

WEED ECOLOGY

Research on the impact of bitou bush on native communities

Research on weeds in the French lab has focused on coastal systems with over a decade of work having been completed.

Recently we have been investigating a range of other weeds along the coastal zone as we notice an increase in the prevalence of species such as lantana and asparagus fern.

Here we highlight some of the results of our work and show some of our current research on how bitou bush affects native coastal communities. We have also investigated the impacts of different management strategies on native communities.

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A Very Brief Introduction to Coastal Dunes.

Coastal dunes can vary significantly from one beach to the next. However, the morphology and vegetation of coastal dune systems can be classified into zones that run roughly parallel to the shore line. The communities differ in terms of vegetation structure, composition and disturbance history. These are important differences when studying invasive species, because they have the potential to moderate the impacts and degree of invasion within a community.

The three main zones of a coastal dune system are described below:

1. Strand

The first vegetative zone immediately behind the beach is referred to as the 'strand' or 'pioneer zone'. This area is inhabited by primary stabilizing plants, predominantly *Spinifex sericeus* (Hairy Spinifex). When dunes first begin their development, the primary species are the first to inhabit the area. They promote the establishment of secondary species by trapping additional sand and stabilizing existing sand. This results in further dune formation and build-up behind the strand line, and the development of a fore dune.

2. Fore dune

Coastal fore dune communities are typically comprised of shrubland (<1.5m tall) vegetation. Storm action and proximity to the beach mean inhabiting species must tolerate a harsh and disturbed environment that is often exacerbated by human recreation. Common plant species include shrubs such as *Acacia longifolia* var. *sophorae* (Coastal Wattle) and *Leucopogon parviflorus* (Coastal Beard-heath), and ground-cover species such as *Scaevola calendulacea* (Fan Flower) and *Carpobrotus glaucescens* (Pigface).

3. Hind dune

Lying behind the fore dune, the hind dune environment is buffered from much of the natural and human induced disturbances experienced by fore dune communities. The underlying soils are also much more stable allowing for the presence of tall (>10m) canopy species along with shrubs, grasses and herbs. Hind dune communities are often classified as woodland or forest and may include canopy species such as *Banksia integrifolia* (Coastal Banksia), *Eucalyptus pilularis* (Blackbutt) and *Cupaniopsis anarcardioides* (Tuckeroo).

Impacts on Ecosystems

1. *Bitou bush alters the ground level microclimate*

We have found that bitou bush increases the canopy cover on the fore dune (Fig 1) which causes changes to the ground level microclimate so that it is moister, darker (Fig 1) and cooler, which is very different to the usual ground level conditions created by the hot and dry sand.

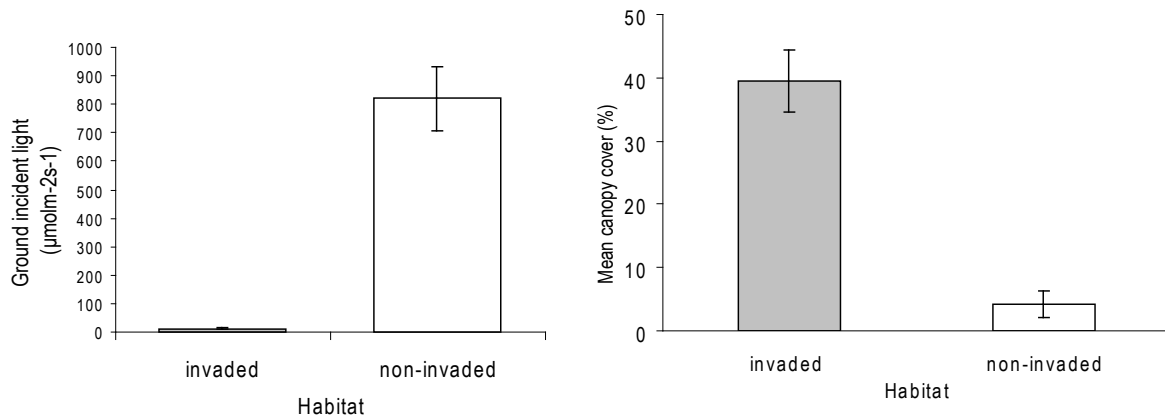


Fig 1: Ground level light in the bitou bush invaded and non-invaded habitats

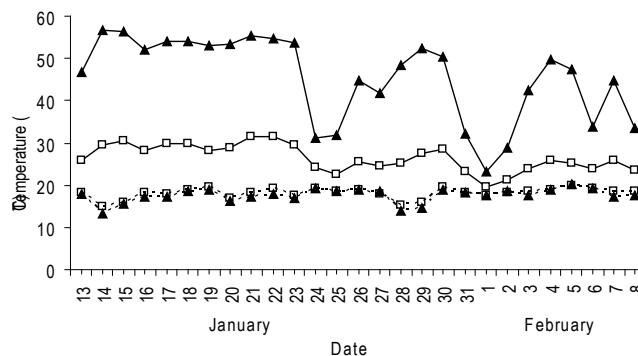


Fig 2: The mean daily minimum and maximum temperature on the ground below bitou bush canopies (open squares) and native canopies (closed triangles) in January and February 2007

2. *Bitou bush alter the decomposition rates and increases the abundance of invertebrate decomposers*

Using litterbags placed in different habitats and containing either native or bitou litter, we found that the succulent bitou leaves decomposed at a significantly higher rate than the sclerophyllous native leaf mix. Time to 99% leaf loss was estimated to be 0.9–1.3 years for bitou and 3.1–4.4 years for the native species. This reflects the physical properties of the leaves and the lower leaf mass area of bitou. Bitou leaves decayed faster in coarse mesh bags compared to fine mesh,

indicating leaf litter invertebrates positively influenced their decomposition. Bitou leaves generally decomposed faster within the weed infestations, partly due to invasion creating a protected environment with an altered microclimate. Replacement of native species with *C. monilifera* will alter nutrient cycling through changes in litter quality and decomposition rates which has implications for ecosystem resilience and stability.

3. Bitou bush alters the nitrogen cycle of sand dune vegetation

Field samples have identified that there is a greater input of litter to native areas, which is highly seasonal, compared with the bitou habitat. Together with a slower decomposition rate, this results in a greater mass of litter on the ground in the native areas. The litterfall is estimated to contain more than twice the amount of nitrogen and phosphorous within the native areas, because of the high leaf fall rate rather than a higher nutrient content. However, the total soil nitrogen was two to five times higher in the invaded areas than within the native areas. This was accompanied by an increase in ammonia content. The bulk density was lower in invaded areas, but there was no clear trend in the change in soil pH. The higher soil nitrogen beneath the bitou infestations could increase the competitive superiority of *C. monilifera* directly by increasing growth rate, or indirectly by impairing the establishment of native species that are adapted to growing in nutrient-poor soils.

Further reading:

Lindsay E.A. and French K. (2005) Litterfall and nitrogen cycling following invasion by *Chrysanthemoides monilifera* spp. *rotundata* J. *Appl. Ecol.* **42**, 556-566.

Lindsay E.A and French K. (2004) *Chrysanthemoides monilifera* ssp. *rotundata* invasion alters decomposition rates in coastal areas of New South Wales, Australia. *Forest Ecology and Management* **198**, 387-99.

Impacts on animals

Changes to plant communities caused by the invasion of woody weeds such as bitou bush can have flow on consequences for the fauna that live or feed within those communities.

The abundance and diversity of invertebrates could be altered by changes to the density of leaf litter settling below plants. Bird assemblages could be altered in response to invertebrate abundance or changes to other plant derived food sources. Structural changes to habitat, such as an increased density of shrub layer plants, could encourage the presence of feral pests such as rabbits or rats.

Within the French lab numerous projects have been carried out to investigate the relationship between animals and bitou bush invasion.

Particular attention has been given to the effects of invasion on:

Bird communities

Invertebrate communities

The effect of bitou invasion on bird communities.

Birds play an important role as pollinators while foraging for nectar, while others act as dispersers by eating fruit and excreting seed. Bitou bush produces large quantities of fleshy fruit suggesting it is likely to be a species that attracts seed dispersers. Because of this, the invasion of bitou bush could alter bird assemblages within coastal communities by attracting frugivorous (fruit-eating) birds.

We found that there was no difference in the total bird species richness and abundance between native and bitou infested habitat (Zubovic). However, when we characterised the birds into feeding guilds, specialist feeders (i.e. seed, flower and fruit eaters) were more abundant and diverse in native habitats.

Carl Gosper investigated the relationship between birds and bitou bush as part of his PhD research. He compared bitou bush fruiting characteristics with those of co-occurring, bird dispersed native species to assess the relative attractiveness of bitou to bird species. He also measured the removal rate of fruits from these species and assessed the effect of bitou bush dominance on the species richness and abundance of birds. The results found that while the fruiting characteristics of bitou bush make it desirable for fruit-eating birds, they did not make bitou fruits more desirable than some native coastal species. The main distinction between bitou bush and co-occurring native species was the phenology (i.e. the timing of fruiting and flowering). Bitou bush produces fruit throughout the entire year with peak production occurring between April and July when there are fewer

coastal native species in fruit. This benefits bitou by exposing it to a wider diversity of potential dispersers and accommodating those bird species that may have otherwise moved on to another food source once the native fruits had finished.

Carl also found that the removal of bitou affected the bird community. Herbicide treated habitat had a reduced number of birds that had previously been observed feeding on bitou. These results are discussed further along with the effect of herbicide treatment on seed dispersal in "impacts of management".

Ben Owers investigated bird behaviour in more detail for 4 species. Little Wattlebirds and New Holland Honeyeaters exploited only native resources in infested habitats while Silvereyes and Superb Fairy-Wrens exploited bitou bush resources. However, the Superb Fairy-Wren spent less times foraging on the ground in infested habitats

Nest predation rates were compared between infested and uninfested areas using artificial nests. Open nests were used to imitate the nest of a New Holland Honeyeater, and closed nests to imitate a Superb Fairy-Wren. Open nests showed no difference in overall nest predation however, significantly higher predation was found in infested habitats for closed nests. Higher rodent predation was found in infested habitats for both nest types. These results suggest that bitou bush infestation may impact upon birds with covered nests, and that rodent predation may be an important source of nest predation in these habitats.

Further reading:

French, K. and Zubovic, A. (1997) Effect of the weed *Chrysanthemoides monilifera* (bitou bush) on bird communities. Wild. Res. 24, 727-735.

Gosper, C., Whelan, R.J. and French. (2006) The effect of invasive plant management on the rate of removal of vertebrate-dispersed fruits. Plant Ecology. 184, 351-363

Gosper, C.R. (2004) Fruit characteristics of invasive bitou bush, *Chrysanthemoides monilifera* (Asteraceae), and a comparison with co-occurring native plant species. Aust. J. Bot. 52, 223-230.

Gosper, C.R. (1999) Plant food resources of birds in coastal dune communities in New South Wales. Corella 23, 53-62.

Impact of bitou invasion on invertebrates

The presence and abundance of invertebrates (e.g. insects, spiders, worms) can affect a vegetation community in a number of ways. Invertebrates act as an additional food source for seed dispersers such as birds and small mammals, participate in nutrient cycling by aiding leaf litter decomposition, and can moderate the presence of plant species by feeding upon them or harvesting their predators (e.g. ants and aphids).

A survey of leaf litter invertebrates was carried out by French and Eardley (1997) who found no difference in overall species richness or abundance between native and bitou infested habitats. However, they did find a difference in the abundance

of certain taxa reflecting an overall difference in species composition. The species that increased in abundance were species associated with litter decomposition that preferred moister environments.

Liz Lindsay found that excluding invertebrates significantly decreased the rate of bitou leaf decomposition but did not alter the rate of native (*Leptospermum laevigatum*, *Acacia longifolia* var. *longifolia*) leaf decomposition. This result suggests that the presence of Bitou may encourage the presence of some invertebrate decomposers that prefer it as a food source. If this is true, it may be possible to see a difference in the composition or abundance of invertebrate species between native and bitou infested habitats.

The results of French and Eardley's survey do confirm that bitou invasion can affect invertebrate communities. However, they do not confirm the precise causes of these effects. Differences between the habitats may be caused by changes to soil moisture or leaf litter depth as a result of invasion, or possibly an increased abundance of a preferred food source (i.e. bitou). Further investigations taking into account invertebrate functional groups may shed some light on this subject.

Further Reading:

French, K and Eardley, K. (1997) The impact of weed infestations on litter invertebrates in coastal vegetation. In: *Frontiers in Ecology*. (Eds: N Klomp and I Lunt) Elsevier Science, London.

French, K. and Zubovich, A. (1997) Effect of the weed *Chrysanthemoides monilifera* (bitou bush) on bird communities. *Wild. Res.* 24, 727-735.

Gosper, C., Whelan, R.J. and French. (2006) The effect of invasive plant management on the rate of removal of vertebrate-dispersed fruits. *Plant Ecology*. 184, 351-363

Gosper, C.R. (2004) Fruit characteristics of invasive bitou bush, *Chrysanthemoides monilifera* (Asteraceae), and a comparison with co-occurring native plant species. *Aust. J. Bot.* 52, 223-230.

Gosper, C.R. (1999) Plant food resources of birds in coastal dune communities in New South Wales. *Corella* 23, 53-62.

Lindsay, E.A and French, K. (2004) *Chrysanthemoides monilifera* ssp. *rotundata* invasion alters decomposition rates in coastal areas of New South Wales, Australia. *Forest Ecology and Management* 198, 387-399.

Vegetation Impacts

Impacts on Dune Vegetation

Bitou bush is a highly competitive weed. Since its introduction to stabilize sand dunes in the late 1960's, it has invaded approximately 80% of the NSW coastline. It is a prolific seeder that grows quickly to form dense stands which replace native vegetation and threaten numerous native communities, particularly those that inhabit coastal dunes. NSW NPWS believe bitou bush is the dominant plant species along approximately 36% of the states coastline.

Tanya Mason investigated the impacts of bitou invasion on dune vegetation as part of her PhD research. Specifically, she examined effects on vegetation structure, the richness of both native and exotic plants and variability in fore and hind dune plant communities.

By measuring the presence and relative abundance of species within a site, Tanya found that bitou bush differs in its impact on fore and hind dune zones. In fore dune shrublands, there was significantly reduced species richness of climber, graminoid (grass-like) and herb growth forms following bitou bush invasion. However, there was no difference in species richness of shrubs. In forested hind dunes, the shrubs did have significantly reduced species richness following bitou invasion. Density of the vegetation increased at the shrub level in both fore and hind dune bitou-invaded, relative to non-invaded communities. In the fore dunes, the density at the ground declined at bitou-invaded sites compared with non-invaded sites reflecting the reductions in herb and graminoid species. In hind dunes, canopies were more open in invaded habitats.

It is clear that the effects of bitou invasion differ between the fore and hind dune zones of coastal vegetation. This is likely to be influenced by the differences that already exist naturally between these two zones. For example, the diversity of fore dune shrub vegetation is naturally lower than that of the hind dune. Therefore, the effects of invasion (as described above) do not affect diversity because there are fewer species to be replaced by the invader.

Emile Ens has investigated the impact of invasion on physiological stress levels and reproductive output in four native plants; *Monotoca elliptica*, *Corea alba* and *Lomandra longifoli* as part of her PhD. She measured physiological stress in terms of photosynthetic yield and counted reproductive and vegetative buds on plants throughout a year. While summer is the period of least stress in northern hemisphere plants, our results show that summer is the most stressful season for native plants on coastal dunes with plants showing maximum yield in winter. However, we found no differences in stress levels between plants in invaded versus uninvaded plants. For most plants there were no differences in the numbers of reproductive buds or vegetative buds, however there was evidence of higher variability in reproductive output in some species.

One important aspect of Emilie's work is the identification of a difference in the population structure of the species she studied. For all 3 species, there were few

new recruits in the invaded sites, indicating that weed invasion is interrupting population growth. Furthermore, this highlights the fact that competition is likely to be most important as the seedling stages.

The impact of invasion on soil seedbanks has been investigated for hind dunes and is currently being investigated in foredunes. The results are included on the Impacts on Seedbanks page.

Implications for management

If the impacts of invasion differ between the fore and hind dune, it is possible that the resilience and recovery of these communities will also differ. For these reasons it may be necessary to alter the management of bitou bush according to the habitat it has invaded. We found little evidence for a serious impact on adult growth and reproduction. Instead our results have highlighted that the changes in communities are likely to be occurring at the seedling establishment phase.

The impacts of current bitou control methods are discussed further in the management section of the webpage

Affiliated publications

Mason, T. and French, K. (2007) Management regimes for a plant invader differentially impact resident communities. *Biological Conservation* 136; 246-259

Is bitou allelopathic?

Our studies have shown that bitou bush creates a new environment on the sand dunes which is different from native habitats. Further work by Emilie Ens for her PhD has suggested that bitou bush releases toxic chemicals into the sand which inhibit the germination and growth of several native plants

We compared extracts from bitou bush roots, leaves and soil to those from the dominant native shrub, *Acacia longifolia* var. *sophorae* (coastal wattle) and found that both the hydrophobic (containing oils and resins) extracts from the bitou bush root and soil significantly inhibited the seedling growth of coastal wattle, *Actites megalocarpa* (coastal dune thistle), *Lomandra longifolia* (mat rush) and *Banksia integrifolia* (coastal banksias).

Although the hydrophobic extract of the coastal wattle roots also affected the seedling growth of some species, there was no comparable effect of the soil extract from under *Acacia* which suggests that these phytotoxic compounds are not released into the sand and therefore do not have the potential to affect the establishment of native species as the bitou bush root and soil extracts did.



Figure 1: Banksia seedlings grown in bitou bush root hydrophobic extract (Left) and in water (Right)

To investigate which phytotoxic hydrophobic compounds might be released by the bitou bush into the soil we made up resin bags (see photo below) which were designed to adsorb hydrophobic or volatile compounds that are present in the soil. We put the resin bags out into bitou bush invaded sand, sand below coastal wattle and bare sand and compared the chemical profile of these environments.

We found that in the sand below bitou bush there was a much higher concentration of volatile compounds called terpenes that are known to inhibit plant, fungi and bacterial growth. Some of these compounds were only found associated with the bitou bush. Similarly, we also found that some compounds that were present in the sand below the native vegetation were absent in the bitou bush invaded sand. Therefore bitou bush does change the chemistry of the sand dunes which is

likely to inhibit native plant growth and create vacant space for more bitou bush to grow.



Figure 2: Resin bags (left) and placing resin bags in the sand under bitou bush, Wyrrabalong NP (right)

Further work is being undertaken by Emilie to isolate, identify and test some of the terpenes from the bitou roots.

Management implications

There will be difficulty in using seed stock to regenerate areas while bitou is still present and shortly after it has been managed.

There is likely to be some residual toxic chemical effects from the presence of bitou bush even after it has been removed. As most of the toxic compounds we identified in the bitou bush invaded system were low molecular weight volatile compounds, they are likely to evaporate from the sand as it heats up following the removal of bitou bush and be broken down by biotic and abiotic factors. Decay rates of the allelopathic chemicals have not been investigated yet, however, we suggest that seed addition may be less successful initially and may need to be repeated after a few months when soil has returned towards its normal chemical state. This will also be facilitated in time by the growth of native plants that will add "native" compounds back into the soil. Planting seedlings may facilitate the process, although we have not tested whether these compounds influence established plants.

Climate change and weeds

Content TBI

Which species are most affected by bitou invasion?

A major focus of our work has been the identification of plant species affected by bitou bush invasion and weed management. It is hoped that such identification will aid managers by highlighting species that may require extra planting or attention during regeneration.

The list below identifies species that have shown a reduced abundance or an increased in the work we have done to date. While all disadvantaged species show reduced abundance in infested or managed areas, significant differences (*) have only been established for a some species due to the rarity of species in survey sites. The list features both native (n) and exotic (e) species identified within the fore- (f) and hind- (h) dune zones of coastal dunes along the New South Wales coastline.

Species	native/exotic	fore/hind	signif.
Disadvantaged by bitou invasion			
<i>Actites megalocarpa</i>	n	f	*
<i>Correa alba</i>	n	f	*
<i>Desmodium varians</i>	n	h	
<i>Dianella crinoides</i>	n	f	*
<i>Dichondra repens</i>	n	h	
<i>Microlaena stipoides</i>	n	h	
<i>Pelargonium australe</i>	n	f	*
<i>Pittosporum revolutum</i>	n	h	
<i>Pteridium esculentum</i>	n	f	*
<i>Rapanea variabilis</i>	n	h	
<i>Scaevola calendulacea</i>	n	f	*
<i>Senecio lautus</i>	n	f	*
<i>Spinifex sericeus</i>	n	f	*
<i>Zoysia macrantha</i>	n	f	*
Disadvantaged by bitou management			
<i>Acacia longifolia</i> var. <i>sophorae</i>	n	h	
<i>Banksia integrifolia</i>	n	h	
<i>Banksia serrata</i>	n	h	*
<i>Cissus antarctica</i>	n	h	
<i>Cryptocarya triplinervis</i>	n	h	
<i>Cupaniopsis anarcardioides</i>	n	h	
<i>Dianella caerulea</i>	n	h	*
<i>Glochidian ferdinandi</i>	n	h	
<i>Gonocarpus teuroides</i>	n	h	*
<i>Hibbertia scandens</i>	n	f	
<i>Leptospermum laevigatum</i>	n	f	
<i>Lomandra longifolia</i>	n	h	*
<i>Monotoca elliptica</i>	n	f	
<i>Oplismenus aemulus</i>	n	h	

<i>Pratia purpurescens</i>	n	h	*
<i>Sarcopetalum harveyanum</i>	n	h	

Disadvantaged by bitou invasion and management

<i>Acacia longifolia var. sophorae i</i>	n	f	*
<i>Acacia ulicifolia</i>	n	h	
<i>Banksia serrata</i>	n	h	
<i>Carpobrotus glaucescens e</i>	n	f	*
<i>Cynodon dactylon</i>	n	f	*
<i>Gonocarpus teucroides</i>	n	h	
<i>Hibbertia linearis</i>	n	h	
<i>Hibbertia obtusifolia</i>	n	h	
<i>Leucopogon parviflorus</i>	n	f	*
<i>Oxalis rubens e</i>	n	f	*
<i>Poa poiformis</i>	n	h	
<i>Pratia purpurascens</i>	n	h	
<i>Rhagodia candolleana e</i>	n	f	*
<i>Ricinocarpos pinifolius</i>	n	h	
<i>Solanum prinophyllum</i>	n	f	*
<i>Viola hederacea</i>	n	f	*

Advantaged by bitou management

<i>Asparagus aethiopicus i</i>	e	f/h	
<i>Bidens pilosa</i>	e	h	
<i>Cayratia clematidea</i>	n	h	*
<i>Conyza sumatriensis</i>	e	h	
<i>Erhardta erecta</i>	e	h	
<i>Lantana camara i</i>	e	f/h	
<i>Ochna serrulata</i>	e	h	
<i>Senna pendula</i>	e	h	
<i>Solanum nigrum</i>	e	f/h	
<i>Sonchus oleraceus</i>	e	f/h	
<i>Stephania japonica</i>	n	h	*

i effect only found in intensively managed sites

e effect only found in extensively managed sites

Current Management

The Invasion of Native Plant Communities by *Chrysanthemoides monilifera* is listed as a Key Threatening Process on Schedule 3 of the *Threatened Species Conservation Act 1995*. This, in conjunction with the Weeds of National Significance (WONS) program, means the control of bitou bush has become an environmental priority for many coastal councils and community members as well as the National Parks and Wildlife Service.

But just how do we control a weed that has already spread to over 80% of the NSW coastline and dominates approximately 39% of NSW coastal communities?

The current methods of bitou control can be classified into three main areas of management described below:

1. Intensive management.

This form of management often involves National Parks and Local Council co-ordination with volunteer groups. Work is generally carried out by hand (or with small-scale application of herbicide) and incorporates both weed removal and native species re-vegetation. Intensive management is generally focused on small areas of vegetation that may gradually move or increase as native regeneration improves.

2. Extensive management.

This includes large-scale or aerial herbicide application. Dilute glyphosate is sprayed over an entire bitou infested community during the winter months. Spraying during winter is intended to leave native species unharmed, while the bitou is killed and left in place. Aerial spraying can target large areas of vegetation at a time, however, it is rarely followed up with regeneration.

3. The introduction of bio-control agents.

This involves the release of exotic insects that naturally prey on bitou bush. There have been 6 bio-control agents released on the NSW coast each with varying success.

<http://www.csiro.au/resources/ps21w.html>

Plant invasion is a direct threat to the biodiversity and integrity of our natural communities. The management of this threat is therefore of great importance to conservation. Within conservation reserves, the control of invaders is common practice and sometimes involves the large scale removal of an invasive species. However, assessments of ecological outcomes following such management are rarely carried out despite the increase in disturbance they are likely to cause.

The French Lab has investigated

- 1) differences between the impacts of intensive and extensive control measures.
- 2) bio-control agents (Strakosch Thesis).
- 3) impacts on seedbanks
- 4) impacts of different herbicides on invertebrates

The impacts of management

Plant invasion is a direct threat to the biodiversity and integrity of our natural communities. The management of this threat is therefore of great importance to conservation. Within conservation reserves, the control of invaders is common practice and sometimes involves the large scale removal of an invasive species. However, assessments of ecological outcomes following such management are rarely carried out despite the increase in disturbance they are likely to cause.

Impacts on vegetation

We compared the effects of intensive versus extensive control in fore dune areas and intensive management in hind dune communities (Mason and French). We found that on the fore dune, extensive management created communities that differed from native sites while intensive management was more effective (although not perfect) in achieving pre-invasion site conditions. However, intensively managed fore dune sites were also richer in other exotic species than extensively managed sites suggesting that while native species are improved with intensive management, the risk of weed invasion increases.

In the hind dune, the plant communities at managed sites were very different from non-invaded sites. Managed sites had higher numbers of exotic species and similar bitou bush seedling abundance as both non-invaded and bitou-invaded sites.

Impacts on the soil seed bank

We examined seed banks in heavily-invaded, sparsely-invaded and managed hind dunes. While management of bitou bush may have reduced the density of bitou bush seeds in the soil, it did not reduce the richness of other weed species. Native tree species richness was significantly higher in seed banks of sparsely-invaded than either heavily-invaded or managed sites, perhaps indicating a permanent shift in community structure following invasion. However, remaining indices of native seed bank diversity were similar across all invasion categories, indicating that seed banks of many native species were unaffected by both invasion and management. While examination of seed banks is informative in assessing past and potential community dynamics, low similarity between the species in the standing vegetation and seed bank at all sites indicated that the future plant communities that develop following disturbances, may differ substantially from the current vegetation and that many hind dune species had other storage or regeneration modes.

Impacts on seed dispersal

The impacts of plant invasions can alter the foraging patterns of vertebrates and compound the effects of invasion. For example, the increased presence of an invader with fleshy fruits, such as bitou, can reduce the consumption and consequent dispersal of native fruits by competing for a limited number of dispersers. Conversely, the removal of a dominant invader could also reduce the overall attractiveness of a community to fruit eating animals (frugivores) if there are not enough native fruits remaining in that community.

The impacts of bitou management on the dispersal of seed was investigated by Carl Gosper as part of his PhD research. First he investigated the removal rate of bitou and native seed (from selected species) as an indication of frugivore activity. There was no difference found for the removal of seed between native and bitou-invaded sites suggesting that the native species used for this experiment were not competing for a limited fruit-remover resource and that each had equal opportunity for dispersal. However, the removal of bitou fruits from within managed (herbicide-treated) sites was significantly lower than from bitou-invaded sites. Lower removal rates indicate that there is less potential for the dispersal of bitou seed from treated areas.

Impacts on invertebrates

Postgraduate research by Liz Lindsay investigated the effects of herbicide application on the abundance and diversity of leaf litter invertebrates. These animals play an important role in any plant community as they assist in the breakdown of dead foliage and the cycling of nutrients. Specifically she tested the effects of spraying a 1:100 dilution of glyphosate (Roundup® Biactive™) to heavily infested hind dune sites. This is a commonly used herbicide and dilution in the extensive management of Bitou bush.

Liz found that herbicide had no effect on the abundance or composition of leaf litter invertebrates for the four months following application. Invertebrate assemblages were found to be highly variable over small spatial scales, however they were more influenced by other abiotic factors such as temperature and rainfall than glyphosate application.

Sarah Buckley investigated another herbicide Metsufuron methyl (Brushoff) and its effects on invertebrates during her honours. Results were similar for this herbicide as for glyphosate. Differences in the invertebrate community after spraying were more influenced by weather conditions than the herbicide. It appears that both common herbicides used to control bitou bush do not affect invertebrate communities.

Further reading:

Mason, T.J., French, K. and Russell, K.G. (2007) Moderate impacts of plant invasion and management regimes in coastal hind dune seed banks. *Biological Conservation* **134**, 428–439.

Mason, T. and French, K. (2007) Management regimes for a plant invader differentially impact resident communities. *Biological Conservation* **136**, 246 –259.

Gosper, C., Whelan, R.J. and French. (2006) The effect of invasive plant management on the rate of removal of vertebrate-dispersed fruits. *Plant Ecology*. **184**, 351-363

Lindsay, E.A. and French, K. (2004) The impact of the herbicide glyphosate on leaf litter invertebrates within Bitou Bush infestations. *Pest Management Science* **60**, 1205-1212.

Impacts on Seed Banks

Content in Preparation

Impact of Herbicide treatment

The herbicide glyphosate is commonly used to control bitou bush on the New South Wales coastline. To a lesser extent metsulfuron methyl is being used as a herbicide in some areas. We investigated the impact of these two herbicides on invertebrate communities to determine if direct toxicity or indirect effects could be identified.

Sarah Buckley investigated the impacts of spraying the sulfonureas herbicide, metsulfuron-methyl, for her honours project. She followed changes in litter invertebrates for 125 days following spraying to investigate direct toxic and indirect effects of spraying.

Overall there was no effect of spraying on abundance, species richness or composition of litter invertebrates. In general, abundance and richness declined with time in both sprayed and unsprayed sites, suggesting that climatic factors were far more important in determining invertebrate communities than the effects of the spray. Even changes in cover of vegetation as a result of death of the weed resulted in few measurable effects on invertebrates.

Liz Lindsay, as part of her PhD, investigated glyphosate effects. Control and impact sites were selected in coastal hind dunes heavily infested with bitou, and the impact sites were sprayed with a 1:100 v/v dilution of glyphosate-isopropyl (Roundup Bioactive). Leaf litter invertebrates were sampled before spraying and after spraying by collecting fixed areas of leaf litter.

She found no significant direct or indirect effects on leaf litter invertebrate abundance or community composition in the four months following herbicide application.

The litter invertebrate assemblages were highly variable on a small spatial scale, with abiotic factors more strongly regulating leaf litter invertebrate numbers than glyphosate application.

These results conflict with previous studies, indicating that the detrimental indirect effects herbicide application has on non-target litter invertebrates may depend upon the application rate, the vegetation community and structure and post-spray weather.

Further reading:

Lindsay, EA and French K. (2004) The impact of the herbicide glyphosate on leaf litter invertebrates within Bitou bush, *Chrysanthemoides monilifera ssp rotundata*, infestations. *Pest Manag Sci* 60:1205–1212

French K and Buckley S. The effects of the herbicide metsulfuron-methyl on soil invertebrate communities in coastal dune invaded with *Chrysanthemoides monilifera spp. rotundata*. *Weed Science* in review

Other Weeds

Content in Preparation

Restoration Guidelines

Content in Preparation

Thesis Abstracts

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Key Words	Student	Title
Metsulfuron methyl	Sarah Buckley	Response of litter invertebrates to the application of metsulfon methyl in <i>Chrysanthemoides monilifera</i> (Bitou Bush) infested coastal vegetation.
Ground invertebrates	Karen Eardley	Arthropod diversity in native coastal dune systems and systems invaded by <i>Chrysanthemoides monilifera</i> .
Fruit/bird interactions	Carl Gosper	Consequences of weed infestation and control on plant-bird interactions and bird communities.
Ecosystem processes	Elisabeth Lindsay	The impact of <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> (bitou bush) on coastal ecosystem processes.
Plant communities	Tanya Mason	Impacts of plant invaders and management techniques on native communities: ecological and social perspectives at regional and global levels
Bird behaviour	Ben Owers	The effect of bitou bush infestation on the behaviour and nest predation of birds in coastal woodlands.
Control Strategies	Kristen Prattis	An investigation into the effects of <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> (Bitou Bush) infestation and treatment on the vegetation community at Booderee National Park.
Biocontrol	Naomi Strakosch	Does predation limit the establishment of the biological control agent <i>Tortrix</i> sp. in <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> infestations?
Bird communities	Anita Zubovic	Effects of <i>Chrysanthemoides monilifera</i> on native bird and arthropod population assemblages.

Response of litter invertebrates to the application of metsulfon methyl in Chrysanthemoides monilifera (Bitou Bush) infested coastal vegetation.

Author: Sarah Buckley
Year: 2002
Degree: BSc (Hons)

Abstract:

The continued invasion of the South African weed, *Chrysanthemoides monilifera*, into native vegetation communities along the New South Wales coastline is a serious threat to floristic diversity. This environmental weed has successfully naturalized along a large proportion of the coastline and is still competing with and displacing native vegetation. In attempts to reduce current infestations of *Chrysanthemoides monilifera* and avoid additional invasions, a variety of control methods have been utilized.

Herbicide management of *Chrysanthemoides monilifera* infested vegetation is of particular concern, as applications can have both a directly toxic on soil fauna and an indirect effect after a reduction in canopy cover. Soil invertebrates are responsible for the recycling of nutrients and are necessary for the primary production of terrestrial ecosystems, and therefore they should be an important consideration in the herbicide management of *Chrysanthemoides monilifera* infested vegetation.

With the proposal to introduce the broad scale use of the herbicide metsulfuron methyl to try and control *Chrysanthemoides monilifera* in New South Wales, it is necessary to assess the potential effects of the herbicide on the soil fauna inhabiting these areas and consider the implications for the remaining vegetation.

This study aimed to assess the response of litter invertebrates to the application of the herbicide metsulfuron methyl on *Chrysanthemoides monilifera* infested habitats. The abundance, richness and community composition was assessed before the herbicide application and then directly after spraying had occurred to consider the direct toxic effects. Once defoliation was evident, an assessment of the effects of canopy loss was also made.

Temperature and precipitation data were obtained for each sampling of litter invertebrates to assess if fluctuations in abundance, diversity and community composition were related to changes in weather conditions.

Affiliated Publications:

French, K and Buckley S The effects of the herbicide metsulfuron-methyl on soil invertebrate communities in coastal dune invaded with *Chrysanthemoides monilifera* spp. rotundata. Weed Research minor revisions March 2007

Arthropod diversity in native coastal dune systems and systems invaded by *Chrysanthemoides monilifera*.

Author: Karen A. Eardley
Year: 1995
Degree: MEnvSc (Hons)

Abstract:

The South African weed, *Chrysanthemoides monilifera* is successfully competing with and displacing native vegetation in coastal systems of New South Wales. This displacement poses a serious threat to floristic diversity in these areas but little is known of its effects on faunal assemblages, particularly arthropods. In this study species richness and abundance of arthropods from the orders *Amphipoda*, *Blattodea*, *Collembola*, *Coleoptera*, *Dermaptera*, *Diptera*, *Hemiptera*, *Hymenoptera*, *Isopoda*, *Lepidoptera*, *Myriapoda*, *Siphonaptera* were compared for two coastal habitat types – native vegetation and *C. monilifera* invaded vegetation.

The study has shown that vegetation communities invaded by *C. monilifera* provide habitat for a diversity of arthropod species and that the richness and abundance and composition of arthropods between the sites which suggests there are differences in arthropod assemblages in native and *C. monilifera* habitat. To determine the extent of these differences further investigation and classification of arthropods to genus or species is required.

The main findings of this study have highlighted the fact that although a weed, *C. monilifera* provides sufficient habitat to support a diversity of arthropod species which will in turn support other taxa. As a result the biodiversity value of weed invaded communities requires further ecological investigation and consideration. Current management practices focus on total weed eradication from coastal systems which may not be the most positive action in terms of biodiversity conservation outcomes.

Affiliated Publications:

French, K and Eardley, K. (1997) The impact of weed infestations on litter invertebrates in coastal vegetation. In: *Frontiers in Ecology*. (Eds: N Klomp and I Lunt) Elsevier Science, London.

Consequences of weed infestation and control on plant-bird interactions and bird communities.

Author: Carl R. Gosper
Year: 2004
Degree: PhD

Abstract

Introduced plants can have a variety of impacts in ecosystems in which they become invasive. These impacts can include the disruption of interactions between native plant and animal species, such as seed dispersal and pollination. Subsequently, other interactions and mutualisms can be affected, both at the site of the plant invasion and elsewhere. Interactions can also become established between the invasive plant and native and invasive animal species. The removal of an invasive plant has the potential to disrupt these newly formed interactions, thus disadvantaging some fauna and potentially affecting subsequent interactions involving these species. While control of invasive plants is typically a goal of conservation management, the consequences of control for other species are rarely fully considered or investigated. In this study, I have tested several hypotheses regarding the interaction of an invasive plant with fauna, and the effects of the plants invasion and control on plant-animal interactions.

Bitou Bush (*Chrysanthemoides monilifera* ssp. *rotundata*) is an invasive plant in coastal New South Wales (NSW), Australia. South African in origin, it has now spread to occupy at least 80% of the NSW coastline. Fruit production in *C. monilifera* is prolific and fruits are consumed and dispersed by vertebrates, especially birds. In addition to other effects of *C. monilifera*, this plant-animal interaction has the potential to affect the seed dispersal of other vertebrate-dispersed plants and also the composition of the bird community, which may subsequently affect other plant-bird interactions.

In order to quantify the magnitude of these possible effects, I designed this study with the following five major components:

- (i) comparison of the fruiting characteristics of *C. monilifera* with those of co-occurring bird-dispersed native plant species;
- (ii) description of the plant-bird interactions that involve flowers and fruits in vegetation that has been invaded or is at risk of invasion by *C. monilifera*;
- (iii) measurement of the rate of removal of *C. monilifera* fruits and those of some co-occurring bird-dispersed plant species in: habitat dominated by *C. monilifera*, where *C. monilifera* had been eliminated by the application of herbicide, and uninvaded vegetation;
- (iv) assessment of the effect of *C. monilifera* removal by herbicide application on the species composition and abundance of the bird community; and
- (v) assessment of the effect of dominance of the vegetation community by *C. monilifera* on the species composition and abundance of the bird community.

I found that the fruits of *C. monilifera* are within the range of physical dimensions and nutrient composition of those of co-occurring native species. The greatest distinction in fruit characteristics is in phenology and the combination of phenology and morphology, as peak production of *C. monilifera* fruits occurs when native fruits are scarce. Consequently, *C. monilifera* fruits are attractive to vertebrate

dispersers, especially birds. At least 25 species of birds feed on *C. monilifera* fruits in NSW, most of which are indigenous and are likely to disperse viable seeds.

In an experimental study using feeding stations, I found that the rate of removal of fruits of native plant species was unaffected by either dense infestation of *C. monilifera*, or its elimination. This is likely to be due to highly facultative relationships between frugivorous birds and plants, combined with differences in phenology and, in some cases, the morphology of fruits of native plants and *C. monilifera*. Consequently, in this system there has been little impact of an invasive plant on this plant-bird interaction. The rate of removal of *C. monilifera* fruits, however, was less in herbicide-treated habitat. This has implications for long-term *C. monilifera* control, because herbicide treatment often leaves scattered individual plants alive, which would have poorer seed dispersal than plants in dense *C. monilifera* stands.

The removal of *C. monilifera* affected the bird community, with the overall abundance of birds declining in herbicide-treated areas after the *C. monilifera* died. Only those birds that consume *C. monilifera* fruits were affected, while other groups of birds that do not directly use *C. monilifera* resources were unaffected. Although this impact was minor, it illustrates that removal of an invasive plant can affect bird communities, and these impacts should be considered before control programs are implemented. Dominance of the vegetation by *C. monilifera* also affected bird communities, with overall bird abundance, specifically that of insectivorous birds, and at some locations nectarivorous birds, being lower in *C. monilifera* than native habitat. The quantity of remaining native vegetation, particularly of nectar-producing plants widely used by birds, appears to be important in determining bird community composition in invaded areas.

In this study, I have demonstrated that both dominance of the vegetation by an invasive plant, and the control of an invasive plant, can induce change in fauna communities, and disrupt some plant-animal interactions. These changes will need to be considered carefully in planning management actions to conserve coastal bird communities and their interactions with plants. While continued efforts to control *C. monilifera* are clearly justified, these should form part of a broad strategy for coastal community conservation, including consideration of other threats to native communities that act independently or in concert with *C. monilifera* invasion. These considerations should include the potential impacts of other invasive plant species, targeted sites and species for control efforts, and other forms of habitat loss and degradation.

Affiliated Publications:

Gosper, C., Whelan, R.J. and French. (2006) The effect of invasive plant management on the rate of removal of vertebrate-dispersed fruits. *Plant Ecology*. **184**, 351-363

Gosper, C.R. (2004) Fruit characteristics of invasive bitou bush, *Chrysanthemoides monilifera* (Asteraceae), and a comparison with co-occurring native plant species. *Aust. J. Bot.* **52**, 223-230.

Gosper, C.R. (1999) Plant food resources of birds in coastal dune communities in New South Wales. *Corella* **23**, 53-62.

The impact of Chrysanthemoides monilifera ssp. rotundata (bitou bush) on coastal ecosystem processes.

Author: Elizabeth A. Lindsay
Year: 2004
Degree: PhD

Abstract:

On the southeast coast of Australia, there are extensive infestations of the environmental weed *Chrysanthemoides monilifera ssp. rotundata* (L.) T. Norl. (Bitou bush). This weed is highly invasive and persistent, yet little is known about how it impacts on coastal ecosystems. Plant invasions can greatly alter the area they invade, and can modify primary productivity, plant species composition, species diversity, decrease ecosystem stability and disrupt ecosystem processes. This research aimed to determine if *C. monilifera* invasion changes leaf litter decomposition and nutrient cycling. Leaf litter invertebrates were also investigated as they play key roles in functioning of forest ecosystems and can greatly enhance litter decomposition and nutrient cycling. The herbicide glyphosate is widely used to control *C. monilifera*, however there have been few studies examining the effects of this herbicide on invertebrate communities in the field, especially on sand dunes. I aimed to determine if glyphosate application impacts leaf litter invertebrate involved in decomposition.

Field studies and experiments were undertaken in five sites along the NSW coastline, each with an area heavily infested with *C. monilifera* and in native uninfested area. A litterbag decomposition study found that the succulent *C. monilifera* leaves decomposed at least three times faster than a sclerophyllous native leaf mix (*Acacia longifolia* var. *longifolia*, *Banksia integrifolia* and *Leptospermum laevigatum*) with the decomposition rates being related to the physical properties of the leaves. Nutrients were leached and mineralised quicker from the *C. monilifera* leaves, mostly due to the rapid decay. There was some immobilisation of sulphur and phosphorous in the native leaves when placed in the native sites and more immobilisation is expected with time. *C. monilifera* leaves decayed significantly faster in coarse mesh litterbags compared to the fine mesh, indicating leaf litter invertebrates positively influenced their decomposition. Mesh size had little effect on the native leaf decomposition rate. All *C. monilifera* litterbags and the coarse native litterbags decomposed faster and generally had greater nutrient loss within the *C. monilifera* infestations. This is due to an increase in invertebrate detritivores within the *C. monilifera*, and dense infestations creating a protected environment with an altered microclimate.

There was a greater input of litter to the native sites, and this was highly seasonal compared to the *C. monilifera* areas. Maximal litter fall corresponded with period of peak flowering and growth (spring-summer). Due to the higher leaf fall rate there is a greater input of nutrients to the forest floor in the native sites, even though large amounts of nutrients were withdrawn from the leaves before abscission. The slow decomposition and high litter fall resulted in greater amounts of litter accumulating on the native forest floor, which appears to act as a nutrient sink.

Invasion by *C. monilifera* in coastal areas does not appear to change the nitrogen budget, but there are differences in where nitrogen is stored in comparison

to uninvaded areas. The total soil nitrogen and ammonia nitrogen were significantly greater in most of the bitou bush sites, whereas in the native vegetation there was more nitrogen held within the leaf litter layer. Nitrogen appears to be cycled faster in the weedy areas, mainly as result of the increase in leaf quality and the speed of breakdown.

Leaf litter invertebrate abundance and assemblage were compared between habitats over twelve months. The total abundance was not significantly reduced in the weedy habitat but the abundance of mites, thrips, spiders, ants, and centipedes was reduced at many sites. The invertebrate assemblages also differed between habitats, with the *C. monilifera* supporting a lower diversity of beetles. However, the millipedes, amphipods, earthworms, pseudoscorpions and isopods appeared to respond positively to the invasion, occurring in higher abundance and detected more frequently in the weedy areas. This has been attributed to the change in microclimate within *C. monilifera* infestations, which are moister and darker, which these invertebrates tend to prefer. Furthermore as the leaf litter is of lower quantity and higher quality, and possibly higher palatability, than the native sclerophyllous vegetation, the detritivores assemblages seems to have responded positively.

To determine the impact of the herbicide glyphosate on the non-target litter invertebrates control and impact sites were selected in coastal hind dunes heavily infested with *C. monilifera*. The impact sites were sprayed with a 1:100 dilution of Roundup® Biactive™. The herbicide application had no direct or indirect effect on leaf litter invertebrate abundance or community composition in the four months following application. The litter invertebrate assemblages were highly variable on a small spatial scale with abiotic factors more strongly regulating leaf litter invertebrate numbers than glyphosate application. These results conflict with previous studies, indicating the detrimental indirect effects herbicide application has on non-target litter invertebrates may depend upon the application rate, the vegetation community and structure and post spray weather.

Invasion by *C. monilifera* has changed the movement of leaf litter and the cycling of nutrients within coastal ecosystems, mainly through a change in quality and quantity of leaf litter. It has impacted on the litter invertebrates, which has amplified the increase in decomposition rate. The change in soil nutrient availability could increase the competitive superiority of *C. monilifera* directly by increasing growth rate, or indirectly by impairing the establishment of native species.

Affiliated Publications:

Lindsay, E.A. and French, K. (2006) *Chrysanthemoides monilifera* ssp. *rotundata* invasion alters coastal leaf litter invertebrates. *Biological Invasions* 8(2), 177-192.

Lindsay, E.A. and French, K. (2005) Litterfall and nitrogen cycling following invasion by *Chrysanthemoides monilifera* ssp. *rotundata*. *J. Appl. Ecol.* 42, 556-566.

Lindsay, E.A. and French, K. (2004) The impact of the herbicide glyphosate on leaf litter invertebrates within Bitou Bush infestations. *Pest Management Science* 60, 1205-1212.

Lindsay, E.A and French, K. (2004) *Chrysanthemoides monilifera* ssp. *rotundata* invasion alters decomposition rates in coastal areas of New South Wales, Australia. *Forest Ecology and Management* 198, 387-399.

Impacts of plant invaders and management techniques on native communities: ecological and social perspectives at regional and global levels

Author: Tanya Mason

Year: 2006

Degree: PhD

Abstract:

Plant invasions of natural communities threaten biodiversity and ecosystem processes across many biomes and trophic levels. Understanding and managing invader impacts are therefore significant steps in achieving conservation. Both causes and management of invasion are dependent on human behaviour and ecologists must consider this human dimension in developing management protocols. While control of invaders is routine in many conservation reserves, assessment of ecological outcomes following control is rarely enacted. Management is itself a disturbance and the compounding effects of both invasion and management on biodiversity merit rigorous assessment. While species-level responses to plant invasion have been widely reported, functional group and seed bank responses to invasion and management are rarely investigated. Generalisations about invader impacts are urgently required for targeted restoration. In this thesis, I used qualitative review, field study and meta-analysis to address ecological, social and land management issues of invasion biology.

Firstly, I reviewed policy instruments and asked: are government, land managers and the scientific community using available social levers to achieve optimal invader management? I found that while important policy principles have been developed, they require greater enactment. Release of significant funds will be required to resource long-term invader control and restoration activities. Education and voluntary incentives require a strong extension service to maintain involvement and standards of control. Rigorous monitoring systems are an under-utilised but important tool in achieving adaptive invader management.

I then used the invasive shrub bitou bush, *Chrysanthemoides monilifera ssp. rotundata*, to analyse invasion and management impacts in coastal dune communities of eastern Australia. I compared the effects of intensive, manually-based invader control with those of extensive control (mainly herbicide spraying from aircraft) across fore dune communities. I examined one management regime, which was typically intensive, in hind dune communities. My main aim was to test the prediction that intensive methods would achieve better biodiversity outcomes than extensive approaches in fore dune communities. I found that extensive management created native species complements that diverged from non-invaded sites while intensive management approached non-invaded site conditions. However, intensively managed sites were also richer in other exotic species than extensively managed sites. Thus, while biodiversity outcomes were better under intensive management, the risk profile of such sites was increased by the greater array of exotics that could potentially replace the original invader. The positive effects of management evident on some fore dunes were not found in hind dunes, where managed sites had the highest exotic species richness and similar bitou bush seedling abundance as both non-invaded and bitou-invaded sites. Hind dune managed sites were also compositionally distinct from non-invaded sites. For all sites, even after intensive management, follow up control is

required to avoid substitution of the primary invader by other aggressive invaders.

In order to characterise invader impacts beyond species-level comparisons, I compared bitou bush impacts on vegetation structure, richness of both native and exotic growth forms and community variability in fore and hind dunes. I found that bitou bush impacts were context specific: in fore dune shrublands, functionally distinct graminoid, herb and climber rather than shrub growth forms had significantly reduced species richness following bitou bush invasion. However, in forested hind dunes, the functionally similar native shrub growth form had significantly reduced species richness following bitou invasion. Density of vegetation structure increased at the shrub level in both fore and hind dune bitou-invaded, relative to non-invaded communities. Fore dune ground-level vegetation density declined at bitou-invaded sites compared with non-invaded sites reflecting significant reductions in herb and graminoid species richness. Hind dune canopy-level vegetation density was reduced at bitou-invaded compared with non-invaded sites. Bitou bush invasion also affected fore dune community variability with significant increases in variability of species abundances observed in bitou-invaded compared with non-invaded sites. In contrast, there was similar variability among all hind dune sites. The results suggest that effects of bitou bush invasion are mediated by the vegetation community.

In addition to standing vegetation dynamics, I investigated soil-stored seed banks affected by bitou bush invasion and management, to further elucidate levels of community resilience. While management of bitou bush may have reduced the density of bitou bush seeds in the soil, it did not reduce the richness of other exotic species. Native tree seed richness was significantly higher in seed banks of sparsely-invaded than either heavily-invaded or managed hind dune sites, perhaps indicating a permanent shift in community structure following invasion. However, remaining indices of native seed bank diversity were similar across all invasion categories, indicating that seed banks of many native species were unaffected by both invasion and management. While examination of seed banks is informative in assessing past and potential community dynamics, low similarity between the standing vegetation and seed bank at all sites indicated that many hind dune species had other storage or regeneration modes and seed banks cannot be relied upon for comprehensive dune restoration.

Finally, I used meta-analysis to contextualise my field studies of bitou bush invasion using 20 international invasion studies. I hypothesised that plant invaders act as biotic filters and more strongly affect representation of some plant traits over others in the resident community. I analysed the effects of graminoid and woody invaders on species richness for native growth form, longevity, seed mass and flowering phenology traits. I found that graminoid invaders disproportionately affected species with graminoid and herbaceous growth forms, perennial strategies and small seed masses. Woody invaders disproportionately affected graminoid or shrub species and perennials. Woody invaders had a consistently greater negative effect on native species than graminoid invaders, perhaps due to pre-emption of light resources. In contrast, it made no difference to native richness as to whether species flowered at the same time as the invader, indicating little interaction between invader and native pollination dynamics.

Plant invaders non-randomly affect resident species in turn changing community attributes. Current management of invaders may not re-instate pre-invasion conditions. Restoration is dependent on recognising the impacts of an invader

and both supplementing native traits adversely affected by invasion and enacting long-term follow-up control of primary and secondary invaders.

Affiliated Publications:

Mason, T.J., French, K. and Russell, K.G. (2007) Moderate impacts of plant invasion and management regimes in coastal hind dune seed banks. *Biological Conservation* 134, 428–439.

Mason, T. and French, K. (2007) Management regimes for a plant invader differentially impact resident communities. *Biological Conservation* 136, 246 –259.

Mason, T.J., Lonsdale, W.M. and French, K. (2005) Environmental weed control policy in Australia: current approaches, policy limitations and future directions. *Pacific Conservation Biology* 11(4), 23-45.

The effect of bitou bush infestation on the behaviour and nest predation of birds in coastal woodlands.

Author: Ben Owers
Year: 1999
Degree: BSc (Hons)

Abstract:

It has been established that disturbance and habitat alterations have an impact on bird communities. In particular, weed infestations have been shown to result in a reduction in the abundance and diversity of many faunal communities. However, the impact of disturbances on individual populations has only been dealt with in a small number of studies. In particular, behaviour and nest predation may be important in determining the quality of a disturbed or altered habitat. The aim of this study is to examine the impact of the infestation of the environmental weed, bitou bush, on the behaviour and nest predation of bird populations.

Bitou bush infestation was found to change the vegetation structure of infested habitats compared to uninfested habitats by reducing the percentage cover of native vegetation, but increasing the overall percentage cover. There is evidence that the severity of bitou bush infestation has increased over the last 19 years.

The behaviour and habitat use of the Little Wattlebird, New Holland Honeyeater, Silvereeye and Superb Fairy-Wren were examined in areas with and without bitou bush infestation. A significant difference in behaviour was found for the Little Wattlebird, but not for any other species. This species and the New Holland Honeyeater exploit only native resources in infested habitats. The Silvereeye and Superb Fairy-Wren exploit bitou bush resources. However, the Superb Fairy-Wren appears to spend less times foraging on the ground in infested habitats. It appears likely that bitou bush infestation alters the availability of food resources for honeyeater species and changes to habitat structure are important for Superb Fairy-Wrens. Silvereeyes appear to be unaffected by bitou bush infestation.

Nest predation rates were compared between infested and uninfested areas using artificial nests. Infestation by bitou bush may attract generalist predators due to a higher availability of fruits. Alternatively predators may find nests harder to detect due to higher vegetation density infested habitats. Open nests were used to imitate the nest of a New Holland Honeyeater, and closed nests to imitate a Superb Fairy-Wren. For New Holland Honeyeater nests, no difference in overall nest predation was found between infested and uninfested habitats for both nest types. Significantly higher predation was found in infested habitats for Superb Fairy-Wren nests. Higher rodent predation was found in infested habitats for both nest types. Less bird predation was found on open nests in infested areas. These results suggest that bitou bush infestation may impact upon closed and nested birds, and that rodent predation may be an important source of nest predation in these habitats.

The results found here suggest that nectar dependent species of bird are impacted upon by bitou bush infestation, however the impact of infestation on nectar production needs further investigation. Generalist frugivorous species appear to not be impacted by bitou bush infestation, however the impact on more specialized species needs further investigation. Changes to vegetation structure appear to be impacting upon insectivorous species. Higher levels of nest predation by rodents in infested habitats suggest that there may be an increase in rodent density in infested habitats. It appears that low nesting, closed nested species are more likely to be impacted than open nesting species. However, the data presented here on nest predation must be related to real nests. Overall, it is likely that the removal of bitou bush, or retention of native vegetation in infested habitats, would benefit birds in coastal woodlands.

An investigation into the effects of *Chrysanthemoides monilifera* ssp. *rotundata* (Bitou Bush) infestation and treatment on the vegetation community at Booderee National Park.

Author: Kristen Elise Prattis
Year: 2004
Degree: BEnvSc (Hons)

Abstract:

The invasion of *Chrysanthemoides monilifera* ssp. *rotundata* (bitou bush), is one of the most serious threats posed by a weed species to the natural ecosystems along the New South Wales coastline. Booderee National Park is one of the most important natural communities in Australia, and bitou bush is the most significant weed within the park and threatens its ecological integrity.

In an attempt to reduce the current infestations of bitou bush within the park a number of control strategies have been utilized. These include herbicide control with glyphosate, biological control methods and the use of fire. An integrated control strategy incorporating the use of all three of the above techniques is presently recommended. However, the impacts on the species composition of vegetation communities that have undergone any of the various control strategies that exist for bitou bush have been poorly studied.

This study is aimed at assessing the response of the bitou invaded vegetation community to the application of a variety of bitou control strategies. The first study investigated the short-term response of the bitou infested community to a spray with the herbicide glyphosate®, and the subsequent application of a controlled burn. The second study compared four habitats including; an undisturbed native habitat, an untreated bitou infested habitat, a bitou infested habitat that had been treated with a single spray of glyphosate from 2001 to 2002 and a previously bitou infested habitat that had been treated with a spray-burn-spray technique over three consecutive years commencing in 2000.

It has been found that the single treatment of a bitou infestation without undertaking a secondary treatment is insufficient to control the bitou infestation or encourage native regeneration. There was no significant difference in the abundance and richness of native vegetation between the bitou infested and post-spray habitat compared to the native habitat. This may potentially indicate that an alteration in the leaf litter decomposition rates of the habitat have occurred, which would affect the supply of nutrients and organic matter to the soil.

Results indicate that a spray-burn-spray technique applied to a bitou infested habitat is more effective than a single spray treatment at decreasing the density of bitou and regenerating native species. However, full regeneration of the habitat after bitou treatment may not be possible without restoration occurring after the cycle of bitou treatment has been completed. Furthermore, a number of weed species were found to invade the habitat after the bitou was removed. To decrease the level of weed invasion occurring in habitat after the bitou removal, it is recommended that restoration measures be undertaken.

Does predation limit the establishment of the biological control agent *Tortrix sp.* in *Chrysanthemoides monilifera ssp. rotundata* infestations?

Author: Naomi Strakosch

Year: 2004

Degree: BSc (Adv) (Hons)

Abstract:

One of Australia's most common coastal weeds is bitou bush, *Chrysanthemoides monilifera ssp. rotundata*. Native flora is often overtaken and displaced by the vigorous growth and spread of *C. monilifera ssp. rotundata* infestations. *Tortrix sp.*, a South African moth, has great potential as a biological control agent for *C. monilifera ssp. rotundata* in Australia as it is the most destructive leaf herbivore known to consume *C. monilifera ssp. rotundata* in its native habitat. This moth has been released in Australia onto *C. monilifera ssp. rotundata* numerous times since its initial release in 2001, but only four instances of establishment of *Tortrix sp.* have been documented from thirty three release sites. Of these, three are in headland habitats. It has been observed that generalist predators such as ants and spiders have had an impact on the survival of *Tortrix sp.* Eggs and larvae in the field. The aim of this study is to investigate whether *Tortrix sp.* establishment failure is caused by predation or a result of habitat incompatibility for other reasons. Also in this study, I aim to find the assemblage of invertebrates that inhabit *Chrysanthemoides monilifera ssp. rotundata*, and whether this differs between headland and dune habitats; there has been no previous survey on the invertebrate inhabitants of bitou bush.

The release of *Tortrix sp.* onto *C. monilifera ssp. rotundata* was performed at ten sites on the NSW Central Coast, five headland habitats, and five in dune habitat. At each site, three replicated treatments were applied – a predator exclusion, a procedural control and a control. Eight hundred eggs were released into each plot in June, 2004. Restricted canopy fogging using carbon dioxide was used to recover canopy invertebrates that inhabit *C. monilifera ssp. rotundata* in the months of March and April of 2004 on the NSW Central Coast.

Overall very low survival of *Tortrix sp.* was found in this study, however headland habitat appears to have more favourable conditions for *Tortrix sp.* Increased survival of *Tortrix sp.* larvae on headland sites was found especially in the predator exclusion plots by the last day of this experiment ($H_c = 10.535$, $df = 1$, $p < 0.01$), and more eggs remained uneaten in headland sites (667 ± 30) than dune sites (611 ± 32) ($F = 0.0079$, $df = 1$, $p = 0.0055$). There was some recovery of second generation *Tortrix sp.* last instar larvae at four release sites, though at very low densities.

The canopy invertebrate survey found 155 morphospecies from 17 orders. The number of invertebrate species present did not differ between habitats ($F = 0.5679$, $df = 1$, $p = 0.455$), though there was higher canopy invertebrate species richness in dune habitat than headland ($F = 9.957$, $df = 1$, $p = 0.003$). There was also a significant difference in the abundance of predatory arthropods between headland and dune habitat ($F = 5.141$, $df = 1$, $p = 0.0288$).

Better survival and higher recovery of *Tortrix sp.* in headland habitat than dune habitat in this study can be partially attributed to the interference and predation of eggs and larvae by invertebrate predatory guilds that were more abundant in dune areas. Predation, however, was not the main cause of the lowered levels of survival in dune habitat.

It is highly likely that other factors, such as bitou stand structure and age, or climatic conditions, are most influential to survival of *Tortrix sp.* between habitats, though at this stage the main reason has yet to be quantified.

Whether or not future releases of *Tortrix sp.* for the biological control of *Chrysanthemoides monilifera ssp. rotundata* will be successful is not clear. Perhaps with more favourable climatic conditions there would have been more larval survival, although without further study into the causes of *Tortrix sp.* mortality in the field, there is no way of knowing for certain the cause.

Effects of Chrysanthemoides monilifera on native bird and arthropod population assemblages.

Author: Anita Zubovic
Year: 1994
Degree: BSc (Hons)

Abstract:

Introduced plant species often have a negative effect on the native ecosystem. These weeds may alter community characteristics such as abundances of native plants and animals, species composition, the structure of communities and their functions. They are also thought to cause the loss of many native plants. *Chrysanthemoides monilifera* (from South Africa) is a major weed which grows along the east coast of Australia.

The main aims of this study were to investigate whether the presence of *C. monilifera* in the understorey of native coastal woodland affects the native bird community in terms of species richness and abundance. Another aim was to investigate whether native birds in these woodlands are effective dispersers of *C. monilifera* seeds and thus the spread of *C. monilifera*.

Structural complexity in vegetation and floristic composition is thought to be a major determinant of food supply and availability and therefore on bird species diversity and abundance. Therefore, I investigated whether *C. monilifera* infested woodland habitats and native habitats differed structurally, which they did, and whether bird species richness and abundance differed similarly in these two habitats.

The species richness and abundance of arthropods was also measured in both the *C. monilifera* infested and native habitats to determine whether their community composition differed between the weed infested and native habitats. The aim of this was to find if there were any correlations between arthropod composition and the native bird community, which use arthropods as a food source.

There were no significant differences between total bird species richness and abundance in between the *C. monilifera* infested and native habitat, however there were significant differences between the two habitats when birds were grouped into guilds according to their foraging and food preferences. Insectivorous canopy (Guild 1) and understorey (Guild 2) birds did not show any consistent patterns between the two habitats at all sites (although this may have been due to some site specific factor not associated with *C. monilifera*). Birds which are more specialist feeders (Guild 3) and which feed on fruit, seeds and/or nectar did show a consistently significant difference between habitats, that is, they had more species and higher abundances in the native habitats. Arthropods, however, showed no consistent pattern between habitats indicating that the abundances and species richness of this food source did not show a positive correlation with bird assemblages. However, arthropod composition would have to be measured over a longer time period before a true measure of correlation may be determined.

The results indicate that different guilds (or bird species) are influenced to different degrees by the structural complexity of vegetation and floristic composition. So the effect of *C. monilifera* on native bird communities varies with different guilds and different bird species.

Affiliated Publications:

French, K. and Zubovich, A. (1997) Effect of the weed *Chrysanthemoides monilifera* (bitou bush) on bird communities. Wild. Res. 24, 727-735.

Publications

French, K and Buckley S The effects of the herbicide metsulfuron-methyl on soil invertebrate communities in coastal dune invaded with *Chrysanthemoides monilifera* spp. *rotundata* *Weed Research* minor revisions March 2007

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