Effect of vegetation on oxygen concentration in water and flooded soil

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1. Introduction

Oxygen is one of the most important elements for almost all living organisms. There are different opportunities to gain oxygen. In general, the main source of oxygen is the atmosphere, in which molecular oxygen was accumulated as a waste product by autotrophic cyanobacteria, one of the first oxygen producers. Previously, a virtually oxygen-free, anaerobic atmosphere existed on Earth. Today our main oxygen producers are plants that produce oxygen by photosynthesis. Consumption of oxygen splits in respiration of plants, animals, microbes and chemical processes. In water the concentration per volume of oxygen is lower than in the atmosphere.

Aquatic plants can modify their environment in the short term. They are the main producers of oxygen under water through photosynthesis (Caraco et al. 2006).

There are different morphological types of water plants: They can be completely submersed, partly submersed or floating. The different morphology could lead to different impact to the environment. In our experiment, we will monitor the oxygen changes in the aquatic system provided by different plant species – *Glyceria maxima*, *Lemna minor*, *Potamogeton crispus*, *Sphagnum riparium* - and Algae, once in dark conditions and once in the light. For comparison, we will also measure with only water and second with soil and water as controls. With these we want to test whether the morphological type of the plant could influence the exchange of oxygen in the aquatic system. We hypothesize that different morphological plant types will affect the oxygen concentration in an aquatic system. We expect floating leaved plants to deplete the oxygen in the aquatic system, while submersed plants will provide it.

2. Material and Methods

Five taxa (Table 1) were selected and assigned to three morphological groups according to their general growth form as follows: submersed, for plants restricted to completely submersed life; emergent, for rooted plants whose photosynthetic tissue is both submersed and exposed to the overlying atmosphere and; floating, for non-rooted plants whose photosynthetic tissue is completely exposed to the overlying atmosphere. Plant material was collected in the species habitat a week before the experiment. Two replicate flasks were filled with water (250 ml) and the plant material. Flasks were exposed to the atmosphere (i.e. not covered). The experiment also included two replicate flasks filled with only water and two filled with water and 3,92 grams of

sediment (dry mass), which were collected in the habitat waterbed and kept under the same conditions as the plant material. Experiments were kept under dark conditions for 6 hours. Oxygen concentrations were measured in the middle of the water column (~5 cm depth) on each flask using a fiber-optic oxygen meter (Fibox 3 LCD trace v7, PreSens GmbH, Regensburg Germany). Measurements were taken between 15:00 and 19:00 h (local time, GMT+1). Measurements from the two replicate flasks were performed approximately every 30 minutes for each treatment (i.e. water, sediment, *Lemna*, algae etc.). Additionally, pH and temperature were measured on each flask during the experiment.

Table 1. Species used in the experiment and their morphological types.

Species	Morphological type
Lemna minor	Floating
Potamogeton crispus	Submersed
Algae	Submersed
Sphagnum riparium	Emergent
Glyceria maxima	Emergent

3. Results

During 2.7 hours, concentrations of oxygen (µmol/L) were measured in each flask (see figure 1 and 2). It varied between 67.45 and 231.07 µmol/L for the 1st replicate and 101.51 to 227.31 µmol/L for the 2nd replicate. Multiplying concentration by volume, we calculated concentration per flask in [µmol/flask]. By dividing these results by the Dry Weight (DW), we obtained plant mass specific oxygen concentrations in [µmol O_2/gDW].

After a linear regression and a comparison of the slopes, we found that oxygen in soil flask was decreasing, and increasing in all plant flasks under light conditions (figure 3 and 4).

In the 1st replicate, *P. crispus* had the highest level of oxygen, then algae, *S. riparium, L. minor* and *G. maxima* followed for the same duration. In the 2nd replicate, *P. crispus* was also the first, followed by *L. minor, algae*, *S.riparium* and *G. maxima* in descending order.

Plants with the lowest oxygen concentration at the beginning of the experiment (0:00) were *G. maxima* and *S. riparium*. Plants with the highest oxygen concentration at the

beginning (0:00) were *P. crispus, L. minor* and then algae (with the maximum) in the replicate 1; and *L. minor, P. crispus* and *algae* (with the maximum) for the replicate 2.

The exchange rate of oxygen per hour (µmol/g/h) (figure 5), showed only negative values in soil sediment flasks, proving O_2 was consumed. For all other plants, the exchange rate per hour increased, showing O_2 was produced. For the 1st replicate, *G. maxima* had the lowest exchange rate (1.3 µmol/g/h); followed by *L. minor* (8.9 µmol/g/h), *S. riparium* (25.8 µmol/g/h), algae (28 µmol/g/h) and *P. crispus* with the highest rate (98.2 µmol/g/h). For the 2nd replicate, *G. maxima* had also the lowest exchange rate (1.3 µmol/g/h), but *S. riparium* moss was the next lower (14.8 µmol/g/h); followed by *L. minor* (25.1 µmol/g/h), algae (27.6 µmol/g/h) and finally *P. crispus* (119.5 µmol/g/h).

Finally, we measured the oxygen concentration for 21 hours for *L. minor* and *P. crispus* (Figure 6). For 15.5 hours, there was no light for the plants. Thus, *L. minor* oxygen rate decreased from ~220 µmol to 60 µmol; for *P. crispus* also decreased from 305 µmol to 20 µmol. When there was light, *L. minor* increased slightly to 100 µmol and *P. crispus* had a peak reaching 485 µmol in less than 5 hours.

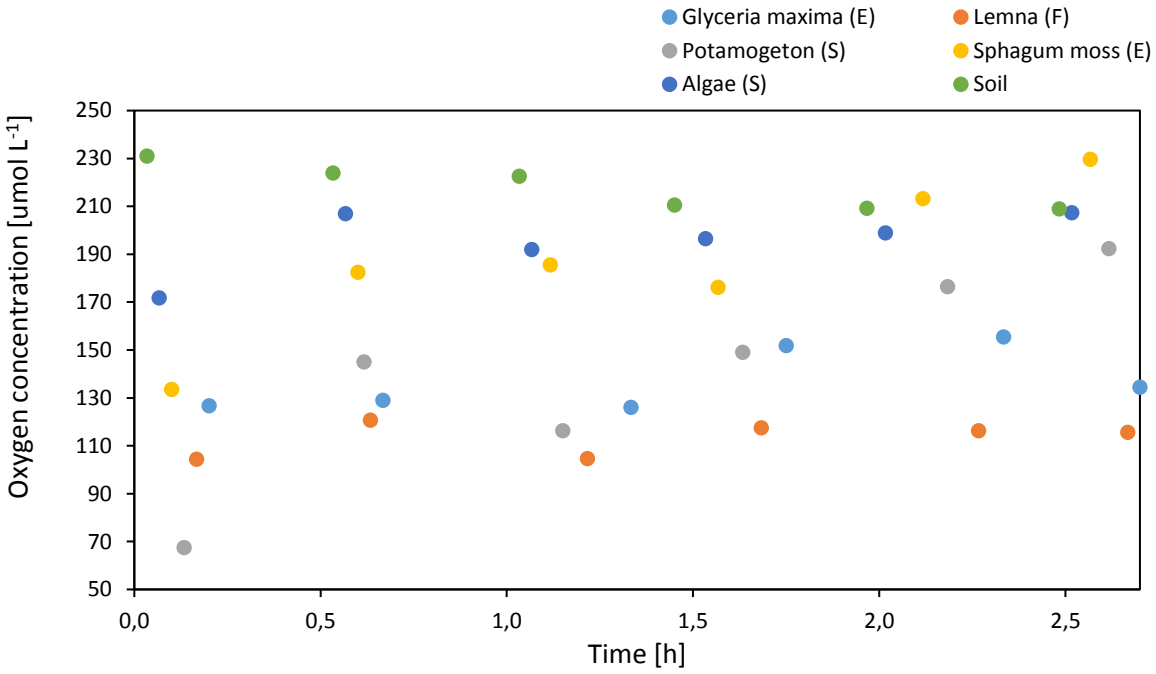

Figure 1: Raw data of the first Replicate of all investigate Species.

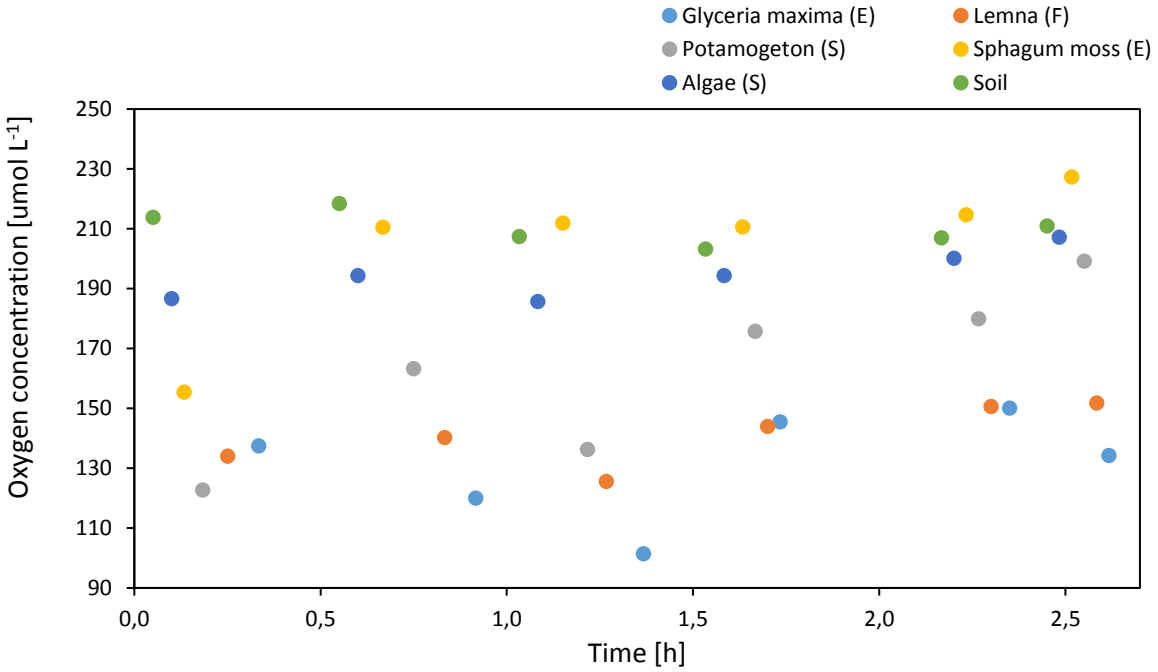

Figure 2: Raw data of the second Replicate of all investigate Species.

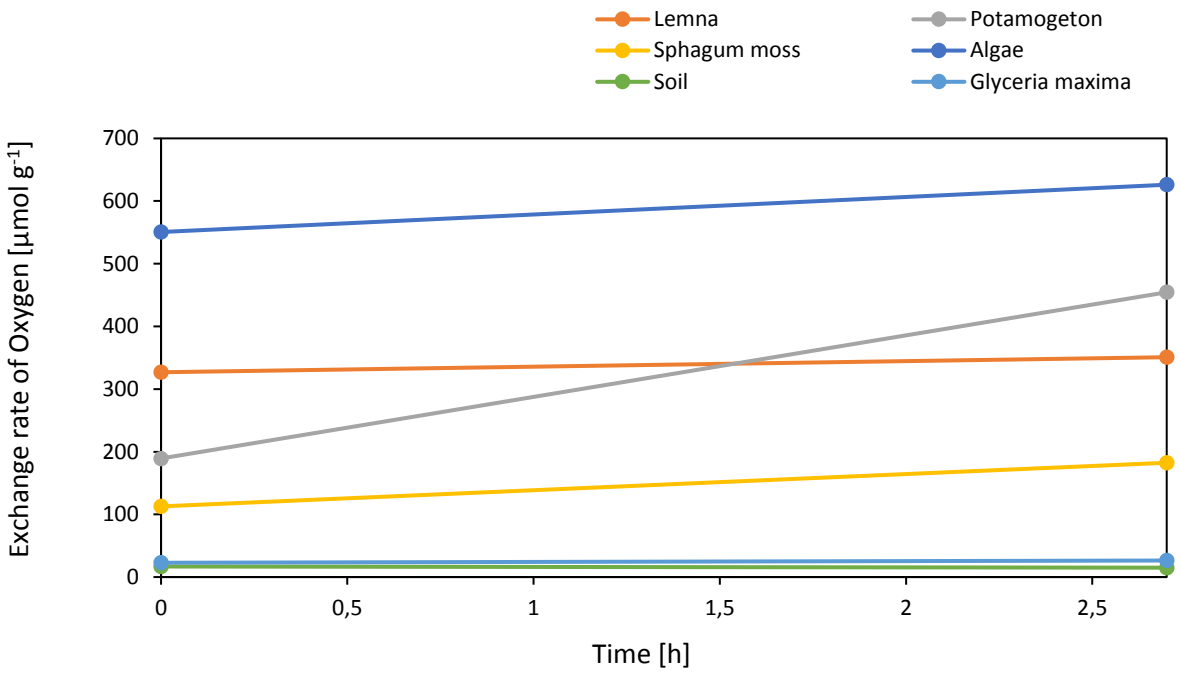

Figure 3: Change rate of oxygen concentration normalized over the dry mass, for all species of the first replicate-group.

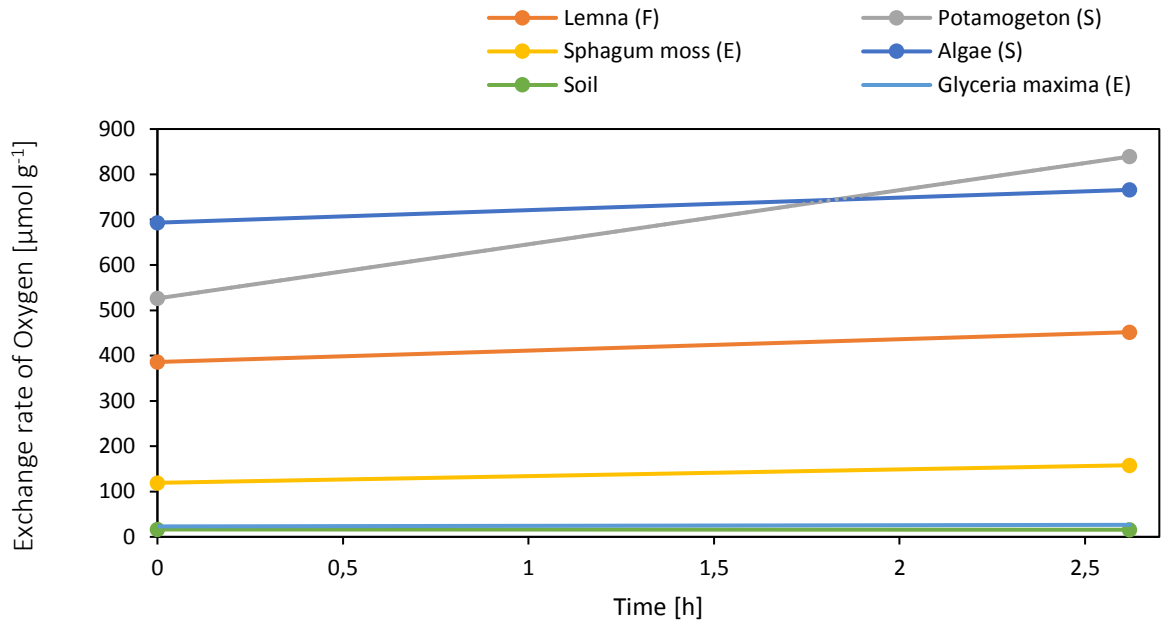

Figure 4: Change rate of oxygen concentration normalized over the dry mass, for all species of the second replicate-group.

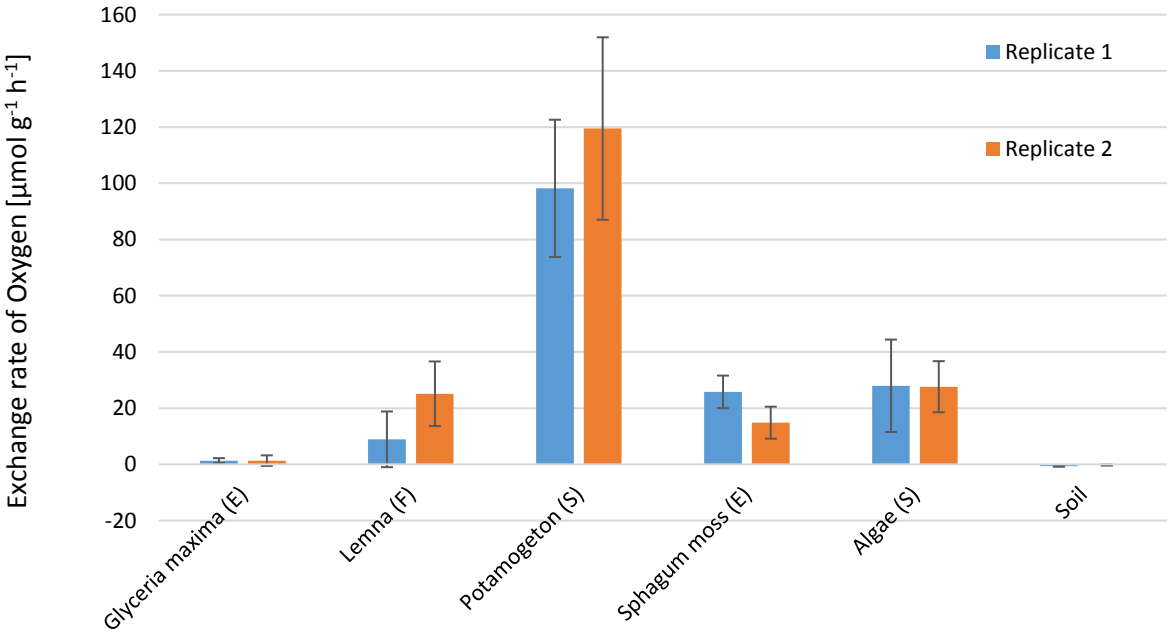

Figure 5: Comparison of the different oxygen concentration rates normalized over the dry mass and time for all replicas.

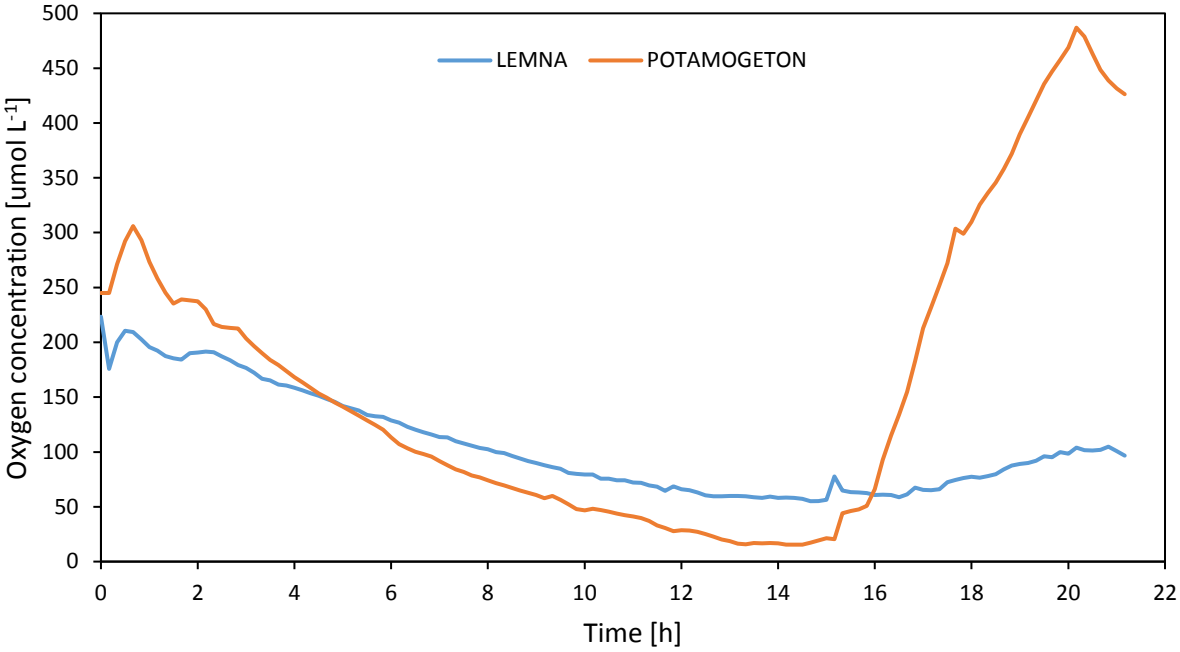

Figure 6: Third Replica. A measurement on Lemna and Potamogeton over 21 hours under different light conditions.

4. Discussion

Our results demonstrate that all the species in our experiment increased oxygen concentration in the water under light conditions. We also observed there were important differences in O_2 exchange between species (i.e. *Glyceria, Potamogeton*) and that there were not between morphological types. As we expected, the submersed plant *P. crispus* increased oxygen concentration the most due to the oxygen release directly to the water environment instead to the atmosphere. In contrast, *G. maxima* increased oxygen level the lowest, given it was an emergent plant and released oxygen directly to the atmosphere. In our "long-term" follow-up with *P. crispus,* we also observed oxygen saturation as shown by the amount of visible bubbles in the flasks. In nature this condition could lead to problems for some water living organisms. Furthermore, *L. minor* and *S. riparium* increased the oxygen similarly. Both increased, but not as *G. maxima* did.

Aquatic plants can have drastic effects in the aquatic system over the short term. Oxygen levels are dynamic due to night-day-regimes of plant photosynthesis. This levels can strongly affect life in the system (Baird et al., 2004). Animals require specific amounts of dissolved oxygen to live in the aquatic environment (Strayer et al., 2003).

For example, critical concentration of oxygen may cause the death of several fish species (Dybas et al. 2005). Thus, if there is less oxygen there can be a damage to fish, trophic chains and functioning of the system (Carpenter et al., 1992).

Our experiment had several limitations. It is difficult to establish whether there are similar responses according to the species life-forms (i.e. emergent, floating or submersed). Despite species could be considered as having similar life strategies they vary greatly in size and thus, oxygen production and consumption would not be easily comparable. This would require a more complex experimental design including a bigger number of species within each category and analysing it accordingly (e.g. using generalised mixed model using life-form as the fixed effect and the species as random effect; Bolker et al. 2009). In addition, the limited number of replicates and time to conduct the experiment did not allow us to extract clear patterns. In this regard, our experiment would benefit strongly if followed for a longer period using more replicates enabling to identify clearer trends on how the different species can affect the oxygen levels in water.

However, despite all the limitations described above for our experiment, this type of studies can be very useful to understand the functioning of aquatic environments (Duarte et al. 2004), describe the role of the different species in their habitat and identify critical oxygen levels and threats to water ecosystems (Baird et al., 2004).

5. Literature

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