

Factors contributing to the formation of a deep chlorophyll maximum in a hypertrophic, monomictic lake



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LERNZ
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Introduction

In meso and oligotrophic lakes during thermal stratification, phytoplankton biomass can become concentrated at intermediate depths, forming a deep chlorophyll maximum (DCM).

DCM formation can relate to:

- Avoidance of harmful light levels.
- Vertical gradients in grazing.
- Vertical gradients in light or nutrients.
- *In situ* growth of auto or mixotrophic algae.
- Behavioral characteristics of flagellate aggregations.
- Depth-differential sinking of non-motile phytoplankton.

Some studies have recognised a close relationship between DCM and euphotic depth (e.g., Hamilton *et al.*, 2010).

Objectives

The major objective of this study was to identify the processes responsible for DCM formation in a hypertrophic lake setting, and contrast these with DCM development in meso and oligotrophic lakes.

Lake Ōkaro

Trophic status = Hypertrophic
Mixing regime = Monomictic
Surface area = 0.32 km²
Mean depth = 12 m
Catchment area = 3.9 km²
Land use = c. 95% pastoral

Sampling methodology

Vertical profiles of temperature and fluorescence, photosynthetically active radiation (PAR), dissolved nutrients, phytoplankton cell counts and biovolumes were taken from up to nine stations at weekly to monthly time scales (Figure 1).

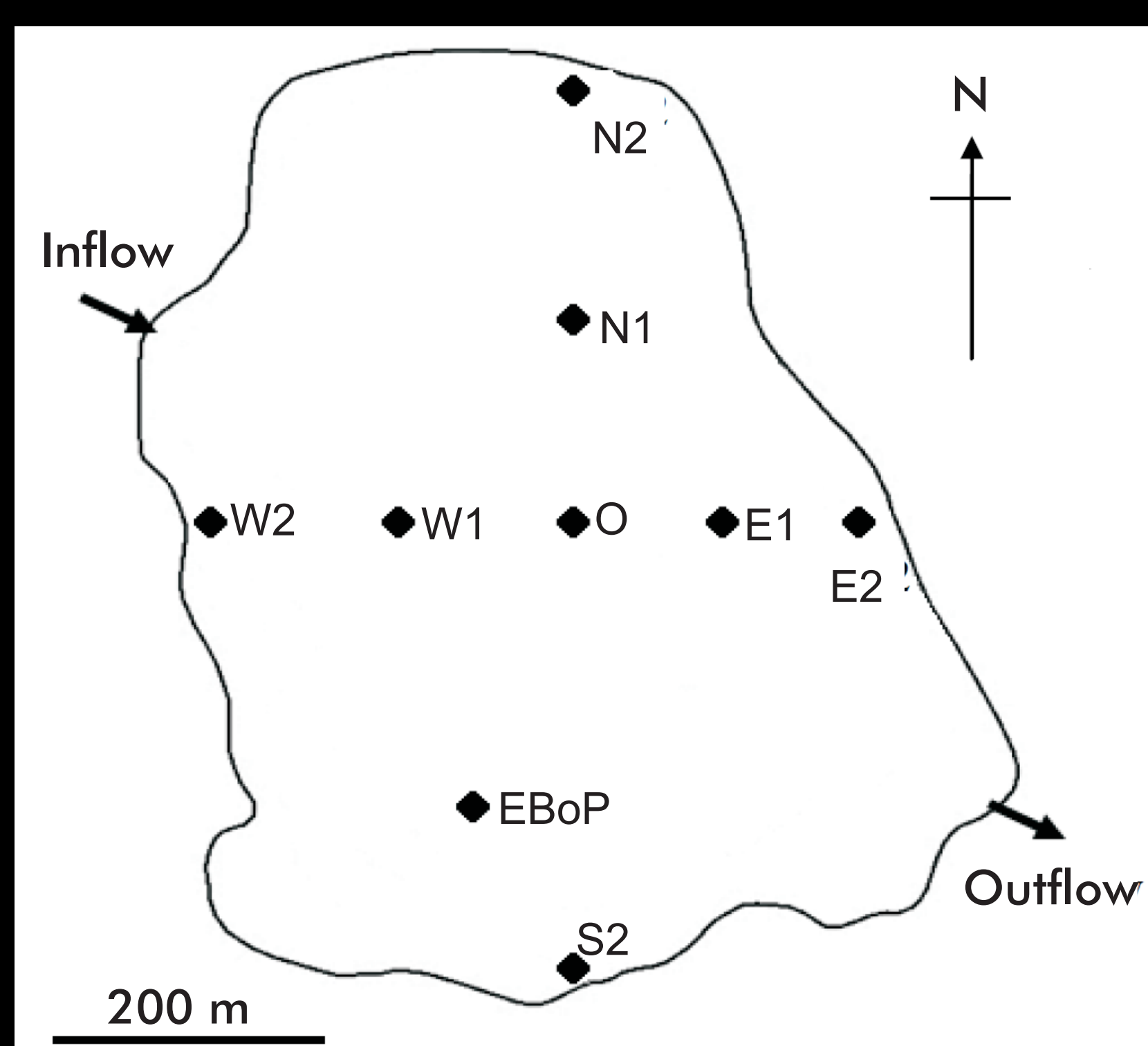


Figure 1. Lake Ōkaro and sampling stations. Shallow sites are indicated by "2", deep sites indicated by "1".

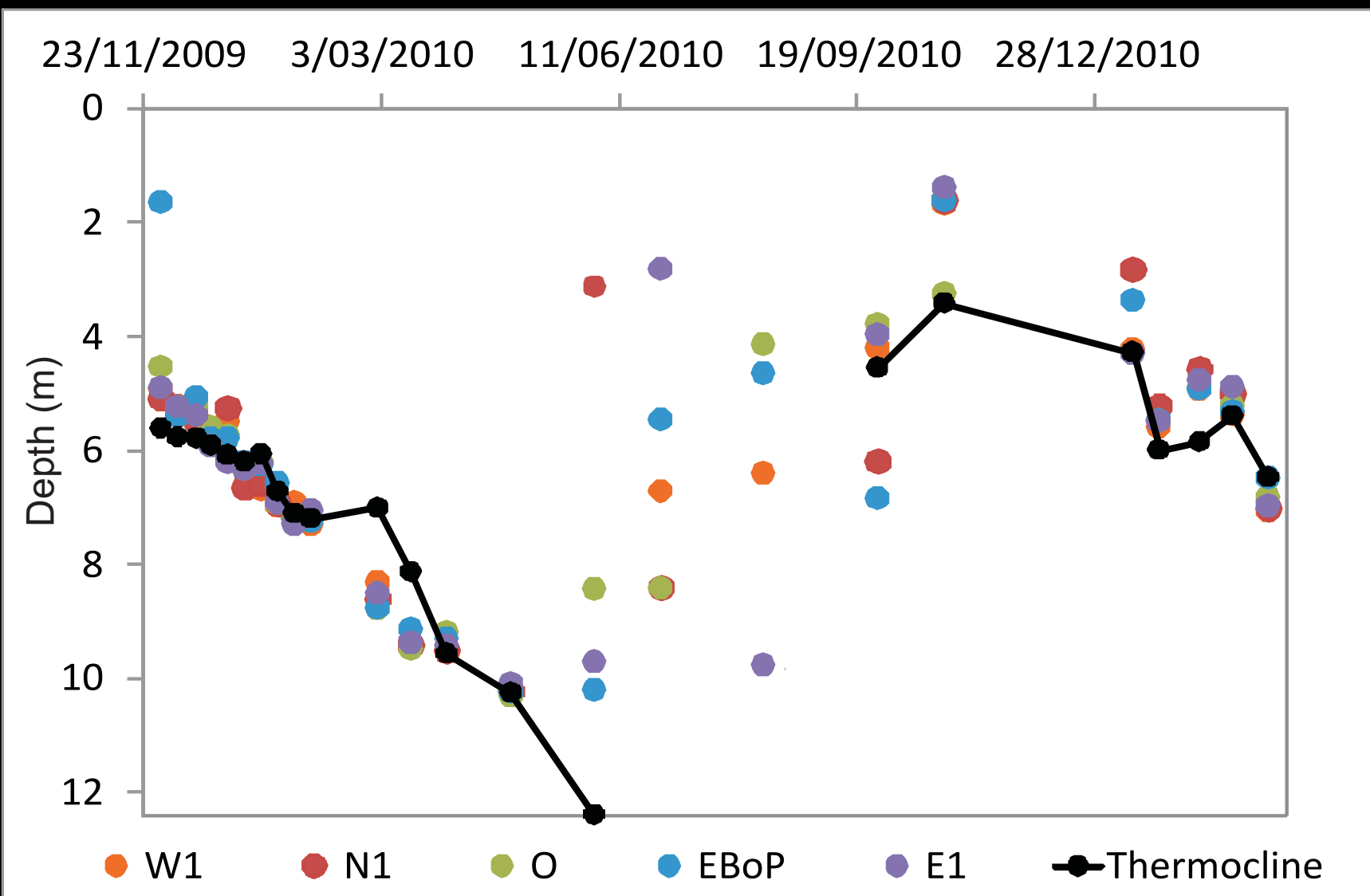


Figure 2. Depth of peak fluorescence values with mean thermocline depth at deep stations from December 2009 to March 2011. No thermocline was present from June 2010 to September 2010.

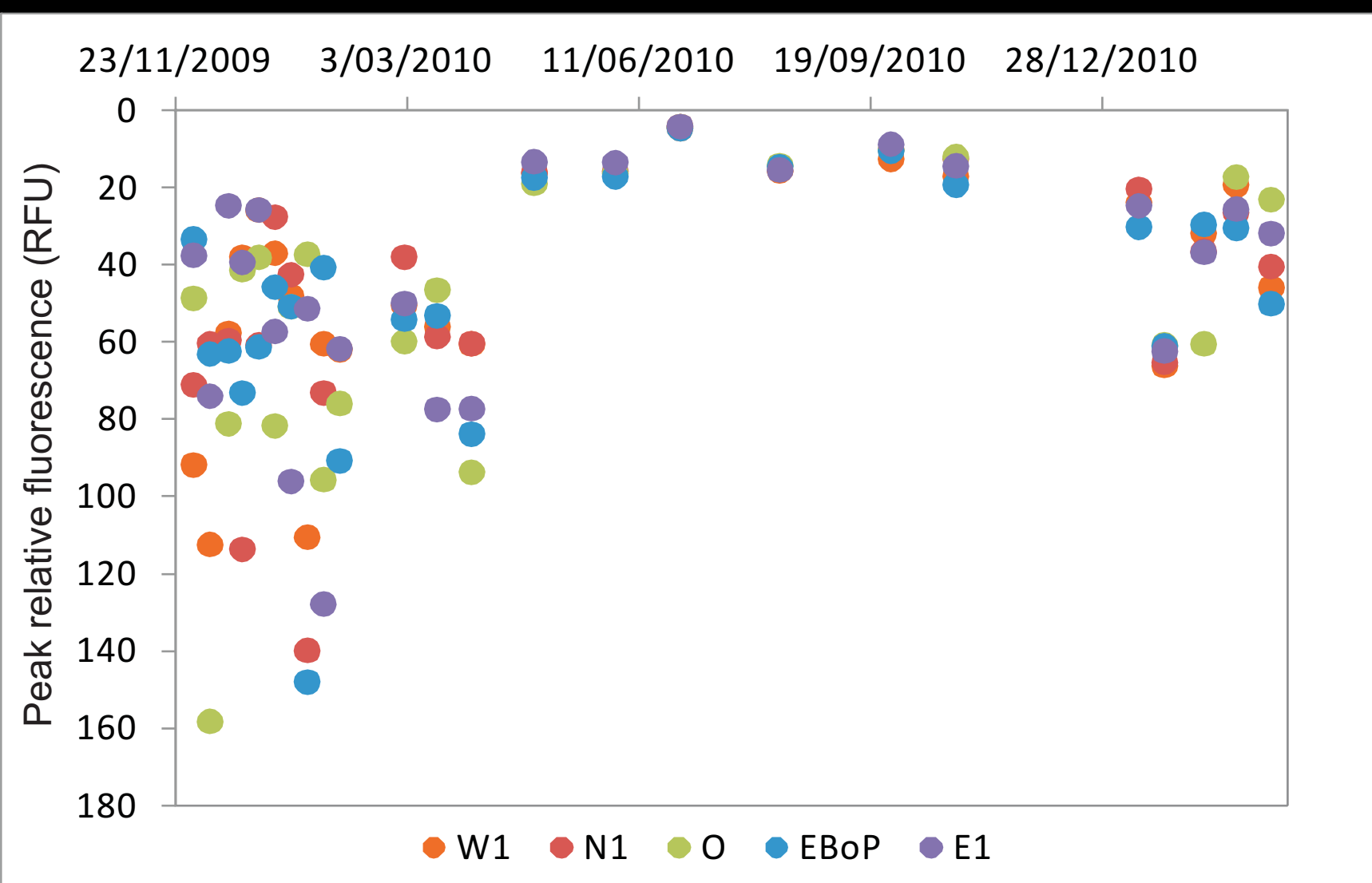


Figure 3. Peak chlorophyll fluorescence (RFU) at deep stations from December 2009 to March 2011.

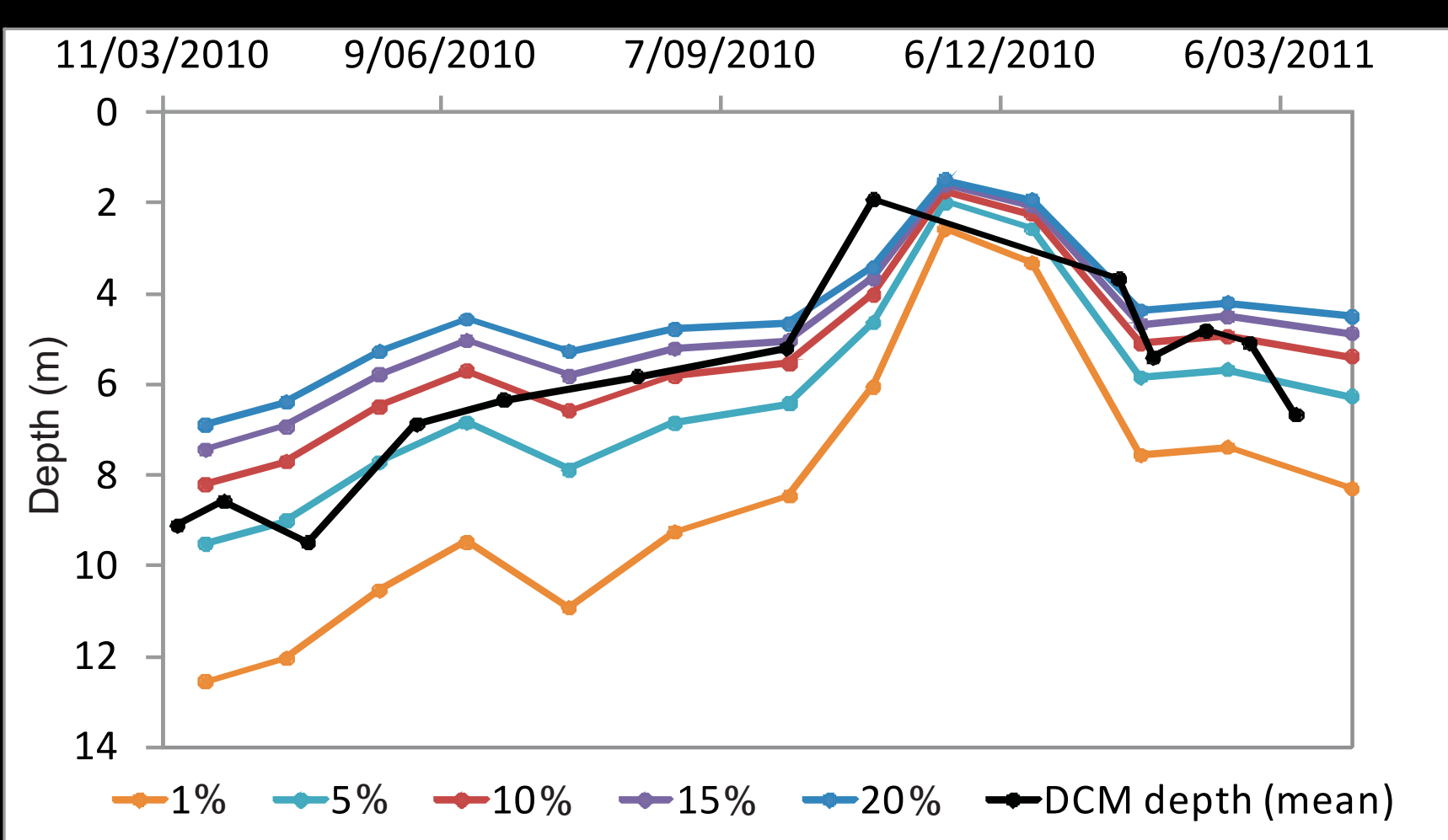


Figure 4. Depth of DCM with isolume values (% surface PAR) derived from seasonal PAR at surface and light attenuation coefficient from March 2010 to March 2011.

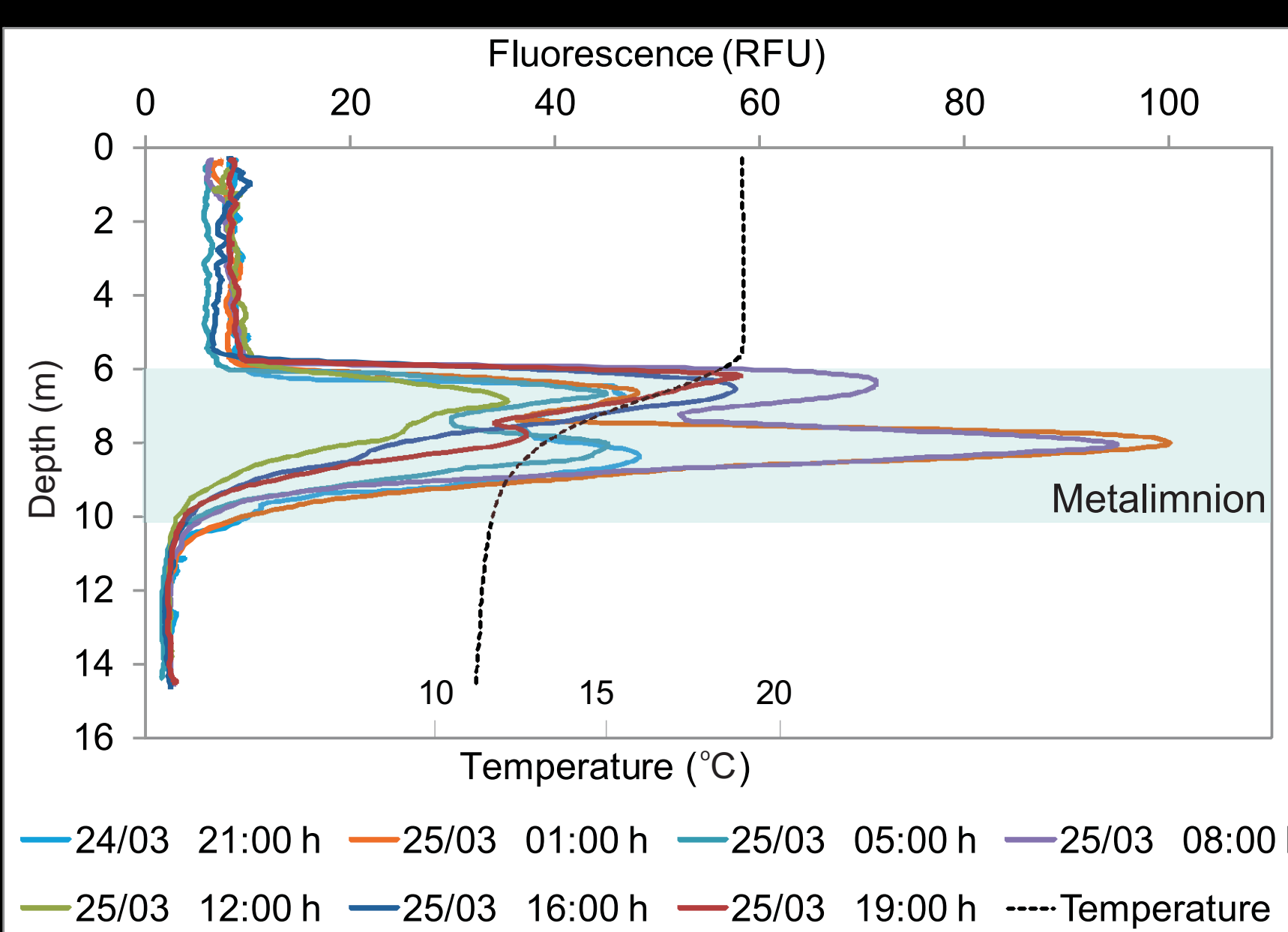


Figure 5. Fluorescence profiles at station W1 for 24-hour high-frequency sampling period (24-25 March 2011).

Results

- A Pearson's correlation test showed that DCM and thermocline depths were statistically correlated at all deep stations ($P \leq 0.05$) (Figure 2).
- Ammonium ($\text{NH}_4\text{-N}$) and phosphate ($\text{PO}_4\text{-P}$) concentrations at depths \leq thermocline depth were potentially growth-limiting during stratification, with means of 0.027 mg L^{-1} ($\text{NH}_4\text{-N}$) and 0.004 mg L^{-1} ($\text{PO}_4\text{-P}$).
- DCM peak chlorophyll fluorescence was highly variable between stations during thermally stratified periods (Figure 3).
- When Lake Ōkaro mixed from May 2010 to September 2010 there was no DCM.
- When Lake Ōkaro was mixed, chlorophyll fluorescence was homogenous and low.
- DCM depth generally corresponded to between 5 and 15 % surface PAR (Figure 4).
- The solar radiation levels associated with 5 to 15% surface PAR varied significantly, relating to seasonal changes.
- DCM depth did not correspond to a given solar radiation level.
- Two distinct fluorescence peaks were evident on 24-25 March 2011 and showed little variation in depth over time (Figure 5).
- The 6-8 m DCM was due to 65% *Ceratium hirundinella* and 17% *Phacus* spp. by volume.
- The 8-10 m DCM was due to 56% *C. hirundinella* and 41% unidentified colonial picoplankton by volume.

Conclusions

- Euphotic depth (1% surface irradiance) was not closely related to DCM depth.
- Low epilimnetic phytoplankton concentrations increased surface water transparency and supported DCM development (comparable to meso and oligotrophic lakes).
- We propose that the stable DCM depth represented a compromise between threshold light levels, a demand for nutrients sourced predominantly from the hypolimnion and the avoidance of damaging radiation levels near the surface. An alternative hypothesis is that a bacterial maximum at the lower metalimnion facilitated mixotrophy.

HAMILTON, D. P., O'BRIEN, K. R., BURFORD, M. A. & BROOKES, J. D. 2010. Vertical distributions of chlorophyll in deep, warm monomictic lakes. *Aquatic Sciences-Research Across Boundaries*, 72, 295-307.

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