove necessary. At a very minimum, a light profile must be measured at the time the sonde is deployed, retrieved, and during each of the four weekly spatial survey cruises. Review the SOP for continuous water-quality monitoring to determine whether additional light profiles are needed. Light profiles are measured the same for the continuous monitoring station with the following additional requirements:

- i. It is very important that the light profile be measured as close in time as possible with a logging event on the continuous sonde. These logging events occur regularly on the quarter hour.
- ii. It is very important that, in addition to the profiling PAR sensors, the PAR sensors on the continuous YSI sonde not be shaded by the boat or any other equipment or personnel.

Equipment Maintenance, Handling and Precautions

Although LiCor describes the LI-1400 as weatherproof, the O-ring that seals the case is deliberately cut by the manufacturer to allow water vapor out of the case. Consequently, water can get inside the case and damage the circuitry. You may wish to replace the “cut” O-ring with an intact one to resolve this issue. If you do, understand that you will need to keep packets of silica gel inside the case to remove any residual moisture. These should be recharged or replaced each time the case is opened to service the batteries. Also note that several of the pins on the outside D-subminiature connectors carry voltages. If these pins get wet, particularly with seawater, they can become short circuited to ground and corrosion will occur. Take appropriate precautions to ensure that rain and spray do not come in contact with the LI-1400. In wet field conditions you may choose to cap the 9 and 25-pin D-subminiature connectors and the channel I3 BNC connector with dummy plugs and or place the LI-1400 inside a clear vinyl waterproof

camera bag. While the cables will prevent the bag from sealing properly, splash protection will still be afforded.

At the end of each field survey, rinse the underwater sensor and lowering frame with fresh water. If the deck sensor was splashed with seawater, it can also be gently rinsed with freshwater (do not use a high-pressure spray). The LI-1400 should be wiped clean with a wet sponge. Isopropyl alcohol can be used to clean and dry the BNC and D-subminiature connectors on the logger if they were severely splashed with seawater. The deck sensor is weatherproof and can withstand a light spray of fresh water, but should not be immersed. Be careful not to scratch the acrylic optical windows or damage the black paint within the annular rings on either of the sensors. LiCor ships its PAR sensors with protective caps, and these should be used whenever the sensors are in transit or storage. When cleaning the diffuser element on a PAR sensor, do not use alcohol, organic solvents, abrasives, or strong detergents. Mild dishwashing detergent and vinegar are acceptable cleaning agents.

References

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