THE EFFECTS OF CLEAR FELLING MANGROVES ON SEDIMENT ANAEROBIOSIS

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SHAMSUDIN IBRAHIM. 1990. The effect of clear felling mangroves on sediment anaerobiosis. Four (15 x 15 *m*) plots were established within a natural stand of *Rhizophora stylosa* at Chunda Bay near Cape Ferguson, Australia. Two of the plots were clear felled and changes in redox potentials (Eh) and sulphide concentrations within sediments following clear felling were investigated. Clear felling reduced the redox potential but increased the concentrations of sulphide of mangrove sediments. Clear felled plots showed a clear trend in which redox potentials decreased steadily over time and depth. The concentrations of sulphide increased steadily from 31.8 to 62.2$\mu g\, g^{1}$ wet soil over the eight month period in clear felled plots, whereas a small fluctuation from 21 to 33.5$\mu g\, g^{1}$ wet soil was observed in control plots.

Key words: Mangroves - Australia - clear felling - sulphide concentration - redox potential sediment - anaerobiosis

Introduction

Mangrove forests are important coastal resources not only for stabilising sediments (Teas 1977), supporting inshore fisheries (Robertson & Duke 1978), and supplying dissolved nutrients and particulate matter to offshore waters (Boto *et al.* 1989), but also for the production of charcoal, fuel, timber and woodchips especially in southeast Asia. Mangrove forests in many countries are often subjected to heavy exploitation. Changes in chemical properties such as redox potentials (Eh) and sulphide concentrations following clear felling are poorly understood, and so far no systematic studies have been done on these aspects. All available information at present are only limited to studies done in salt marshes. De Laune *et al.* (1983) showed that unvegetated salt marshes have lower redox potential than vegetated areas. A recent study by de la Cruz *et al.* (1989) demonstrated that living *Spartina alterniflora* and *Juncus roemerianus* raised the redox potential of the salt marsh sediment significantly.

Changes of these chemical properties have significant impacts on above ground productivity in salt marshes (De Laune *et al.* 1979, De Laune *et al.* 1984, Linthurst & Seneca 1981, Howes *et al.* 1984). Boto and Wellington (1984) observed that the productivity of above ground biomass in tropical mangroves of northeastern Queensland, Australia, is significantly correlated with redox potentials. This information is particularly important, especially where reforestation of clear felled mangrove forests is carried out. The success of such reforestation depends, to a large extent, on the chemical properties of the sediments. As suggested by Salleh and Chan (1987), changes in sediment quality are probably the main factors that contribute towards lower site productivity in the second generation stands of mangroves at Matang, Peninsular Malaysia. This suggestion, however, has not been supported by any scientific evidence.

The present study was initiated to examine changes in redox potentials and sulphide concentrations in sediments after mangroves have been clear felled. Besides comparison between treatments (clear felled *versus* control), the soil properties were also compared between sites after clear felling. The properties were expected to vary with depth, and hence depth variations were also examined in this study. Variation in sulphide concentration with depth, however, was not examined because the titration took a long time and only a few samples could be examined during the time available.

Description of study area

The study area was located along a narrow strip of mangrove vegetation beside Sandfly Creek at Chunda Bay near Cape Ferguson (Lat. 19° 16'S, Longtd. 147° 04'E) in northeastern Queensland, Australia (Figure 1). Here, the mangrove vegetation flourishes behind a fine-sand barrier which was developed into a broad bar and provides excellent protection against wave action and currents. *R. stylosa* is the dominant species along the creek at the seaward area, and in some locations along the creek, individuals of *Avicennia marina* and *Ceriops tagal* occur sporadically together with *R. stylosa*. Rainfall within the study area was not recorded directly, but data from a nearby meteorological station (Lat. 19° 15'S, Longtd. 146° 46'E) indicated that the area around Townsville received < 800 $mm\ y^{1}$ from 1980 to 1987. Maximum and minimum temperatures were recorded within the study area from July 1988 to March 1989 with the highest value recorded at 35.5°C in January 1989 (summer) and the lowest value recorded at 11.8°C in July 1988 (winter).

Materials and methods

Four plots of 15 × 15 m each were established in an almost pure stand of *R. stylosa* parallel to the bank of Sandfly Creek. These plots were used to test for effects of clear felling on changes in anaerobiosis of sediments. Two of the plots (Plots 1 & 3) were randomly chosen for clear felling and the remaining two plots (Plots 2 & 4) were left uncut to serve as control. Cutting was done above the highest prop roots using chain saws and all logging debris including stems and branches were manually removed from the area to reduce obstacles while taking soil samples. They were collected within a 5 × 5 m permanent quadrat at the centre of each plot. This provided a buffer zone of 5 m to each side of the centre quadrats to reduce the effects of neighbouring trees.

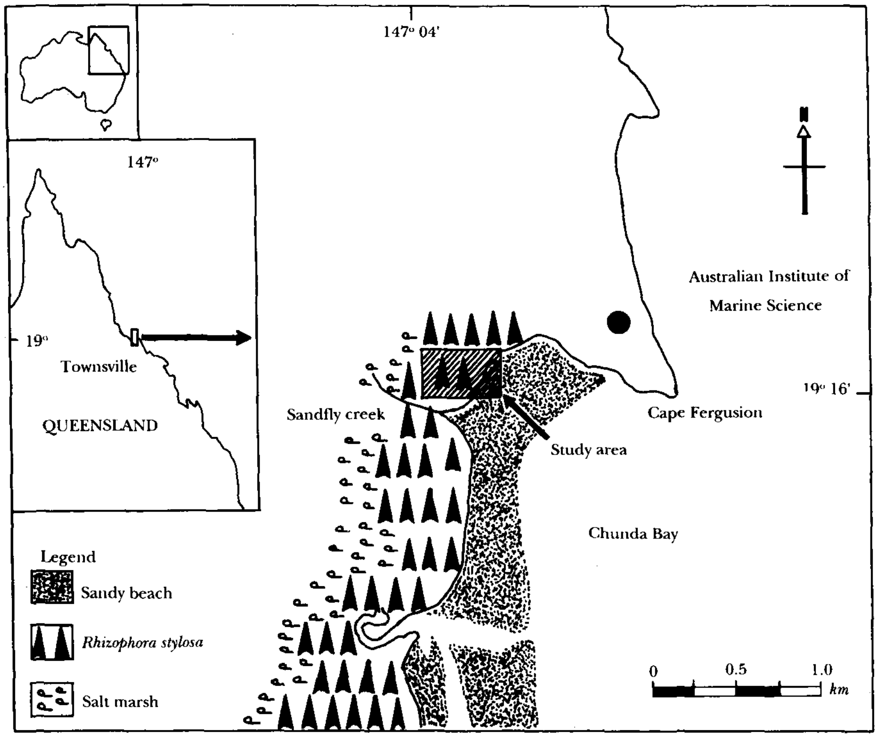

Figure 1. Location of study area

Core samples were collected with a large diameter corer (120 × 5 *cm*) (description given in Boto 1984). A total of five replicate cores were randomly collected in each plot on each sampling day. The sampling period was from 15 June 1988 to 27 February 1989. Redox potential (Eh) measurements were taken immediately after core samples were withdrawn from substratum by inserting the Eh electrode at 10 *cm* intervals to a depth of 40 *cm*. The readings were corrected by adding 244 *mV* in order to relate to the Standard Hydrogen Electrode reference. Eh of the core samples were measured using a temperature compensated Eh metre with silver chloride as the reference electrode.

For analysis of sulphide concentrations, 2 to 3 *g* samples of mangrove sediment were collected from a depth of 20 *cm* using a D-corer (described in Dartnall & Jones 1986), and samples were transferred into bottles containing 15 *ml* of sulphide anti-oxidant buffer and 15 *ml* deaerated distilled water (Boto & Nott 1983). The titration procedure followed the potentiometric titration methods (described in Vogel 1961). Samples were collected from 11 July 1988 to 13 March 1989.

Data on redox potential and sulphide concentrations in control and clearfelled plots were analysed using the analysis of variance (ANOVA). This approach was used to test differences between treatments, sampling times, plots (nested within treatments) and, in some cases, depths. Because of the mixture of fixed and random factors, and orthogonal and nested factors, appropriate F-denominators were determined using the methods described in Underwood (1981) and Winer (1971). Student Newman-Keul tests were used to determine which means differed significantly from one another, should a given analysis indicate significant effects.

Results and discussion

Redox potentials were consistently lower in clear felled than in control plots, indicating greater anaerobiosis in the former (Figure 2). This was supported by the analysis of variance which indicated that the effect of clear felling on redox potential was significant (Table 1). Significant differences in redox potentials were observed not only between treatments but also between depths. Figure 3 shows that mangrove sediments at deeper layers are more anaerobic than shallower ones. The pattern, however, was most consistent in the clear felled plots, whilst in the control plots the redox potential readings were much more variable between depths.

Table 1. Summary of four-way ANOVA for redox potential of ma 'e sediments (** = $P<0.005$; * = $P<0.01$; NS = not significant)

Source of variance	Redox potential (Eh)
Time	**
Depth	**
Treatment	**
Plot	NS
Time × Depth	NS
Time × Treatment	*
Time × Plot	NS
Depth × Treatment	NS
Depth × Plot	NS
Time × Depth × Treatment	NS
Time × Depth × Plot	NS

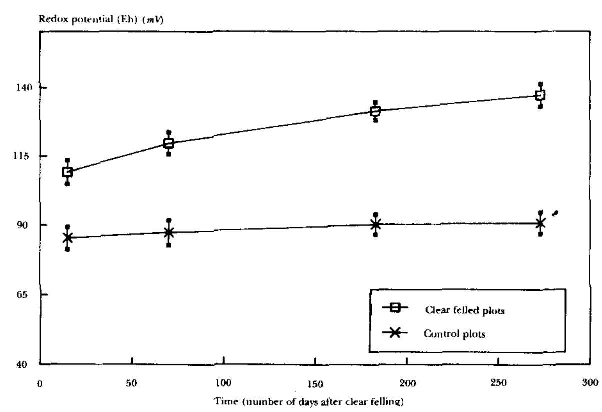

Figure 2. Mean redox potential (± SE) of mangrove sediments over time in clear felled and control plots

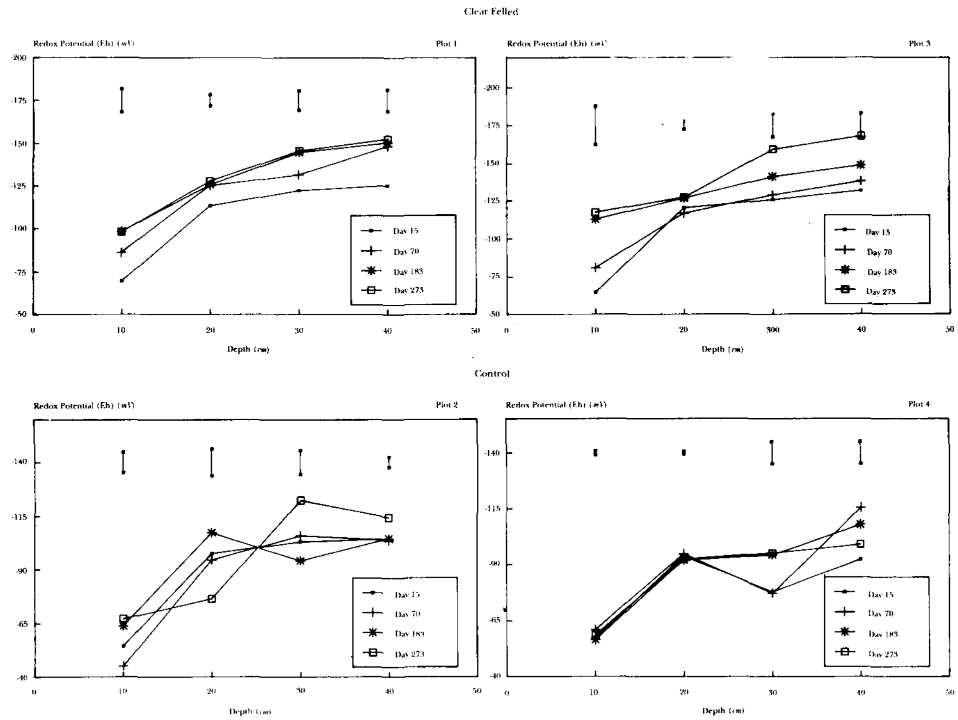

Figure 3. Mean redox potential (± SE) of mangrove sediments at different depths in each plot on each sampling day

The experiment clearly demonstrated that clear felling led to decreased redox potentials of mangrove sediments. This supports the hypothesis that mangrove sediments are more aerobic at sites with a greater density of trees (Boto & Wellington 1984). This can be well explained by the diffusion process whereby oxygen is translocated to below ground root systems through above ground tissues in undisturbed mangrove systems (Scholander *et al.* 1955). This process helps to create aerobic zones within soil-root systems (Howes *et al.* 1981). In clear felled plots, the system of transcolating oxygen to below ground roots is permanently disrupted and hence the sediments become more anaerobic with increasing depths. Greater fluctuations in redox potential readings at all depths in control plots reflect variations in the degree of oxygenation of sediments at various depths. This variability supports an earlier observation made by Ingold and Havill (1984) that complex interactions exist between plants and soil environments.

Analysis of sulphide clearly indicated sulphide concentrations were consistently greater in clear felled plots than in control plots (Figure 4). The concentrations of sulphide increased from 31.8 to 62.2 $\mu g\ g^{1}$ wet soil over an eight-month period in the clear felled plots, whereas the concentrations fluctuated from 21 to 33.5 $\mu g\ g^{1}$ wet soil in the control plots. Analysis of variance indicated a significant difference not only between treatments but also between times and a significant interaction between time and treatment (Table 2). This result reflects that overall, sulphide concentrations increased over time; and sulphide increased consistently over time in the clear felled plots, whereas in the control plots, concentration increased over the first 167 days but then declined till the end of the experiment. It is hard to think of any convincing biological explanation for the fluctuation of sulphide concentrations observed in the control plots. This fluctuation again reflects the complex interactions that exist between plants and soil environments. Sulphide concentrations are related inversely to the degree of oxygenation of soils (Connell & Patrick 1969), and this implies that mangrove sediments become more anaerobic after an area has been clear felled. In anaerobic conditions, sulphide is produced as a metabolic by-product by sulphate-reducing bacteria (especially the genus *Desulphovibrio*) (Bloomfield 1969, Boto 1984).

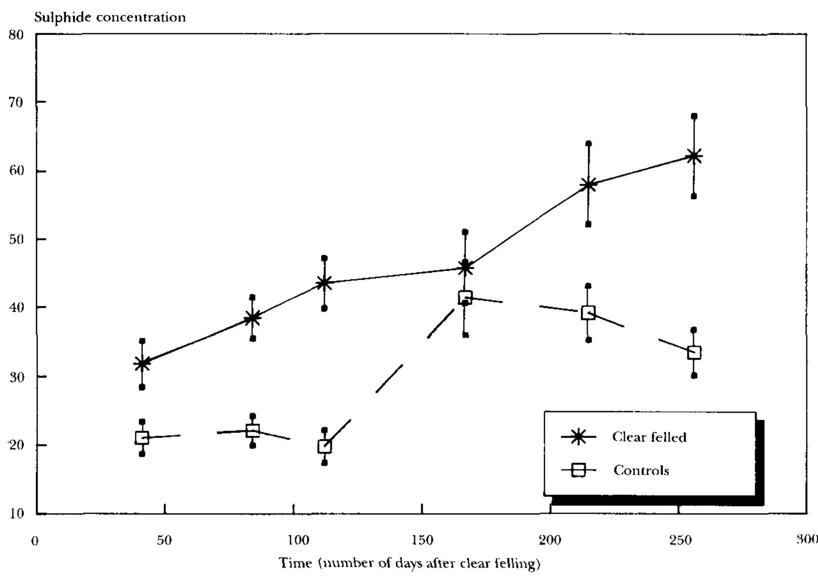

Figure 4. Mean concentration of sulphide (± SE) in mangrove sediments at 20 *cm* depth over time in clear felled and control plots

Table 2. Summary of three-way ANOVA for sulphide concentrations of mangrove sediments (** = P<0.005; * = P<0.05; NS = not significant)

Source of variance	Sulphide concentration
Time	*
Treatment	**
Plot	NS
Time × Treatment	*
Time × Plot	NS

Lower redox potentials and high concentrations of sulphides in sediments have been shown to be toxic to plant growth (Mitsui 1965). The critical level of redox potentials and sulphide concentration in mangrove sediments that may cause injurious effects to seedlings is unknown. Plant species of salt marshes such as *S. alterniflora* have been shown to be intolerant to sulphide concentrations >10 $\mu g\, g^{1}$ dry soil (De Laune *et al.* 1983). It has been shown that sulphide toxicity may affect plant growth by interfering with the plant's ability to absorb nutrients such as ammonium and nitrate (De Laune *et al.* 1983, Morris & Decay 1984). Reduction in nutrient uptake may cause a rapid drop in the concentration of nutrients in the shoot and may result in a considerable reduction in growth rates of young plants (Throught & Drew 1980).

Conclusion

Results from this study confirm the hypothesis that clear felling mangroves would lead to a high degree of anaerobiosis in mangrove sediments. Consistently low redox potentials and high concentrations of sulphide were observed in clear felled mangroves, despite the area being inundated and flushed by tides twice daily. Although the study showed significant changes in the chemistry of sediments after clear felling of mangroves, it is still unknown whether these changes will have an adverse effect on mangrove seedlings especially at the early stage of their growing period. Therefore the effect of these chemical changes in sediments on growth of planted seedlings in logged over mangrove forests need to be investigated. Such information is particularly important in southeast Asian countries where replanting following harvesting forms an essential component in the management system of mangrove forests. This will verify an earlier suggestion that clear felling caused lower productivity in the second rotation crops.

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