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Assessing the geo-eco-psycho-socio-economic impacts

LEADING THE SEARCH FOR WEED SOLUTIONS

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by Roger Cousens, David Kennedy, Grainne Maguire, Kathryn Williams

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Foreword

Australia's narrow terrestrial coastal fringe of some 60,000 km is of great significance to the nation. Our beaches are part of our social fabric, with a high proportion of the population either living near the sea or visiting the coast for their vacations. They also attract international visitors, providing a considerable input into to our economy. The coast is also of considerable ecological importance, providing nesting sites for millions of sea birds as well as being a habitat for plant and animal species found nowhere else.

However, this fragile habitat is undergoing a 'coastal squeeze': on the seaward side sea levels are rising, reducing the width of beach available, and on the landward edge there is severe threat from urbanisation, disturbance from tourism and invasive species, for both plants and animals, particularly in the south and east. Intact habitat, with its unique flora and fauna, is now fragmented and increasingly rare. When standing on a shore in southern Australia, much of the plant life observed consists of exotic species that have been deliberately planted for dune stabilization, have escaped from gardens or have been introduced inadvertently.

The knowledge of the impacts of coastal weeds is scant. These species affect native plants, native and exotic animals, coastal geomorphology and people, but these impacts have seldom been measured. This project estimated that at least $12 million p.a. is currently spent on managing coastal weeds. It should be noted, however, that the researchers found it impossible to obtain financial data at an appropriate resolution and the true figure is possibly as high as $30 million. The activities of community groups such as Coastcare, significant players in coastal weed management, are often not collated and are seldom coordinated across regions.

This project collated existing information on the impacts of weeds in coastal ecosystems of southern Australia, collected new data on impacts on animals, people and dune morphology, identified those species considered by managers to be the greatest threats (and those being actively managed) and identified the gaps in our knowledge and reporting systems. Importantly, it involved the public, as "citizen scientists" in the collection of new data. Coastal weeds were shown to have a wide range of direct impacts, both negative and positive, on native, invasive and domestic animals. Impacts of weeds on occasional visitors to beaches appear to be slight, but weeds clearly influence the actions of community groups. While almost all coastal weeds are poorly researched, the report identifies the geographically widespread and abundant sea wheatgrass, sea spurge and marram grass as the species most in need of further investigation.

The project is part of the National Weeds and Productivity Program, which was funded to 30 June 2012 by the Australian Government with the goal of reducing the impact of invasive weeds on farm and forestry productivity as well as on biodiversity. All RIRDC research investments in this Program are overseen by the Weeds R&D Advisory Committee in accordance with the National Weeds and Productivity Research Program R&D Plan 2010-2015 that has been approved by the Minister for Agriculture, Fisheries and Forestry.

Solutions to weeds in Australia require a long-term, integrated, multi-stakeholder and multidisciplinary approach. RIRDC is seeking project applications that involve collaboration between stakeholder groups, and where possible, including external contributions both monetary and in-kind.

This report is an addition to RIRDC's diverse range of over 2000 research publications which can be viewed and freely downloaded from our website www.rirdc.gov.au. Information on the Weeds Program is available online at http://www.rirdc.gov.au/programs/national-ruralissues/weeds/weeds_home.cfm.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

Craig Burns
Managing Director
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About the Authors

Roger Cousens, Kathryn Williams and David Kennedy are academics in the Department of Resource Management and Geography at the University of Melbourne, while Grainne Maguire works for BirdLife Australia, a science-based not-for-profit conservation organisation. Professor Roger Cousens is a plant ecologist who has specialised in the study of weeds and invasive plants for almost 30 years. He has particular interests in seed dispersal, spatial pattern within species and competition between plants. Associate Professor Kathryn Williams works in the field of environmental psychology, exploring how human perception, thought, feeling and behaviour shape human-environmental interactions. Over a period of 15 years at the University of Melbourne she has contributed to understanding of social acceptance of forest management, management of native vegetation, and human preferences and benefits from urban greening. Dr David Kennedy is a coastal geomorphologist who specialises in the impact of climatic and environmental factors on coastal landforms. He has undertaken research in a variety of environments from dune systems to coral reefs and rocky cliffs. Dr Grainne Maguire is an ornithologist specialising in coastal birds and human-wildlife conflicts. For the past 7 years, she has managed BirdLife Australia's national Beach-nesting Birds Program, which oversees the recovery of the threatened hooded plover in Victoria and South Australia via research, on-ground management and community engagement.

Acknowledgments

Research Assistants

Charlotte Catmur planned and coordinated many of the activities, as well as collating survey and citizen scientist data; Lani Perlesz and Teresa Konlechner conducted original research; Alison Farrar, Josephine Woods and Sarah McSweeney assisted with data collection; Jemima Milkins collated and analysed data; Eleanor Soh conducted the literature review; Renee Mead and Aimie Cribbin measured nesting habitat of hooded plovers; and Susan Ebeling helped prepare the final report.

Monthly community monitors

Anne Ballard , Anna Hicks, Lai Aw, Ann Matei, Beth Gaze, Bernadette Sanders, Carl Clifford, Chris Willocks, Don Hanran-Smith, John Peter, Judy Spafford, Jenny Westwood, Laurie Allen, Lynda Avery, Laurie Martin, Leonie Stubbs, Mandy Anderson, Natalie Krawczky, Peter Hutt, Rod Brooks, Rosie Smith, Rob Tanner, Stuart Cameron, Sarah Campbell, Sue Dajnko, Sue Proust, Steven Romankus, Vivian Kershaw, Vicki Vivian

Other community contributors

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Miscellaneous

David Hill and Paul Fitzsimons educated us about the practices of the Soil Conservation Authority and shared their collection of resources with us.

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What the report is about

Australia's coastal regions are being threatened by many invasive plants. This project attempts, for the first time, to collate existing information on the impacts of these invaders, collects new data on impacts on animals and people, and identifies the gaps in our knowledge and reporting systems.

Who is the report targeted at?

Policy-makers, coastal land managers, scientists.

Where are the relevant industries located in Australia?

This project is of national relevance: it applies to Federal bodies funding natural resource management and all States and Territories with coastlines. Within these regions, it applies to multiple tiers of government, agencies that are responsible for managing land state-wide and local community groups. Special attention was paid to the southern half of the country. The main industries affected are tourism and the protection and management of Australia's biodiversity.

Background

Australia has a narrow terrestrial coastal fringe of 60,000 km. This fragile habitat is undergoing a 'coastal squeeze': on the seaward side sea levels are rising, reducing the width of beach available, and on the landward edge there is severe threat from urbanisation, disturbance from tourism and invasive species, of both plant and animal, particularly in the south and east. Intact habitat, with its unique flora and fauna, is now fragmented and increasingly rare.

Aims/objectives

The project aims were to document existing knowledge of the impacts of coastal weeds and to gain additional information through survey and observation.

Methods used

Scientific information on the impacts of coastal weeds/invasive plants was reviewed. All local government and state authorities were surveyed to determine expenditure on coastal weed management and on the main species that are actively managed. The Coast Action/Coastcare coordinators were contacted to assemble data on in-kind contributions from community groups. About fifty "citizen scientists" made monthly records of animals interacting with invasive plants. BirdLife Australia volunteers and researchers in southern Australia made observations and measurements on the interaction between hooded plovers and weeds. Around 200 residents, visitors and coastal managers in the Bass Coast Shire completed a survey; follow-up interviews were conducted on a smaller sample, to understand perceptions of weeds in coastal landscapes. Aerial photographs between 1940 and today were reviewed to map shoreline stability since the incursion by major weeds.

Field mapping and laser surveying was undertaken at sites in Victoria to ground-truth the aerial mapping, and to quantify how foredune morphology changes in response to weed infestation.

Results/key findings

- There is remarkably little scientific information on the impacts of coastal weeds in Australia. Most research has been on one or two species and most observations are not based on rigorous scientific study (Bitou Bush/Boneseed is the notable exception). Most weed control activities are not assessed for ecological impact, just (in some cases) herbicide efficacy.

- It is almost impossible to obtain data on weed management costs in most states. Coastal weed management costs of at least $12 million have been accounted for, but this is a considerable underestimate particularly with respect to the State government sector. The actual figure is more likely to be around $30 million.

- Local governments listed the top five species being actively controlled as African boxthorn, sea spurge, Bitou bush/boneseed, Geraldton carnation weed and bridal creeper.

- With the exception of scenes dominated by marram grass, visitors tended to have slightly lower preferences for weed-infested sand dune systems.

- All foredunes in Victoria are now composed of a mix of exotic and native species with the majority of sites showing the exotics to be replacing native species. Marram grass, sea spurge and sea wheatgrass are the dominant invasive species displacing natives. Marram grass appears to cause dunes to become higher and narrower while sea wheatgrass produces lower foredunes more seaward than those dominated by native species.

- Marram grass significantly impacts the availability and suitability of nesting habitat for beach-nesting birds such as hooded plovers.

Implications for relevant stakeholders

- In probably the widest-ranging inter-disciplinary study of weeds ever undertaken, it has been illustrated just how little is known about these weeds and their impacts. In most cases, the weeds invade with impunity, with the exception of strong (though patchy) community action against a few species and a concerted effort against Bitou bush. Without impact data, control decisions will tend not to be made in the face of alternative demands for resources. Without post-control monitoring data, it will not be able to ascertain if the expenditure has been worthwhile.

- Much of the burden of management is shouldered by community volunteer groups.

- Rapid change is currently occurring in dune shape and stability on the Victorian coast driven by weed invasion. This will significantly impact how shorelines respond to storms, leading to possible beach loss and consequences for town planners.

Recommendations

A national survey is needed to document the state of our terrestrial coastal fringe vegetation, including invasion by exotic species, so that more informed decisions can be made. More scientifically rigorous studies of the main weedy/invasive species are needed; in southern Australia sea wheatgrass and marram grass would seem to be the most urgent of these. Where control is initiated, there should be more deliberate attempts to estimate the impacts of management action (and inaction). Critically, the response of dunes dominated by weeds to storm events needs to be quantified to enable managers to respond appropriately to coastal erosion.

1. Introduction

Australia has a narrow terrestrial coastal fringe of around 60,000 km in length. This fragile habitat is undergoing a 'coastal squeeze': on the seaward side sea levels are rising, reducing the width of beaches, and on the landward edge there is severe threat from urbanisation, disturbance from tourism and invasive species, both plant and animal, particularly in the south and east. Intact native habitat, with its unique flora and fauna, is now fragmented and increasingly rare.

When visiting a beach in southern Australia, much of the vegetation seen is comprised of species from another part of the world. The same can be true of rocky headlands and other habitats restricted to coastal regions. Whether these are regarded as "weeds" or not depends on your perspective. Some of them have been deliberately planted to stabilise the sand; others have escaped from gardens; some have arrived by accident. In addition, as land management practices have changed and native species have been transplanted beyond their original ranges, some Australian species have reached levels of abundance where they are regarded by some people as weeds. A summary of species listed as weeds in a sample of sources – plant identification books, regional management plants and floral surveys (Appendix 1) – shows that there are well over 200 species of "weeds" growing around the coast. Many of them are still spreading, unchecked, around Australia's coastline. Not all of the species are confined exclusively to the coast (i.e. adapted to coastal conditions themselves) but they are perceived as being in some way unwanted or unwelcome in these areas (Fig 1.1).

Figure 1.1. Greens Beach, Tasmania where uncontrolled sea spurge dominates the foredunes.

It was clear that management of these unwanted plants is mostly uncoordinated, with the exception of a few legally declared plants ("noxious weeds") and "Weeds of National Significance" for which Federal or State funding is available. Some weeds may be controlled by councils or land managers (such as National Parks authorities); in many coastal areas the responsibility is taken up solely by community groups (such as Coastcare). Each agency or group has decided independently, on the basis of some criteria, that action is warranted. In many areas weeds are not controlled and are left to increase in abundance and spread unimpeded. Should we be managing them more effectively? Should we be investing more money? Are we wasting current efforts: should we spend less money? How important is the management of coastal weeds – to the coastal landscape, the economy, the plants and animals living there and to the enjoyment of people? To answer such questions, factual knowledge of their impacts is required. Without this knowledge, it will be difficult to justify the allocation of resources or to argue for more coherent programs.

This project did not find any published estimates of how much coastal weeds are costing, at any level of organisation. It was also unable to find any previous attempt to collate information on their environmental or social impacts. Many coastal managers have views, often strongly held and sometimes conflicting with other managers, about these impacts, but there appear to be few formal studies of these impacts. Moreover, the existing information is not readily available. Impacts, by their definition, are interactions with other components of the ecosystem. Weeds interact with other plants and animals (native and introduced), people and the physical environment (Figure 1.2). These impacts can be either negative or positive (though people often focus on just the negative impacts of invasive species). There may be complex, indirect interactions involving weeds: for example, weeds causing changes in sand dune shape will determine what other plants can grow there and hence what animals will be attracted or deterred; the different dune profiles may change how shorelines respond to storms, leading to possible beach loss and consequences for town planners. Impacts can be measured in many ways, for example: impacts on plants can be measured by changes in biomass or number; impacts on animals requires that we assess their use as food and shelter and their effects on nesting behaviour; impacts on people can be economic, behavioural, aesthetic; impacts on the physical environment include soil chemistry, water retention and sand accumulation. Some of these are much easier to measure than others.

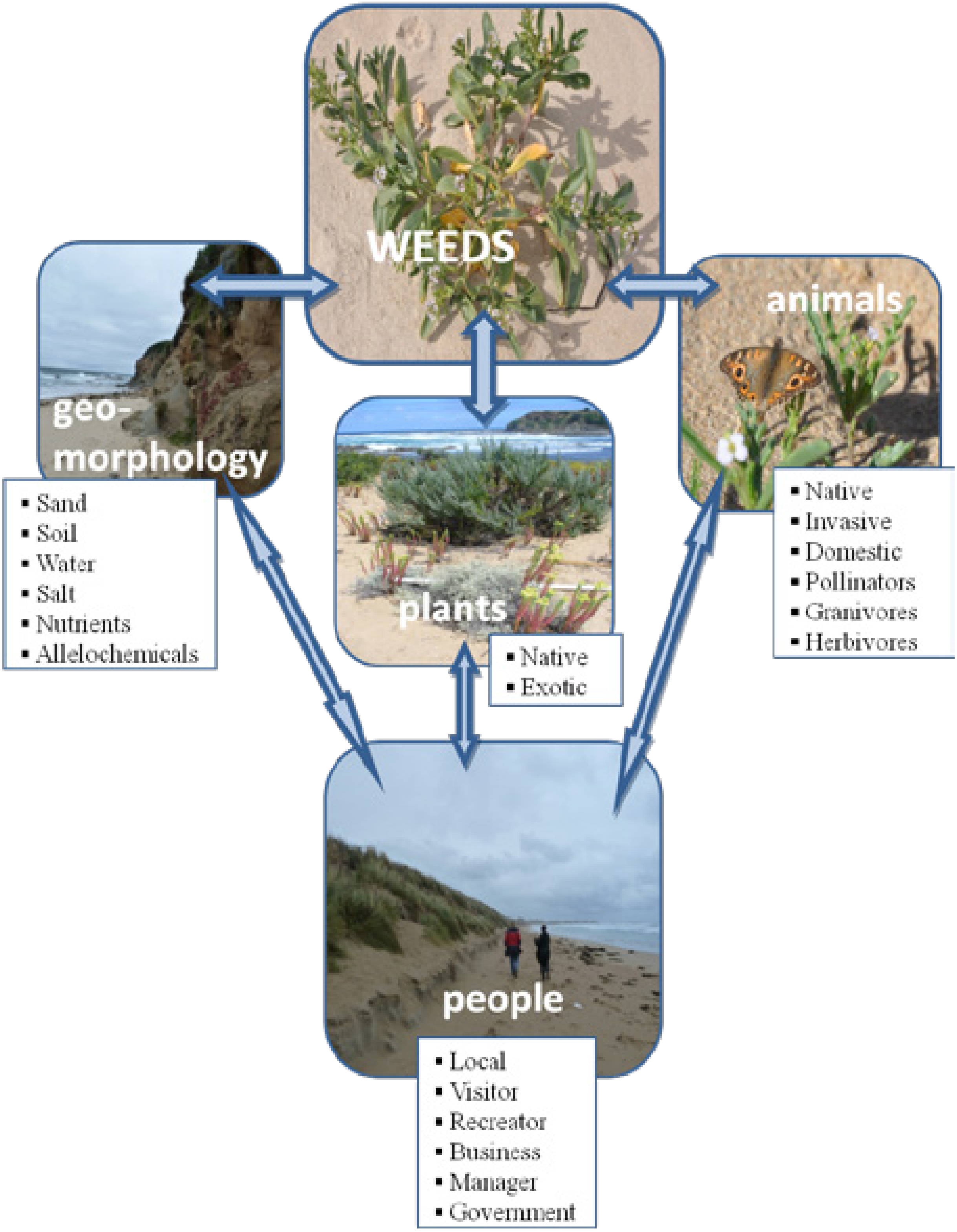


Figure 1.2: Illustration of the various interactions of weeds with other components of coastal ecosystems.

The aims of the project were to determine the extent of existing information on weed impacts in coastal ecosystems in southern Australia and to collect new data where there are clear gaps. This project does not attempt to cover knowledge from overseas, even if this concerns species that are found here. The research was funded by a research grant from the National Weeds and Productivity Research Program administered by RIRDC. Funding enabled research to be conducted over approximately a year. In this report, information is presented under headings related to direct interactions of weeds with single factors: other plants, animals, the physical environment (specifically geomorphology) and people (social and financial). While the researchers are aware that there may be complex interactions these have seldom been documented and new research on them is difficult to achieve in such a short period. Also, for some aspects the project considered all coastal ecosystems, in others the attention was on sand dune systems, and sometimes just in Victoria, in order to illustrate the impacts that are taking place. Southern Australia was selected because the vast majority of information comes from this part of the country, which in terms of this project was considered to be all regions south of the NSW-Queensland border and south from Geraldton.

The research identified three types of interaction that were clearly under-represented in the scientific literature and these were selected for more detailed work: weed impacts with animals, people and coastal geomorphology.

2. Impacts of weeds in southern Australia: A Literature Review and Data Search

2.1. Methods

A literature search targeted published papers on impacts of coastal invasive weed species on native plants and animals and the physical environment in southern Australia. The database Web of Science was searched using the common and scientific names of seventeen weed species as primary search terms (Table 2.1). Other databases (JSTOR, Wiley Online etc.) were searched using The University of Melbourne Discovery Search and Google Scholar, which also uncovered information from governmental websites and vegetation management plans. A search of the Australian Weeds Conference Proceedings (1987-2010) was also undertaken. Reference lists of the papers gathered in this process were examined, leading to additional published and unpublished papers and books not referred to in the databases. Key scientists working on specific weeds and in various states were identified and contacted for access to additional publications. The range of literature in this review is reasonably comprehensive. It distinguished between the type of information about a species that was given in the paper: Scientific experiment (A), Scientific observation (B), Casual observation (C), and Opinion (D). A range of government department officers in all States were contacted to determine the extent to which unpublished impact data may have been collected; these people were determined through existing networks and through suggestions by others (i.e. a "snowballing" method). Enquiries focussed on two types of data: those on the impact of weeds on the natural communities/ecosystems (how had the ecosystems changed post-invasion?); and those on the response by those communities/ecosystems to weed removal (how well do they recover?). Information was not sought for control efficacy (how well do control methods work?).

2.2. Results

Table 2.2 shows the number of references containing (apparently) primary information on the impacts of weeds and the type of information contained; Appendix 2 summarises the information for each species in more detail. While some of the species are well investigated using scientific experiments (e.g. *Chrysanthemoides monilifera)*, the only information for several species is observational or opinion. For several species no information could be found on impacts.

Weeds can (though not always) clearly have a wide range of interactions with other components of coastal ecosystems. Although focus is often on those impacts that we perceive to be negative (to the particular component), some impacts may be positive while others may cause the system to be merely "different". The lack of information on a particular interaction should also not be perceived as necessarily indicating a lack of impact. Some types of impacts are simply seldom studied by scientists. The most obvious impact is that weeds can reduce the abundance and diversity of other plants (note however that those choosing to study weed impacts tend to have a botanical training). Through changing the environment weeds may also facilitate the invasion of other plants or animals. Native animals – birds, mammals and invertebrates – may decrease in abundance and diversity, but some may increase. Some weeds provide food for native and exotic granivores (especially a number of parrots) and frugivores, perhaps enabling the animal populations to be maintained or increased. This may occur through changing the timing of availability of food rather than just by altering food quantity. Some weeds can cause physical injury to animals, inhibit feeding, affect nesting or burrowing behaviour and fledging success. They may also provide shelter from the weather and protection from predators.

Table 2.1: List of coastal weed species reviewed.

Scientific names	Family	Common names
Ammophila arenaria	Poaceae	Marram grass
Arctotheca populifolia	Asteraceae	Beach daisy
Arctotis stoechadifolia	Asteraceae	White arctotis
Cakile edentula	Brassicaceae	American sea rocket
Cakile maritima	Brassicaceae	European sea rocket
Chrysanthemoides monilifera spp. monilifera	Asteraceae	Boneseed
Chrysanthemoides monilifera spp. rotundata	Asteraceae	Bitou bush
Ehrharta villosa	Poaceae	Pyp grass
Euphorbia paralias	Euphorbiaceae	Sea spurge
*Lantana camara**	Verbenaceae	Lantana
Lycium ferrocissimum	Solanaceae	African boxthorn
*Malva dendromorpha**	Malvaceae	European tree mallow
Pennisetum clandestinum	Geraniaceae	Kikuyu
Polygala myrtifolia	Polygonaceae	Butterfly bush
Spartina spp.	Poaceae	Cordgrass
Thinopyrum junceiforme	Poaceae	Sea wheatgrass
Trachyanda divaricata	Asphodelaceae	Dune onion weed

(*Species not searched extensively)

Information on impacts with the physical environment was scarce and mostly focussed on particle accretion and erosional susceptibility of dunes. This can change the profile of sand dunes, may narrow the beach, make or stabilise islands and may silt up estuaries. The implications of such physical changes for other ecosystem components, while widely quoted, are rarely studied formally and are merely inferred (for example, impacts of changes in geomorphology affecting bird nesting behaviour or people's use/enjoyment of beaches). Weeds can change soil chemistry and litter accumulation; no information on the impacts of coastal weeds on fire was found.

Table 2.2: The types of information on weed-plant impacts found in the literature search

(see Appendix 2 for more details). Scientific experiment (A), Scientific observation (B), Casual observation (C), Opinion (D). Each letter refers to a different source. Only species for which we found at least one reference are included.

Scientific name	Frequency of study type			
	Plant	Animal	Physical/chemical	Human
Ammophila arenaria	A,D	A	B	
Arctotheca populifolia		D	D	D
Cakile spp.	C	B		
Chrysanthemoides monilifera	A,A,A,A,A,A,A,A,B,B,B,B,B,C,C,D	A,A,A,A,A,A,A,A,B,B,D,D,D	A,A	
Ehrharta villosa	C			
Euphorbia paralias	A,C,C		C	
Lantana camara	A,D			
Lycium ferrocissimum	A,D,D	A,D		
Pennisetum clandestinum	A	B,C		
Polygala myrtifolia	B,C,C	B		
Spartina spp.	B,B,C	B,B,C,C	B,B,C	C,C
Thinopyrum junceiforme	B,D	B,D	B,C,D	

All contacts with government and council officers indicated that it is very rare to assess the impacts of coastal invasive species in a formal way. They were in possession of almost no data other than those already published. We were told, however, that current community action weed projects funded under

Caring for Our Country have a requirement for formal assessment of the responses to weed management.

2.3. Conclusions

There may be some bodies of information that were missed (not everyone could be contacted). However, it is clear that there are few data on the impacts of coastal weeds in Australia. For some species, such as marram grass (Fig 2.1), overseas data are able to be drawn on, assuming they are applicable locally. While a few of the species (and one in particular) are well investigated using scientific experiments, the only information for many species is casual observation or opinion. For some species no information could be found on impacts at all (and overseas data was also lacking). The adoption of the Blind Freddy[1] impact assessment method appears to be almost universal in Australia for coastal weeds: the impacts are visually so obvious that it is needless to undergo formal assessment. It is also noted, however, that good assessments of invasion impact (but not impact of weed removal) are difficult to make: for example, the popular approach of measuring variables such as species diversity in plots containing different levels of weed infestation relies on an assumption of cause and effect that may not exist.

Figure 2.1: Marram grass dominated dune in Gippsland.

Decisions on coastal weed management (and decisions to ignore them) are therefore being made in a vacuum of information – both on their impacts on ecosystems and on the ability of the ecosystems to respond to weed removal. It cannot therefore be assessed whether current management programs are achieving value for money, or whether lack of action is resulting in major adverse ecological or economic outcomes. Of course, decisions cannot wait until data are available for every species to a high scientific level: early action is essential to the effective management of invasive species. There may also be a tension between allocating scarce resources away from on-ground weed control to scientific studies. But only one government example was found where correcting the impact information gap was observed. Policy decisions are perhaps needed to ensure that more impact data are collected in future.

[1] Grice AC, Field AR & McFadyen REC (2004) Quantifying the effects of weeds on biodiversity: beyond Blind Freddy's test. Proceedings of the 14th Australian Weeds Conference, pp. 464-468.

3. Perception of weeds by coastal managers in southern Australia

3.1. Methods

The aim of this part of the project was to identify which weeds are considered by managers to pose the greatest threat, and those which are actively being managed, along the southern Australian coastline. Questionnaires were sent to as many relevant organisations as possible with direct management responsibility: these included local governments, Catchment Management Authorities, Boards of Management and similar organizations (this varied among States). For example, each council from Geraldton in WA to the Queensland/NSW border that has some of its boundary as coastline was sent an email asking for contact details for the person in charge of organising natural resource management. That person was then sent an email containing a short questionnaire. These emails were often followed up with a telephone call. In some cases the respondent indicated other organizations/people to contact.

The responses requested were:

- ‘Please rank the worst coastal weeds in your organisation’s/council jurisdiction’. A definition of “coastal weeds” was provided: *weeds present in sand dunes, rocky headlands, coastal woodlands or coastal heath lands, with an understanding that the same species may be present in other systems and not necessarily confined to the coast. ..*
- ‘Which of these weeds does the organisation spend funding on managing their impact’.

3.2. Results

Response rates to surveys were generally good. For New South Wales, 38% of councils contacted returned the survey. Out of the councils that responded, 94% fund coastal weed management. The response rate of South Australia was 30% and all the councils have funding allocated towards coastal weed control. Fifty percent of Tasmanian councils responded to the survey and again 100% of these councils spend money managing coastal weeds. Victoria had the largest response overall with 63% of councils responding to the survey and 90% of the councils with funding allocated towards coastal weed control. Western Australia had a response rate of 26%; 100% of them have coastal weed funding allocation. Each state also had at least three other bodies that supplied data for this survey.

This method relied heavily on the respondents for species identification and this may introduce errors; respondents usually used common names. Moreover, common names may be loosely applied to more than one species: in such cases it was either assumed what the species was, based on regional distributions, or related weeds were amalgamated (e.g. *Asparagus* spp.)

Since weeds are varied in their geographic distributions, a crude overall ranking at State as well as national levels was obtained. In order to determine which weed is considered the most important, the rank that each organisation gave each of the weeds (from 10 down to 1) were summed at a State level.

Weeds were then ranked by this score. The State scores were normalized by adjusting for the proportion of respondents and then added together to produce a national total: this was then used to produce a national rank.

In total, 150 different species were listed by respondents as important (full list is given in Appendix 3), but only 131 species were listed as actively managed. There are seven species that appear on more than one State 'top ten' list (Table 3.1): *Leptospermum laevigatum, Euphorbia paralias, Ehrharta erecta, Coprosma repens, Chrysanthemoides monilifera* (this includes both subspecies), *Asparagus asparagoides*, and *Lycium ferocissimum*. Victoria had the most in common with the other States, with six of the species listed also mentioned in other top ten State lists. The two most geographically (and climatically) distant States, Western Australia and New South Wales, have the fewest in common with other States, with only two species each between them that appear on other state lists.

Table 3.2 shows that *Lycium ferocissimum* was the species most often cited as the worst coastal weed in southern Australia; this is also the most commonly managed species. It appears in each State's list except New South Wales. It should be noted that most species are not confined to the coast: they are weeds of many ecosystems. The two strictly coastal species that rank most highly are *Euphorbia paralias* and *Euphorbia terracina.*

Table 3.1 Top 10 perceived worst weeds for four Australian states. Species shown in bold feature on the list for more than one State.

	NSW	Total Value	SA	Total Value	Tasmania	Total Value	Victoria	Total Value	WA	Total Value
1	***Chrysanthemoides monilifera***	**105**	***Lycium ferocissimum***	**95**	***Euphorbia paralias***	**72**	***Lycium ferocissimum***	**56**	*Euphorbia terracina*	58
2	*Asparagus spp.*	87	***Euphorbia paralias***	**38**	*Ulex europaeus*	60	***Asparagus asparagoides***	**41**	*Trachyandra divaricata*	58
3	*Lantana camara*	86	*Gazania rigens*	36	*Rubus spp.*	49	***Chrysanthemoides monilifera***	**37**	***Leptospermum laevigatum***	**54**
4	*Anredera cordifolia*	53	***Asparagus asparagoides***	**30**	***Coprosma repens***	**43**	*Delairea odorata*	37	*Tetragonia decumbens*	53
5	*Ipomoea indica*	46	*Acacia longifolia*	29	***Lycium ferocissimum***	**42**	***Coprosma repens***	**34**	*Pelargonium capitatum*	48
6	*Acetosa sagittata*	42	*Acacia cyclops*	20	***Chrysanthemoides monilifera***	**36**	*Polygala myrtifolia*	33	***Euphorbia paralias***	**41**
7	*Ipomoea cairica*	40	*Tribulus terrestris*	18	*Ammophila arenaria*	29	***Ehrharta erecta***	**32**	*Ehrharta villosa*	35
8	*Senna pendula*	28	*Asphodelus fistulosus*	17	*Erica lusitanica*	24	*Dipogon lignosus*	23	*Zantedeschia aethiopia*	22
9	***Ehrharta erecta***	**27**	***Leptospermum laevigatum***	**16**	*Spartina spp.*	22	***Euphorbia paralias***	**23**	*Oenothera drummondii*	21
10	*Bryophyllum delagoens*	26	*Asparagus declinatus*	16	*Cortaderia* spp.	21	*Thinopyrum junceiforme*	22	*Tamarix aphylla*	20

Table 3.2: Comparison between the top ten perceived coastal weeds in southern Australia and the top ten coastal weeds that are managed.

PERCEIVED		MANAGED
Lycium ferocissimum	1	*Lycium ferocissimum*
Euphorbia paralias	2	*Chrysanthemoides monilifera*
Chrysanthemoides monilifera	3	*Euphorbia paralias*
Euphorbia terracina	4	*Asparagus asparagoides*
Asparagus asparagoides	5	*Rubus spp.*
Coprosma repens	6	*Euphorbia terracina*
Rubus spp.	7	*Coprosma repens*
Ammophila arenaria	8	*Asparagus aethiopicus**
*Asparagus aethiopicus**	9	*Polygala myrtifolia*
Trachyandra divaricata	10	*Ehrharta erecta*

* It has been assumed that the NSW listings of "asparagus fern" all relate to this species.

3.3. Conclusions

A very large number of weeds are seen as important to at least some local managers. Eighty-seven percent of the 150 species are controlled by at least one manager. This does not necessarily mean that many species are controlled by many managers. Most focus on a small number identified as being in greatest need of control.

It should not necessarily be assumed that the "Top 10" weeds are the ones that should receive most management attention, State-wide or nationally. Abundant species may often be seen as beyond hope at a local level, with action no longer being cost-effective. Local management may instead just identify species at the start of their invasion as management targets: species known to be bad weeds elsewhere that would justify pre-emptive action now. An example might be pyp grass (*Ehrharta villosa*) in some areas. Examples of abundant weeds seldom identified by local managers as worthy of control are sea rockets (*Cakile* spp.) and hare's tail grass (*Lagurus ovatus*) where impacts are perceived as low, sea wheatgrass (*Thinopyrum junceiforme*) in South Australia and Victoria where the species and its (probably major) impacts are not widely appreciated (and control methods may be ineffective), and marram grass which is both highly abundant – and therefore beyond cost-effective action – and of positive as well as negative impacts. Marram grass was still being planted until quite recently as part of erosion control projects and so it may still be viewed positively by coastal managers.

There is a clear knowledge gap here. While it is known what weeds are considered bad and worth controlling by managers, what species are actually present and in what abundance? Do management decisions reflect the reality of the impact or threat? Very few examples of formal weed surveys by trained ecologists were found, and these often consist of species presence lists rather than a formal measure of abundance or biomass. Species lists may be a poor reflection of the dominance of weeds in some plant communities. A formal survey is needed around our coasts, to document the actual extent of the weed problem.

The National ranking of problem coastal weeds should be treated with considerable caution, since it combines data over a huge geographic and climatic range. Some weeds appearing high in the ranking are of great importance in just some regions (e.g. *Chrysanthemoides monilifera* ssp. *rotundata* and *Euphorbia terracina*). However, there is clearly support for the Weed of National Significance status of *Lycium ferocissimum, Chrysanthemoides monilifera, Asparagus asparagoides* and *Rubus spp.*

4. Economic impact of coastal weeds in southern Australia

4.1. Methods

The aim of this part of the study was to estimate how much money is spent on managing coastal weeds and where this money comes from. The questionnaires sent to local governments (see section 3.1) included three questions: for the most recent 12 month period for which data are available,

- 'How much does your organisation spend annually managing coastal weeds',
- 'Where does your funding come from?'
- 'Do you fund any other groups in coastal weed management?'

Telephone calls were also made to all people that we could identify as involved in coastal management, or budget management, within all relevant State government departments, other relevant organisations (e.g. Natural Resource Management (NRM) bodies, Catchment Management Authorities (CMAs)), researchers and private individuals. They were asked to estimate the amount in their budget that would correspond to coastal weed management. Regional Coastcare and Landcare (and similar community groups) coordinators were contacted to try to obtain details of number of person-hours spent in weed control by volunteer groups. A value of $30 per hour for volunteer labour, a figure commonly used by regional coordinators was used. The intention was to be as comprehensive as possible, knowing that there would be gaps. It was simply not possible to identify every key individual in every organization. However, this aspect of the project involved many days over a two month period on the telephone for considerable amount of time. For one Weed of National Significance, complete data were available for 2009/10 but not since (WoNS coordinators now report only on Caring for Our Country targets whereas previously they reported against the National WoNS Strategy goals). Finally, details of coastal weed management programs funded by community action grants under the Caring for Our Country federal program were extracted. Care was taken throughout to ensure that there was no double accounting; however, given the overlap in responsibilities between bodies, some repeated accounting was inevitable. It was not attempted to calculate full costs, i.e. organizational overheads that are necessary to support weed activities, only the direct costs.

4.2. Results

Funding for coastal projects comes from a range of sources, especially from government at Federal, State and Local levels. Other sources are private grants or forms of fundraising. Response rates varied considerably. Response rates for local government were 38% for New South Wales, 30% for South Australia, 50% for Tasmania, 63% for Victoria and 26% for Western Australia. Six Natural Resource Management (NRM) groups from South Australia also responded with information, 2 NRM groups, 4 Park and State groups, 1 weed group and 2 volunteer organisations from Tasmania, 6 volunteer groups with three sets of the volunteer information supplied by the Department of Sustainability and Environment in Victoria, and 3 Department of Environment and Conservation regions and 2 volunteer groups in Western Australia. One of the volunteer groups returned the survey on behalf of a local council because they perform the majority of the coastal weed work. In summary, 88 different organisations responded to the survey.

Table 4.1: Total amount of funding for coastal weed management across southern Australia.

NSW	SA	Tasmania	Victoria	WA	Research	Total
$6,753,390	$1,586,790	$820,945	$1,745,320	$682,421	$500,000	$12,088,866

Table 4.2: Breakdown of funding sources.

	NSW	SA	Tasmania	Victoria	WA
Federal Government	$82,390	$17,290	$28,390	$75,660	$36,100
State Government	$3,400,000	n/a	$167,000	n/a	$120,321
Local Councils	$2,851,000	$425,300	$168,400	$1,210,000	$516,000
Other Bodies	$400,000	$1,144,200	$40,000	$404,660	n/a
Volunteer groups	$20,000	n/a	$417,155	$55,000	$10,000

n/a indicates that no data were available.

The amounts that we were able to account for towards coastal weed management are listed in Tables 4.1. and 4.2. Availability of data varied from detailed to none at all. Some weed-specific programs replied immediately with precise information which they had at hand. Many organizations with multiple management roles, that we contacted by telephone, stated that they were simply unable to provide any data at the required resolution. Typically, weed management in most large State agencies is budgeted at a regional level, where regions include large inland areas. Moreover, for many organizations weed control is aggregated with other coastal work such as fences and even litter removal. Regional volunteer coordinators in some areas kept comprehensive lists of hours spent on activities, whereas others did not. Some Landcare facilitators indicated that they would help collect such data in the future if they had sufficient warning.

Coastal weed funding is difficult to obtain and to quantify. Large organisations, particularly at state government level, said that they were simply unable to provide any figures at all. In many cases, budgets are at a regional rather than habitat basis: coastal weed management projects are not separated from other weed management initiatives further inland in government reports. If the project is primarily a coastal initiative, it may also be in conjunction with physical habitat management, such as boardwalk construction. Thus our figures are expected to be a considerable under-estimate. Volunteers perform a large number of the tasks required to manage weeds and their work can also be difficult to collate.

There may be some overlap as it was not uncommon for organisations to receive funding from a variety of sources. Federal funding is only included for projects specifying coastal weed management: for example, funds that support the general operation of NRM bodies that abut the coast was not included.

Most organisations considered that their funding for weed management and revegetation was inadequate. Many commented across all States that they feel as though they are barely able to keep up with emerging issues; they receive enough funding to remove the current problem weed but not enough to tackle emerging weeds. They do not receive funding until the emerging weeds become large enough in scale to be a significant enough problem to warrant funding for management. There is also the concern, particularly voiced in South Australia that volunteers are relied upon too heavily for assistance in management. There is a fear that volunteers may become 'burnt out' and work that governments have not funded in the past will need to be included in future budgets.

4.3. Conclusions

While the lack of availability of data and low response rates were disappointing, our research has accounted for at least $12 million spent annually on coastal weed management costs in southern Australia. The true figure is likely to be very much higher. Adjusting for a response rate by local government of approximately 30%, the total figure would double to $24 million. It is suspected that State government expenditure by their own conservation agencies would take the figure to at least $30 million, but this project was unable to provide justification for such an estimate.

It is clear that much of coastal weed management is done by volunteer groups and our ability to access this data was very patchy. Huge volunteer efforts are going into some regions, for example the SPRATS group annually flying into western Tasmania to hand-pull sea spurge, and detailed activity summaries are available for these. Also, some regional Coastcare coordinators (but far from all) make special efforts to collate data on volunteer activities. Several regional Landcare coordinators indicated that they could obtain such data, but not within the timeframe of this study.

5. Community-based monitoring of weed interactions with animals

5.1. Methods

Given that information on weed impacts with animals is generally sparse (see Section 2), in this part of the project we used an existing network of volunteer individuals interested in nature, spread across the country, to collect new data for sandy beaches. Such an approach is being referred to increasingly as “citizen science”: consistency and precision obtained from a single observer (e.g. a scientist) at a few sites is traded off against a greater volume of data collected across a wide geographic area.

Invitations to participate in the research were sent to all Birds Australia (now Birdlife Australia) members in New South Wales, Victoria, Tasmania, South Australia and Western Australia, as well as to the Threatened Bird Network. Given the diversity of expertise among such groups, it is essential to keep data collection simple and to use very specific protocols. The task they were given was to make monthly observations on any interactions between animals (from invertebrates to vertebrates) and ten common weed species on a stretch of their beach, according to a standard set of protocols. Those who responded to the invitation received a welcome package which included three documents: an initial observation sheet to give an overall picture of the beach they were to monitor; a monthly observation sheet to record interactions on the beach; and a weed identification sheet so that they could be confident in the species that we were asking them to focus on (they were not asked to study every weed on their beach). Over 200 welcome packs were sent out, but only 40 individuals finally engaged with the project by sending in monthly observation sheets: 16 in Victoria, 8 in NSW, 5 in South Australia, 3 in Tasmania and 8 in Western Australia (Figure 5.1). Others provided one or two observation sheets and small amounts of information on specific interactions they witnessed on the beach. Many of those who had originally expressed interest in the project contacted the team specifically to explain that they were no longer able to engage in the project. Numerous reasons were expressed including, lack of time to get to the beach, lack of weeds on the beach that they frequent and also natural events that have meant not being able to get to the sites.

Volunteers were asked to list beach-nesting birds, beach-using birds, insects and other animals on their beach, based on the user’s knowledge of the beach and whether they witnessed them ‘regularly’, ‘occasionally’ or ‘never’. On their first beach visit for the survey, they were asked to select a 100 m length of beach and to assess, by starting at one end and concentrating on the beach and the foredunes, the presence of the different weeds and native species present. Each plant species present, weed or native, was to be categorised as ‘none’, ‘few scattered plants’. ‘common, low density’ and ‘very abundant’.

The monitoring sheet included some preset selections and other sections for adding further detail. Categories to select from included type of animal (bird, insect, other animal) and interaction type (feeding on, foraging among, pollinating, roosting, perching/sitting on, nesting in, nesting under, nesting by, use for shade/shelter and taking cover). There was opportunity to specify the species or order of the animal.

Volunteers were also invited to post their photographs on a web site:
http://natureshare.org.au/collection/171/

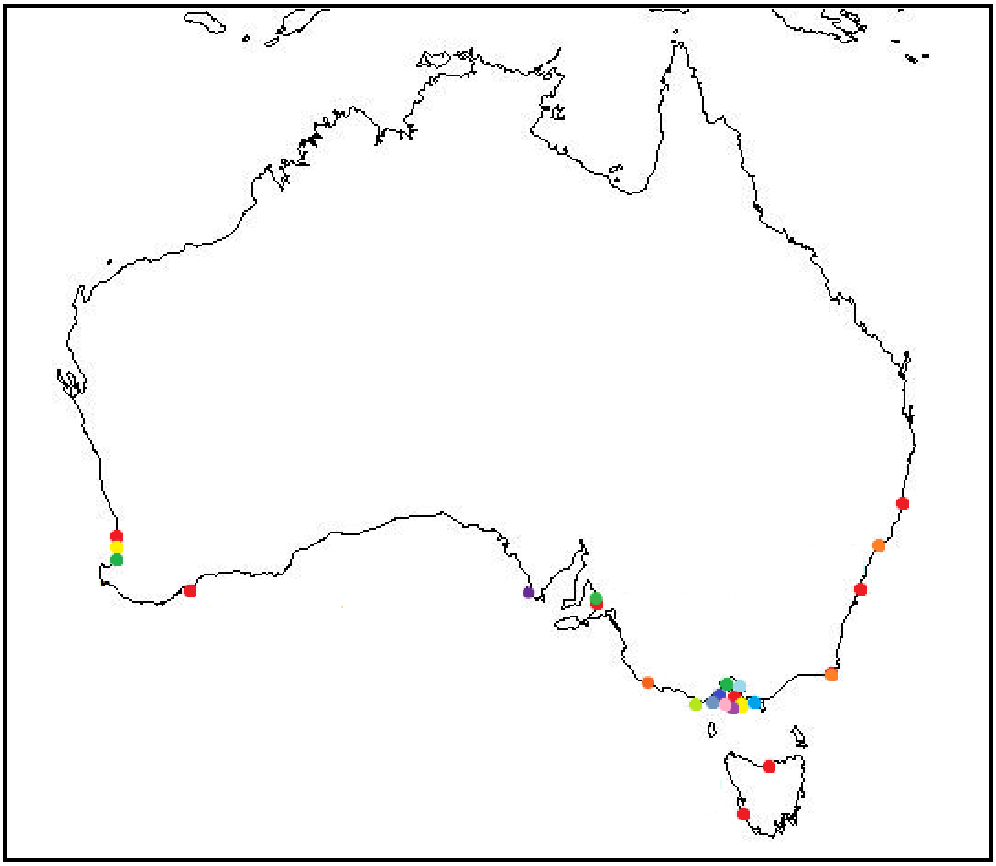


Figure 5.1: Geographic spread of monthly community-based environmental monitors.

5.2. Results

The most frequently observed weeds on volunteers' beaches were sea rocket, sea spurge and marram grass (Figure 5.2). As expected from the distributions of the species, any one beach only had a few of the species present. Birds predominantly using sandy beaches typically fall into two categories, shorebirds including resident and migratory species (the latter in summer months) and seabirds including gulls and terns (Figure 5.4 and 5.5). Silver gulls and crested terns were unsurprisingly the most sighted by volunteer observers. Birds of prey such as Nankeen kestrels are common in dune systems, and ravens and magpies commonly forage amongst beach wrack; these were frequently recorded by observers. Occasional beach use occurs by insectivorous passerines such as chats, willy wagtails and singing honeyeaters, but these consistently utilise dune shrubbery. Insects and dogs were the most frequently observed non-bird animals seen on beaches (Figure 5.6).

The most frequently observed weed-animal interactions were foraging among, feeding on and perching upon (Figure 5.7). Interactions varied among the weed species, as expected: for example, beach daisy was most often pollinated by insects and the seeds fed on by birds; in contrast, insects were usually under or sitting on (wind-pollinated) sea wheatgrass, while birds foraged amongst it. Birds were never seen interacting with sea spurge (Figure 5.8).

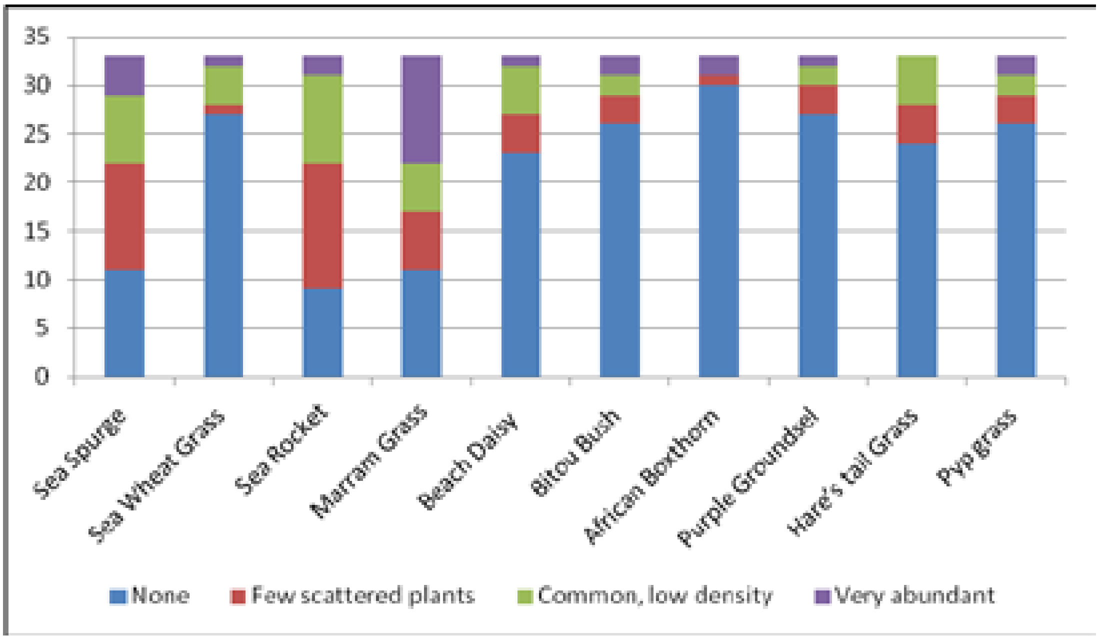


Figure 5.2: Presence of specific coastal weed species on volunteer observers' beaches. Y-axis indicates the number of observers.

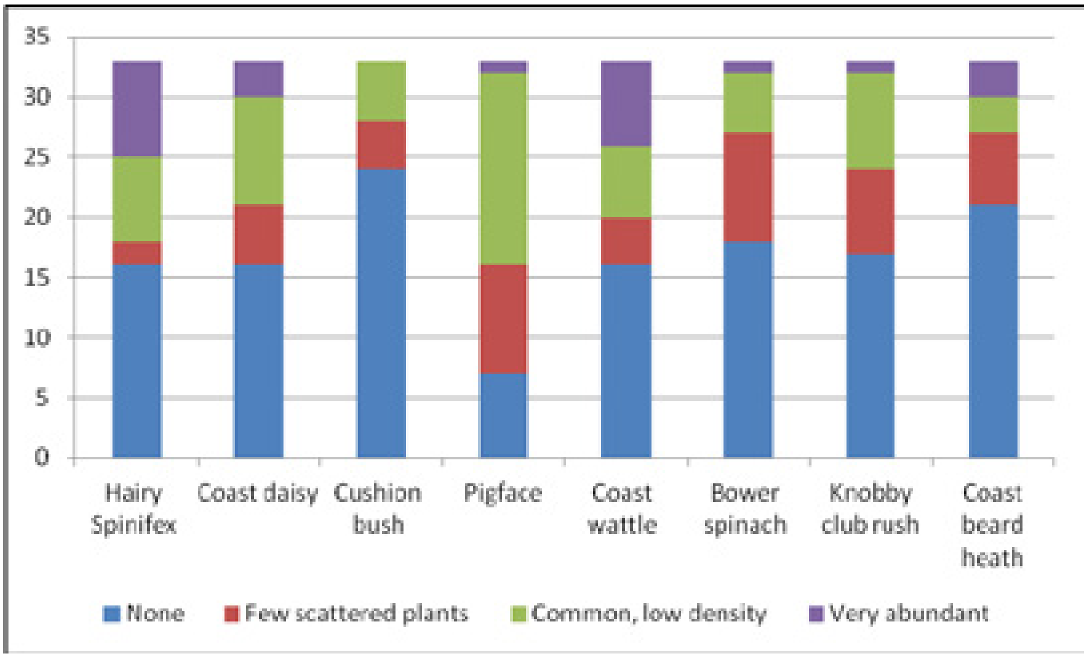


Figure 5.3: Presence of specific native plant species on volunteer observers' beaches. Y-axis indicates the number of observers.

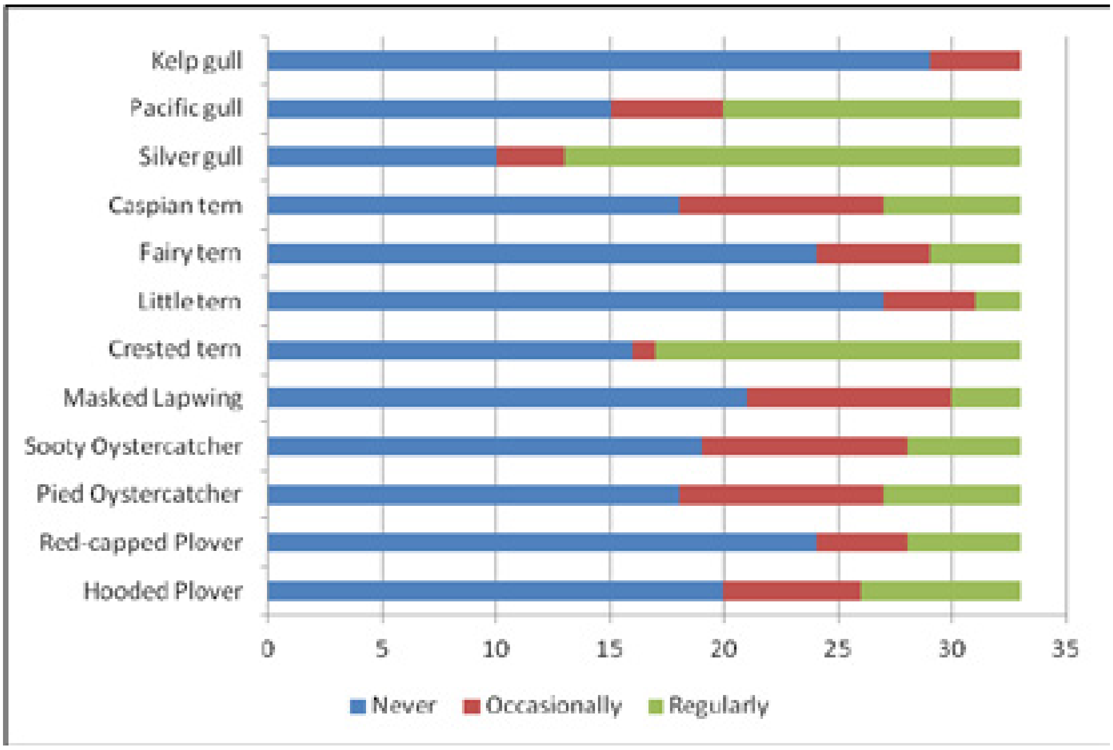


Figure 5.4: Presence of beach-nesting birds on volunteer observers' beaches, based on previous knowledge. X-axis indicates the number of observers.

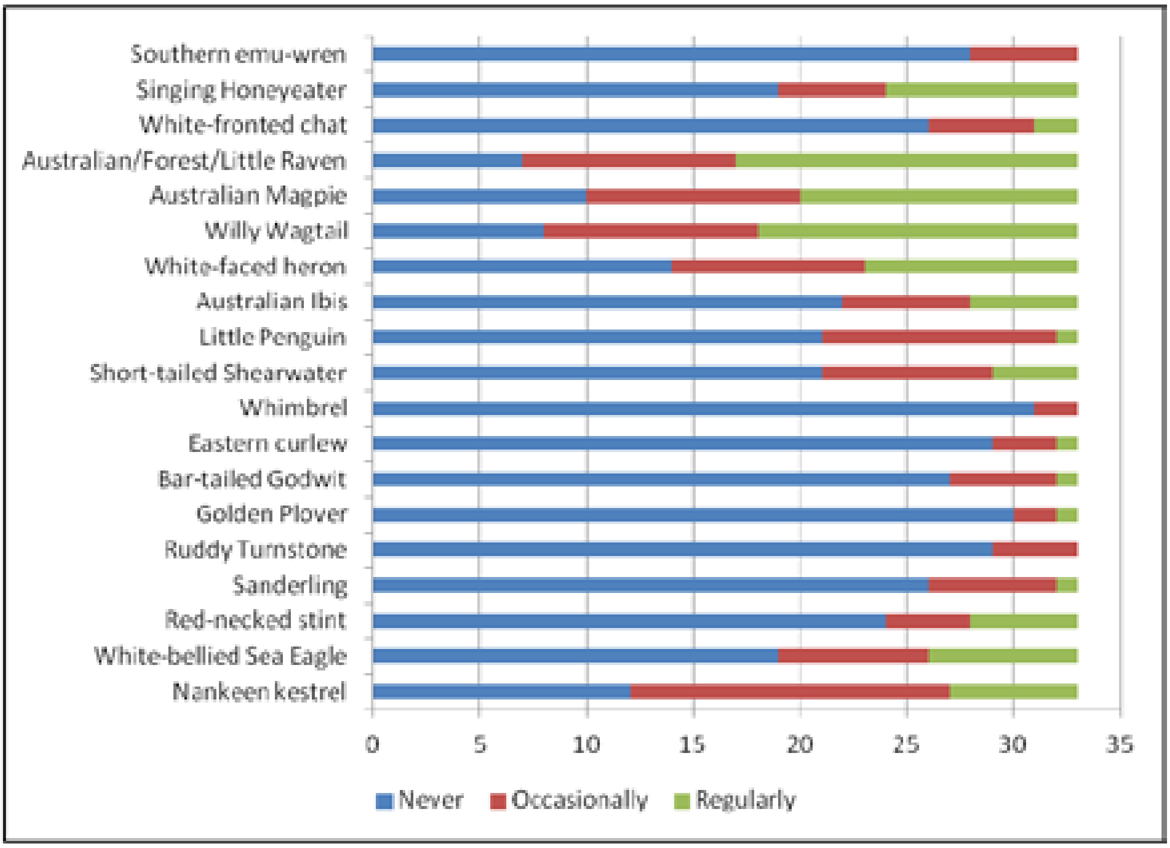


Figure 5.5: Presence of beach-using birds on volunteer observers' beaches, based on previous knowledge. X-axis indicates the number of observers.

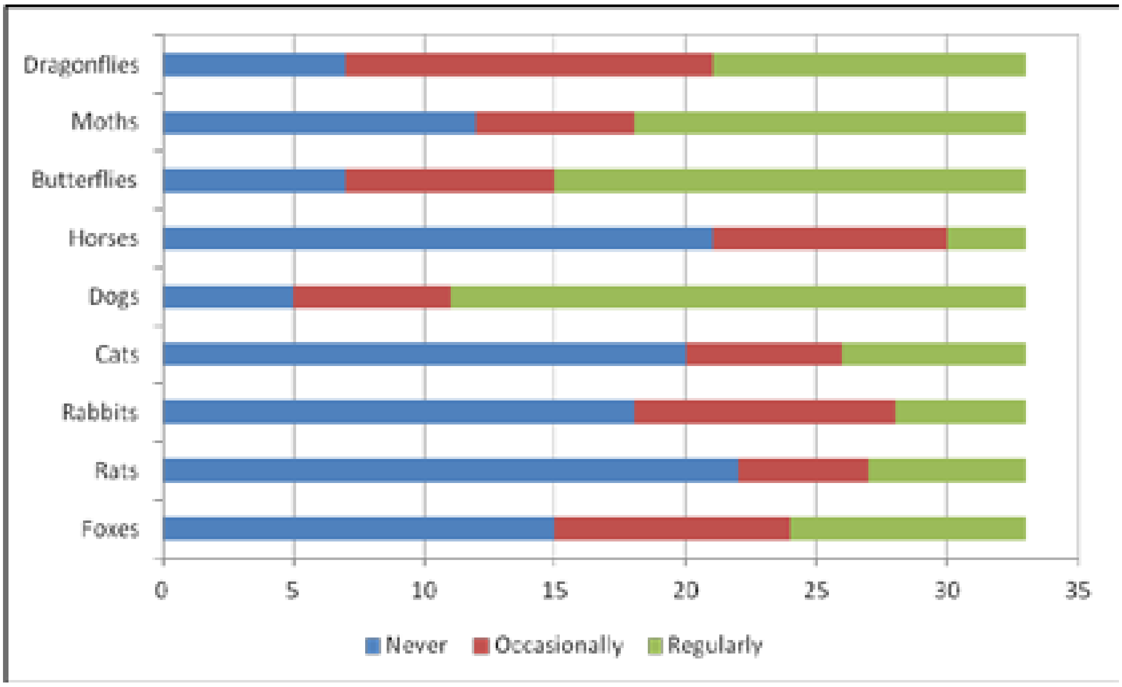


Figure 5.6: Presence of non-bird fauna species on volunteer observers' beaches, based on previous knowledge. X-axis indicates the number of observers.

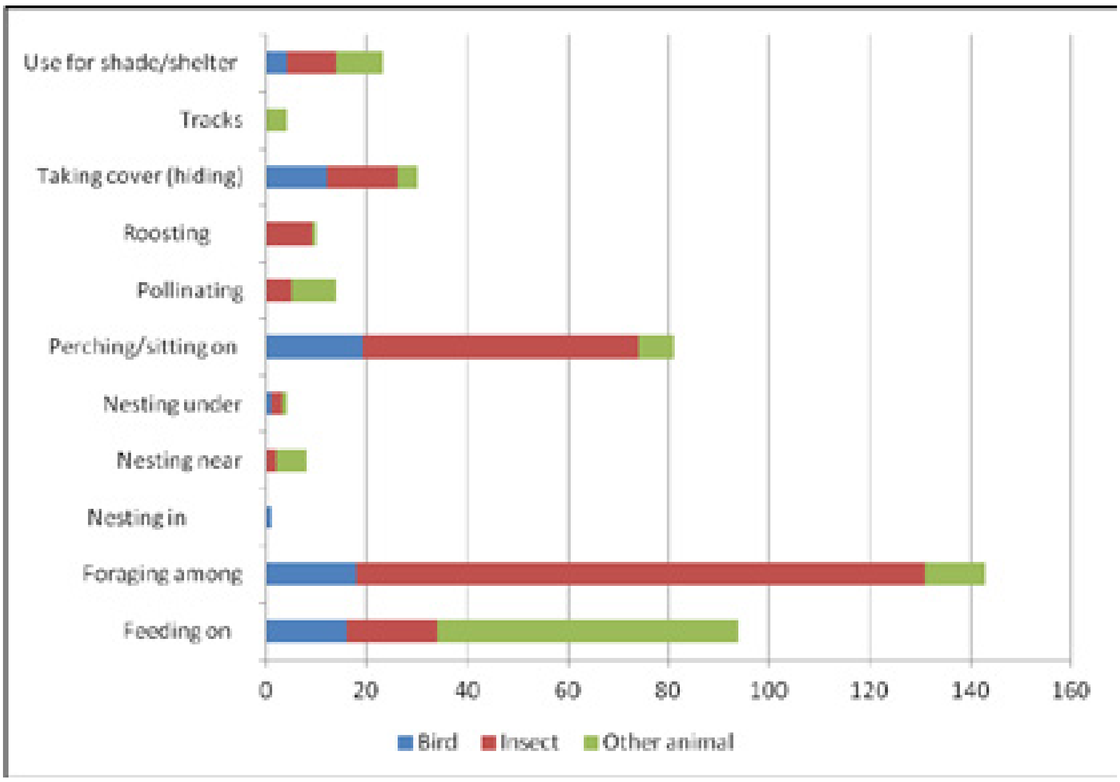


Figure 5.7: All interactions between animals and coastal weeds observed by volunteers, by animal type.

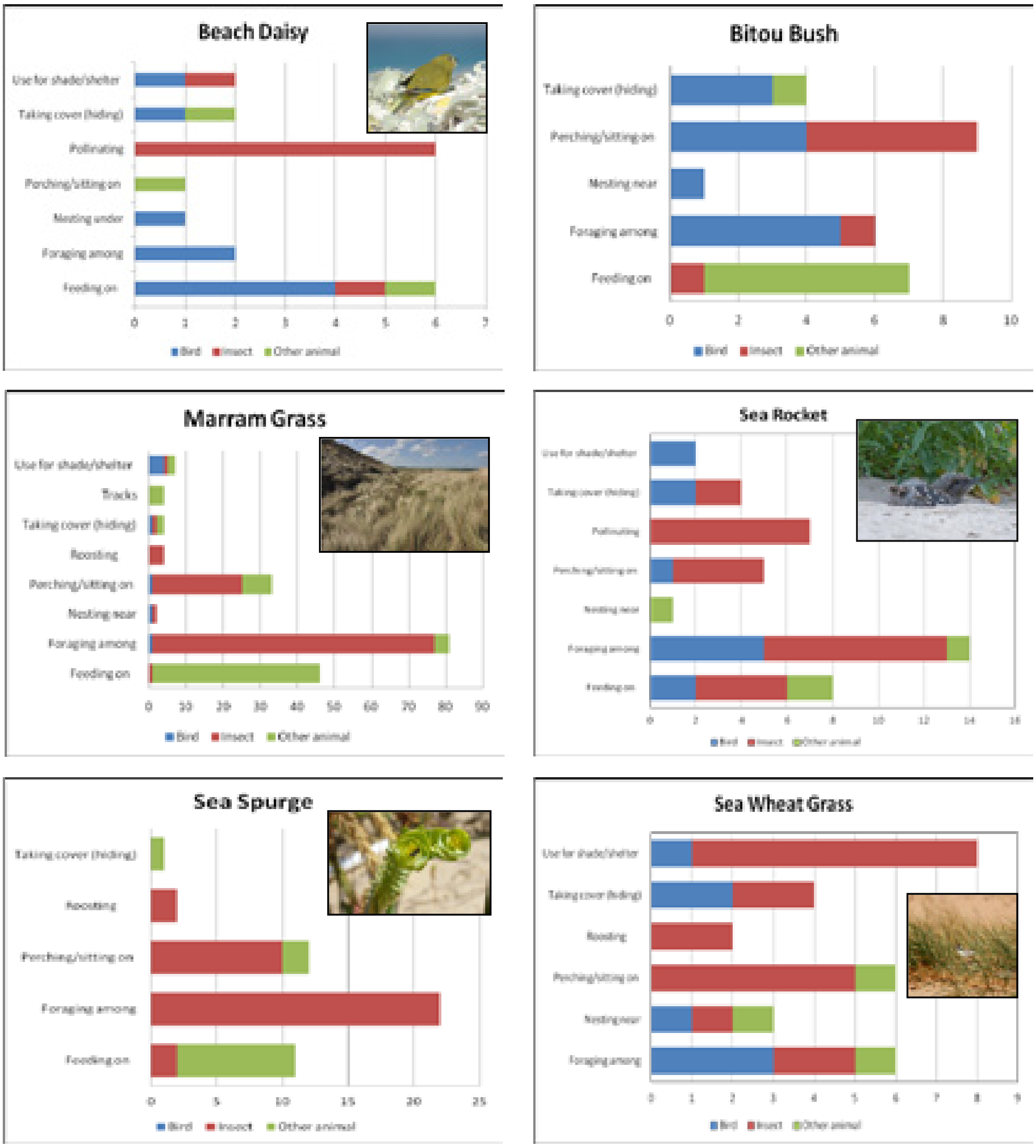


Figure 5.8: Interactions between animals and six coastal weeds observed by volunteers, by animal type.

5.3. Conclusions

Although the quality of data collected by citizen scientists is highly variable, it is was a conscious decision to replace scientific rigour with a greater frequency of visits and wider geographic scope. Observers who were already participants of natural resource projects were targeted, thus having existing, if not variable, skills in bird and plant identification. Moreover, involvement of the public in such exercises not only takes advantage of their enthusiasm, but it helps to spread awareness of the issues of weed management and natural resource management. The communication and education benefits should thus not be underestimated. Similar experiences have occurred through the use of volunteers to gain invaluable information on mortality/survival of beach-nesting birds. Our volunteers identified a wide range of animals, both native and introduced, interacting with weeds on sandy coastlines. No doubt there were also many species and interactions that were missed (and would have been missed by scientists making infrequent visits). It was not possible to obtain a full species list because often the only information was at a family level (e.g. "moth"). Clearly, a more detailed survey, capturing individuals and indentifying them formally, would show the true extent of the animal-weed community. The information is also biased towards daylight interactions; some pollinators may only appear at night, as would most mammals. These limitations need to be addressed. Finally, the nature of the interactions was often difficult to interpret. For example, large numbers of snails can be found attached to coastal weeds: what are they using the weeds for? It would also be of interest to know how important these animal interactions are to the population dynamics of the species and the benefits that weeds provide to native species: for example, do they provide a greater or less seasonal supply of nectar than the native plants that they have replaced? Would weed removal (that is not staged or coupled with simultaneous native revegetation) have detrimental impacts on the fauna that are using these species? How important are these weeds in supplying the needs of invasive animals? Such questions require experimental research.

Figure 5.9: Insects interacting with coastal weeds

(photos by volunteers N. Thomas (left) and Beth Gaze (right)).

6. Relationship between hooded plover nesting and weeds

6.1. Methods

The previous part of the research took advantage of volunteer networks to collect very superficial data. Every year, volunteers locate and then protect nests of certain beach-nesting bird species. This information allowed us to visit a large number of nests across Victoria to make targeted observations on vegetation near hooded plover (*Thinornis rubricollis*) nests. These birds are threatened in their Eastern range, listed as Vulnerable in Victoria (DSE State Advisory List; Flora and Fauna Guarantee Act) and South Australia (National Parks and Wildlife Act), and critically endangered in NSW (Threatened Species Conservation Act). The aim was to try to understand to what extent weeds affect their nesting behaviour: do they tend to use beach plants, e.g. to protect their nests, or do they tend to avoid weeds (and other vegetation)?

During the 2011/2012 breeding season, 76 hooded plover nests were located across the Victorian coast (between Eumeralla (Yambuk) Coastal Reserve to the West and Wilsons Promontory to the East). The micro-habitat around the nest scrape was systematically measured using four 1 m x 1 m quadrats. In addition, the distances to the nearest weed and non-weed were measured, and the height, growth form and species also recorded. Hooded plover pairs have multiple nests, but only one nest for a given pair was sampled during the season to maintain independence of samples.

6.2. Results

In general, hooded plovers select areas with a low density of vegetation. On average, the two metre-square area around hooded plover nests contained 5.11% weed vegetation and 2.82% non-weed vegetation. Five species of weeds were recorded as the closest vegetation to hooded plover nests (Table 6.1). Hooded plover nests were distanced between 1 cm (sea wheatgrass) and 5.6 m (marram grass) from weed species, but on average were 1.95 m from a weed. There was no significant difference in the distances of hooded plover nests from the five different species of weed recorded ($F=2.234$, $df=4$, $p=0.074$). The 10 species of native plants and their distance to the nearest hooded plover nests are summarised in Table 6.2.

Table 6.1: The most frequently observed weeds near hooded plover nests.

Scientific name	Common name	# nests near	Mean distance to nest (cm)	Mean height (cm)
Ammophila arenaria	Marram grass	31	515.03	45.89
Thinopyrum junceiforme	Sea wheatgrass	23	91.93	20.52
Euphorbia paralias	Sea spurge	11	657.20	9.20
Cakile maritima	European sea rocket	10	231.55	11.46
Actites megalocarpa	Dune thistle	2	118.00	9.50

Table 6.2: The most frequently observed native plant species close to hooded plover nests.

Latin name	Common name	# nests closest to	Mean distance (cm)	Mean height (cm)
Spinifex sericeus	Hairy spinifex	44	386.41	23.01
Carpobrotus modestus	Pigface	13	717.54	5.78
Leucophyta brownii	Cushion bush	7	211.86	15.64
Ozothamnus turbinatus	Coastal everlasting	4	291.75	45.00
Ficina nodosa	Knobby club rush	2	350.50	36.00
Tecticornia flabelliformis	Beaded glasswort	1	6.00	7.00
Salsola tragus subspp. pontiac	Prickly saltwort	1	47.00	8.00
Olearia axillaris	Coast daisy	1	187.00	18.00
Leucopogon parviflorus	Coastal beard heath	1	325.00	22.00
Leptospermum continentale	Prickly tea tree	1	3300.00	90.00

Hooded plover nests were located slightly closer to weed species than non-weed species (mean distance to weed species = 1.947 m ± 0.090; mean distance to non-weed species = 2.213 m ± 0.083; t=2.627, df=75, p=0.010). Weeds closest to the nest were significantly taller than non-weed species (27.88 cm ± 3.11 versus 21.40 cm ± 1.69; t=-1.238, df=75, p=0.036). It is unlikely that the birds would be selecting for proximity to weeds if they are taller as they are likely to pose a greater obstruction to visibility while on the nest. There was no difference as to whether a weed or non-weed will be closer to the nest according to the habitat of the nest (i.e. beach, dune, estuary nests; χ^2=0.28; p=0.868). Dune nests were – not surprisingly – typically closer to vegetation of any type than beach nests, and estuary nests furthest from vegetation (Table 6.3).

Table 6.3: Proximity (cm) of non-weed and weed vegetation to hooded plover nests according to habitat type.

	Beach	Dune	Estuary
Non-weed	502.46	208.79	1874.5
Weed	322.38	125.18	1192.8

6.3. Conclusions

Hooded plovers appear to be highly selective of open areas of sand for nest placement. Weed species were typically closer to the nest than non-weed species, which may either relate to: a) the prevalence of weed versus non-weed species at particular sites and the greater likelihood of their colonisation of bare areas of sand; or b) a preference shown by hooded plovers for weed vegetation. Given that weed species are typically denser and taller than native species, it is unlikely that the birds are showing a preference for these growth forms as these would obstruct their view of predators and interfere with their passive nest defence strategies. It is therefore likely that the prevalence of weeds is driving the proximity of nests to weeds, as it becomes impossible to 'avoid' these species. To determine whether this is the case, a comparison of nesting sites to multiple randomly placed quadrats within that habitat type within the nesting territory could be made, or alternatively the prevalence of weed versus non-weed vegetation quantified across the territory.

Weed colonisation of the dunes over time is likely to mean that areas of bare sand become vegetated, often densely vegetated with very little exposed sand, and that nesting habitat becomes permanently lost (in the absence of weed control). As this occurs, this alters the options this species has available for nest placement and means that more nests occur in beach habitat. Recent studies have shown that along the Victorian coast, dune placed nests are under-represented in western Victoria (Warrnambool to Portland) and this is presumably related to the lack of bare and sparsely vegetated dunes in this region, which is conversely related to the density of marram grass along this coastline.

It has also been shown that the grassier the dune, the more likely that a nest will be predated, particularly by rodents, and that hooded plovers are selective of barer patches for nest placement. This suggests the species is making decisions to reduce predation risk. The colonisation of bare sand dunes by weeds thus has multiple impacts on the nesting success of this species, both by reducing availability of nesting habitat and by increasing predation risks (i.e. attractiveness of habitat to predators).

Experimental removal of marram grass and sea wheatgrass within hooded plover territories would allow for manipulation of dune environments and enable us to compare pre and post removal nest placement decisions. It would shed light as to whether we can recreate habitat and improve nest placement decisions (e.g. ‘encourage’ nesting away from locations heavily used by people and domestic dogs, which would greatly benefit this highly threatened species).

Figure 6.1: Hooded plover chick amongst sea wheatgrass.

7. Perceptions of weeds in coastal landscapes

7.1. Methods

It is rare in any ecosystem to determine the impact of weeds on people, other than in economic terms to the land-owner. Coastal systems have many stakeholders who can potentially be impacted, not just those who own or manage the land. Our aim here was to identify whether/how coastal weeds impact upon human enjoyment and use of beaches, through understanding how people evaluate beaches with different types of vegetation including weeds. In particular, we sought to determine:

- What quality considerations are evident in preferences of residents, visitors and coastal managers for beach scenes; how do weeds influence these considerations?

- How do different types of weeds influence preferences for coastal landscapes?

- How do preferences differ among residents, visitors and coastal managers?

A survey was conducted of residents, visitors and coastal managers within the Bass Coast Shire, southern Victoria. Participants were shown 24 photographs of coastal landscapes. All scenes were of dune beaches. Scenes were selected within the study region, maintaining consistent view points. Scenes were selected to ensure a range of types of weeds and native plants. Five broad classes of images were used to guide selection, including scenes where the vegetation was dominated by sea spurge, marram grass, sea wheatgrass, hairy spinifex, or a mix of these plants. Each cluster was represented by at least 4 scenes, and each group included a variety of characteristics (e.g. presence of scarping, variations in sky colour, presence of rocks); however it was not possible to vary these in a controlled way.

Participants rated their preferences for the 24 photographs. The instructions or the questionnaire stated: "The enclosed photo booklet contains 24 photographs of coastal landscapes in the Bass Coast Shire. You are asked to rate these photographs according to how much you like the beach and foredunes shown in the photograph. As much as possible, please consider the coastal landscape rather than the quality of the photograph or weather conditions. There are no right or wrong answers; we are simply interested in your views. For each coastal landscape, tick one box to indicate how much you like that coastal landscape." Responses were on a 7-point scale ranging from 1=not at all to 7=very much. Participants also provided information about their residence, involvement in coastal management, amount and type of beach use, and basic demographic details.

The survey was conducted using mixed modes. Almost all residents and coastal managers completed the survey online, although a few were posted a print copy of the survey at their request. Visitors completed the survey on a print version. In the online version of the survey, the order of presentation was randomised. Two different orders of presentation were used in the printed version of the survey. In all other regards, the two forms of survey were identical. It took about 10-15 minutes to complete.

7.2. Results

In total, 229 participants completed the survey including:

- 50 coastal managers (mostly volunteer, but some professionals as well), obtained by email to Coastcare volunteer groups

- 73 residents of Bass Coast Shire not involved in coastal management, obtained by letters posted to a random selection of 600 homes in the study region

- 100 visitors to the area not involved in coastal management , obtained by intercepting people at key tourist sites on Phillip Island

- A few participants who could not be assigned to one of these groups

Coastal managers were more likely to be female. Three quarters of coastal managers lived in the Bass Coast Shire, and the remainder elsewhere in Australia, mainly Greater Melbourne. Visitors and coastal managers tended to be younger and more educated than residents.

It is worth noting the overall range of preferences for the 24 coastal areas. While the full range of the scale was used for all scenes (i.e. at least one person assigned the highest value possible, and at least one person assigned it the lowest value), mean preferences ranged between 4.08 (Photo 6) and 5.49 (Photo 16) on the 7-point scale (see Figure 7.1). All mean preferences were above the midpoint of the scale. In the most general terms this suggests that whatever negative impact weeds have on human enjoyment of beaches, on average it is not a high level of impact. Similarly, it highlights that impact of weeds on enjoyment/preference is not necessarily negative since the most preferred scenes were dominated by marram grass.

Photo 16

Photo 6

Figure 7.1: Most preferred coastal landscape (left) and least preferred (right)

Principal Components Analysis (PCA) was used to explore the dimensions underpinning preferences for coasts: that is, what factors (including but not limited to presence of weeds) might explain why people like or dislike dune beaches. Preferences for all 24 images were entered into PCA, including data from all three participant groups. 'Eigenvalues>1' rule suggested three components be extracted, and these explained 68% of the variance in preferences. Figure 7.2 provides examples of scenes loading strongly on each of these components.

By far the greatest variance (52%) was explained by the first component. Of the 23 photographs, 15 had a loading of 0.4 or more on this component. Images with highest loadings on the components were all dominated by sea spurge, however it was not clear that this was the only defining factor at

Component 1	Component 2	Component 3
Mean preference for scenes clearly loading on this component: 4.6	Mean preference for scenes clearly loading on this component: 4.8	Mean preference for scenes clearly loading on this component: 5.4

Figure 7.2: Images loading most strongly on three components extracted using Principle Components Analysis

play. Scenes seemed to be characterised by a relatively strong distinction between areas of sand and vegetation, and more frequent evidence of scarping often paired with a flat rather than a steeply sloping beach. Scenes loading on the component also included those dominated by marram grass or sea wheatgrass, but where this was the case, the vegetation was relatively clumpy compared with marram grass or sea wheatgrass scenes loading on other components. In general, the vegetation in photographs loading more strongly on component 1 tended to be more dense and dark green than those loading on Component 2, and less smooth and neat than vegetation loading on Component 3. Average preference for scenes loading primarily on this component was relatively low.

The second component explained around 10% of variance. Images loading on this factor were characterised by relatively low density vegetation and included landscapes dominated by both sea wheatgrass and hairy spinifex. The images most strongly loading on the component were characterised by trailing hairy spinifex which seems to be the strongest characteristic of this component. Dunes tend to be of a more uniform convex profile than dunes in Component 1, and less uniform in profile than Component 3. The third factor explained just over 5% of the variance. Only two scenes loaded strongly on this component and were most strongly characterised by smooth stretches of marram grass dominated vegetation and with a smooth dune profile.

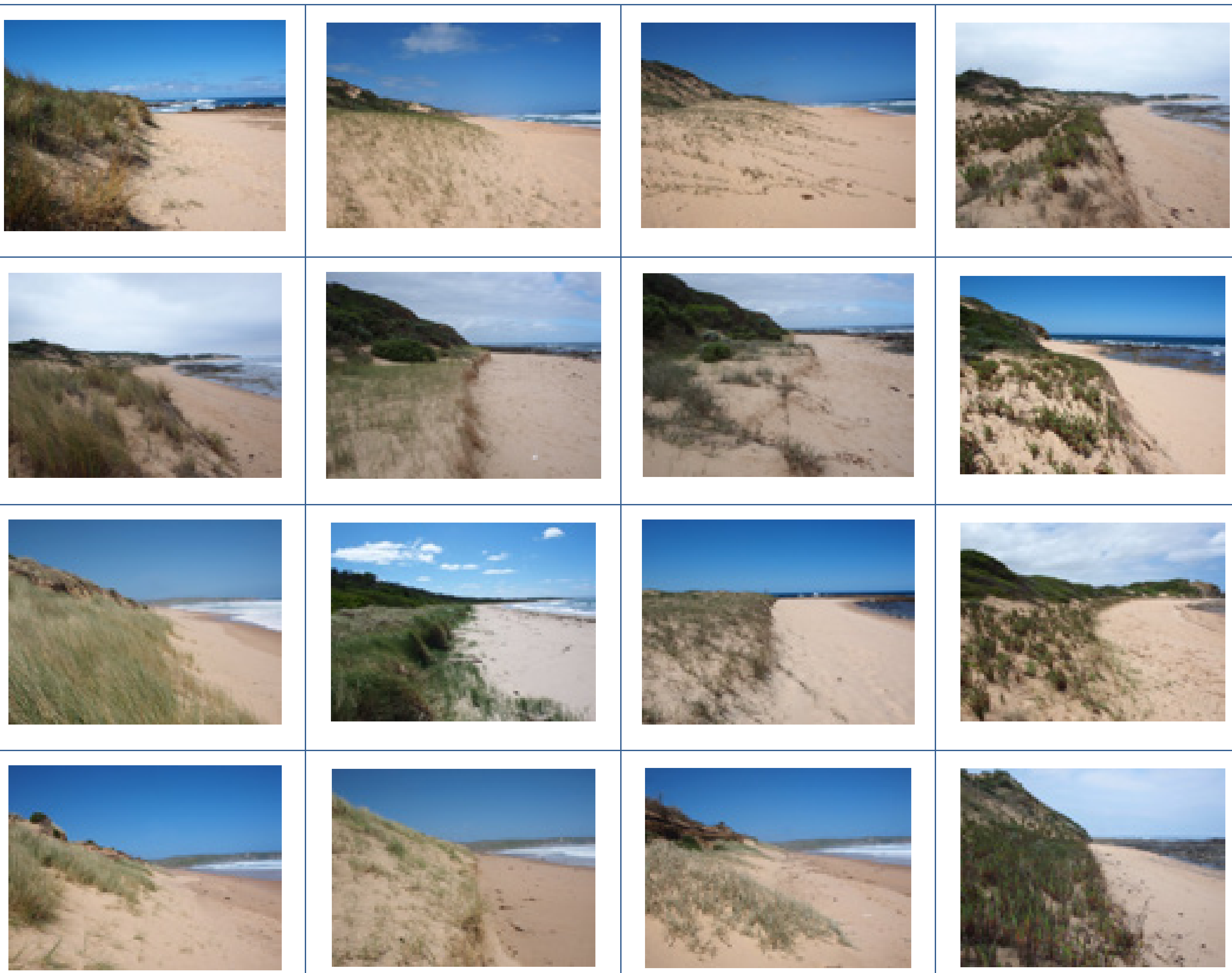
There were significant cross loadings for 9 of the 24 photographs. This is not surprising given that many scenes included a mix of vegetation types. Cross-loadings could also be meaningfully interpreted based primarily on the type and appearance of vegetation depicted. For example, photograph 20 (Figure 7.3) loaded on both Components 2 and 3. The scene included a distinct area of smooth marram grass vegetation (as per Component 3) and a distinct area of trailing hairy spinifex vegetation more characteristic of Component 2. Photo 21 loaded strongly on Component 1 and weakly on Component 3. It was dominated by sea spurge vegetation, but included marram grass plants clearly in the foreground.

Photo 20

Photo 21

Figure 7.3: Examples of images loading on more than one component.

Altogether, this preliminary analysis suggests that vegetation is playing a role in shaping preferences for coastal landscapes, although the effect is not especially strong in regard to average preference. The fact that components are differentiated by more than the type of weed suggests that other factors are at play. It is also important to consider that the influence of weeds on preferences is not likely to be explained by vegetation in isolation. Rather preferences are likely to be influenced by more complex interactions between vegetation and form of the beach and dune.



Marram grass dominated scenes (1, 15, 16, 17)	Sea wheatgrass dominated scenes (Photos 9, 10, 11, 23)	Hairy spinifex dominated scenes (Photos 12, 13, 14, 24)	Sea spurge dominated scenes (Photos 6, 7, 8, 22)
Mean preference: 5.1	Mean preference: 4.8	Mean preference: 4.7	Mean preference: 4.4

Figure 7.4: Mean preferences for four categories of coastal landscapes (marram grass, sea wheatgrass, hairy spinifex, and sea spurge dominated scenes) with example photographs.

A second analysis was conducted to test the impact of different types of weeds on preferences for coastal landscapes. Four new variables were created representing mean preference for scenes clearly dominated by only one vegetation type; images contributing to each variable are shown in the table below. Preferences for eight scenes with mixed vegetation were not included in this analysis. Mean preference for the vegetation types was compared, based on responses of all participants. Coastal scenes dominated by marram grass were most preferred on average. Scenes dominated by sea spurge were least preferred.

Preferences of the three participant groups were compared based on mean preferences for the four vegetation types. A multivariate General Linear Model (GLM) test was used to examine overall differences between groups (Table 7.1). With exception of scenes dominated by marram grass, visitors tended to have lower preferences for all landscapes. We cannot rule out the possibility that mode of delivery of the survey (online versus print) had some influence on this, but it seems more likely that people who have chosen to live near or care for coastal landscapes will express higher preference for these scenes than other people. Coastal Managers and residents expressed significantly higher preference for landscapes with hairy spinifex than did visitors. Coastal managers were the only group for whom scenes with hairy spinifex were on average the most preferred landscapes. Interestingly, residents expressed higher preference for landscapes with both sea wheatgrass and sea spurge than did other visitors. Possibly this reflects higher overall preference for coastal landscapes rather than greater preference for these weeds. Sea spurge is the least preferred category for each type of participant.

Table 7.1: Mean preferences of coastal managers, residents and visitors for coastal landscape dominated by marram grass, hairy spinifex, sea wheatgrass and sea spurge.

		Mean preference			
Participant group		Marram grass	Hairy spinifex	Sea wheatgrass	Sea spurge
Coastal managers	Mean	5.10a,x	5.13a,x	4.81a,xy	4.20b,xy
	N	50	49	50	50
	Std. Dev.	1.24	1.21	1.19	1.59
Residents	Mean	5.32a,x	5.08b,x	5.12b,x	4.67c,x
	N	73	73	73	73
	Std Dev.	1.42	1.4	1.45	1.65
Visitors	Mean	4.98a,x	4.30b,y	4.53c,y	4.17d,y
	N	99	96	99	100
	Std Dev.	1.04	1.25	1.14	1.39

^{abcd} For each row, same superscript indicates no significant difference. ^{xy} For each column, same superscript indicates no significant difference

Three separate repeated measure GLM tests were conducted to examine differences in preference for landscape categories within each of the three participant groups. Interestingly, there were no significant differences in coastal managers preferences for scenes with marram grass, hairy spinifex and sea wheatgrass, but this group expressed significantly lower preference for scenes with sea spurge (perhaps small sample size/low statistical power is at play here). Residents expressed significant higher preference for marram grass scenes and lower preference for sea spurge, but made little distinction between sea wheatgrass and hairy spinifex. Visitors expressed greatest preference for marram grass scenes, followed by sea wheatgrass, then hairy spinifex and finally sea spurge. All differences were significant (noting largest sample size).

7.3. Conclusions

Overall the analyses suggest that different weeds impact differently on enjoyment of beaches, and that this impact can be positive (marram grass) or negative (sea spurge). The impact is, however, quite small. It also suggests that while the impact is statistically different for different participant groups, in general terms it follows the same pattern. That is, for all participants, sea spurge (or more likely, sea spurge and related interactions) makes the beach less preferable. Similarly, for most participants, marram grass (and related interactions) tends to be associated with a beach that is more preferred; the only exception is among coastal managers for whom it makes little difference.

Further research is required to confirm and extend these findings. For example, this research cannot explain why scenes with sea spurge were the least preferred and those with marram grass often most preferred. Qualitative research and experimental research may clarify whether this is related to characteristics of the plant, interaction between the plant and dunes or wildlife, or some other factor. It is not clear why coastal carers make relatively little distinction between marram grass, hairy spinifex and sea wheatgrass scenes, and this deserves greater attention.

This study provides some preliminary insights to perceptions and preferences for coastal landscapes affected by weeds. Many questions regarding the impacts of weeds on human enjoyment of beaches remain unanswered. For example, how does the presence of weeds influence the ways people actually use beaches and dune areas? How do weed management activities impact on volunteer coastal managers both positively (e.g. providing opportunities for exercise and community involvement) and negatively (e.g. stress, or lost opportunities for more enjoyable activities). Research is also required to understand the social impacts of weeds in a wider range of landscapes, including rocky coasts, and coastal dunes in other regions.

8. Impact of Coastal Weeds on Dune Geomorphology

8.1. Methods

There is research from overseas which indicates that introduced coastal plants – marram grass in particular - can change the morphology of our coastline. However, little information is available for Australian beaches and for other abundant species. Anecdotal observations and opinions abound, but these have not been quantified. This part of the study aimed specifically to identify if/how coastal weeds alter the morphology of foredunes of the Victorian Coast.

Key questions included:

- What are the dominant weed species on Victorian foredunes?
- How does the morphology (width, height, slope, shape) of foredunes formed by these species differ from that of the indigenous dune plants?
- How stable is the position of the shoreline, hence what is the "accommodation space" for weed species and dune development?

Laser surveying was undertaken at 27 sites from Nelson to Cape Conran to quantify how the morphology of incipient foredunes changes in response to differing levels of weed infestation (Figure 8.1). Shore-normal transects were surveyed from the intertidal zone (normally at or close to mean sea level elevation) to the seaward-most established foredune with a SOKKIA SET5X total station with the data reduced using the CivilCAD software. Multiple transects were surveyed where the incipient foredune was dominated by more than one species to allow comparison of dune morphology formed by different species in the same geomorphic setting (Figure 8.2). Transects representative of the alongshore foredune morphology were surveyed at sites dominated by a single species. The elevation of geomorphic and botanical features including the last high tide, relative density of species present and evidence of past erosion events were recorded along each profile.

Aerial photographs between 1948 and today were geo-rectified and analysed in ArcGIS (version 9) to map shoreline stability since the incursion by major weeds at 24 locations along the Victorian coast (Figure 8.3, Table 8.1). The locations mapped were determined by the availability of suitable aerial photography and their representativeness of a coastal region or dune type. Where possible the sections of coast mapped were located in the centre of embayment's to ensure that any changes in shoreline position were indicative of long-term trends in shoreline stability. The shoreline at each site was defined by the toe of the vegetated foredune. The shoreline was mapped at each location to an accuracy of at least ± 10m, depending on the scale and quality of the aerial photographs and the alongshore uniformity of the vegetated foredune.

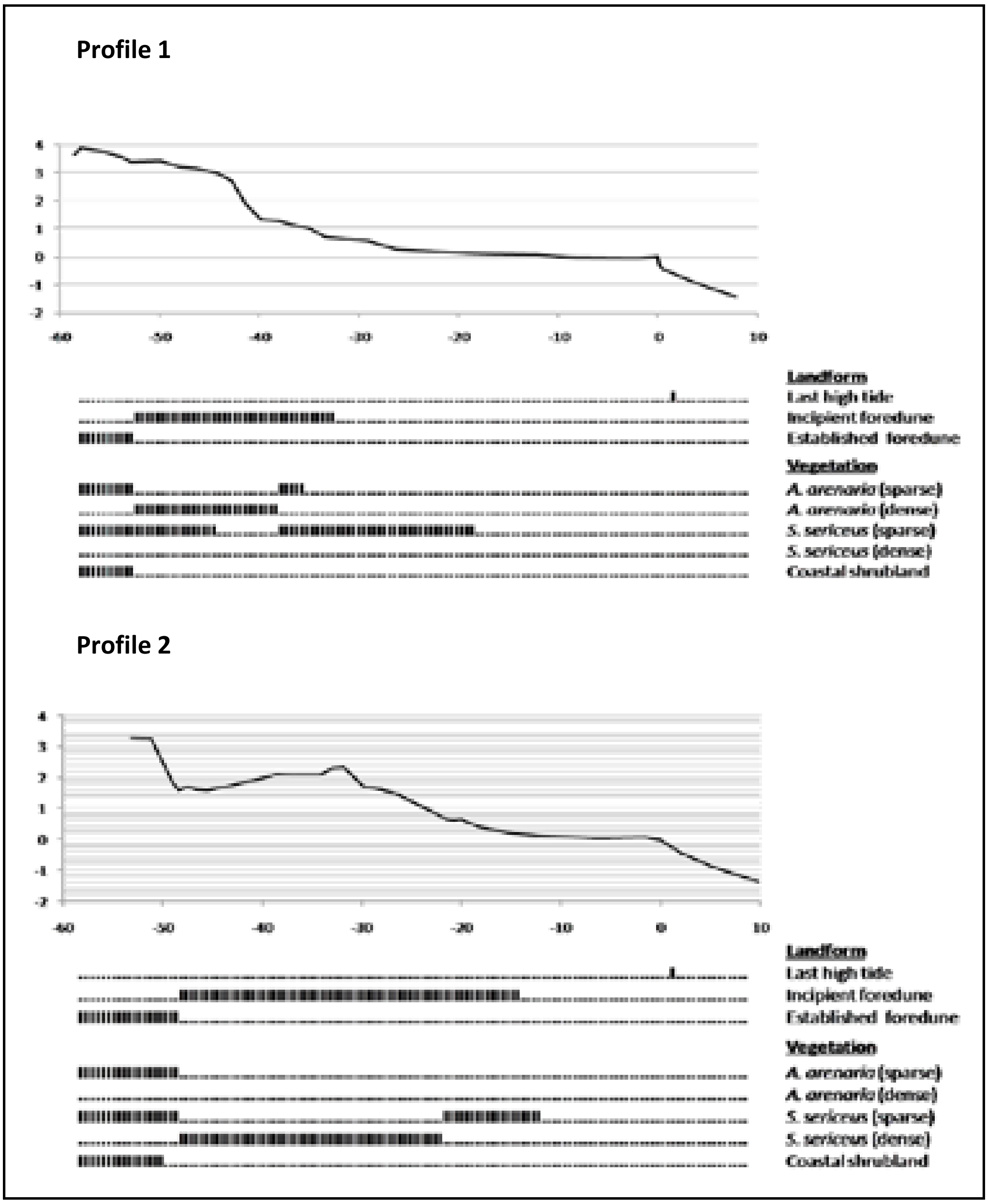


Figure 8.1: Example of laser surveyed shore-normal transects with relevant geomorphic and botanical features

Lakes Entrance (-37.8°S, 148.0°E). Profile 1 and Profile 2 were separated by 20 m alongshore. The incipient foredune on Profile 1 was dominated by marram grass. The incipient foredune on Profile 2 was dominated by hairy spinifex. Comparisons between these profiles show, for example, that the incipient foredune on Profile 1 was 1.1 m higher (as measured from the elevation of the last high tide) and 1.27 m wider (as measured from the established foredune to the toe of the incipient foredune).

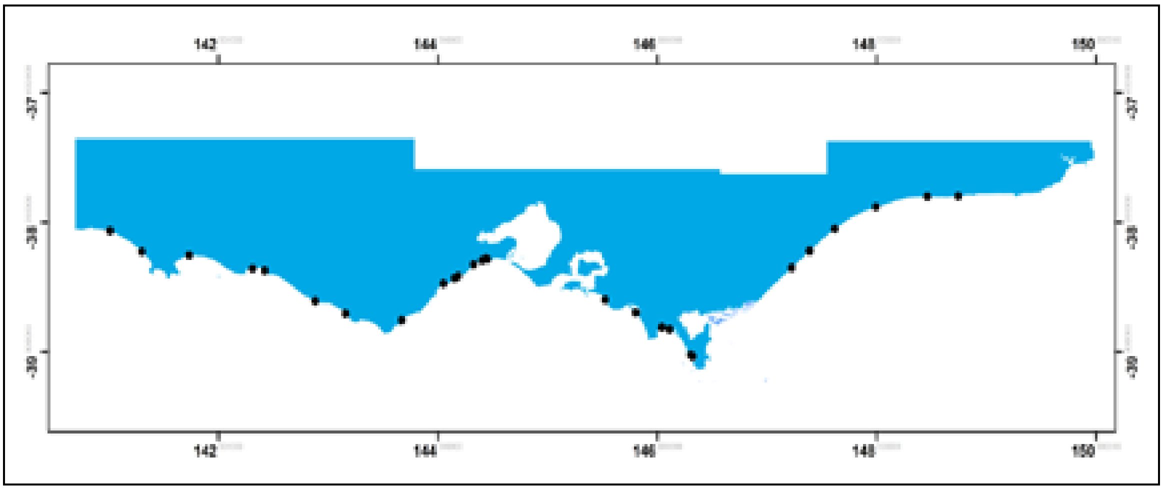


Figure 8.2: Locations of shore-normal transects examined in this study.

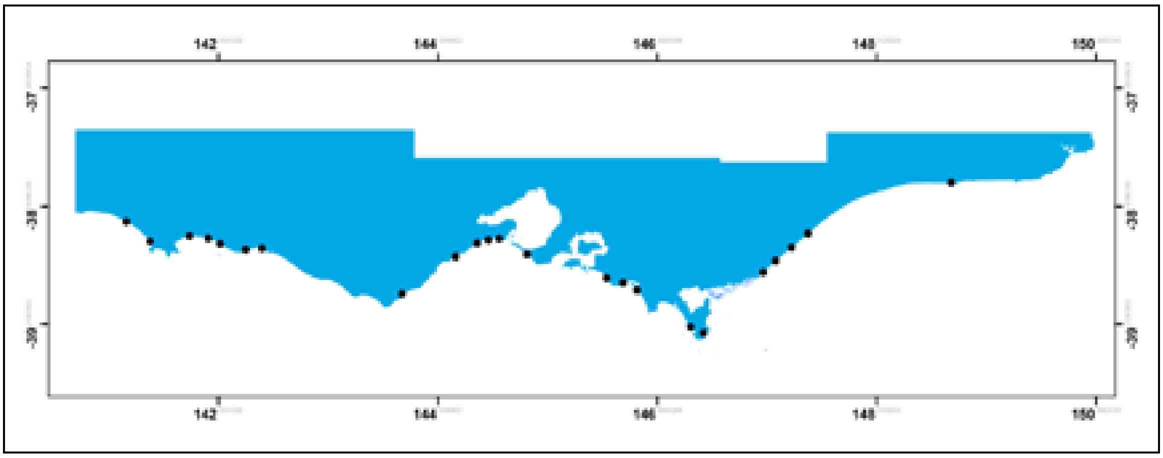


Figure 8.3: Locations of coastlines mapped from aerial photographs to assess shoreline stability.

The shorelines for each mapping location were overlain and the degree and direction (progradation or erosion) of change measured (Figure 8.4). An additional 63 dune-systems along the Victorian coastline were visited to ground truth the aerial mapping, and to map the distribution of key weed species (Figure 8.5). Sites were selected based on their accessibility, their representativeness of a coastal region or dune type, and to give as great a coverage of the Victorian Coast as possible. At each site the dominant species present, the coastal zone occupied by each species (back-beach, incipient foredune, established foredune), the incipient foredune type (ridge, terrace, ramp), the alongshore uniformity of the incipient foredune, and evidence of recent and historic erosion events were recorded.

Table 8.1: Locations, date of aerial photographs and length of coastline mapped to assess shoreline stability.

	Site location	Dates of aerial photography		Length of coastline (km)
1.	Discovery Bay (1) (-38.132°Lat, 141.162°Long)	1949	2011	2,595.43
2.	Discovery Bay (2) (-38.298°Lat, 141.378°Long)	1952	2011	2,483.18
3.	Narrawong (-38.253°Lat, 141.738°Long)	1954	2010	2,768.32
4.	Codrington (-38.272°Lat, 141.874°Long)	1954	2010	5,255.32
5.	Yambuk (-38.320°Lat, 142.019°Long)	1957	2011	1,921.79
6.	Port Fairy (-38.370°Lat, 142.251°Long)	1957	2011	1,693.26
7.	Dennington (-38.38.36°Lat, 142.251°Long)	1949	2007	3,078.85
8.	Warrnambool (-38.272°Lat, 142.907°Long)	1948	2011	1,890.55
9.	Apollo Bay (-38.744°Lat, 143.674°Long)	1950	2008	1,629.51
10.	Anglesea (Sth) (-38.429°Lat, 144.167°Long)	1857	2008	1,594.53
11.	Torquay (-38.315°Lat, 141.359°Long)	1950	2009	1,450.88
12.	Barwon Heads (-38.285°Lat, 144.463°Long)	1957	2009	3,076.69
13.	Collendina Beach (-38.275°Lat, 144.558°Long)	1955	2010	2,567.39
14.	St Andrews Bay (-38.412°Lat, 144.815°Long)	1953	2010	2,469.65
15.	Wonthaggi (-38.610°Lat, 145.537°Long)	1951	2010	4,051.61
16.	Inverloch (-38.650°Lat, 145.692°Long)	1951	2010	1,061.34
17.	Venus Bay (-38.711°Lat, 145.816°Long)	1951	2010	4,227.32
18.	Squeaky Beach (-39.025°Lat, 146.305°Long)	1965	2009	591.26
19.	Waterloo Bay (-39.075°Lat, 146.426°Long)	1965	2012	482.35
20.	Woodside beach (1) (-38.561°Lat, 146.968°Long)	1965	2006	1,923.21
21.	Woodside beach (2) (-38.464°Lat, 147.081°Long)	1965	2006	2,226.98
22.	Honeysuckles (-38.351°Lat, 147.225°Long)	1965	2010	3,174.77
23.	Golden Bay (-38.233°Lat, 147.375°Long)	1965	2006	6,174.31
24.	Cape Conran (-37.801°Lat, 148.679°Long)	1962	2008	3,455.62

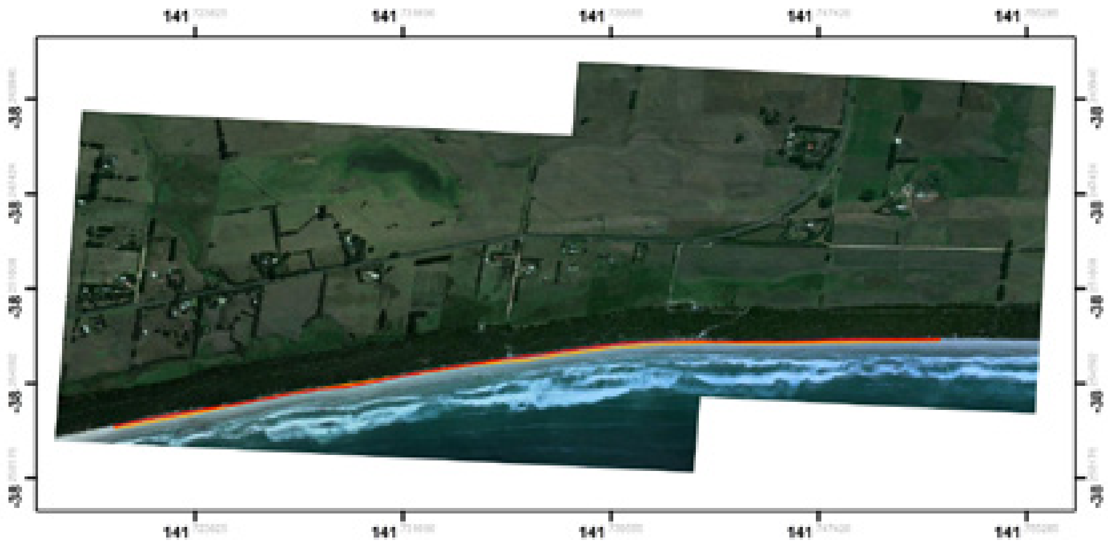


Figure 8.4: Example of aerial photograph analysis to determine shoreline stability

Narrawong (-38.3°S, 141.7°E). The position of the shoreline in 1954 is identified by the yellow line. The shoreline in 2010 is identified by the red line. The coastline at Narrawong has been predominantly erosional since 1954, with the 2010 shoreline located up to 18 ± 10 m landward of the shoreline in 1954.

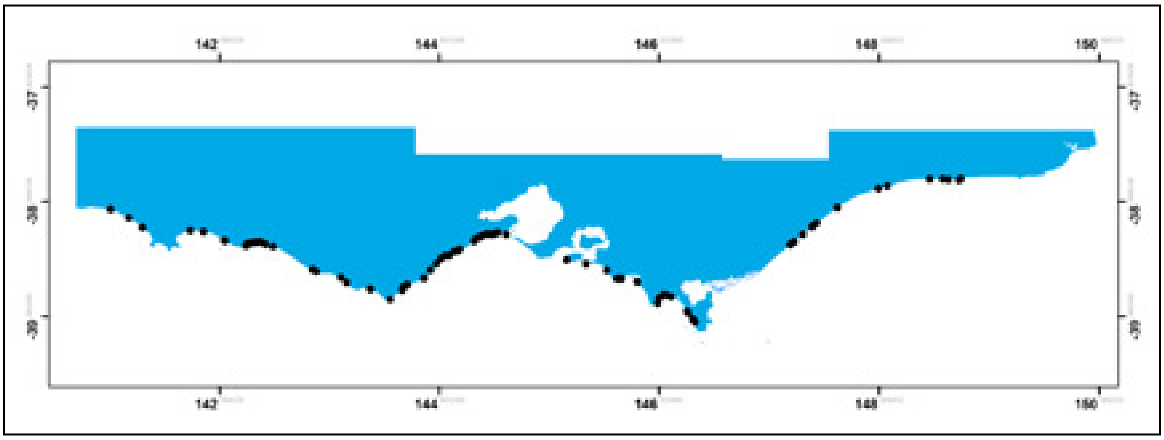


Figure 8.5: Locations of dune systems visited to ground truth aerial mapping and to survey weed distribution.

8.2. Results

The incipient foredunes of the Victorian coast are dominated by four species that have the potential to modify dune morphology: marram grass (*Ammophila arenaria)*, sea wheatgrass *(Thinopyrum junceiforme),* sea spurge *(Euphorbia paralias)* and hairy spinifex *(Spinifex sericeus)*. Hairy spinifex is indigenous to the Victorian coast. Marram grass, sea wheatgrass and sea spurge have all been introduced. These plants share certain characteristics. All are perennial and have the ability to grow vertically in response to burial by sand. Marram grass, sea wheatgrass and hairy spinifex produce rhizome or stolons. Sea spurge does not, but does grow vertically by the production of side branches when buried. The exotic sea rocket (*Cakile* spp.) is also important. This species forms small incipient dunes on the back-beach, between high tide and the toe of the incipient foredune proper. Sea rocket is an annual, hence unless these dunes are colonised by a perennial species they are unlikely to persist beyond a year of growth. Sea rocket is unlikely to have much direct effect on dune morphology, although it may have an indirect influence by facilitating the establishment of other less salt tolerant species.

Exotic plants are prevalent on the incipient foredunes of the Victorian coast. Hairy spinifex is widespread but marram grass, sea wheatgrass or sea spurge was present in all dune-systems visited. The foredunes of some coastal regions are dominated by exotics. For example, marram grass is the dominant species between Port Fairy and Warrnambool while sea wheatgrass dominates between Wonthaggi and Darby Beach. Marram grass was present in almost all dunes visited, probably reflecting the widespread planting of this species during the 1960's and 1970's for sand stabilisation purposes. Sea wheatgrass and sea spurge were absent or very sparse in some coastal regions (e.g. 90 Mile Beach). These species have established on the Victorian Coast relatively recently and probably do not occupy their full potential range.

Recent storm events (2010 and 2011) had resulted in the removal of the seaward margins of the existing foredunes and formation of dune scarps along much of Victorian coast. This has made establishing links between dune morphology and plant species difficult. Nonetheless it was found that marram grass and sea wheatgrass have the potential to alter dune morphology. For example on the marram grass dominated dune at Honeysuckle Beach in the Gippsland Lakes region the foredune was tall and steep with an incipient foredune not being able to form. In contrast at Lakes Entrance the dunes were dominated by hairy spinifex and formed at lower elevation with a distinct series of incipient foredunes being present in front of the foredune which was covered in coastal trees and scrub (Figure 8.6). The effect of sea spurge is not clear. It is commonly associated with relatively low (0.5 –2 m high), flat foredune “terraces”. The alongshore morphology is continuous, lacking substantial “hummocks”. Excavating individuals of sea spurge shows that on some dunes these plants have grown vertically by up to 30 cm, indicating that the upper 30 cm of these foredunes have developed in association with sea spurge; however, it seems likely that much of the current foredune developed in association with other species. The presence of sea spurge is probably the result of subsequent colonisation once the foredune had formed.

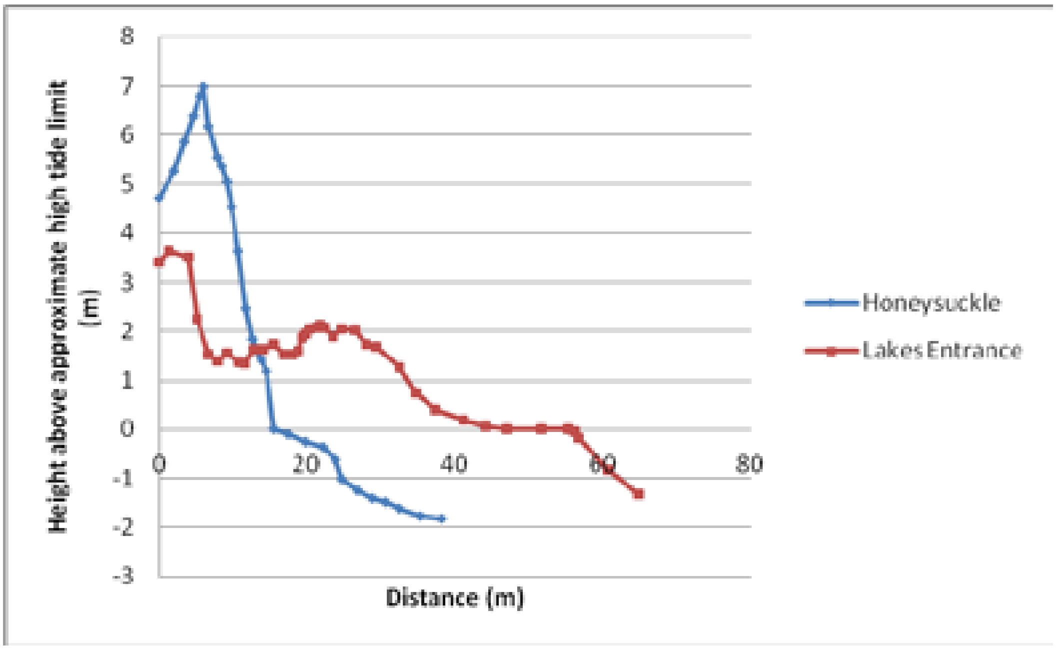


Figure 8.6: Contrasting beach and dune profiles on dunes dominated by marram (Honeysuckle Beach) and spinifex (Lakes Entrance) grasses.

Comparison of the surveyed dune profiles shows that marram grass forms foredunes that are typically higher, steeper and narrower than those formed by either sea wheatgrass or hairy spinifex. The height and steepness of the seaward face means that erosion of marram grass dunes leads to higher dune scarps than those formed by sea wheat or hairy spinifex. Scarps formed by marram grass may be less persistent than those formed by sea wheatgrass or hairy spinifex. The rapid vertical growth of marram grass in response to burial facilitates the rapid recovery of the seaward dune profile. In contrast the more horizontal growth of sea wheatgrass and hairy spinifex tends to result in a wider but lower foredune in front of the existing scarp. In both cases dune recovery post erosion is dependent on a source of propagules at the base of the scarp and a sufficient period free from disturbance by waves for plants to establish and begin trapping sand.

Sea wheatgrass and hairy spinifex form similar foredunes on the Victorian coast. Both species are associated with low flat terraces on coasts with limited sediment supply or low foredune ridges where sand deposition is abundant. Sea wheatgrass has replaced hairy spinifex from the seaward face of the incipient foredune, and where present with marram grass and sea spurge typically forms a dense band closest to the sea in what is effectively a monoculture.

Sea wheatgrass can rapidly form relatively wide, continuous alongshore foredunes, which are probably able to form at lower elevations than those associated with any other foredune species present on the Victorian coast. This may lead to a narrowing of the back-beach and an increase in dune erosion and the resulting formation of dune scarps.

The potential for exotic plants to alter the morphology of Victorian foredunes is highest where the accommodation space for dune formation is greatest (e.g., beaches characterised by a high sediment supply, wide back-beach, and infrequent storm surge). Such beaches have the potential for high, wide dunes to form, emphasising the differences in dune morphology associated with different plant species. Analysis of aerial photos has shown that there has been little change in the location of the shoreline since the 1940's along much of the Victorian coast, mostly in the order of ± 10 – 30 m (e.g., Figure 8.4). Such coasts can be expected to be frequently scarped; hence the potential for dune development is limited.

Site visits provided further supporting evidence that the impact of exotic plants is limited by a lack of accommodation space for dune development. Most dunes around the Victorian coast show signs of frequent erosion, both recent and historical, and many display similar morphologies irrespective of the species present — foredunes consist of a narrow incipient foredune terrace in front of an established foredune vegetated primarily with coastal shrubs. The incipient foredune is often freshly scarped with few indications of substantial profile recovery post erosion.

8.3. Conclusions

Beach and dune systems around the Victorian coast are very dynamic and the shape of these landforms is affected by the vegetation that is present as well as the available sediment supply. The same is likely to be true in other States since the processes are universal. Marram grass dunes appear steeper and taller than those dominated by other grasses and also appear to have less incipient foredune development. The impact of herbs such as sea spurge on dune shape is unknown as it appears either to be displacing current grass species or it is colonizing gaps among the grasses created by disturbance. Dunes dominated by sea spurge may have obtained their shape from the effects of the grasses that were there first, or the herb may have trapped the sand itself. The precise effect is currently unknown.

All beaches show the effect of storms in late 2011. The ability of the dunes to recover from this erosion event is related to the vegetation but also the accommodation space and sediment supply. That is, those areas with ample sand (such as a wide beach or a nearby estuary) and a flatish area above high tide for sediment to build up) could rebuild dunes; however, many beaches appeared to still be erosional. Erosional beaches tended to be in areas with more weed species but a direct link between species and erosion is difficult to establish as most weeds occur in combination with each other. The initial results presented here strongly suggest a negative impact of weeds on beach systems.

Over a decadal scale the dune systems appear to be stable and characterised by an increase in vegetative cover. This analysis was, however, limited to only two aerial photo sets so could not distinguish short term erosion cycles such as occurred in 2011. More detailed aerial photo analysis is required and in areas which are likely to be less stable, such as at estuary mouths and at the ends of embayments.

Figure 8.7: Terrace foredune composed of sea wheat grass near Barwon Heads.

The efficiency of sea wheat grass to trap sediment is apparent with wind blown sand being trapped on the front of the dune. A scarp covered in grass is also present in the dune related to erosion during a storm in the past few years.

9. Concluding remarks

Coastal weeds are allowed, in most cases, to invade with impunity along our coasts, with the exception of strong (though patchy) community action against a few species such as sea spurge and a concerted effort against Bitou bush. Our knowledge of their impacts, particularly with regard to fauna, humans and geomorphology, is scant. With so little impact data, decisions to control weeds will tend not to be made in the face of alternative demands for resources. Even so, we have estimated that at least $12 million p.a. is currently spent on managing coastal weeds and possibly as much as $30 million. Given Australia's long coastline, and the value of these landscapes to the nation's economy, this may be seen as very little investment. Without post-control monitoring data from managed areas, we do not know whether this expenditure has been worthwhile.

A number of coastal invasive plants have already spread widely, to the extent that eradication is no longer possible. Even attempts at local eradication for asset protection will be thwarted by long-distance seed dispersal from ocean currents and animals. Thus, their management is often a long-term mitigation exercise. The problems will not go away (unless, perhaps, biological control reduces their abundance to very low levels) and continued investment will be required. For major weeds having geomorphological impacts, their total annual costs could be in the hundreds of millions: by changing the beach profile, the stability of dunes could be decreased, threatening coastal towns and developments. Some weeds may tip vulnerable animals, like the hooded plover, into extinction even through quite subtle impacts. Other weeds may have little impact at all. For the weeds that are still in their early stages of invasion, it is vital that we make decisions early, as an investment to avoid future major impacts. Whether the action is pre-emptive or mitigative, the expenditure required may be considerable. For a policy-maker or land manager to justify large investments, hard facts are required, not just the many anecdotes that constitute the entire pool of knowledge for the impacts of most beach invaders. Otherwise, action will only be taken once the impacts are so bad that they are obvious (the historical pattern in Australia). State weed risk assessment systems can classify potential species threats at a very superficial level, but on their own they will not provide a compelling case for action – at least in comparison with weeds of primary production.

Coastal weeds clearly have a wide variety of inter-dependent impacts. In probably the widest-ranging inter-disciplinary study of weeds ever undertaken, this study illustrated just how little is known about these impacts. Although new data was collected, most issues were barley touched. The overall lack of data leads the study's authors to argue strongly for the need for further scientifically rigorous studies of our main coastal weedy/invasive species; in southern Australia sea wheatgrass, sea spurge and marram grass would seem to be the most urgent of these. Where control is initiated, there should be more deliberate attempts to estimate the impacts of management action (and inaction). Such analysis should seek to identify both positive and negative impacts of weeds, and consider a wide range of social and ecological impacts that may occur. Investment into weed control should be targeted with clear objectives and outcomes for the overall coastal environment. For example, to tackle marram grass infestation of the coast around western Victoria as a whole would require enormous logistical and economic investment, and social perception research suggests it would greatly impact dune aesthetics. Instead, targeting hooded plover territories for marram grass removal at a smaller scale with the aim of improving habitat would have outcomes that could be directly measured, and if effective, would relate weed control directly to improving biodiversity values of that investment.

Social impacts of weeds are particularly under-researched. Work to date shows that weeds may have a modest positive or negative impact on people's preferences for coastal landscapes. This tells us little about whether the presence of weeds may also influence how people use beaches. For example, do weeds discourage or encourage people to use of foredunes? Does this influence differ across different user types (e.g. swimmers and horse riders)? This would require systematic on-site observations across different beach types and systems. As well as providing insight to social impact of weeds, such research may provide insight to interactions between people, weeds and wildlife.

Figure 9.1: Beach on Phillip Island where shore-nesting birds must survive alongside weeds, exotic and domestic animals and humans.

Appendices

Appendix 1. Weed species listed in various regional coastal plant picture books (West Australia and south-eastern Australia) and coastal reserve management plans (South Australia). This table is meant to be illustrative rather than comprehensive.

Scientific Name	Family	Common Name
Acacia cyclops	Fabaceae	Western coastal wattle
Acacia longifolia var. longifolia	Fabaceae	Sallow wattle
Acacia saligna	Fabaceae	Golden wreath wattle
Acetosa sagittata	Polygonaceae	Turkey rhubarb
Aeonium spp.	Crassulaceae	Succulent
Agapanthus africanus	Liliaceae	Agapanthus
Agava americana	Agavaceae	Yucca
Ageratina adenophora	Asteraceae	Crofton weed
Ageratina riparia	Asteraceae	Mist flower
Ageratum houstonianum	Asteraceae	Blue billy goat
Ammophila arenaria	Poaceae	Marram grass
Anagallis arvensis	Primulaceae	Scarlet pimpernel
Anredera cordifolia	Basellaceae	Madeira vine
Araujia hortorum	Asclepiadaceae	Moth plant
Arctotheca calendula	Asteraceae	Capeweed
Arctotheca populifolia	Asteraceae	Beach daisy
Arctotis stoechadifolia	Asteraceae	White arctotis
Argyranthemum frutescens	Asteraceae	Marguerite daisy
Argyranthemum frutescens ssp. foeniculaceum	Asteraceae	Teneriffe daisy
Artemisia arborescens	Asteraceae	Wormwood
Arundinaria spp.	Poaceae	Bamboo
Arundo donax	Poaceae	Giant reed

Asparagus aethiopicus	Liliaceae	Asparagus fern
Asparagus asparagoides	Liliaceae	Bridal creeper
Asparagus plumosus	Liliaceae	Climbing asparagus fern
Asphodelus fistulosus	Asphodelaceae	Wild onion
Avena barbata	Poaceae	Bearded wild oat
Baccharis halimifolia	Asteraceae	Groundsel bush
Bidens pilosa	Asteraceae	Cobblers peg
Briza maxima	Poaceae	Large quaking-grass
Briza minor	Poaceae	Shivery grass
Bromus diandrus	Poaceae	Great brome
Bryophyllum delagoense	Crassulaceae	Mother of millions
Bryophyllum pinnatum	Crassulaceae	Resurrection plant
Buddleja madagascariensis	Scrophulariaceae	Buddleja
Cakile edentula	Brassicaceae	American sea rocket
Cakile maritima	Brassicaceae	European sea rocket
Canna indica	Cannaceae	Canna lily
Cardiospermum grandiflorum	Sapindaceae	Balloon vine
Carpobrotus edulis	Aizoaceae	Hottentot fig
Carpobrotus virescens	Aizoaceae	Coastal pigface
Casuarina glauca	Casuarinaceae	Swamp sheoak
Catharanthus roseus	Apocynaceae	Madagascan periwinkle
Celtis sinensis	Ulmaceae	Chinese elm
Cenchrus echinatus	Poaceae	Mossman River grass
Cestrum parqui	Solanaceae	Green cestrum
Chamelaucium uncinatum	Myrtaceae	Geraldton waxflower
Chloris gayana	Poaceae	Rhodes grass
Chondrilla juncea	Asteraceae	Skeleton weed

Chrysanthemoides monilifera ssp. monilifera	Asteraceae	Boneseed
Chrysanthemoides monilifera ssp. rotundata	Asteraceae	Bitou bush
Cinnamomum camphora	Lauraceae	Camphor laurel
Commelina benghalensis	Commelinaceae	Hairy commelina
Conyza albida	Asteraceae	Tall fleabane
Coprosma repens	Rubiaceae	Mirror bush
Coreopsis lanceolata	Asteraceae	Coreopsis
Cortaderia selloana	Poaceae	Pampas grass
Cotoneaster spp.	Malaceae	Cotoneaster
Cotyledon sp.	Crassulaceae	Cotyledon
Crassula glomerata	Crassulaceae	Crassula
Critesion spp.	Poaceae	Barley grass
Crocosmia X crocosmiiflora	Iridaceae	Montbretia
Cuscuta epithymum	Cuscutaceae	Lesser dodder
Cynara cardunculus	Asteraceae	Artichoke thistle
Cynodon dactylon	Poaceae	Common couch
Delairea odorata	Asteraceae	Cape ivy
Desmodium uncinatum	Fabaceae	Silver leaf Desmodium
Dimorphotheca pluvialis	Asteraceae	Cape marigold
Dittrichia graveolens	Asteraceae	Stinkwort
Drosanthemum candens	Aizoaceae	Rodondo creeper
Ehrharta calycina	Poaceae	Perennial Veldt grass
Ehrharta villosa	Poaceae	Pyp grass
Eleusine indica	Poaceae	Crows foot grass
Eragrostis curvula	Poaceae	African lovegrass
Erythrina X sykesii	Fabaceae	Coral tree
Euphorbia cyathophora	Euphorbiaceae	Painted spurge

Euphorbia paralias	Euphorbiaceae	Sea spurge
Euphorbia peplus	Euphorbiaceae	Petty spurge
Euphorbia terracina	Euphorbiaceae	False caper
Ferraria crispa	Iridaceae	Black flag
Ficus elastica	Moraceae	Indian rubber tree
Foeniculum vulgare	Umbelliferae	Fennel
Fraxinus rotundifolia	Oleaceae	Desert ash
Fumaria capreolata	Fumariaceae	White fumitory
Galenia pubescens var. pubescens	Aizoaceae	Coastal Galenia
Gazania rigens	Asteraceae	Gazania
Genista spp.	Fabaceae	Broom
Gladiolus gueinzii	Iridaceae	Coastal gladiolus
Gloriosa superba	Liliaceae	Gloriosa lily
Gomphocarpus fruiticosus	Asclepiadaceae	Swan plant
Hydrocotyle bonariensis	Umbelliferae	American pennywort
Hypochaeris glabra	Asteraceae	Smooth cat's ear
Hypochoeris radicata	Asteraceae	Flatweed
Ipomea cairica	Convolvulaceae	Mile a minute
Ipomea indica	Convolvulaceae	Common morning glory
Juncus acutus	Juncaceae	Spiny rush
Lagurus ovatus	Poaceae	Hare's tail grass
Lantana camara	Verbenaceae	Lantana
Leptospermum laevigatum	Myrtaceae	Coast tea-tree
Ligustrum lucidum	Oleaceae	Large-leaved privet
Ligustrum sinense	Oleaceae	Small-leaved privet
Lilium formosanum	Liliaceae	Formosa lily
Limonium companyonis	Plumbaginaceae	Statice
Lobularia maritima	Brassicaceae	Alyssum

Lolium perenne	Poaceae	Perennial ryegrass
Lonicera japonica	Caprifoliaceae	Japanese honeysuckle
Lotononis bainesii	Fabaceae	Lotononis
Lupinus consentii	Fabaceae	Blue lupin
Lupinus hirsutus	Fabaceae	Lupin
Lupinus luteus	Fabaceae	Lupin
Lycium ferocissimum	Solanaceae	African boxthorn
Macfadyena unguis-cati	Bignoniaceae	Cat's claw creeper
Macrotilium atropurpureum	Fabaceae	Siratro
Malva dendromorpha	Malvaceae	Tree mallow
Medicago polymorpha var. polymorpha	Fabaceae	Burr medic
Medicago truncatula	Fabaceae	Barrel medic
Melaleuca lanceolata	Meliaceae	Dryland tea-tree
Melilotus indicus	Fabaceae	Hexham scent
Melinis repens		Red Natal grass
Mesembryanthemum crystallinum	Aizoaceae	Ice plant
Metrosideros excelsa	Myrtaceae	New Zealand Christmas Bush
Moraea setifolia	Iridaceae	Thread iris
Nephrolepis cordifolia	Davalliaceae	Fishbone fern
Ochna serrulata	Ochnaceae	Mickey Mouse plant
Oenothera drummondii	Onagraceae	Beach primrose
Oenothera stricta ssp. stricta	Onagraceae	Common evening primrose
Olea europaea ssp. europaea	Oleaceae	Olive
Olea europea spp africana	Oleaceae	African olive
Opuntia stricta	Cactaceae	Prickly pear
Osteospermum fruticosum	Asteraceae	Seascape daisy

Oxalis depressa	Oxilidaceae	-
Oxalis pes-caprae	Oxilidaceae	Soursob
Panicum maximum	Poaceae	Guinea grass
Parapholis incurva	Poaceae	Curly ryegrass
Parietaria judaica	Urticaceae	Pellitory
Paspalum spp.	Poaceae	Paspalum
Passiflora edulis	Passifloraceae	Passionfruit
Passiflora foetida	Passifloraceae	Stinking passionfruit
Passiflora suberosa	Passifloraceae	Corky passionfruit
Passiflora subpeltata	Passifloraceae	White passionfruit
Pelargonium capitatum	Geraniaceae	Rose pelargonium
Pelargonium sp.	Geraniaceae	Pelargonium
Pennisetum clandestinum	Geraniaceae	Kikuyu
Pennisetum setaceum	Poaceae	Fountain grass
Phyllostchys spp.	Poaceae	Bamboo
Phytolocca octandra	Phytolaccaceae	Inkweed
Pinus ellioti	Pinaceae	Slash pine
Pinus radiata	Pinaceae	Radiata pine
Plantago coronopus	Plantaginaceae	Bucks-horn plantain
Plantago lanceolata	Plantaginaceae	Ribwort plantain
Polygala myrtifolia	Polygonaceae	Butterfly bush
Polygala virgata	Polygonaceae	Butterfly bush
Portulaca oleracea	Portulacaeae	Common purslane
Psidium cattleianum	Myrtaceae	Cherry guava
Psidium guajava	Myrtaceae	Red guava
Psidium littorale	Myrtaceae	Yellow guava
Pyrostegia venusta	Bignoniaceae	Golden shower
Ranunculus repens	Ranunculaceae	Creeping buttercup

Raphanus raphanistrum	Brassicaceae	Wild radish
Reichardia tingitana	Asteraceae	False sowthistle
Rhamnus alaternus	Rhamnaceae	Buckthorn
Ricinus communis	Euphorbiaceae	Castor oil plant
Rivina humilis	Phytolaccaceae	Coral berry
Rosmarinus officinalis	Lamiaceae	Rosemary
Rubus fruticosus	Rosaceae	Blackberry
Rumex crispus	Polygonaceae	Curled dock
Sansevieria trifasciata	Agavaceae	Mother in law's tongue
Scabiosa atropurpurea	Dipsacaceae	Scabious
Schefflera actinophylla	Araliaceae	Queensland umbrella tree
Schinus terebinthifolia	Anacardiaceae	Broad-leaved pepper tree
Senecio angulatus	Asteraceae	Canary creeper
Senecio elegans	Asteraceae	African ragwort
Senecio madagascariensis	Asteraceae	Fireweed
Senna pendula var. glabrata	Fabaceae	Cassia
Setaria sphacelata	Poaceae	Pigeon grass
Sisymbruim orientale	Brassicaceae	Indian hedge mustard
Solanum mauritianum	Solanaceae	Tobacco bush
Solanum nigrum	Solanaceae	Blackberry nightshade
Solanum seaforthianum	Solanaceae	Climbing nightshade
Sonchus asper	Asteraceae	Prickly sow thistle
Sonchus oleraceus	Asteraceae	Common sow-thistle
Sorghum halepense	Poaceae	Johnson grass
Sporobolus indicus	Poaceae	Parramatta grass
Stenotaphrum secundatum	Poaceae	Buffalo grass
Syagrus romanzoffianam	Arecacea	Cocos palm

Tagetes minuta	Asteraceae	Stinking Roger
Tamarix aphylla	Tamaricaceae	Tamarisk
Taraxacum officinale	Asteraceae	Dandelion
Tecoma capensis	Bignoniaceae	Cape honeysuckle
Tetragonia decumbens	Aizoaceae	Sea spinach
Tetragonia nigrescens	Aizoaceae	Black spinach
Thinopyrum distichum	Poaceae	Sea wheatgrass
Thinopyrum junceiforme	Poaceae	Sea wheatgrass
Thunbergia alata	Acanthaceae	Black-eyed Susan
Tithonia diversifolia	Asteraceae	Japanese sunflower
Trachyandra divaricata	Asphodelaceae	Dune onion weed
Tradescantia fluminensis	Commelinaceae	Wandering Jew
Tropaeolum majus	Tropaeolum	Nasturtium
Vicia monantha ssp. monantha	Fabaceae	Spurred vetch
Vulpia sp.	Poaceae	Silver grass
Watsonia meriana	Iridaceae	Watsonia
Wedelia trilobata	Asteraceae	Singapore daisy
Zantedeschia aethiopica	Araceae	Arum lily
Zantedeschia stricta	Araceae	Arum lily
Zebrina pendula	Commelinaceae	Variegated wandering Jew

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Appendix 2. This table briefly summarises the impacts of seventeen coastal weeds that were mentioned in publications. We include an assessment of the type of information on which the statement was based (TO: Type of observation, A: Scientific experiment, B: Scientific observation, C: Casual observation, D: Opinion).

No.	Weed species	Impacts			Suggested explanation/ mechanism or evidence	TO	Source
		Native plants	Native animals	Dune morphology			
1	*Ammophila arenaria*	Reduces the average vascular plant species from 16 to 12 on Burril and Wairo Beaches, NSW	Reduces the average morphospecies of ants from 22 to 16 on Burril and Wairo Beaches, NSW	-	Lack of structural complexities	A	1
		-	-	Builds 4 to 5m tall hillocks on foredunes and changes dune characteristics beyond infested area	Diminished sand supply to other areas	B	2
		Replaces 2 native beach grass communities and 5 other coastal dune plant communities	-	-	-	D	3
2	*Arctotheca populifolia*	-	Threatens shorebird nesting	Alters beach landform and affect public amenity	Ability to grow between strandline and foredune where few native plants are present		
3	*Cakile spp.*	-	Provides food for native birds, crimson rosellas and emus. Also a major food source for the orange bellied parrot during its autumn migration	-	Crimson rosellas silt open Cakile fruit segments to get to the seeds. Emus nip off top of Cakile branches, including buds, flowers and fruits	B	4
		C.maritima displaces *Festuca littoralis*	-	-	-	C	5
4	*Chrysanthemoides monilifera*	-	Decreases abundance of bird species that feed almost exclusively on plants in coastal woodlands on the south coast of NSW	-	Loss of floristic diversity may mean that dietary requirements are not met in weed-infested areas	B	6
		-	Decreases abundance of bird species that are predators of vertebrates and large insects in coastal woodlands on the south coast of NSW	-	Dense midstorey cover of Bitou bush provides coverage for prey		
		-	Decreases variety of epigaeic ants within nature reserves on the central coast of NSW	-	-	A	7
		-	Supports a different invertebrate assemblage of lower diversity	-	Bitou bush leaf litter decompose faster than native leaf litter, providing different food source and habitat	A	8

			Supports higher abundance of invertebrate detrivores				
		Outcompetes *Acacia sophorae* in acquiring water and phosphorus	-	-	Shifts resource allocation from above-ground to below ground structures	A	9
		-	Lowers species richness of food web (36 in Bitou-free area, 9 in Bitou-threatened and 6 in Bitou-infested)	-	-	A	10
		-	Increases the number of native herbivores being parasitised in coastal heathlands on central-northern coast of NSW	-	Success of Bitou bush seed fly increases population of native parasitoids		
		Lessen periods of fruit shortage, that is characteristic of native coastal vegetation	-	-	Extended fruiting season as compared to native species	A	11
		Reduces vascular plant species from (12+/- 1.1) to (6.8+/-1.6)	Increases presence of mites (11-16%), isopods (4.1-8.9%), pseudoscorpions (2.1-7.0%), and Geophiloda centipedes (2.1-3.2%)	-	Dense structure of Bitou bush and lower C:N content in its leaves create a dark and moist microhabitat favourable to detritivores	A	12
		Influence ability of native plant species to compete in infested communities	Decreases species abundance of orders Blattodea, Dermaptera and Hymenoptera and seed-removing ants	-	Native species rely on ants for seed burial which protects seeds from fire and predators	A	13
		Decreases native tree species richness in seed banks on hind dunes of north coast NSW	-	-	-	A	14
		Prevents growth of native understorey vegetation	-	-	-	C	15
		Reduces chances of fire-dependant native species from regenerating	-	-	Reduced litter loads and moist nature of weed litter could retard fire and decrease intensity		
		Decreases above-ground vegetation of coastal heathland at Hat head National Park in northern NSW by 75%	-	-	-	B	16
		Decreases native species richness in soil seed banks of foredunes and alters community composition in NSW coast	-	-	Native species richness in soil seed banks of foredunes was greater in native relative to invaded sites. Invaded sites has largest difference in community composition	B	17
		Displaces *Acacia longifolia* on the south coast of NSW	-	-	Has higher level of seed production Possess greater overall chlorophyll and higher assimilation of water	A	19
		Reduces native species riches by 25% in an average of 90 invaded sites surveyed in Tasmania, South Australia and Victoria	-	-	Decreases seed bank of native shrubs and trees	A	20

		-	Causes decline of small birds habitats	-	Decreases infant motility of nest predators due to abundance of Bitou fruits over-winter	D	21
		-	Decreases abundance of canopy and understorey insectivores and nectarivores along coastline of eastern Australia	-	Lacks nectar resources for birds	D	22
		-	Adversely affects native species and functional group richness and composition in foredune communities Alters vegetation structure in both fore and hind dune communities	-	-	A	23
		Inhibits growth of native plants especially the dominant *Acacia longifolia var. sophorae* in Puckey's Estate, Wollongong	-	-	Exudes sesquitepenes in the sand, significantly altering the soil chemistry	A	24
		Suppresses native species, especially Coastal Wattle in Bundjalung National Park	-	-	Native species show increasing cover-abundance, particularly Coastal Wattle, with Bitou Bush control	B	25
		Reduces native plants cover abundance and increases exotic species richness in NSW coastal dune system	-	-	Intensive weed management resulted in recovery of some native species but risk secondary invasion of other weed species	B	26
		60% of vegetation communities and plant species were subject to significant invasion and at risk of displacement; 20-30% were potentially at risk; 10% has been substantially replaced	A list of vertebrates were identified as vectors except for seed predator, *Crimson Rosella*	-	-	D	27

		Displaces *Haekea dactyloides, Casuarina littoralis, Leptospermum laevigatum* & *Eucalyptus viminalis* at coastal heathland of Awabakal Nature Reserve, NSW	-	-	Takes up much of the phosphorus from the soil and alleopathy affects native seed germination	A	28
		Reduces seed production of coastal wattle at Moruya, NSW, while *Lomandra* locally reduces seedling input of Bitou bush	-	-	-	B	29
		-	Bitou bush seeds ingested by foxes remain viable in their scats	-	90% of seeds planted in beach sand germinated	A	30
5	*Ehrharta villosa*	Decreases coverage of *Acacia longifolia* and *Olearia acillaris* on Sir Richard Peninsula	-	-	Climbs over and cover coastal shrubs of 2-3m	C	31
6	*Euphobia paralias*	Colonises native herb field and grassland in north-east Tasmania	-	-	-	C	32
		Affects nesting habitat of the hooded plover on Mornington Peninsula National Park and Philip Island Nature Park	-	-	-		
		-	-	Transforms shape of beaches	Invades incipient foredunes, building ridges up to a meter high	C	33
		Reduces germination of native seeds and growth of native seedlings	-	-	Weed litter and/or roots exudes allelochemicals	A	34
7	*Lantana camara*	Indirectly contributes to native species decline	-	-	28 native birds consumes and disperses lantana seeds in native communities	D	35
		Displaces 2 native species for every percentage increase of lantana cover above 75% in North Coast Wet Sclerophyll Forest along the south-east coast ranges of NSW	-	-	-	A	36
8	*Lycium ferrocissimum*	Potential to dominate vegetation on Carnac Island in Western Australia	-	-	Grey-breasted white-eyes *Zosterops lateralis* and silver gulls breed on the island and may disperse fruits of the weed	D	37
		Displaces *Nitatia billardierei*	Traps nesting birds	-	Competes for limited growing medium with native flora. Young hatchlings become impale on the thorns, resulting in death	D	38
			Removes shelter and shade for sea lion pups	-			
		Reduces percentage coverage of native mat plants at Althrope Island in South Australia	Provides food for the little raven, *Corvus mellori* and the starling, *Sturnus vulgaris* Prevents short-tailed shearwaters, *Puffinus tenuirostris*, from burrowing	-	Increased mean percentage cover of native mat plants and density of short-tailed shearwater burrows over 4 years after Boxthorn removal	A	39
9	*Pennisetum clandestinum*	-	Kills 2 to 3% of penguins on Montague Island in NSW	-	Entangles and strangles penguins trap in the kikuyu mass	C	40

		-	Tall and dense kikuyu grass prevents penguins from nesting	-	Restricts penguins access to deeper areas	B	41
		Displaces native couch, *Cynodon dactylon,* in dry habitats	-	-	Outcompetes native couch in the absence of inundation stress	A	42
10	*Polygala myrtifolia*	Potential to outcompete native plants with relatively larger seeds, e.g. *Acacia retinodes* and *Acacia sophorae*	Facilitates invasion of Argentine ants, *Lineipithema humile*.	-	Argentine ants removed significantly more small seeds of *P.mytifolia* than native ants at uninvaded sites	B	43
		Competes with native shrubs and shades out native ground flora, reducing the integrity of bushland	-	-	Isolated satellite infestation occurring in disturbed areas extends into relatively undisturbed vegetation as a front	C	44
		Reduces species richness and abundance and the regeneration potential of native vegetation	-	-	Dense infestations form closed understorey canopy	C	45
11	*Spartina spp.*	-	Reduces native annelid, *Boccardia* sp., from 139 to 3 at little Swanport estuary in Tasmania	-	-	B	46
		Competes with and excludes seagrass such as *Zostera* spp., and lowers salt marsh plants, such as *Salicornia quinqueflora*	-	-	-	C	47
		Increases survival rate of native *Avicennia marina* at Andersons Inlet	-	-	Causes sediment accretion up to 7cm per annum, stabilising marsh surface and shelters young seedlings from wave action	B	48
		1) Reduces diversity of strandline vegetation 2) Affects movement of groundwater and may cause death of trees in adjacent woodland	3) Reduces value of estuarine sites as habitats for wading birds	4) Fungi associated with *Spartina* may contribute to decomposition in salt marsh	1) Causes greater uniformity of drift deposits 2) Superior silt-trapping ability causes poor drainage 3) Reduces area of intertidal mudflats	B	49
		-	1) Causes waders at Andersons Inlet to not gain enough body fat for long migration. Thought to have caused the absence of Sharp-tailed Sandpiper	2) Creates management problem for landowners. Reduces recreational access	1) Colonises intertidal mudflat, prevents waders from feeding and roosting 2) Grows in some of the farm drainage lines	C	50
		-	Potential to cause drastic decline of waders at Andersons Inlet 1) Facillitates formation of other saltmarsh species	2) Makes beaches unpleasant, if not impossible to use 3) Narrows river channels	1) Forms marsh islands 2) Forms dense swards and meadows 3) Traps sediments and builds terraces	C	51

12	*Thinopyrum junceiforme*	Displaces *Spinifex* from the stoss face of the foredune at Younghusband Peninsula	Potential to decrease habitat of hooded plover	Builds incipient 3-4m high ramp foredunes	Colonises gaps in the foredune and occupies areas of the backbeach not normally colonized by *Spinifex*. Increases accretion rate which narrows the beach	B	52
		-	-	Scarps new foredunes altering the geomorphology of beaches in southeast of south Australia	-	C	53
		-	Threatens shorebird species (Little Tern Sterna, Fairy Tern Sterna, Caspian Tern, Hooded Plover, Red capped Plover, Pied Oystercatcher)	-	Colonises vegetation free nesting sites	D	54
		Displaces *Festuca littoralis* and *S.sericeus*	-	Forms dunes with high profile	-	D	55

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Appendix 3. List of perceived worst coastal weeds in southern Australia identified by managers. Each council indicated their worst weeds on a 1 to 10 scale (10 being the worst): within a State, these were summed and divided by the number of councils in that region. The Total is simply the sum of the State values.

SPECIES	VIC	WA	TAS	SA	NSW	TOTAL
Acacia cyclops				1.67		1.67
Acacia longifolia		0.62		2.42		3.04
Acacia saligna					0.71	0.71
Acetosa sagittata	0.45				2.47	2.92
Agapanthus praecox			0.58			0.58
Agave americana		0.77		0.75		1.52
Ageratina adenophora					0.35	0.35
Ageratum houstonianum					0.12	0.12
Allium triquetrum	0.64					0.64
Alternanthera pungens				0.67		0.67
Ambrosia tenuifolia					0.06	0.06
Ammophila arenaria	1.63	1.31	2.42	0.67	0.18	6.21
Anredera cordifolia					3.12	3.12
Arctotheca populifolia		0.54		0.83	0.47	1.84
Arctotis stoechadifolia		0.62		0.75		1.37
Argyranthemum frutescens				0.42		0.42
Asparagus aethiopicus	0.73				5.11	5.84
Asparagus asparagoides	3.73	0.46	0.83	2.5	0.24	7.76
Asparagus declinatus				1.33		1.33
Asphodelus fistulosus		0.54		1.42		1.96
Aster subulatus				0.17		0.17
Avena barbata		0.38		0.08		0.46
Billardiera heterophylla				0.5		0.5
Brassica rapa	0.54					0.54
Brassica tournefortii				0.08		0.08
Bryophyllum delagoense					1.53	1.53

SPECIES	VIC	WA	TAS	SA	NSW	TOTAL
Cakile edentula				1.08	0.35	1.43
Cardaria draba	0.73					0.73
Cardiospermum grandiflorum					0.47	0.47
Carpobrotus edulis	0.09	0.08				0.17
Carduus pycnocephalus			0.33			0.33
Carrichtera annua				0.67		0.67
Celtus sinensis					0.24	0.24
Cenchrus incertus				0.42		0.42
Cenchrus longispinus					0.06	0.06
Centranthus ruber			1.67			1.67
Cestrum parqui					0.94	0.94
Chrysanthemoides monilifera	3.36		3	1.08	6.18	13.62
Cirsium arvense			0.58			0.58
Conium maculatum			0.33			0.33
Conyza bonariensis		0.31				0.31
Coprosma repens	3.1		3.59	0.75		7.44
Cortaderia species		0.46	1.75			2.21
Cotyledon orbiculata	0.27					0.27
Cynodon dactylon	1.9	0.38			0.29	2.57
Cytisus scoparius			1.17			1.17
Delairea odorata	3.36		1.08		0.18	4.62
Diplotaxis tenuifolia				0.58		0.58
Dipogon lignosus	2.09	0.62				2.71
Dittrichia viscosa		0.38				0.38
Asphodelus fistulosus				1.5		1.5
Erica lusitanica	0.55		2			2.55
Ehrharta calycina	0.36	0.54		0.5		1.4
Ehrharta erecta	2.9				1.59	4.49
Ehrharta longiflora	0.82					0.82

SPECIES	VIC	WA	TAS	SA	NSW	TOTAL
Ehrharta villosa		2.69	0.25	1		3.94
Eichhornia crassipes					0.24	0.24
Eragrostis curvula					0.41	0.41
Eucalyptus botryoides	0.45					0.45
Euphorbia lathyris			0.58			0.58
Euphorbia paralias	2.09	3.15	6	3.17	0.88	15.29
Euphorbia terracina		4.46		4.33		8.79
Ferraria crispa		0.62				0.62
Foeniculum vulgare	0.18					0.18
Fumaria capreolata		0.31				0.31
Galenia pubescens	0.64			0.83		1.47
Gazania linearis		0.46	0.5		0.82	1.78
Gazania rigens	0.82			3		3.82
Genista monspessulana			0.33			0.33
Harrisia spp					0.35	0.35
Hedera helix			1.67			1.67
Hirschfeldia incana				0.08		0.08
Hydrocotyle bonariensis					0.47	0.47
Hyparrhenia hirta				0.58	0.12	0.7
Ipomoea cairica					2.35	2.35
Ipomoea indica					2.71	2.71
Juncus acutus	1.18			0.75	0.24	2.17
Lagunaria patersonia		0.15				0.15
Lantana camara					5.06	5.06
Leptospermum laevigatum		4.15		1.33		5.48
Ligustrum lucidum					0.59	0.59
Lycium ferocissimum	5.09	1.38	3.5	7.92		17.89
Macroptilium atropurpureum					0.18	0.18
Malva dendromorpha		0.08				0.08

SPECIES	VIC	WA	TAS	SA	NSW	TOTAL
Malva parviflora			0.42			0.42
Marrubium vulgare			0.42	0.58		1
Medicago polymorpha	0.27					0.27
Melianthus comosus				0.42		0.42
Mesembryanthemum		1.23		0.58		1.81
Nephrolepis cordifolia					0.24	0.24
Nassella neesiana	0.91					0.91
Ochna serrulata					0.29	0.29
Oenothera drummondii		1.62				1.62
Olea europaea		0.54		1.08	0.53	2.15
Opuntia stricta				0.33	0.35	0.68
Osteospermum moniliferum		0.31				0.31
Oxalis pes-caprae		0.38		0.42		0.8
Paraserianthes lophantha			0.42			0.42
Parietaria judaica					0.76	0.76
Passiflora mollisima					0.35	0.35
Pelargonium capitatum		3.69				3.69
Pennisetum clandestinum	1.45	0.46		0.08	0.71	2.7
Pentzia suffruticosa				0.75		0.75
Phormium tenax			0.5			0.5
Phyla canescens	1.64			0.42		2.06
Pinus halepensis				0.33		0.33
Pittosporum undulatum			0.67			0.67
Polygala myrtifolia	3	0.77		1.08	0.24	5.09
Protoasparagus aethiopicus					0.59	0.59
Protoasparagus densiflorus					0.18	0.18
Reseda lutea			0.17	0.17		0.34
Retama raetam		0.46		0.17		0.63
Rhammus alaternus		0.46		0.25		0.71

SPECIES	VIC	WA	TAS	SA	NSW	TOTAL
Ricinus communis					0.29	0.29
Rubus spp.	1.91	0.54	4.08		0.35	6.88
Rumex crispus				0.08		0.08
Salpichroa origanifolia	0.55					0.55
Salvinia molesta					0.29	0.29
Schinus terebinthifolius		0.92			0.17	1.09
Senecio angulatus		0.15			0.24	0.39
Senecio elegans		0.92	0.75			1.67
Senecio glastifolius		0.77				0.77
Senecio jacobaea			1			1
Senecio madagascariensis					0.18	0.18
Senecio pterophorus					0.47	0.47
Senna pendula					1.65	1.65
Silybum marianum			0.5			0.5
Solanum elaeagnifolium					0.24	0.24
Solanum linnaeanum				0.83		0.83
Solanum nigrum	0.09					0.09
Sollya heterophylla	1		0.42			1.42
Sonchus oleraceus	0.45					0.45
Spartina spp.			1.83			1.83
Sporobolus fertilis					0.18	0.18
Stenotaphrum secundatum		0.54				0.54
Tamarix aphylla		1.54		0.33		1.87
Tetragonia decumbens		4.08				4.08
Thinopyrum distichum		0.08				0.08
Thinopyrum junceiforme	2	0.38	0.92			3.3
Trachyandra divaricata		4.46		1.17		5.63
Tradescantia albiflora	0.36				0.06	0.42
Tradescantia fluminensis					0.18	0.18

SPECIES	VIC	WA	TAS	SA	NSW	TOTAL
Tribulus terrestris				1.5		1.5
Ulex europaeus			5			5
Verbesina enceloidies		0.92				0.92
Vicia sativa	0.36					0.36
Vinca major	0.36		0.08			0.44
Zantedeschia aethiopica		1.69				1.69

Just how bad are coastal weeds?

By Roger Cousens, David Kennedy, Grainne Maguire and Kathryn Williams

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Australia's coastal regions are being threatened by many invasive plants. This project attempts, for the first time, to collate existing information on the impacts of these invaders, collects new data on impacts on animals and people, and identifies the gaps in our knowledge and reporting systems.

The findings will be of interest to Policy-makers, coastal land managers and scientists.

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