Photosynthetic responses of the mangrove *Avicennia marina* subsp. *australasica* to a New Zealand winter

Catherine M. Beard, T.G. Allan Green, Warwick B. Silvester, Chrissen E.C. Gemmill
Department of Biological Sciences, The University of Waikato, Hamilton, New Zealand

INTRODUCTION

Latitude 38ºS is the southern limit of New Zealand's only mangrove species, *Avicennia marina* (Forsk.) Vierh. subsp. *australasica* (Walp.) (Figure 1).

Historically this limit has been attributed to the effects of low winter temperatures and frosts (Chapman,1958).

This study investigated photosynthesis in *Avicennia* under natural conditions in the field during the course of a New Zealand winter. The effects of frosts and chilling were assessed in relation to tissue damage, leaf chlorophyll content and photosynthetic performance.

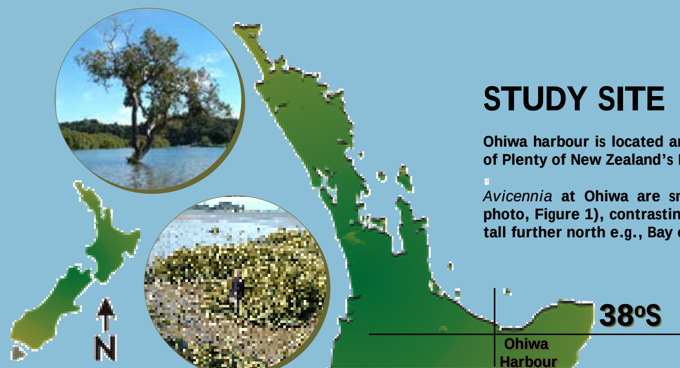

Figure 1

STUDY SITE

Ohiwa harbour is located around latitude 38ºS in the Eastern Bay of Plenty of New Zealand's North Island (Figure 1).

Avicennia at Ohiwa are small trees <1.5 m in height (bottom photo, Figure 1), contrasting with specimens that grow up to 10m tall further north e.g., Bay of Islands (upper photo, Figure 1).

Plate 1. Exposed (top) and protected (bottom) leaves of *Avicennia marina* subsp. *australasica*

METHODS

Measurements were made *in-situ* on sets of fully exposed outer leaves and protected inner-canopy leaves (Plate 1) at intervals of 5 to 6 weeks from April - October.

Gas exchange was measured under saturating light using a CIRAS-1 portable photosynthesis system and PLC leaf cuvette (PP-systems UK). Chlorophyll *a* fluorescence after 15 mins dark-adaptation was measured with a Mini-Pam fluorometer (Walz, Germany) and leaf chlorophyll content was assessed with a handheld SPAD-502 chlorophyll meter (Minolta Camera Co., Japan).

Air temperatures were recorded on-site in and above the mangrove canopy with Hobo TidBit temperature loggers (Onset Computer Co.,USA)

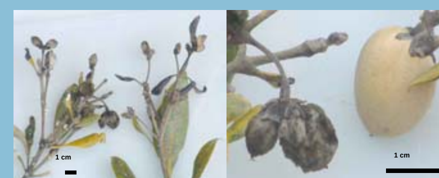

Plate 2. Frost damage in leaves (left) and in developing propagules (right) of *Avicennia*.

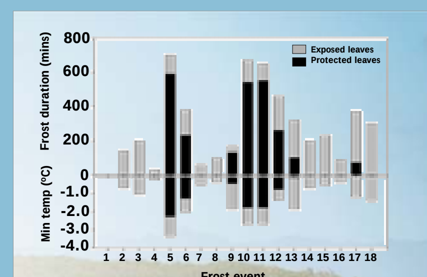

Fig 2. TOP panel: Duration of frost (minutes) in the positions of exposed leaves (light grey bars on graph) and protected leaves (black bars on graph. BOTTOM panel: lowest recorded minimum air temperature during each frost event at Ohiwa Harbour, May - Oct.

RESULTS

Average daily max/min air temperatures ranged from 20.2/9.6ºC in April, to 13.8/2.5ºC in July. Absolute lowest overnight minimum was -3.4ºC (Figure 2). Frosts and chilling nights were most frequent during July with 23 nights in the month <4ºC. Frosts caused severe damage and wilting in leaves, branchlets and developing propagules positioned in the top 10 to 25 cm of the mangrove canopy (Plate 1).

Exposed leaves were subject to significantly higher light levels than protected leaves. By midwinter (July/August) following a period of frequent frost nights and sunny days, chlorophyll a + b content in the exposed leaves had declined to 76.3% of April values but was relatively unchanged in protected leaves (Figure 6)

CO_2 assimilation rates (Figure 4) and stomatal conductance (Figure 5) were similar in all leaves throughout the study. Maximal rates of c. 7.9 μmol CO_2 m^{-2} s^{-1} occurred in April and deteriorated in both leaf types during winter. In October all leaves showed some recovery of photosynthetic function, but rates of CO_2 uptake were still low (mean between 1.5 and 2.5 μmol CO_2 m^{-2} s^{-1}).

Maximal yield of photosystem II (*Fv/Fm*) in both leaf types was at a minimum in July with exposed leaves at 43.7% of April values and at 81% in protected leaves (Figure 3). Slight recovery in both leaf types was evident in October.

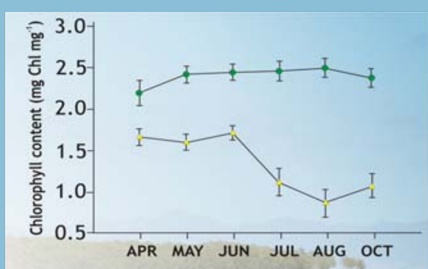

Fig 3. Seasonal variations in the foliar chlorophyll content of exposed and protected leaves of *A. marina* subsp. *australasica*.

Fig 4. Seasonal variation in the mean CO_2 assimilation rate (μmol m^{-2} s^{-1}) in exposed and protected leaves of *A.marina* subsp *australasica*.

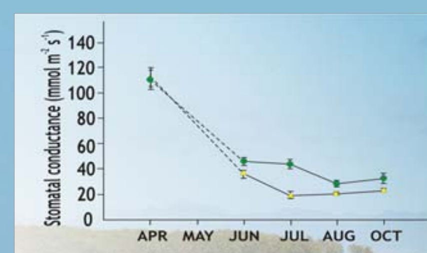

Fig 5. Seasonal variation in the mean stomatal conductance (mmol $m^{-2}s^{-1}$) in exposed and protected leaves of *A.marina* subsp *australasica*.

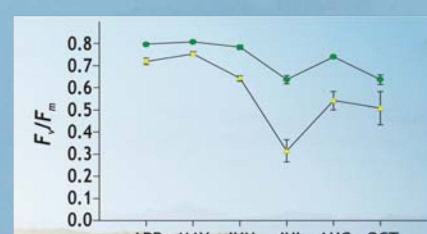

Fig 6. Seasonal vvariation in mean maximal quantum efficiency of PSII (the ratio of variable to maximal chlorophyll fluorescence, *Fv/Fm*), in exposed and protected leaves of *A. marina* subsp *australasica*.

CONCLUSIONS

Frosts were responsible for much of the visible tissue damage in *Avicennia* at Ohiwa harbour during winter. Leaves, young growing tips, developing propagules and branches in the upper and/or outer canopy often sustained lethal frost injuries while those inside the canopy and close to the ground remained visibly unaffected. However, although many leaves escaped physical injury, all exhibited some form of functional impairment after exposure to not only frost, but non-freezing (chilling) temperatures up to approximately 5ºC.

Net photosynthesis was severely depressed to about the same extent in both exposed and protected leaves during winter. However, the combination of light- and cold-stress in the exposed leaves led to decreased *Fv/Fm* and ultimately to chronic photoinhibition and loss of leaf chlorophyll.

Frosts and winter chilling severely impact photosynthesis in *Avicennia* and as such may be key factors in determining the geographical limit of this species.

References

Chapman V. & Ronaldson J. (1958) *The Mangrove and Salt-marsh flats of the Auckland Isthmus* (Bulletin 125). New Zealand Department of Scientific and Industrial Research.

Acknowledgements

Funded by The Royal Society of NZ (Marsden Fund)