MEASURING AND MODELLING THE DYNAMIC RESPONSE
OF REMOTE MOUNTAIN LAKE ECOSYSTEMS TO
ENVIRONMENTAL CHANGE

A programme of **MO**untain **LA**ke **R**esearch

MOLAR

WATER COLUMN PROFILING

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Water Column Profiling (Work Package 3)

1. Sampling objective

The main objective of water column sampling in work package 3 is to provide data for: (a) modelling the coupling between weather conditions, lake physics and lake biogeochemistry; and (b) studying the seasonal variability in mountain lakes with enough resolution to improve our understanding of organisms as environmental indicators.

2. Sampling design

Two sets of variables have to be considered: those fundamental for resolving the seasonal change of the lake, and for validating the models, which will be recorded at regular intervals; and those variables that can be measured occasionally in order to increase the potentiality of the models, and to investigate the causes of some of the responses observed in the master variables. Therefore, we will consider a regular sampling, which is mandatory for all sites in work package 3, and an occasional sampling with lower sampling frequency and with some optional variables.

3. Sampling point

Profiles should be carried out in the deepest part of the lake.

4. Regular sampling

The measurements during regular sampling are temperature, oxygen, pH, conductivity, chlorophyll, and ice-cover description during winter. Most of the quantitative modelling will be based on those measurements, hence they require a minimum sampling frequency, sampling depths and common methods which are stated below.

4.1. Frequency

The recommended minimum sampling is monthly during the ice-free season and at least three times during the ice-cover period. This winter minimum sampling is required for studying the oxygen consumption in the lake, as a proxy for total metabolism. Therefore, in case of carrying out only these three winter surveys, please, avoid initial conditions with clear ice, where primary production in the water column is still possible; and also the melting period, when a lot of water is entering the lake disturbing the oxygen profile. Because these two transition periods are quite interesting from the point of view of the partitioning of the seasonal variability, we strongly encourage to carry out extra surveys during these periods, if possible.

In case of very severe sampling restrictions, the very minimum required sampling to have some idea of the seasonal dynamics is three times during ice-free season and twice during ice-cover period. Nevertheless, please consider that with these data any model will be hardly applied.

4.2. Sampling depths

If submersible probes are available for in situ measurements of some variables, then a minimum of every meter recording should be carried out. For measurements requiring analytical work, the number of sampling depths depends on the maximum depth of the lake.

For lakes shallower than 15 m a minimum of 5 depths regularly spaced are required; for deeper lakes a minimum of 10 depths. Regular distribution of the samples greatly facilitates the numerical analysis of the variance in the

lake and interlake comparison. If you think "but I know my lake and ....", then add to the regular mesh those sampling depth you already know are "key points" for your system. In lakes with a fluctuating level, use as reference points distances to the bottom.

Water from the selected depths can be sampled either with limnological bottles or with a pump. Nevertheless, take into account that pumping can enhance gas exchange if bubbling occurs during the process, therefore, it is not recommended when oxygen is going to be determined using BOD bottles.

4.3 Temperature

This measurement requires a higher resolution than chemical measurements, we suggest a 0.5 m resolution for shallow lakes and 1 m for deeper lakes. Measurements should be reliable to 0.1 ^{0}C, which is provided by most thermistors. Periodical checking of the thermistor readings throughout the sampling period with a precision thermometer is necessary, although most commercial devices are usually quite stable now. A thermistor chain recording at the same rate than weather station is necessary for developing the physical models, otherwise those lakes without sufficient temporal temperature record will be used only for validating some of the models.

4.4 Light

The minimum requirement is the depth of Secchi disk disappearance, any other measurement added will be welcome, but keep measuring Secchi disk.

4.5 Oxygen

If an oxymetre with a long cable is available, vertical profiles should follow the same sampling depths as temperature. If not, measurements from the chemistry sampling depths have to be made. In this latter case, BOD special bottles have to be used, and measurements can be made either with an oxymetre directly in the bottle, or by Winkler titration (iodometric method). Special care is needed when subsampling, it has to be carried out before any other subsampling to avoid bubbling inside the sampler, the outlet tube of the sampler has to be placed just above of the bottom of the BOD bottle; and before the sample is collected the contents of the sample bottle should be displaced at least three times by the flowing water.

WARNING: We are looking for very comparable measurements to follow the seasonal dynamics, in particular, we want to estimate the oxygen consumption during winter, which in some lakes it can represent a drop in concentration of only 0.1 mg l^{-1} $month^{-1}$. Therefore, it is quite important to check the calibration of the oxymetre or the accuracy of the Winkler titration. With the iodometric method a higher precision can be obtained, but accuracy depends a lot on the experience of the analyst, the error titrating can be very large. Therefore, we recommend electrode readings, if titration is not performed by experienced analyst. Cross checking of some samples with both methods is also helpful.

Troubles with oxymetres can mainly come from mechanical problems (electrode membrane integrity, stirring, electronic failure at low temperatures) and calibration. Each device has its own system of calibration, some of them are quite automatic, other are more manual. In any case, it is important to check that the calibration has been done properly, in especial, for those working at high altitude, correction by pressure changes has to be considered. Checking the calibration in the field is important; and it is mandatory to use the same stirring method for both calibration and profiling. A solution without oxygen (zero point) can be easily

obtained by adding to a glass of water an small amount (half tea spoon) of sodium sulphite powder. A saturated solution can be obtained bubbling air

(you can use an aquarium bubbler with batteries) during half an hour through a water sample from the lake surface. Remember to keep the sample close to the original temperature in the lake, in order to avoid significant saturation changes caused by cooling or heating.

4.6 Conductivity and pH

For these measurements follow the water chemistry protocol from work package 1. pH readings from multi-parameter profilers will be not accurate enough unless you stop for quite a while at each depth. pH readings should be comparable with pH measurements for other purposes in the project.

4.7 Chlorophyll

Filter one to several litres of water (depending on final absorbance readings) through glass fibre filters (Whatman GF/F). If not processed immediately, the filters have to be stored frozen, individually packed with aluminium foil and folded in such a way that direct contact between the face of the filter containing the algae and the foil is avoided. Extraction must be carried out just before measurements, avoid storing the pigment solution because alteration of a significant amount of pigments occurs in a day. Using acetone, extraction must include either strong sonication (ultrasound bath used in microbiology are not enough) or mechanical grinding using a glass or Teflon homogeneizer. The extract must be clarified by filtration or centrifugation, usually the former performs better. Then, measure the absorbance in a 1 cm length cell at the following wave-lengths: 750, 663, 647, 630, 480, 430, 410 nm. The 750 wavelength is for checking the turbidity of the extract, hence, it must be as low as possible, and never a significant proportion respect to other wavelength readings, if that happens clarify the solution again by filtration or centrifugationn. For calculations, we propose to use the equations of Jeffrey and Humphrey (1975) because they provide the most accurate specific coefficients for Chl-c

Calculations :

Chl-a (μg/l) = (11.85 (A663-A750) - 1.54 (A647-A750) - 0.08 (A630-A750)) * VOLacet(ml) / VOLfil (l)
Chl-b (μg/l) = (-5.34 (A663-A750)+ 21.03 (A647-A750) - 2.66 (A630-A750)) * VOLacet(ml) / VOLfil (l)
Chl-c (μg/l) = (-1.67 (A663-A750) - 7.60 (A647-A750) + 24.52 (A630-A750)) * VOLacet(ml) / VOLfil (l)

Carotenoid index: (A480-A750) / (A663-A750)
Phaeopigment index: (A430-A750) / (A410-A750)

Reference: Jeffrey and Humphrey (1975), Moss (1967) and Strickland and Parsons (1968).

Please, be careful in the evaluation of the volume of solvent where pigments are dissolved, errors at this point are critical for adequate quantification, most common problems can be evaporation or volume retention during different steps of the extraction. If evaporation is kept null, then the best procedure is to use the initial volume added.

In case of very low chlorophyll levels, fluorimetric methods can be used, but please calibrate them with the above stated method. If you prefer to use other alternative methods, because of the routines in your lab or other personal requirements, please check your method against the one above stated a few times along the surveys, and send the results with your readings.

4.8 Ice-cover description

During winter sampling, a description of the physical structure of the snow and ice cover is required in order to apply dynamic models later on. Minimum measurements must be total thickness and water level in the hole drilled for sampling, these allow for an estimation of the mean density of the cover. An stratigraphical description can be made following very simple conventions such as:

hardness degree:

- very soft: you can intrude into the snow layer your hand closed
- soft: you can intrude into the snow layer four extended fingers wearing gloves
- medium: you can intrude into the snow layer only one finger
- hard: you can intrude into the snow layer a pencil
- very hard: you can intrude into the snow layer a knife

free water:

- dry: you are unable of making a snow ball
- moist: you are able of making a snow ball
- wet: handing some snow you can see the water
- very wet: handing some snow you can appreciate the water moving
- slush: handing a piece of snow water runs out from your hand

grain type:

- new snow
- partially melted snow
- granular rounded
- granular rounded with melting
- granular with facets

An example of their application to mountain lakes can be found in Catalan (1989).

5. Occasional sampling

These includes data necessary for understanding and modelling the seasonal variability but at a lower temporal resolution than the variables in the regular sampling. The set of mandatory variables for the occasional sampling are: major ions, nitrate, ammonium, reactive soluble phosphorus (RSP), total phosphorus (TP), phytoplankton (diatoms and chrysophytes) and zooplankton (cladocera). Furthermore, some optional data can increase significantly the capabilities of some models, although they are not strictly necessary, these optional variables include: nitrite, total dissolved phosphorus (TDP), total dissolved nitrogen (TDN), particulate organic nitrogen (PON), dissolved and particulate organic carbon (DOC, POC), silicate, iron and manganese. On the other hand, recording of lake level fluctuations is desirable, and outflow measurements are valuable data for some models.

5.1 Frequency

Each site have to make his own decision about the frequency of the occasional sampling and which optional measurements will be added. At least one measurement of the mandatory variables in summer and one in winter are desirable.

5.2 Sampling depths

Number of samples is also a site by site decision; priority is for the depth 1 m above sediment.

5.3 Phytoplankton (diatom and chrysophytes) and zooplankton

Please follow the protocols in work package 1.

5.4 Major ions and nutrients

Please, follow the water chemistry protocol for work package 1. For the optional measurements, methods are free in order to encourage the measurements in the different labs involved.

References:

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