

The reaction of $\delta^{13}\text{C}$, $\delta^{18}\text{O}$ and ring width on Larch Budmoth (*Zeiraphera diniana* Gn.) outbreaks in the European Larch (*Larix decidua* Mill.) - A case study in the Lötschental, Switzerland

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Introduction

European Larch (*Larix decidua* Mill.) from the subalpine forest is commonly used for low-frequency temperature reconstructions (Büntgen et al. 2005). These subalpine forests form the habitat of the larch budmoth (LBM; *Zeiraphera diniana* Gn). Normally, the population of this insect strongly multiplies at intervals of 7-11 years. These outbreaks cause a red-brown discoloration of the crowns from larch trees due to the wasteful feeding of the 4th and 5th instar larvae and the drying out of the needles (Baltensweiler and Rubli 1999).

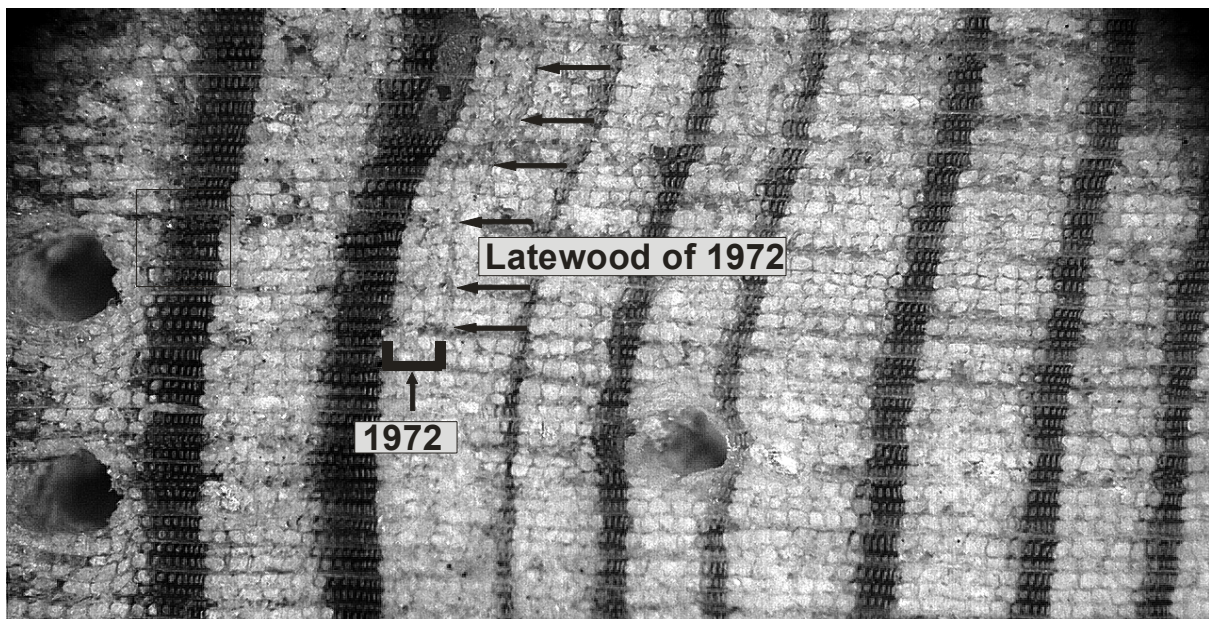


Figure 1: Typical tree-ring pattern due to a LBM outbreak. The 1970-1978 sequence is given showing the outbreak of 1972.

Figure 1 shows a typical pattern caused by these outbreaks which is characterized by an abrupt growth reduction in the year of the outbreak and a slow increase of ring width in the following years. The way trees recover depends on the intensity of the previous outbreak. Obviously a number of plant physiological reactions are disturbed in such a way that trees need a longer period to regain their normal activity. This typical tree-ring pattern causes problems in high-frequency climate reconstructions.

Stable isotopes usually provide better insight into plant physiological processes underlying tree growth. Therefore the aim of this study was to investigate to what extent LBM outbreaks modify the signature of the stable carbon and oxygen isotopes of the corresponding tree-rings. The study area chosen is located in the Lötschental, an inner-alpine dry valley in Valais, Switzerland.

Material and Methods

For inter-annual $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ analyses we took 6 cores of a tree located at 1900 m a.s.l. on the south exposed slope. After measuring the ring widths of the cores with a resolution of 0.01 mm, the cores were dated by synchronizing the ring widths with the corrected master-chronology of the Lötschental (Büntgen et al. 2004). The years of LBM outbreaks were identified by comparison of the tree-ring pattern with historical documentation which exists back to 1850. (Baltensweiler and Rubli 1999). Based on ring width, LBM outbreaks were identified in a quantitative and a qualitative way. For each ring width the relative width reduction was calculated by comparing the mean value of the 4 previous years. The threshold for LBM outbreaks was fixed at 40% of growth reduction. (Rolland et al. 2001). The qualitative way consisted in the visual detection of the typical pattern as described above. The historical documentation confirmed this ring width analysis. Each tree-ring of the time span 1900-1982 was separated from the cores and the wood of the separated tree-rings was pooled after Treydte (1998).

It is usual to extract cellulose to concentrate on one chemical compound because the different components of the wood have different isotopic signatures. Nevertheless, we analysed cellulose and wood for the time span 1950-1982, the idea being that similar results for cellulose and total wood could ease the workload considerably by concentrating on wood. The investigations resulted in a correlation coefficient of $r = 0.84$ for carbon and $r = 0.91$ for oxygen. Therefore, we decided to use only wood for the time period 1900-1950. The samples were measured by using an elemental analyser interfaced to a continuous flow isotope ratio mass spectrometer (Micromass Optima). The resulting δ -values are defined as the isotope ratio R of an element relative to the ratio of an internationally accepted reference material of this element. Thus, e.g.: $\delta^{13}\text{C} = [R_{\text{sample}}/R_{\text{reference}} - 1] * 1000$. These values are normally multiplied by 1000 and thus given as per mill deviation from the reference. The analytical error was $< \pm 0.1\text{‰}$ for carbon and $< \pm 0.35\text{‰}$ for oxygen.

For intra-annual $\delta^{13}\text{C}$ analyses a stem disk of a tree located at 1800 a.s.l. on the south-exposed slope was used. To obtain an intra-annual resolution we took a segment of this disc and prepared micro-slices of 15 μm for the years 1970–1974 including the LBM outbreak of 1972. The complementary climate data originate from the meteorological stations of Kippel (1370 m) and Ried (1480 m) in the Lötschental, extended by the data of Montana, 30 km west of Lötschental (Neuwirth 1998, Neuwirth et al. 2004).

Results and discussion

Outbreaks of LBM were identified for the years 1907, 1944, 1954, 1963 and 1972 on the basis of ring width, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$. As shown in figure 2, comparison with climate data did not

reveal any anomalies in these years. Therefore, the values of the identified years of LBM outbreaks do not result from particular climatic conditions.

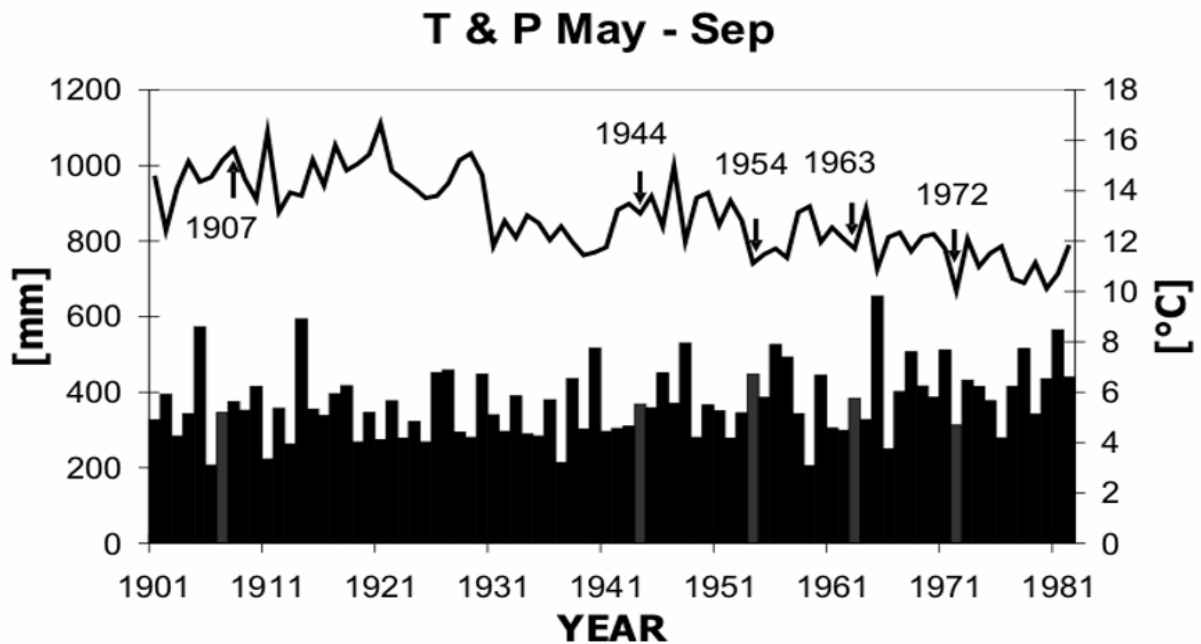


Figure 2: Temperature and precipitation records in the Lötschental during the growth period of the investigated larch. The years of LBM outbreaks are marked.

Tree-ring width, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ records are summarized in figure 3. $\delta^{18}\text{O}$ -values are characterized by a strong decrease in the years of LBM outbreaks except for 1944. Both, ring width and $\delta^{18}\text{O}$ respond to LBM outbreaks with strongly decreasing values. Ring width does not indicate any LBM outbreaks between 1907 and 1944 contrary to $\delta^{18}\text{O}$. On the basis of $\delta^{18}\text{O}$ it cannot be ruled out that during the year 1931 an infestation occurred. Strong LBM outbreaks are related to defoliation (Baltensweiler and Rubli 1999). Generally, transpiration of leaf water leads to a loss of the lighter H_2^{16}O molecules in the intercellular air spaces and consequently to an enrichment in H_2^{18}O (McCarroll and Loader, 2004). The absence of the leaves leads to low $\delta^{18}\text{O}$ values because no transpiration takes place. In general carbon isotopes show a weaker decrease in the year of LBM outbreak as compared to $\delta^{18}\text{O}$ and a stronger decrease one year after the outbreak (Fig. 3). The chemical composition and morphological constitution of the needles is strongly dependent on nutrient reserves of the previous year (Baltensweiler and Fischlin 1988) As a reaction to LBM outbreaks the needle mass in the following year is lower. Therefore, the lower $\delta^{13}\text{C}$ -values in this year are possibly due to a lower photosynthesis rate which in turn results in a reduced isotope discrimination.

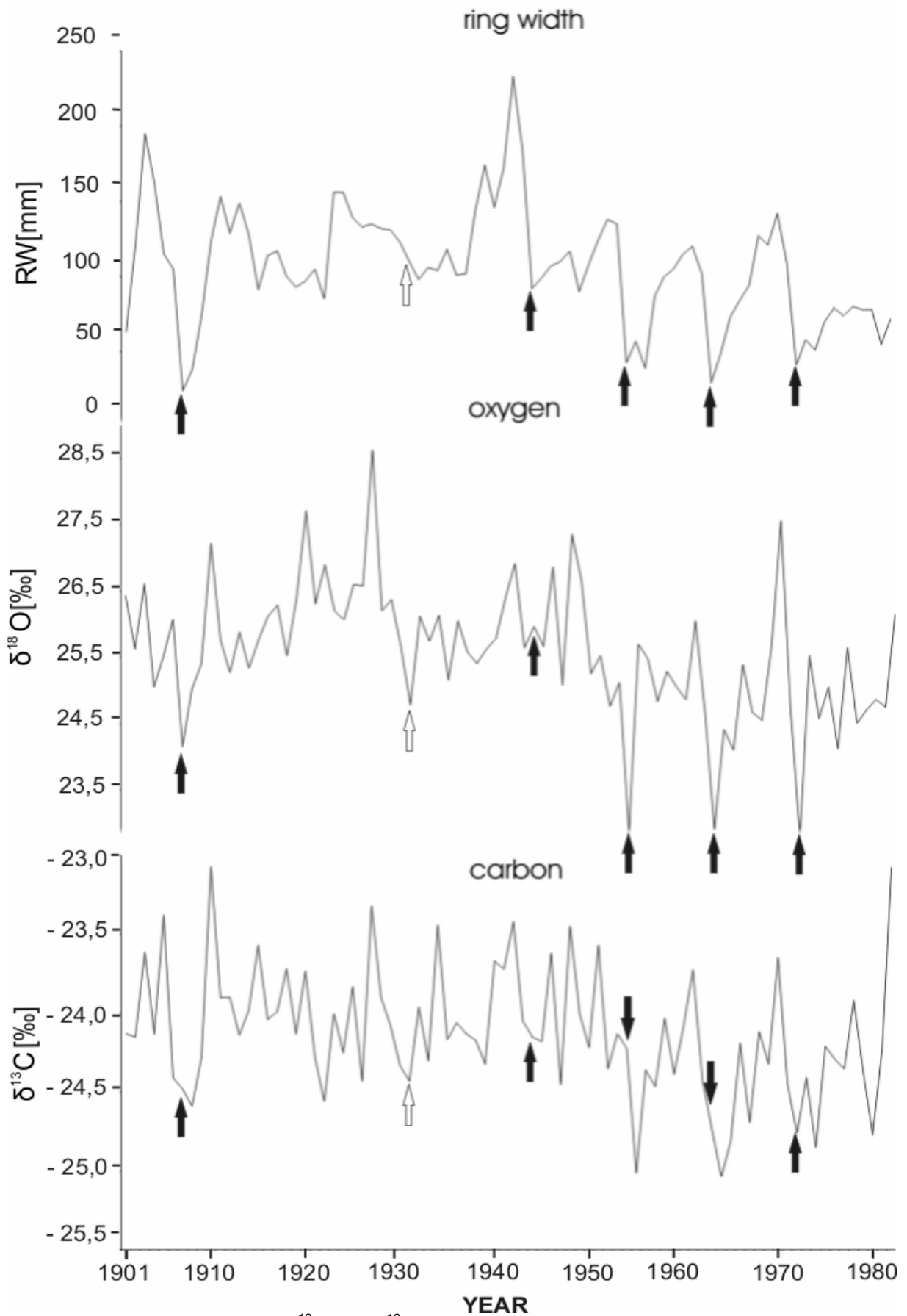


Figure 3: Records of ring width, $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ from total wood for the time period of 1900-1982.

Seasonal variations of $\delta^{13}\text{C}$ 1970-1974

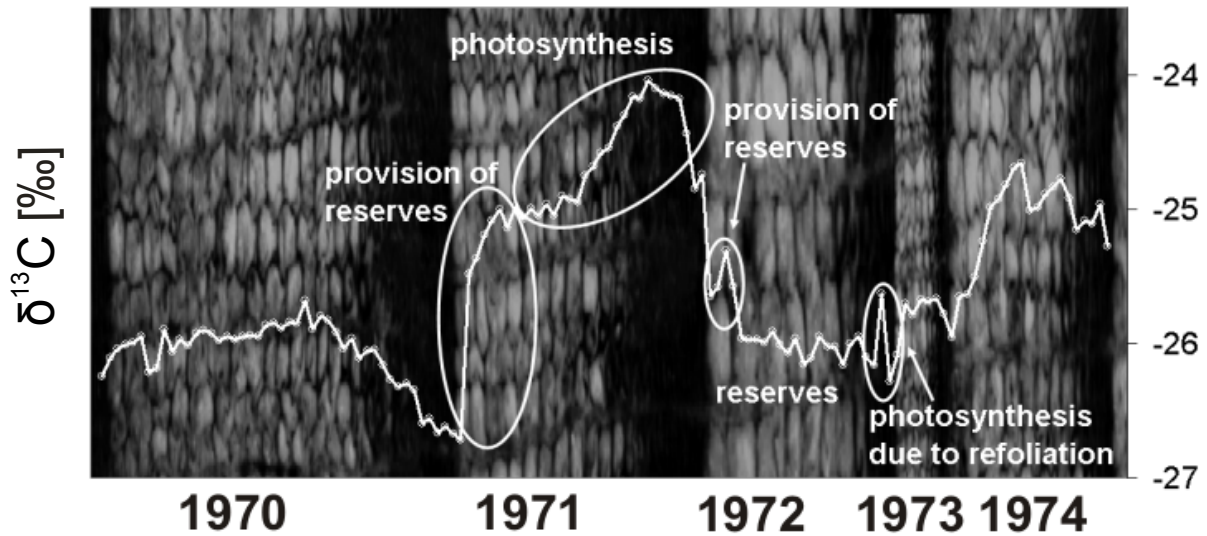


Figure 4: Seasonal variations of the carbon isotopes during the years from 1970-1974 including the LBM outbreak of 1972. (ring width not true to scale)

The seasonal carbon isotope pattern for the years of 1970, 1971, 1974 shows the normal $\delta^{13}\text{C}$ course to be expected. At the beginning of the growing season the $\delta^{13}\text{C}$ -values increase while a decrease is observed in latewood. The seasonality in $\delta^{13}\text{C}$ is due to seasonal changes in isotopic fractionation partly due to photosynthesis (Helle and Schleser 2004, Verheyden et al. 2004). The year of LBM outbreak, 1972, shows a different pattern. After a short increase at the beginning, indicating the standard year to year situation, $\delta^{13}\text{C}$ -values decrease abruptly and remain on a low level without any significant variation. In the latewood a slight increase is observed, however, only for a short time. The initial increase is due to the provision of reserves from the previous year with minor contributions of photosynthates of the current year. After the tree is defoliated, wood formation depends solely on remaining reserves with a lower $\delta^{13}\text{C}$ -value. The $\delta^{13}\text{C}$ -increase in latewood is possibly attributed to the refoliation of the larches. Larches which have been defoliated to more than 50% refoliate within 3-4 weeks (Baltensweiler and Fischlin 1988). Against the background of a decreasing needle mass in 1973, the low $\delta^{13}\text{C}$ -values are possibly caused by a lower photosynthesis rate which normally leads to a higher discrimination.

Conclusions

The results of this initial study revealed similar reactions for ring width and for inter-annual oxygen isotope values to LBM outbreaks. Carbon isotope signatures most likely reveal the influence of reserves. The reasons for the differences in the behaviour of the different parameters to LBM outbreaks are presently not fully understood. But they are due to different tree physiological (yet unknown) processes. Further investigations with more trees are necessary to substantiate the observed pattern. However, this study shows that multi-

parameter investigation bear a great potential for studying the influence of LBM outbreaks on trees. Cores of a site on the south-exposed slope at 2000 m a.s.l. in the Lötschental / Switzerland are currently prepared for inter-annual and intra-annual carbon and oxygen isotope analyses to investigate the reaction on LBM outbreaks of different intensities. This is to obtain more information on the mechanisms which are responsible for the observed behaviour.

Acknowledgement

The authors wish to thank the ICG-V laboratory staff of the Research Centre Juelich for their active assistance within this project.

References

- Baltensweiler, W. and A. Fischlin (1988): The Larch Budmoth in the Alps. In: Berryman, A. (ed.): Dynamics of forest insect populations: 331-349.
- Baltensweiler, W. and D. Rubli (1999): Dispersal: an important driving force of the cyclic population dynamics of the larch budmoth, *Zeiraphera diniana* Gn. *Forest Snow and Landscape Research* 74: 153.
- Büntgen, U., Esper, J., Frank, D. C., Nicolussi, K. and M. Schmidhalter (2005): A 1052-year tree-ring proxy for Alpine summer temperatures. *Climate Dynamics*.
- Helle, G. and G.H. Schleser (2004): Beyond CO₂-fixation by Rubisco – an interpretation of ¹³C/¹²C variations in tree-rings from novel intra-seasonal studies on broad-leaf trees. *Plant, Cell and Environment* 27: 367-380.
- McCarroll, D. and N.J. Loader (2004): Stable isotopes in tree rings. *Quaternary Science Reviews* 23: 771-801.
- Neuwirth, B. (1998): Dendroklimatologische Untersuchungen im Lötschental, Schweiz. Visuelle Jahrringparameter subalpiner Fichten in Abhängigkeit von Höhenlage, Exposition und Standortverhältnissen. Diploma Thesis. Geographical Institute, University of Bonn. Germany.97.
- Neuwirth, B., Esper, J., Schweingruber, F. H., M. Winiger (2004): Site ecological differences to the climatic forcing of spruce pointer years from the Lötschental, Switzerland. *Dendrochronologia* 21 (2): 69-78.
- Rolland, C., Baltensweiler, W. and V. Petitcolas (2001): The potential for using *Larix decidua* ring widths in reconstruction of larch budmoth (*Zeiraphera diniana*) outbreak history: dendrochronological estimates compared with insect survey. *Trees* 15: 414-424.
- Treydte, K. (1998): Dendroklimatologische Untersuchungen im Lötschental, Schweiz. d13C subalpiner Fichten in Abhängigkeit von Höhenlage, Exposition und Standortverhältnissen. Diploma Thesis. Geographical Institute, University of Bonn. Germany. 97.
- Verheyden, A, Helle, G, Schleser, G. H., Dehairs, F., Beekman, H. and N. Koedam (2004): Annual cyclicity in high-resolution stable carbon and oxygen isotope ratios in the wood of the mangrove tree *Rhizophora mucronata*. *Plant, Cell and Environment* 27: 1525-1536.