Dryland salinity, soil degradation and terrestrial biota in south eastern Australia: problems and fallacies

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Abstract

Reports suggest that dryland salinity is a major threat to terrestrial biota in southern Australia, however, very little research has been undertaken that quantitatively links secondary dryland salinity with adverse affects to terrestrial endemic biota. The research performed to date in south eastern (SE) Australia contains invalid assumptions and major problems. The abiotic and biotic principles are poorly understood.

This research investigates relationships between abiotic and biotic metrics taken at ten salinised and non-salinised sites over three years in box/gum grassy woodlands of SE Australia. Biotic surveys included site flora and fauna identification (presence), and photosynthesis efficiency in eucalypt leaves. Results indicate that many endemic fauna and flora species flourish at (highly) salinised and degraded sites; many invertebrates, mammals, frogs and lizards tolerate increased and fluctuating salinity levels. Foxes are present at all sites and are common across the study region, being an obvious major threat to all ground dwellers. Many endemic grass and tree species appear to be relatively salt tolerant, during all stages of their life cycles. This is to be expected, as southern Australia is naturally very salty. Contrary to previous reports, no direct evidence was found linking increased salinity levels with flora or fauna mortality and no evidence was found indicating that increased salinity levels favour exotic species. In southern Australia, it is problematical to directly link increased soil salinity *per se*, with ecological stress, as many other synergistic factors are involved and are probably more significant. These include the compounding adverse effects of increased soil and vegetation degradation due to past and present agricultural activities, particularly intensive livestock grazing.

Introduction

A 'threatening process'?

Quantitative research of the inter-relationships of increased soil salinity levels and endemic terrestrial biota in (SE) Australia is scarce. A number of reports claim that secondary salinisation is a major threat to endemic biota (Taws 2003; Briggs and Taws 2003; Zeppel *et al*. 2003; Thompson and Briggs 2005, Seddon *et al*. 2007), and dryland salinity is listed as a threatening process to biodiversity (EA 2001). However, the mechanisms and principals are poorly understood. Briggs and Taws (2003) extrapolate to suggest that increased salinity levels actually kill endemic vegetation and favours exotic species (weeds). However, these claims also require temporal context; increased salinity levels in southern Australia are not recent and are probably not presently extreme (Crawley 1994). Australian dryland soils are also commonly saline and sodic. Hence, it is likely that endemic biota is relatively tolerant of high and fluctuating salinity levels as suggested by Kreeb *et al*. (1995), Williams *et al*. (1998); McEvoy and Goonan (2003), Malcolm (2005); Bann and Field (2006), (2008), Humphries (2008) and Bui (2009). This paper investigates the affects of increasing soil salinity on terrestrial biota in SE Australia.

Sites

Following extensive site reconnaissance in three states, ten sites were selected with various degrees of apparent salinisation on the Southern Tablelands of NSW in the upper Murray Darling Basin. All sites contain Yellow Box (*Eucalyptus melliodora*) and Blakely's Red Gum (*E. blakelyi*) Grassy Woodlands (YBRGGW), which dominate the more productive soils of the lower slopes and drainage lines, hence, have been extensively cleared and modified for agriculture post European settlement. They are therefore listed as an Endangered Ecological Community and as dryland salinity usually outbreaks in these locations, it is listed as a threatening process (EA 2001). Sites were selected that exhibited minimal levels of disturbance, particularly stock grazing and weed incursion, to reduce these factors confounding the results. This confirmed that all sites were reserves, eight of which were travelling stock reserves (TSRs).

Methods

A suite of biotic and abiotic measurements were performed over three years to investigate interactions between the regolith and biota. Metrics included ground macro-invertebrate (pitfall traps, buried toilet roll termite baits and log disc habitat surrogates) and vertebrate surveys, flora identification and leaf analyses, various field and lab soil and water analyses and the application of the Landscape Function Analysis assessment procedure (Tongway and Hindley 2004). Abiotic metrics included soil EC (1:5w), pH (1:5w), EM38 / 31 surveys, surface compaction, SOM, SOC, CO_3 / HCO_3, slakeness, and nutrient, cation and anion analyses. A number of piezometers were installed. EC was measured at various times to investigate temporal variation. Multivariate statistical analyses were performed using GenStat 10^{th} Edition.

Results and discussion

Sites

Most salinised sites inspected were relatively small and localised, generally less than 1 Ha in size. Sites appeared to be restricted to their current extent, showing no sign of expansion since 2004, which concurs with Wagner (2001). All sites inspected had some degree of fragmentation and/or degradation and had previously been grazed by sheep, thereby influencing soil conditions. Sites that had been fenced off from recent domestic grazing appeared to be responding favourably.

Soils

EC levels are highly variable spatially (laterally and vertically) and temporally, especially following rainfall (20.2 - 1.6 dS/m at the same location, two days apart after rain) and they are generally highest at the soil surface (i.e. from evaporation). Soil pH (w) varied considerably, from 3.8 to 10.6 in the top 5cm of soil (up to 11.2 at 25cm depth) which is an obvious determining factor for biota. Degraded scalded areas lack organic matter (SOM, SOC) and nutrients (N, P), often have increased NO_3, SO_4, Na, K, Mg, Al, Cl, F and Br, decreased Ca (and sometimes other cations) and rarely have an A_1 horizon, exposing the A_2 horizon that is generally sodic, bleached, dispersible and compacted with poor structure.

Fauna

Brush-tailed possums, swamp wallabies and eastern grey kangaroos were common at all sites. Echidnas, frogs, lizards and geckos also inhabit salinised areas. A link between elevated salinity levels and adverse impacts on ground vertebrates was not found. Anecdotal evidence suggests that mortality from foxes is a far greater threat than salt toxicity, being present at all sites. Rabbits and hares were also common. Spiders, centipedes, mites, earthworms and 11 Order of insects including termites (5 spp.), wasps and ants were identified in the salinised zones, In particular, meat ants (*Iridomyrmex purpureus*) appear to favour salinised and degraded areas, often building their large nests within the actual degraded scalded area (so-called 'discharge zones') where the most elevated salinity levels usually occur. Nests are occupied for long periods (years), and extend to a depth well into the subsoil, suggesting that at no period does the groundwater inundate to this level. Many other endemic ant species (>15 spp.) also tolerate the elevated salinity levels. Exotic earthworm species are the most common worms in YBRGGW, however, native species appear to be more abundant than exotic species when salinity levels increase, indicating likely superior salt tolerance. No relationship was found between salinity levels (EC) and biomass, the number of taxa identified, nor the presence of termites, ants, frogs and lizards (see Table 1).

Native trees

The rate of photosynthesis (Photosystem II), a surrogate measure for plant health, of *E. melliodora* leaves measured with a Photosynthesis Efficiency Analyser (PEAmeter) indicates that there is no significant difference between plants growing in salinised areas and those in non-salinised areas. This suggests that *E. melliodora* exhibits tolerance to increased salinity levels, which is not surprising, as all trees growing in the salinised areas, at all ages, appeared to be in a healthy state. *E. blakelyi* also germinate and persist in salinised areas and although they do suffer from dieback (widespread tree health decline), salinity cannot be directly attributed to this as suggested by previous reports. No evidence was found linking increasing salinity to dieback and/or dying trees. Many trees persist in salinised areas everywhere (i.e. in all southern states), and dieback occurs across the entire landscape, from numerous compounding and confounding factors such as drought, insect plagues, cumulative (i.e. historical) management practices including ringbarking and intensive stock grazing, modified surface hydrology and erosion. Blaming salinity for a trees poor health, which in most (all?) cases is only apparent as 'dieback', is unfounded. *E. cinerea, E. bridgesiana* and *E. rubida* also grow in areas with increased soil salinity.

Table 1. Summary of multivariate statistical analyses – EC ANOVA F Probability (p) using multiple regression (adjusted for position affects, or differences between). Similar results were obtained using correlation coefficients. Survey stations included buried toilet rolls used for termite baits, log discs (red gum and pine) placed on the ground as surrogate habitat and two surveys with pitfall traps. Soil $EC_{(1:5)}$ was measured at each station (surface 0-5cm).

VARIANT	EC (1:5w)
Toilet rolls eaten (termites)	X
Ants (presence – log discs, pitfalls)	X
Termites (toilet rolls, log discs & pitfalls)	X
Worms (at stations)*	√
Worms (pine log discs)*	√
Worms (red gum log discs)	X
Lizards, skinks and geckos	X
Frogs**	X
Total number of taxa	X
Log disc and Pitfall taxa number	X
Pitfall total animals (biomass)	X
H_2O_2 (reaction with soil organic matter)	√√

√√ = $p < 0.001$; √ = $p < 0.01$; X = not significant.
Data collected from 10 sites, 66 transects (50m length) and 264 stations (4/transect).
*Worms were mainly exotic spp. **The majority of frogs were found in low lying, saline areas.

Native grasses
At least six endemic grass species that are also drought tolerant and relatively productive as fodder grow in or around the salinised areas, including the most saline scalds (see Bann and Field 2006). In particular, *Cynodon dactylon* (couch grass) is common and grows on the most salinised and degraded sites. Its mat forming growth habit (rhizomes and stolons), capable of growing onto and across the scalded areas, removes the need to germinate within the hostile scalded area. Interestingly, on sites that had not been recently grazed, the boundary between grasses and the bare scalded area is usually abrupt, with no apparent adverse impact on the persisting grasses. The boundary often corresponds with a huge variation in EC and pH levels, usually within 10-20cm, suggesting a sudden change in soil conditions, or simply erosion. At a number of sites, rainfall runoff from the areas of elevated salinity (scalds) drained directly into YBRGGW, with no apparent adverse impacts on the biota.

Weeds
No evidence was found linking increasing salinity with weed dominance as suggested by previous reports, which concurs with Coutts-Smith & Downey (2006). Numerous other factors favour the incursion of weeds, especially those relating to disturbance, which must be considered when investigating the cause responsible for the presence of weeds (Coutts-Smith & Downey 2006). Evidence from this research indicates that increasing salinity favours endemic species; Australian flora and fauna have co-evolved with elevated and fluctuating soil salinity levels for millennia (Crawley 1994).

Predators
As salinity levels are highly variable, biota need to be equipped to tolerate both elevated salinity levels and the large (often sudden) fluctuations. Although some mobile invertebrate predators do not appear to be adversely affected by increased salinity levels, the affects on other functional groups is not as clear. It is likely that the presence of the meat ants in particular would deter many organisms. Areas with high salinity levels are also often bare, exposed, compacted and are often very alkaline, in addition to having formidable predators (meat ants, trapdoor and wolf spiders, wasps); a hostile and dangerous place for any ground dweller to reside. In addition, alkaline and acid soil conditions are not only toxic to the biota, they can severely reduce nutrient availability for plants.

Secondary salinity is a symptom, not a process
It appears that other important soil physical, chemical and biological parameters consequent to vegetation and soil degradation (from stock grazing and landuse practices), including compaction or erosion (removal) of the topsoil (A_1 horizon), altered soil pH levels, nutrients, cation and anion levels (Bann *et al*. this volume) and other symptoms of degradation play a more significant role on terrestrial biota recruitment, survival and persistence than salinity *per se*. It also appears that many salinity expressions are simply another symptom of land degradation, rather than the actual cause. Thence, it cannot be a threatening process. Moreover, as little

evidence was found linking increasing salinity with adverse affects to endemic biota, hence biodiversity, and high salinity levels are a natural phenomenon in this part of the world, we suggest that the habitat associated with increased soil salinity and soil degradation may actually provide an additional opportunity (ecotone) within the YBRGGW ecosystem, allowing endemic species, particularly colonisers, to thrive. This effectively paradoxically increases the overall (gamma) biodiversity levels. Further work on this matter is required.

Conclusions

Many endemic flora and fauna species flourish at salinised areas in SE Australia. This is not surprising, as salt levels in Australian dryland soils are amongst the highest in the world, and have been for millennia. Contrary to previous reports, no evidence was found to indicate that endemic flora and fauna species are directly influenced by elevated salinity levels *per se*. Indeed, a number of problems and invalid assumptions have been identified with this previous research (Bann and Field 2006, 2008). More emphasis needs to be directed towards various trials involving planting endemic grasses and trees, of local provenance, rather than the current focus on exotic and/or pseudo-exotic species (i.e. native and/or hybrid species from another state). Local provenance seed should be collected due to local ecotone variation, such as soil salinity, pH, moisture and clay content. Predicting biodiversity loss and/or ecological change in response to secondary salinisation in SE Australia requires careful consideration of site disturbance, soil degradation and all other relevant synergistic factors.

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