# THE INFLUENCE OF NUTRIENT ENRICHMENT UPON MANGROVE SEEDLING ESTABLISHMENT AND GROWTH IN THE HAWKESBURY RIVER ESTUARY, NEW SOUTH WALES, AUSTRALIA.

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## Abstract

The hypothesis that mangrove exclusion from saltmarsh is attributable to nutrient deficiency is experimentally tested on the Hawkesbury River estuary. Survivorship and growth of seedlings of the grey mangrove *Avicennia marina* were followed for a sixteen month period, in an experiment in which half of all seedlings were treated with a slow-releasing source of phosphorus, nitrogen and potassium. While fertilisation substantially increased growth rate, this occurred in the second summer of growth and fertilisation did not improve the low survivorship of *A. marina* at the mangrove-saltmarsh boundary. Fertilisation had no influence on the root/shoot ratio where measured. It is postulated that factors other than nutrient deficiency are primarily responsible for determining the upslope distribution of mangroves in temperate Australian estuaries.

## Introduction

Comparisons of historical and contemporary air photographs in south-eastern Australia have demonstrated a widespread incursion of mangroves into higher intertidal saltmarsh environments over the previous five decades. These landward incursions have been documented for over sixteen estuaries from south-east Queensland, New South Wales, Victoria and South Australia (Saintilan and Williams 1999, 2000). In many instances, over twenty-five percent of the saltmarsh area has been lost to mangrove (Mitchell and Adam 1989; Evans 1997; Meehan 1997; Morton 1994; Williams and Watford 1997; Wilton 2001).

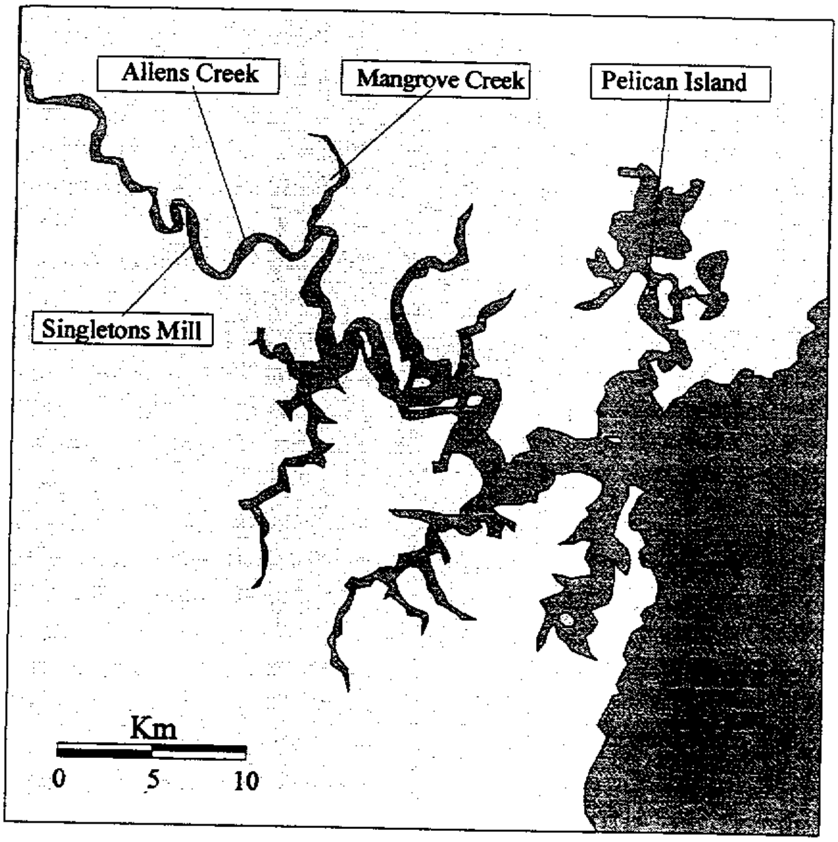
Four leading hypotheses have been presented to account for the colonisation of saltmarsh environments by mangroves (Saintilan and Williams 1999). Firstly, the degree of incursion appears consistent with a rise in sea-level, principally between 1940 and 1965. An alternative or supplementary hypothesis is that urban developments in the catchments of estuaries over the period has increased nutrient concentrations in upper-intertidal environments, enhancing colonisation. Further, rainfall patterns in south-east Australia oscillate between flood and drought dominance over a period of four to five decades (Pittock 1988), with the period 1945-1990 being wetter than the preceding five decades. The freshening of saltmarsh environments might promote the survivorship of mangroves (McTainsh *et al.* 1986). Finally, global warming might favour the growth of mangroves over saltmarsh at the edges of their latitudinal range (Adam pers. comm.).

The hypotheses that increases in nutrients and/or fresh water in the upper intertidal zone have promoted the landward colonisation of mangroves presuppose that mangroves are excluded from these environments by nutrient deficiency and/or soil water salinity. Both of these assumptions are subjected to experimental investigation in the estuary of the Hawkesbury River, New South Wales, where landward incursions of the sympatric mangrove species *Avicennia marina* (Forssk.) Vierh and *Aegicerus corniculatum* (L.) Blanco have been observed by a number of authors (Saintilan 1997; Williams and Watford 1997; Wilton 2001).

**Methodology**

Four sites were chosen on the Hawkesbury River for seedling growth experiments (Figure 1). The tributaries of Mangrove Creek and Allens Creek contain upper intertidal plains where saltmarsh has replaced mangroves with the vertical accretion of silts over the previous 500-1200 years (Saintilan and Hashimoto 1999). Experimental sites were established within saltmarsh adjacent to the mangrove-saltmarsh boundary within both creeks. Sites were also established in lower intertidal mangrove environments in mud (Singletons Mill) and sand (Pelican Island) substrates.

**Figure 1.** Location of experimental sites on the Hawkesbury River estuary, New South Wales.



The salinity of the saltmarsh experimental plots was consistently high over the study period, with an average of 50.0 parts per thousand NaCl for the Allens Creek site and 42.8 parts per thousand NaCl for the Mangrove Creek Site (Saintilan 1997). The Pelican Island site was closer to sea-water salinities (39.19 parts per thousand), while the Singletons Mill sites was freshened by fluvial tidal water (23.6 parts per thousand) (Saintilan 1997).

At each site, four 1.8 by 1.2 metre quadrats were distributed systematically, approximately 10 metres apart and holding elevation constant. All overhanging growth was cleared and a long shovel was used to cut all roots at the perimeter of the quadrat to a depth of 0.5 metres. Propagules of *Avicennia marina* were collected in late Spring from each site and twenty distributed evenly within each quadrat, each within a temporary trap to prevent predation by crabs or the removal of the propagule by the tide. The trap consistent of an open cylindrical polystyrene enclosure of diameter 7 cm and height 7 cm, with a double length of elastic at the top to prevent the propagule escaping. Traps were removed once seedlings had established.

All seedlings within two of the four quadrats at each site were treated with a slow release nutrient source (Osmocote$^{TM}$, a source of nitrogen, phosphorus and potassium). Five grams of Osmocote was placed within the substrate adjacent to each seedling at four month intervals, following the procedure of Clarke (1993). Seedlings were harvested after the second summer of growth, following a growth period of 16 months. The unconsolidated sands at Pelican Island allowed for the recovery of the full root system of each seedling. Seedlings were air dried to constant weight and weighed for dry shoot, leaf and where possible root mass.

**Results**

The application of fertiliser had no influence on the survivorship of seedlings at any site. While the survivorship of *Avicennia marina* was significantly lower in the saltmarsh sites of Mangrove Creek and Allens Creek (Figure 2), this was true of both fertilised and unfertilised seedlings.

While not increasing survivorship, the application of fertiliser greatly increased growth at all sites, and for both species (Figure 3), though the rate of extension suggests that this was not until the second summer of growth when cotyledon reserves were exhausted. The highest growth was attained at the fresher Singletons Mill site within the mangrove forest. The root/shoot ratio was unaffected by fertilisation at the Pelican Island site where this could be measured. The average root/shoot ratio was 0.9 (Figure 4).

**Figure 2.** Survivorship of mangrove seedlings at four locations on the Hawkesbury River estuary.

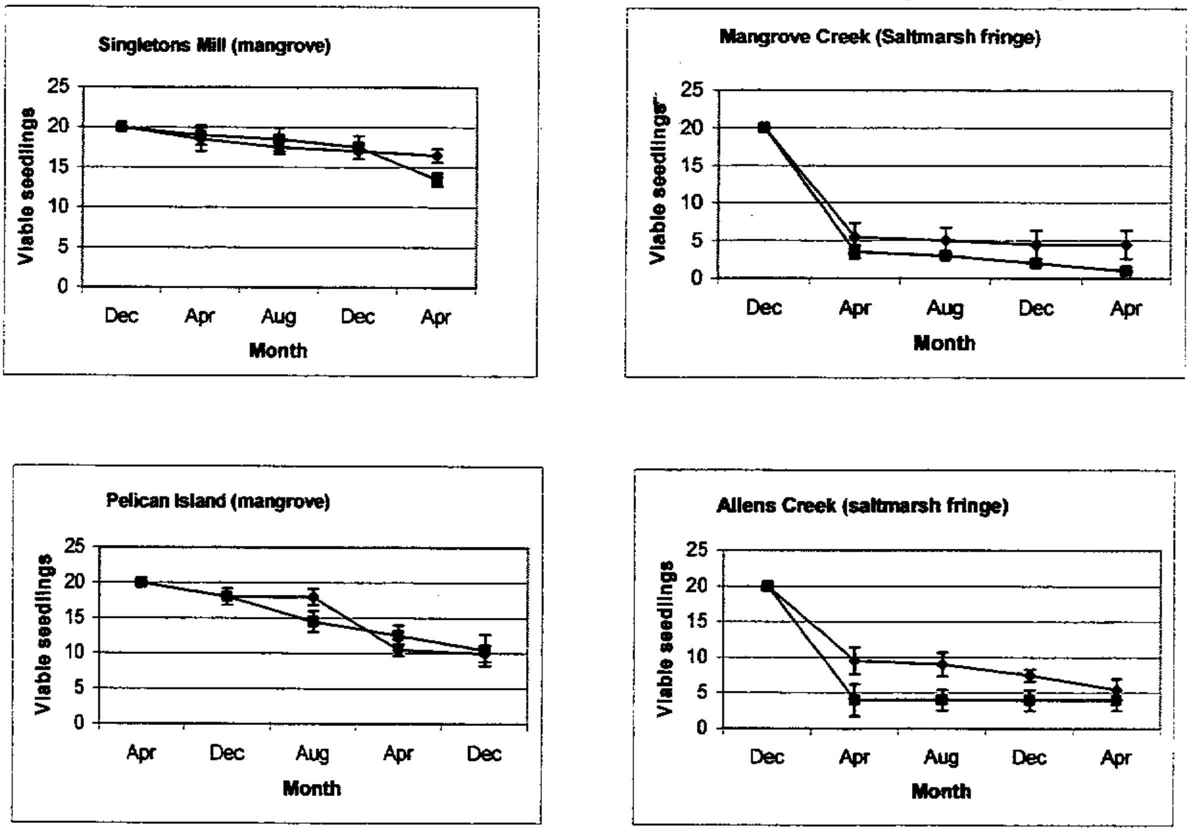



**Figure 3.** Growth of seedlings under control ( ■ ) and fertilised (♦) treatments at 4 sites in the Hawkesbury River estuary.

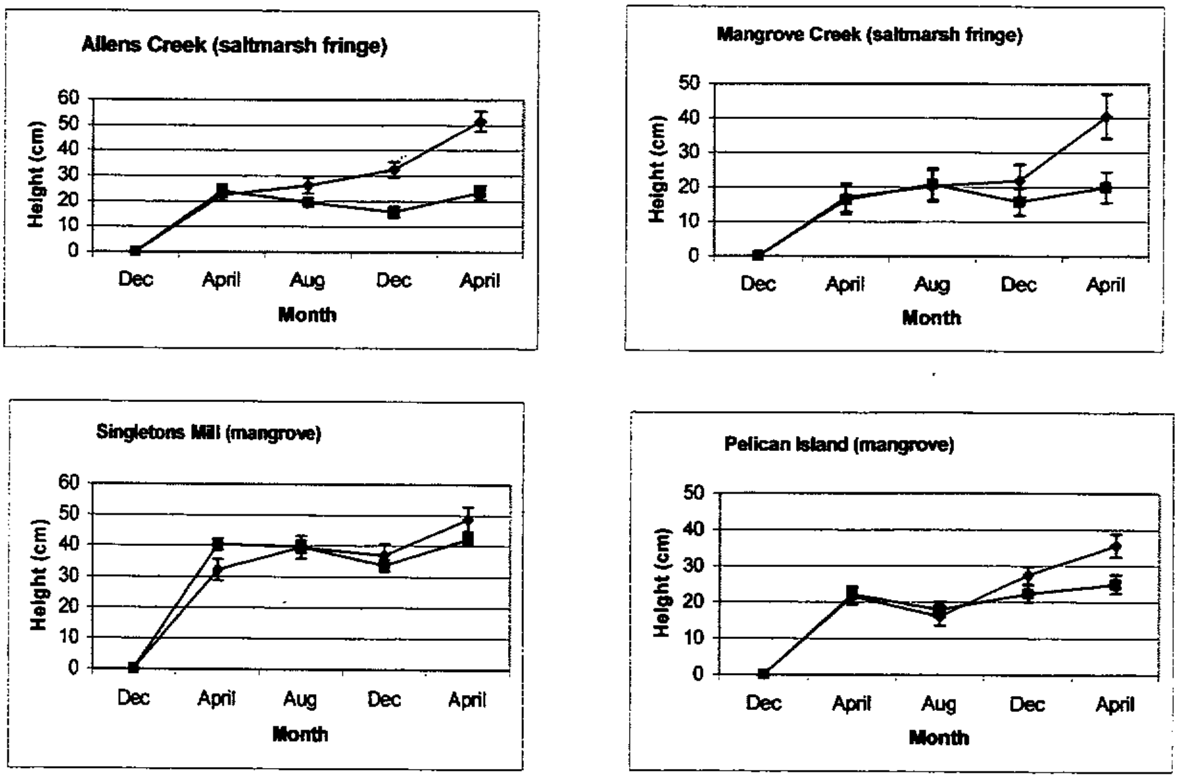
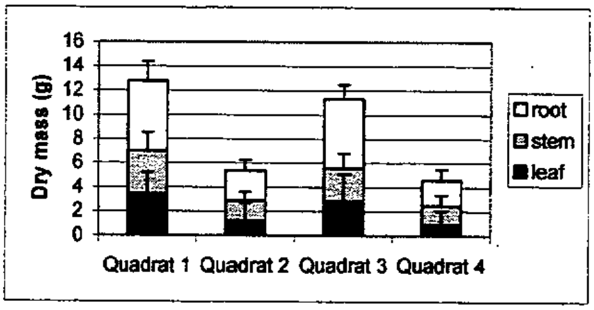
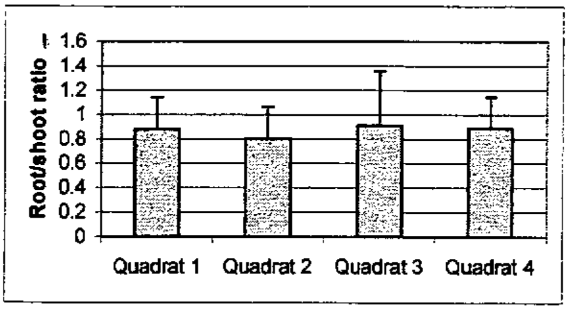


**Figure 4.** Average root mass, shoot mass and root/shoot ratio of fertilised and unfertilised seedlings of *A. marina* and *A. corniculatum* at Pelican Island.




**Discussion**

The hypothesis that recent mangrove incursions into saltmarsh is the outcome of higher nutrient levels in saltmarsh soils is seriously questioned in the light of these experimental results. Though photosynthetic function in *A. marina* is adversely affected by salinity-induced potassium deficiency (Ball *et al.* 1987), the low survivorship of *Avicennia marina* in highly saline saltmarsh environments on the Hawkesbury was not enhanced by the addition of nutrients, including potassium.

Nutrient enrichment had a profound effect on growth, an observation consistent with those of Naidoo (1987) and Clarke and Allaway (1993), though this was not evident until the exhaustion of cotyledon reserves. Whatever the cause of the high mortality of *Avicennia marina* seedlings in saltmarsh environments, it occurs while the seedling is still dependant upon cotyledon reserves of nutrients. The suggestion of Clarke & Allaway (1993) that mortality in these environments is probably the result of desiccation, is consistent with these observations.

Following the experimental work of Smith (1987), Robertson (1991) has suggested that predation by sesarmid crabs may exclude *A. marina* from mid to upper intertidal environments in many locations. However, while sesarmids have been observed on the saltmarsh plains of the Hawkesbury, the high mortality of *A. marina* in the Allens and Mangrove Creek saltmarsh sites occurred in spite of protection of propagules within traps.

Root/shoot ratios were only measurable at the Pelican Island site, where the entire root system of the seedlings could be retrieved. The root/shoot ratio of 0.9 was remarkably consistent between treatment and control plots, and corresponds to the root/shoot ratio of 0.8 calculated for mature individuals of the same species at this site (Saintilan 1997). Though it has been suggested that nutrient limitation might also induce high root/shoot ratios (Chapin *et al.* 1986), that this was not the case on Pelican Island suggests that salinity is a more important control over plant mass partitioning, regardless of the influence of nutrients over plant mass at this level of nutrient application.

An increase in sea-level would lead to an increased frequency of inundation in saltmarsh plains, and a correspondingly higher rain of propagules in these locations. However, the increased access of

*A. marina* to these plains would not be sufficient to allow establishment, were it not also for a change in soil conditions, perhaps occasioned by the higher inundation frequency or higher rainfall.

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