NSW GOVERNMENT | Office of Environment & Heritage

Review of the NSW Threat Abatement Plan: Invasion of native plant communities by *Chrysanthemoides monilifera* (bitou bush and boneseed) 2006–2011

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Cover photo: Mark Hamilton, OEH.

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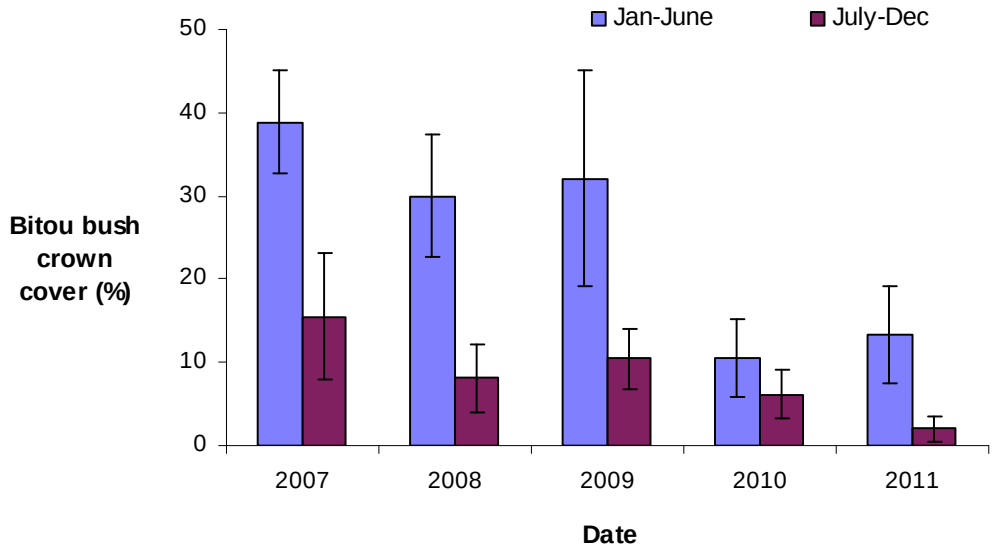
Executive summary

The NSW Bitou Bush Threat Abatement Plan (TAP) was released in 2006 and after five years of implementation, is due for review. During this period stakeholders worked together to protect environmental assets at risk from bitou bush and to reduce its extent. These efforts involved a range of land managers, including the Office of Environment and Heritage (OEH, including the National Parks and Wildlife Service, NPWS), the five coastal catchment management authorities (CMAs) in NSW, the Crown Lands Division of the NSW Department of Primary Industries (former Land and Property Management Authority), local government, community groups, Aboriginal groups and bush regenerators.

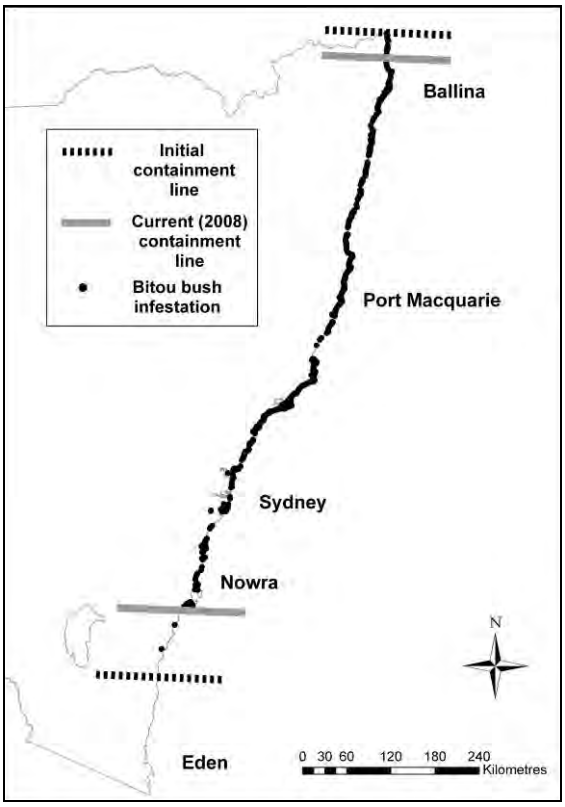
The TAP contains eight objectives, each with criteria for evaluation. This review assesses performance against these criteria. Data and information for the assessment was obtained through a site manager survey, analysis of biological monitoring data, review of approved site management plans, reports prepared by the NPWS Pest and Ecological Management Unit (PEMU) and the National Bitou Bush and Boneseed Management Group, published scientific reports and other information obtained by the TAP Review Working Group and TAP Coordinator.

Five of the eight TAP objectives were achieved, one objective partially achieved and two objectives not achieved over the last five years. Some key achievements of the TAP are:

- 73% of the 157 managed sites were high priority, illustrating funding was directed to sites where control was most likely to protect threatened biodiversity and be successful.
- Standardised site management plans were developed and implemented at 57% of high priority sites.
- Control continued to occur in national bitou bush containment zones. Mapping coordinated by PEMU revealed the density of bitou bush was reduced in containment zones and the containment lines receded (see map below).
- Monitoring programs were established at 76 sites and bitou bush abundance was reduced across priority sites, from a median cover of 26–50% in 2007 to 0–5% in 2011 (see below for bitou bush reduction at a subset of sites that took quantitative measurements).
- Where sufficient monitoring data existed, results in most cases showed long-term management of all weeds delivered a positive response of native species.



- Key resources were developed and provided to stakeholders to increase their capacity to implement the TAP, including: the Bitou Bush Management Manual, the Monitoring Manual for Bitou Bush Control and Native Plant Recovery, an identification guide to the native plants at risk from bitou bush invasion, and educational materials such as site signs, bookmarks, stickers, magnets, and banners.
- A TAP Coordinator at OEH worked collaboratively with five CMAs, the Crown Lands Division of the NSW Department of Primary Industries and over 40 land managers, to deliver on the TAP objectives.
- Over 120 community groups assisted site managers with on-ground control.
- The five coastal CMAs and OEH received Australian Government funds of almost $2 million to implement the TAP.



Objectives 6 and 7 were not achieved and relate to the impacts on fauna of bitou bush invasions, and bitou bush control, respectively. Much of the research required to achieve these objectives was not undertaken due to the differing research priorities of participating institutions. Objective 1, which dealt with site management, was not fully achieved as implementation fell below some performance criteria. For example, 67% of high priority sites were managed and 57% had site management plans prepared, whereas the criteria indicated that 75% of high priority sites should be managed and have site management plans prepared.

This review identified a number of issues to be addressed for improved implementation into the future. They include:

- Site management at most sites has not occurred over the full five years (sometimes starting two or three years into the term of the TAP due to funding) and biodiversity is often at risk from secondary weed invasion or bitou bush reinvasion.

- Control occurred at sites without an approved site management plan and, where plans were prepared, there was often little ownership or few plan updates if conditions changed.
- Though monitoring programs were established at 76 sites, 13 of these were only sampled once (i.e. baseline), and the response of biodiversity to management could not be determined at 59% of the remainder. This was mostly due to the short-term nature of the monitoring or an insufficient number of plots sampled.
- Very few high priority species were monitored and where they were, techniques were mostly ineffective to determine changes in species' populations in response to weed control.
- Site information used to rank sites may be outdated and more bitou bush sites may need to be nominated.

Given the outcomes of this review, future investment and coordination of the Bitou TAP is recommended. This review did not find a need for major revision of the TAP objectives. All objectives are still relevant, particularly Objectives 1 and 2: to ensure bitou bush control occurs in areas where the biodiversity benefits are greatest, and to evaluate the effectiveness of control programs, respectively. This does not preclude improvements that can be made for future implementation however. As a result of this review, the following recommendations are to be considered for future TAP implementation:

- coordination of the TAP to continue across tenure
- the TAP Coordinator to offer a greater level of monitoring guidance and support to site managers, particularly in regard to ensuring plot replication, monitoring frequency and duration are sufficient to detect a biodiversity response, and also the requirement for and extent of monitoring programs to determine effectiveness within limited budgets
- PEMU to be involved in assessment of the feasibility of monitoring certain species, based on the resources required to measure a change in a species' population
- preparation of an overarching monitoring strategy to ensure efficient, targeted and meaningful data is collected
- amendments to the site management plan template to increase useability and reduce preparation time
- where required, information used to rank existing TAP sites is to be updated through the Biodiversity Priorities for Widespread Weeds (BPWW), and new bitou bush sites are to be nominated
- implementation of the BPWW to consider the outcomes and recommendations of this review.

Over the last five years, the TAP has proved successful as an instrument for ensuring bitou bush control occurs at sites where the biodiversity benefits are greatest. The Bitou TAP has involved many stakeholders working in collaboration to implement this important statewide program. It is important to flag here that progress to date has been largely due to a long-term commitment from site managers and community groups, both prior to and during the 2006–2011 period. This review did not find a need for major revision of the objectives. It is recommended that implementation and resourcing of the TAP continue and that future investment in bitou bush management be guided by: i) this review; ii) the BPWW; and iii) the direction set by the National Strategy for Bitou Bush/Boneseed 2012–2017. Future direction of management should be reassessed after 2015, in line with the invasive species reporting required under the NSW State Plan.

1 Introduction

Bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata* (DC.) T. Norl.) is a South African shrub that has invaded large areas of coastal south-eastern Australia. It is widespread along the coast, where it negatively impacts native plants and ecological communities. Bitou bush was deliberately planted in coastal NSW from 1946 to 1968 to stabilise coastal sand drifts (Mort & Hewitt 1953) and to revegetate sand dunes following mining (Barr 1965). Concerns were raised in the mid 1980s about its spread and impacts (Love & Dyason 1985) but it was not until the late 1990s that it was formally recognised as a serious weed, through:

1. listing of bitou bush as a noxious weed under the NSW *Noxious Weeds Act 1993*
2. listing of the invasion of native plant communities by *Chrysanthemoides monilifera* (bitou bush and boneseed) as a key threatening process (KTP) under the NSW *Threatened Species Conservation Act 1995* (TSC Act) in 1999
3. declaration as one of the initial 20 Weeds of National Significance (WoNS), together with boneseed (*Chrysanthemoides monilifera* ssp. *monilifera* (L.) T. Norl.) (Thorp & Lynch 2000)
4. the release of the NSW Bitou Bush Strategy (NPWS 2001), and
5. the preparation of a NSW TAP (DEC 2006) in response to the KTP listing, to reduce, abate or ameliorate the impact of bitou bush and boneseed.

The TAP has two core aims: i) to undertake weed control where benefits to biodiversity are greatest, including control alleviating immediate impacts to priority biodiversity and containing the northern and southern spread of bitou bush, and ii) to evaluate the effectiveness of control programs in protecting biodiversity at risk from bitou bush. During the TAP development, the NSW Department of Environment and Conservation, (DEC, now known as OEH) employed a site-led approach for identifying and prioritising environmental assets and sites for bitou bush control (DEC 2006, Burley *et al.* 2008). The TAP identified a range of native plant species, populations and ecological communities at risk from bitou bush (DEC 2006, Hamilton *et al.* 2008), and 349 sites were prioritised for control based on the environmental assets at risk and the likelihood of effective control.

For the purposes of achieving the outcomes of the TAP on the ground, a proforma was developed to help land managers prepare site-specific management plans. The proforma includes details of the priority biodiversity at the site, a site map (showing location of priority biodiversity and weed species), a site control history, a detailed control strategy that includes initial and follow-up control techniques, other factors that may affect control, the roles and responsibilities of stakeholders, details of consultation with Indigenous people regarding any special interests, and details of monitoring programs to evaluate effectiveness of control (DEC 2006). A core principle regarding the control of bitou bush under the TAP that was included in site management plans, is the staged approach to control. This approach ensures control of the weed focuses on areas where priority biodiversity is located and that follow-up control constraints are considered (DEC 2006). Site managers submitted plans to the TAP Coordinator for approval. A scientific licence under section 132C of the NSW *National Parks and Wildlife Act 1974* (NPW Act) was provided to site managers (if required) upon approval of site plans. Licences were required due to works occurring in proximity to threatened species and ecological communities.

Implementation of the TAP was assisted by establishment of a TAP Coordinator role at DEC and through funding from the Australian Government under the National Heritage Trust (NHT) and Caring for Our Country (CfoC) initiatives. The five coastal CMAs and

DEC collaborated to apply for funding and deliver both projects. A steering committee consisting of the five CMAs and DEC guided the delivery of these projects and the TAP in general.

It is a requirement under section 85 of the TSC Act to review a TAP by the date specified in the plan. The Bitou TAP specifies a review after five years of implementation (2006–2011). This review assesses TAP implementation against the performance criteria of the eight TAP objectives (Table 1).

2 Review methodology

2.1 Working group

A TAP Review Working Group was formed to review current practices under the TAP. Members of the group included representatives from NPWS, CMAs, the Crown Lands Division of the NSW Department of Primary Industries, local government and the Bitou Bush/Boneseed WoNS coordinator. The purpose of the working group was to:

- assist in gathering information on the implementation of the TAP
- assist in the assessment of implementation against the TAP objectives
- provide advice on the review process, structure, and the future of the TAP, and
- provide recommendations to improve the roll-out, implementation and governance of future NSW weed threat abatement strategies, including the BPWW (DPI & OEH 2011).

2.2 Site manager survey

A survey was circulated to the 42 site managers responsible for the 124 TAP sites with approved site management plans. Thirty-nine site managers completed the survey. The survey was composed of site-specific questions relating to TAP implementation and generic questions that related to improving the implementation of weed threat abatement strategies. The purpose of the survey was to:

- provide information on how the TAP performed against its objectives
- indicate how the TAP was implemented in the field
- gather final site statistics, and
- gather site manager comments to improve the implementation of weed threat abatement strategies.

Survey responses included specific information on 123 of the 124 sites with approved site management plans. Site-specific information was also gathered on five more TAP sites that did not have approved site management plans.

Nine of the 124 sites with site management plans did not implement these plans due to lack of funding. General site information was also gathered from site managers (and other sources) for another 41 TAP sites where work was undertaken between 2006 and 2011 (but no site management plans were approved). Information was also collected on 54 non-TAP sites where bitou bush was managed in the last five years.

2.3 Biological monitoring data

Site management plans outline the monitoring program to be undertaken at sites to evaluate the effectiveness of control. They detail the monitoring method, required replication and the interval of sampling. Site managers, bush regenerators, and PEMU collected biological monitoring data throughout TAP implementation. In early 2011, PEMU began collation of biological monitoring data. The data were collated and analysed to determine the effectiveness of site control programs with respect to weed reduction and biodiversity response.

2.4 Bitou bush research relevant to TAP objectives

To supplement results from the surveys, the information held in approved site management plans was reviewed; site manager scientific licence (under section 132C of the NPW Act) reports were reviewed; and a search of the ‘Current Contents’ database undertaken. The latter identified published papers relevant to the review. Data were also obtained from papers prepared by PEMU. In addition, as the University of Wollongong is a leader in bitou bush research, a meeting was held with Professor Kris French to obtain the most up-to-date research on bitou bush.

3 Review of objectives

Table 1 outlines the eight TAP objectives and the actions associated with them.

Table 1: Objectives and actions of the Bitou TAP

Objective	Action
1. Ensure that bitou bush (and boneseed) control is undertaken in areas where the benefits to threatened species, populations and ecological communities are greatest	**1.1** DEC and the Department of Lands (DoL) will undertake bitou bush control programs at high priority sites on their estate. In addition, DEC and DoL will seek agreement from councils to ensure bitou bush control programs are undertaken at high priority sites on council administered land. To measure the biodiversity benefits, bitou bush control will not occur in areas designated as experimental 'no-treatment' areas (see Objective 2).
	1.2 At control category 1 sites, DEC and DoL will help to develop and implement site-specific management plans for bitou bush control programs, based on currently available best practice guidelines. DEC will work with councils and private landholders that agree to Action 1.1, to develop site-specific management plans.
	1.3 Indigenous communities will be encouraged to assist with the development of site-specific management plans.
	1.4 Control of bitou bush is to continue at both the northern and southern containment zones in NSW.
2. Evaluate the effectiveness of control programs with respect to the response of priority species, populations and ecological communities	**2.1** DEC will coordinate the monitoring/measurement of bitou bush control programs at control category 1 sites.
	2.2 DEC will foster research into the effects of herbicide on priority species.
	2.3 DEC will coordinate a statewide (NSW) survey of bitou bush and boneseed infestations (including offshore islands).
	2.4 DEC and other stakeholders will determine the distribution of boneseed in NSW and develop a containment/eradication strategy.
3. Evaluate the ways in which bitou bush causes the decline of native plant species	**3.1** DEC will foster research into the decline in native plant species as a result of bitou bush invasions.
4. Ensure that all stakeholders are involved/participate at each of the priority sites	**4.1** DEC and other agencies will coordinate the training of volunteers (and other stakeholders) who wish to participate in control programs at control category 1 sites.
	4.2 DEC and other agencies will undertake public awareness programs on the impacts of bitou bush, especially to biodiversity, and the importance of its control.
5. Ensure implementation and administration of the Bitou TAP is undertaken	**5.1** DEC will support a position to coordinate the implementation of the Bitou TAP.
6. Determine the effects of bitou bush invasions on fauna	**6.1** DEC will foster research into the effects of bitou bush invasions on fauna.
7. Determine the effects of bitou bush control on fauna	**7.1** DEC will foster research into the effects of bitou bush control on fauna.
8. Establish guidelines for future control programs and research projects based on the outcomes of this TAP	**8.1** DEC and other stakeholders will examine new data and integrate it into future control/management strategies and best practice guidelines for bitou bush.
	8.2 DEC and other stakeholders will examine new data and establish future priorities for bitou bush research.

3.1 Objective 1

Ensure that bitou bush (and boneseed) control is undertaken in areas where the benefits to threatened species, populations and ecological communities are greatest.

Action 1.1 performance criteria

- *Control programs will be established at 75% (127) of the high priority (control category 1) sites within two years of the publication date of this TAP.*
- *Existing bitou bush control programs at all priority sites (i.e. control category 1, 2, 3, 4 and 5 sites) and in other areas where threatened species, populations and/or ecological communities occur will continue.*

Weed management was undertaken at 45% (157 sites) of identified TAP sites during the term of the TAP, 2006–2011 (Table 2). This data is likely an underestimate due to data collection only encompassing the 39 surveyed site managers, site management plans, and the knowledge of the TAP Coordinator. Approximately 46% of all sites managed were located in the Northern Rivers CMA region (Table 3).

The first performance criterion is for control programs to occur at 75% of high priority sites (control category 1). Results indicate control occurred at 114, or 67% of all high priority sites between 2006 and 2011 (Table 2). Though 67% of high priority sites received control, the duration of control at sites varied (Figure 1), with some commencing control in 2009 or 2010. Although this target was not reached, the majority of work (73%) occurred at the highest priority sites, showing funding and site management was mostly consistent with the TAP site prioritisation. This pattern was consistent across land tenures (Table 4).

Table 2: Number of TAP sites managed between 2006 and 2011

Control category*	Number of sites managed	Number of sites listed in TAP	% of sites managed in each category	% of all sites managed
1	114	169	67	73
2	23	71	32	15
3	14	67	21	9
4	5	37	14	3
5	1	5	20	1
Total	**157**	**349**		**45**

*Control category relates to the priorities for control. Control category (cat) 1 = the highest priority, cat 2 = medium/high, cat 3 = medium, cat 4 = medium/low, cat 5 = low. See Appendix 6 of the TAP for further information on site prioritisation.

Table 3: Number of TAP sites managed between 2006 and 2011, by NRM region

NRM (CMA) region	Number of sites	Number of sites listed in TAP	% of all sites in region	% of all sites managed
Northern Rivers	73	136	54	46
Hunter-Central Rivers	39	103	38	25
Southern Rivers	26	64	41	17
Hawkesbury Nepean	10	9*	100	6
Sydney Metro	9	37	24	6
Total	**157**	**349**		**45**

*Two additional sites in Hawkesbury Nepean CMA were nominated after publication of the TAP in 2006.

Table 4: Number of TAP sites managed between 2006 and 2011 across general land tenures

Control category	Crown or local government	NPWS# estate	Mixed tenure*	Federal government
1	44	62	7	1
2	16	6	1	0
3	10	4	0	0
4	3	2	0	0
5	0	1	0	0
Total	**73**	**75**	**8**	**1**

NPWS = National Parks and Wildlife Service.

* Mixed tenure was usually a mix of NPWS land with Crown or Local Government.

The average year that management commenced at TAP sites was 2002, four years before the TAP was released. The oldest managed site had control beginning in 1989 and the newest in 2010 (Figure 1). All sites were still managed in 2010–11, so the criterion that existing bitou bush control programs continue has been met (see Figure 1 for an indication of the number of sites managed prior to the TAP). Seventy-three per cent of site managers surveyed indicated management at these sites will be ongoing past 2011.

There was a large increase in the number of sites managed in 2007 (24 additional sites; Figure 1). The year where the most number of sites had management commence was 2007 (24 sites). This coincided with Australian Government NHT funding of $1.6 m to implement the TAP. The spike in the number of sites commencing management in 2004 (11 sites) coincides with the release of the draft TAP and the heightened awareness that likely ensued. For NPWS sites, 30% of sites commenced work on or after 2006, for Crown or local government land this figure was 47% of sites.

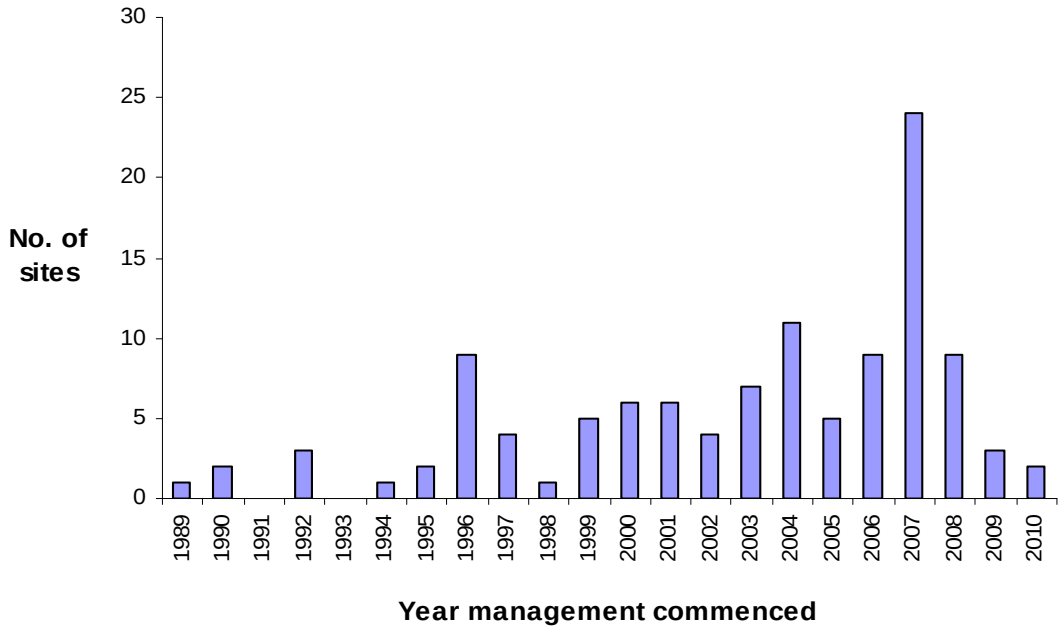


Figure 1: The year weed management commenced at TAP sites

Note: Data for this figure obtained from site survey and from eight site management plans. N=114.

Site managers reported that bitou bush management occurred at an additional 54 non-TAP sites in the last five years. However, 20 of these sites were adjacent to TAP sites (to complement existing TAP work) and another 18 sites were subsequently identified as priority sites in the BPWW (DPI & OEH 2011). Many of these sites were also managed under community bush regeneration projects or to engage the local Aboriginal community or other community groups, such as Dunecare.

Information from Northern Rivers CMA reveals that towards the end of the first five years of the TAP implementation many TAP sites in that CMA: i) had outdated site nomination information; ii) did not have accurate location information; iii) had no bitou bush present; or iv) other circumstances had changed, e.g. sites were now within the northern containment zone or were subject to development applications. This is an indication that some site details need to be updated.

Action 1.2 performance criterion

– *Site-specific management plans to control bitou bush will be developed for 75% (127 sites) of the control category 1 sites within two years of the publication date of this TAP.*

There are 124 sites with site management plans approved by PEMU. Note, often site management plans encompass more than one site, as some site managers found this more efficient where sites were small, closely clustered or management was expected to be similar. Therefore, 97 site management plans were prepared for the 124 sites (Table 5). Six of these sites are yet to have work commence and management ceased at another three sites in 2006. Therefore, 115 of the 157 (73%) managed sites (between 2006 and 2011) were covered by an approved site management plan. For the 114 control category 1 sites where management occurred, 97 (85%) of these had approved site management plans (Table 5). However, these 97 control category 1 sites only accounted for 57% of all control category 1 sites in the TAP (97 of 169). The target of 75% proved difficult to achieve even with funding support from CMAs and the Australian Government and through site manager cash and in-kind contributions. This criterion also precludes a number of sites that did not have site management plans prepared as work had commenced prior to the TAP and management was at an advanced stage, an existing non-TAP plan was in place or a TAP site plan was not required to obtain funding.

Table 5: Number of TAP sites with approved site management plans

Control category	Number of sites with approved plans	% of total site plans approved	Number of sites managed	% of managed sites with approved plans
1	97	78	114	85
2	21	13	23	91
3	4	3	14	29
4	2	2	5	40
5	0	0	1	0
Total	**124***		**157**	**79**

* Includes nine sites with approved plans that were not implemented.

Approved site management plans cover various land tenures, including NPWS (53%) and Crown or local government managed land (39%) (of the 115 sites where management occurred between 2006 and 2011).

Most site management plans were approved in 2007 and 2009 (Figure 2). These dates coincide with funding provided by the Australian Government for two projects under the NHT and CfoC initiatives.

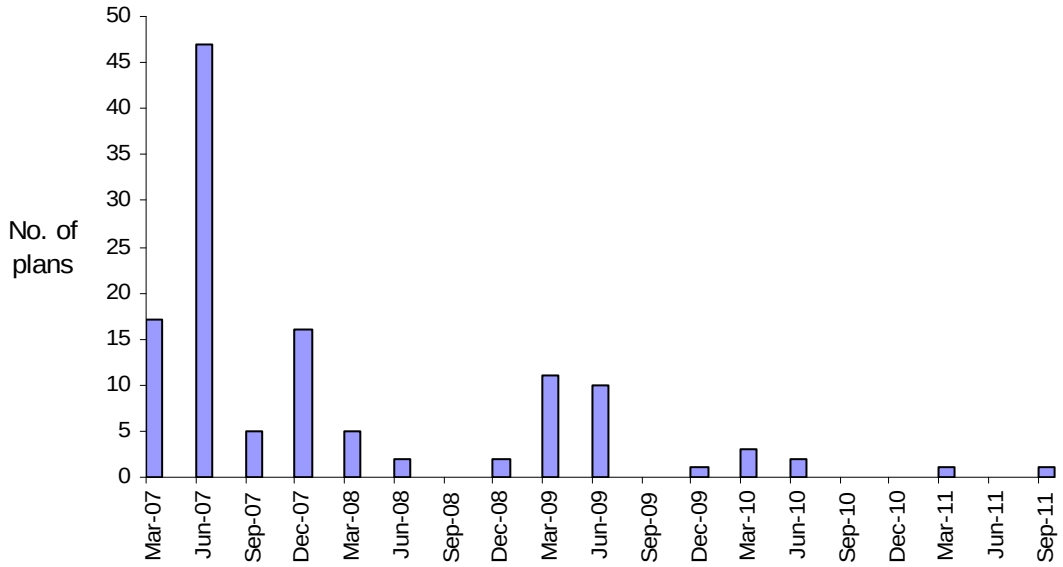


Figure 2: Number of site management plans approved by PEMU at quarterly intervals from the beginning of 2007

In the site manager survey, there were 79 responses relating to the implementation of the site-specific management plans (including if site management plans were updated, useful and whether the staged approach to control was employed) and 89% of these indicated that the majority or all of the site management plans were implemented. Only 18% of the site managers indicated that they did not find the site management plans useful, with 56% indicating it allowed for guidance and assessing progress or was useful to identify site features such as threatened species. However, 49% did not update their site management plans when conditions or circumstances changed. Importantly, only 6% of respondents indicated that management at their sites was not aimed at the protection of biodiversity prior to the TAP and only 7% indicated that the completion of site management plans caused a change in the focus of their management.

The survey responses also indicate the reasons for not completing a site management plan. Responses related to 39 TAP sites where management occurred, but no site management plans were completed. Responses included:

- weed-led programs – sites now in the containment zone or for boneseed eradication (23%)
- external funding did not require a site management plan (23%)
- managed due to the presence of a noxious weed (13%)
- lack of time or resources (13%)
- sites are operating under other planning documents (13%), such as local government plans of management.

Action 1.3 performance criterion

– *Indigenous people are involved in the development of site-specific management plans.*

Section 9 of the TAP site management plan details Indigenous involvement in site management in two ways: 1) identifying Aboriginal cultural heritage sites and detailing how they will be protected, and 2) consulting with Indigenous people with respect to any special knowledge or interest in the site or biota present.

Of the 124 sites covered under an approved site management plan, consultation with Indigenous people occurred for 107 sites. This included consultation with Local Aboriginal Land Councils on the management of 51 sites. In addition, consultation on the management of 36 sites took place with OEH Aboriginal Liaison Officers, such as Aboriginal Cultural and Heritage Officers.

As per the site management plans, 63 sites had Aboriginal significance and a further 50 indicated no or no known significance. However, 10 of the 124 site management plans did not answer the question relating to Aboriginal cultural heritage present at the site.

Action 1.4 performance criterion

- *Control of bitou bush is to continue at both the northern and southern containment zones in NSW. The density of bitou bush at both the northern and southern containment zones is reduced and the zones receded within five years of the publication date of this TAP.*

Between 2006 and 2011, stakeholders sourced significant support and funding for the northern and southern bitou bush containment zones. Both zones have active management strategies in place that were implemented throughout the TAP period (2006–2011).

Mapping of the distribution and density of bitou bush was performed by NPWS in cooperation with land managers in 2001 and 2008. Land managers were asked to outline the 2008 extent and density of bitou bush infestations by drawing on 1:25000 topographic base maps using six density classes. Ground-truthing was conducted by land managers. The 2008 mapping was partially supported by funding provided from the Australian Government for development of the Bitou Bush Management Manual (Winkler *et al.* 2008).

The area and density of bitou bush at both the northern and southern containment zones was reduced and the zones receded between 2001 and 2008. The movement of national bitou bush containment lines over time is depicted in Figure 3 (from Hamilton *et al.* 2012).

The initial northern containment line was established in 1995 along the Tweed River on the NSW–Queensland border. Until recently, this line stood at Letitia Spit, north of Kingscliff, some 8 km south of the initial containment line. In 2011, the containment line progressed to the boundary of Tweed and Byron Local Government Areas (LGAs), 35 km south of the initial line. The containment zone was then defined as coastal areas of NSW north of Byron LGA.

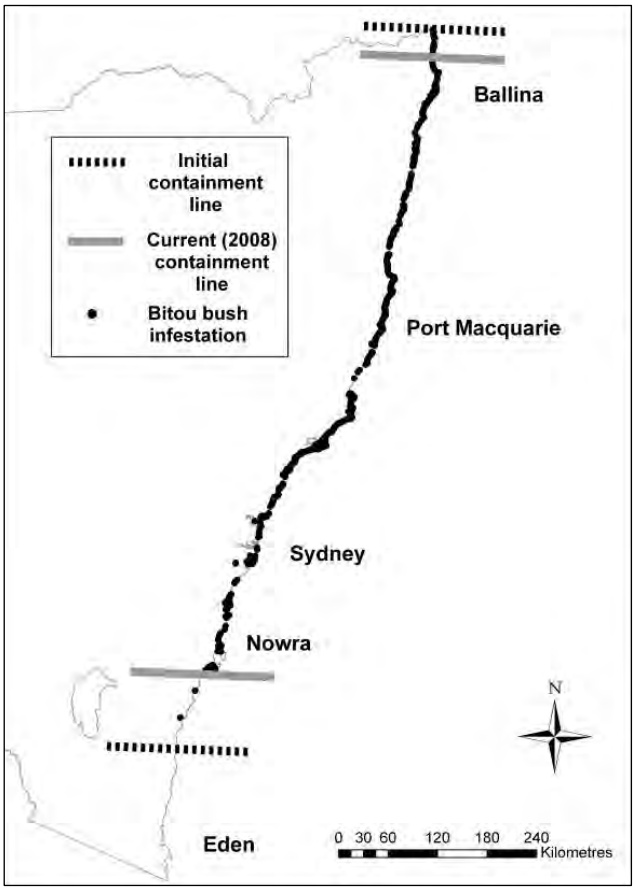


Figure 3: Map showing NSW bitou bush infestations in 2008 with crown cover greater than 10%. Source: Hamilton *et al.* 2012

Notes: Lines represent the locations of the initial and the 2008 national containment lines. Infestation polygons are enlarged to increase visibility. NSW coastline layer source: © Department of Finance and Services.

In the northern containment zone, the total area of bitou bush declined by approximately 8% between 2001 and 2008 (Table 6). The most marked reductions were observed in the heavy (95%) and medium (89%) density classes. This was offset by an increase of 269% in light density (including sparse) infestations (Hamilton *et al.* 2012). Additional mapping from 2011 indicates the density of infestations was reduced further, with 94% of bitou bush area being <10% crown cover.

The southern national containment line was established in 2002 at Tuross Heads, NSW. The line has progressed north 105 km and currently stands south of Sussex Inlet, in Shoalhaven LGA. The containment zone is defined as coastal areas of NSW south of Sussex Inlet.

In the southern containment zone, the total area of bitou bush decreased by approximately 34% since 2001 (Table 6). Again, the most marked reductions were in heavy (88%) and medium (97%) density infestations, with a 14% decrease in light density (including sparse) infestations (Hamilton *et al.* 2012).

The legislative support for bitou containment is strengthened by bitou bush being a Control Class 3 weed (the plant must be fully and continuously suppressed and destroyed) under the NSW *Noxious Weeds Act 1993* in Bega Local Control Area (LCA). A proposal is currently being considered to change the current Class 4 listing to Class 3 in Eurobodalla, part of Shoalhaven and Tweed LCAs.

Table 6: Change in density and area of infestations in the northern and southern bitou bush containment zones in NSW from 2001 to 2008

Source: Adapted from Hamilton *et al.* 2012

Bitou bush density[1]	**Northern containment zone**			**Southern containment zone**		
	2001 (ha)	**2008 (ha)**	**% change**	**2001 (ha)**	**2008 (ha)**	**% change**
Sparse	n/a[2]	128.4	–	n/a[2]	1721.7	–
Light	231.3	725.5	213.6	2,877.0	750.1	-73.9
Medium	371.6	41.3	-88.9	889.2	28.9	-96.7
Heavy	386.8	19.8	-94.9	61.8	7.7	-87.5
Total	**989.7**	**915.0**	**-7.6**	**3828.0**	**2508.4**	**-34.5**

[1] Sparse=one or two plants only (but not measured in 2001); Light <10% cover, infrequently dispersed seedlings, small or large plants and small clumps; Medium=10–40% cover, plants and small clumps readily located, generally uniformly dispersed throughout the site, occasional clumps; Heavy >40% cover, dense clumps forming continuous infestations in patches, with native flora still present in patches or bitou bush plants essentially forming monocultures; [2] not measured in 2001

3.2 Objective 2

Evaluate the effectiveness of control programs with respect to the response of priority species, populations and ecological communities.

Action 2.1 performance criteria

- *Establish monitoring objectives.*
- *Establish an experimental protocol to collect data/information.*

In 2007, PEMU held a series of stakeholder workshops and completed a survey of site managers to determine the level of monitoring undertaken and future monitoring

requirements (King & Downey 2008). Of the 52 survey respondents, 71% indicated they would like to see standard monitoring guidelines developed. A third indicated they have used standard monitoring sheets to record data in the field in the past. However, 84% indicated they would like standard datasheets developed. In response to this need for biological monitoring guidelines, the *Monitoring Manual for Bitou Bush Control and Native Plant Recovery* (Hughes *et al.* 2009) was produced in 2009. This manual details specific monitoring objectives for TAP sites and contains instructions on employing recommended monitoring techniques and completing standardised monitoring datasheets. The manual satisfies the performance criteria to establish monitoring objectives and protocols.

The manual proposed a multi-tier approach to monitoring, where different techniques can be used depending on the species present at a site, and the resources and skills of site managers. The three tiers are Standard, Advanced and Research. The manual was published in stages. The Standard tier was released in July 2009, the Advanced tier in September 2009. The complete manual (including the Research tier) was published in October 2009. Prior to this, the site management plans or monitoring undertaken prior to the TAP (e.g. determining off-target damage to natives during bitou bush control) set the objectives for monitoring.

In 2009, a student research project by K Smith, A Perez and C Perez, under the direction of Associate Professor A Specht and Associate Lecturer K den Exter from Southern Cross University, undertook a review of the advanced monitoring techniques. They concluded that a well planned monitoring program is the key to relevant and reliable information to evaluate effectiveness and that the advanced monitoring techniques addressed most of the key requirements needed for an effective monitoring program. In addition, they suggested that if the advanced techniques were to be taken up as part of control programs, it may provide the ability to demonstrate the effectiveness of bitou bush management.

Action 2.1 performance criteria

- *Establish experiments at as many sites as possible to critically determine the effects of control on bitou bush, priority species and non-target species (including other weed species), using the tier one or tier two monitoring program (discussed in Chapter 8), within 18 months of the publication date of this TAP.*
- *Maintain commitment to undertaking the monitoring programs established over the course of this TAP.*

Initially, the TAP proposed a two-tier monitoring approach for species, populations and ecological communities. The difference between the tiers was based on the robustness and size of priority species' populations and ecological communities to be monitored. However, following the survey of site managers in 2007 and during the development of the monitoring manual, which included further stakeholder consultation and field trialling, a different approach was developed. This approach involved three tiers, each outlining a different level of monitoring based on user level of monitoring skills, resources (time and money) and the aim of bitou bush control. However, some monitoring was set up prior to the TAP and monitoring manual. Thus, when the manual was released, PEMU advised site managers to continue existing monitoring programs to ensure data continuity. As such, the reporting against the above criterion involves monitoring programs set up prior to and after the monitoring manual's release.

Monitoring programs were established at 76 of the 124 sites with approved site management plans and where management had occurred. Of these, only baseline (pre-control) monitoring was conducted at 13 sites, with post-control monitoring yet to occur. Five of the remaining 63 sites had only photopoint monitoring and 58 sites had

quantitative before and after control data. Of these 58 sites, 47 had observations from circular or quadrangular plots, 17 had observations from transects, three had weed distribution mapping, and one had population census data. Data were collected in accordance with the monitoring manual at only 21 sites. The remainder had monitoring established prior to 2009, with monitoring methods similar but not identical to those of the monitoring manual.

The extent and duration of monitoring and the quality of data varied markedly. Extensive monitoring programs that were well replicated and occurred over periods greater than 2–3 years were set up at only a handful of sites. Also, monitoring was often dependent on sourcing external funding, with funds for some sites not received until 2010 and 2011. This, combined with the delayed release of the monitoring manual (three years after the TAP release), may have contributed to only baseline data being collected at 13 sites.

In the site manager survey, respondents reported that approximately $202,000 (including in-kind) was spent undertaking monitoring at 88 TAP sites from 2006 to 2011. They also indicated that once monitoring was initiated at a site, commitment was generally maintained over the term of the TAP. Further, the majority of site managers of the 13 sites where only baseline data were collected, have committed to conducting post-control monitoring.

For those sites where monitoring was not undertaken, the reasons supplied in the survey included insufficient time to undertake the required monitoring (15 responses) and access or terrain issues (6 responses).

Action 2.1 performance criterion

- *Publish and report on the results as part of the review of the TAP (including incorporation of results into best practice guidelines) to land managers and researchers. Results from both tiers of monitoring to be presented.*

Change in bitou bush cover

Bitou bush management occurred at many TAP sites before 2007, and varying levels of control occurred prior to, and during, TAP implementation. Nonetheless, there was an overall reduction in bitou bush cover during the term of the TAP (Figure 4a) at TAP sites where monitoring was undertaken. The median cover class for bitou bush in 2007 was 26–50% cover (N=40 sampling units), while median cover was reduced to 6–25% cover in 2009 (N=99 sampling units) and to 0–5% cover in 2011 (N=62 sampling units).

A subset of these sites had actual percentage cover of bitou bush measured (as opposed to cover classes). At these sites, average bitou bush cover was 38.1% in 2007 (N=22 sampling units), 15.5% in 2009 (N=26 sampling units), and 4.1% in 2011 (N=13 sampling units). There was a significant decrease in bitou bush cover over time ($p<0.0001$); however, this cover fluctuated within years (Figure 4b), with bitou bush often increasing in cover between control events, which indicates that continued follow-up control is essential and that analysis of monitoring data should consider seasonality.

Overall native biodiversity response

Interim monitoring results were presented and published at conferences and in conference proceedings, for example see Burley *et al.* (2008), Hamilton *et al.* (2010 & 2011). In addition, in 2009, site case studies were placed on the TAP website (www.environment.nsw.gov.au/bitoutap/casestudies.htm#), each detailing interim results of control programs.

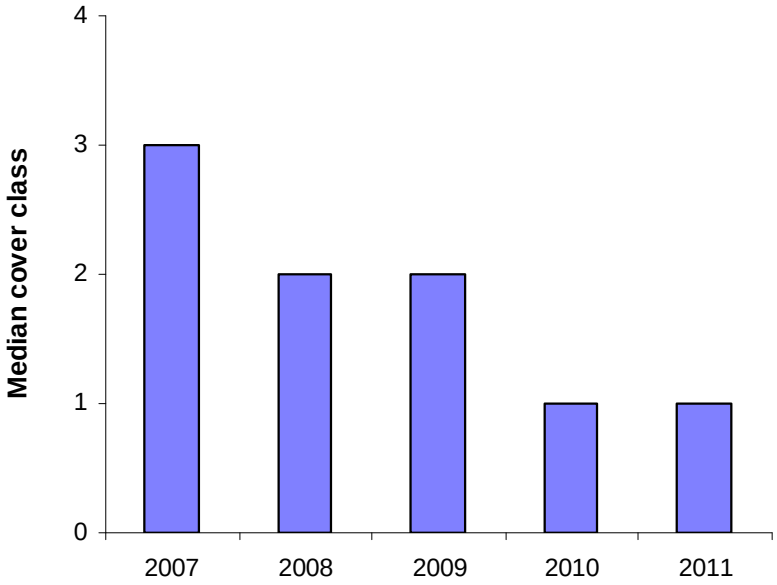


Figure 4a: Change in median bitou bush cover class at TAP sites

Note: Cover class 3 = 26–50% cover, 2 = 6–25% cover, 1 = 0–5% cover. Different sites monitored in different years, with different sampling methods. For 2007 N=40 sampling units, 2008 N=64 sampling units, 2009 N=99 sampling units, 2010 N=80 sampling units, 2011 N=62 sampling units.

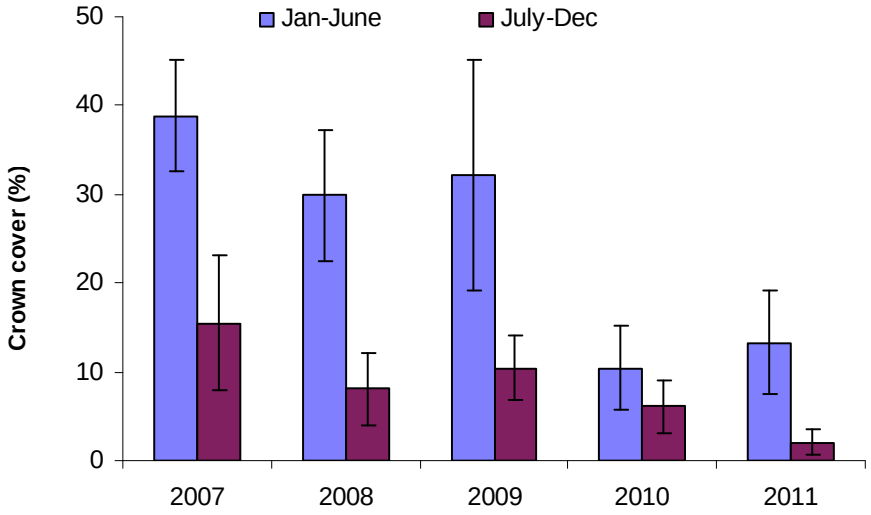


Figure 4b: Change in mean percentage bitou bush cover (±1 standard error) at a subset of TAP sites across six monthly intervals

For this review, to classify the response of biodiversity at sites, five categories were created (Table 7). As mentioned above, methods to measure a biodiversity response varied across sites. Therefore the assessment of whether a response had occurred also varied. Where replication was sufficient, statistical analyses were performed to assess biodiversity response (increase in total native cover or richness). Where statistical analysis was not feasible or meaningful, e.g. low plot replication or photopoint monitoring, it was assumed plots were representative of the site and response was determined by assessing changes in native cover and/or richness. For sites where only one or two priority species were measured, or with only one plot established, the overall biodiversity response could not be detected so sites were scored as 'data insufficient to detect'. The biodiversity response at the 64 sites with before and after control measurements is summarised in Figure 5.

Table 7: Categories identified to determine native biodiversity response at TAP sites

Response category	Definition
Positive response	Total native cover and/or richness increased over time. Where possible, this was determined through statistical tests.
No change but biodiversity protected	Biodiversity changes occurred previously due to extensive control prior to the TAP. Hence, no change detected from 2006 to 2011; however, high native cover and/or richness were maintained.
Data insufficient to detect	Spatial or temporal replication was insufficient to detect a response of biodiversity across the site, e.g. there were too few plots and/or monitoring occurred over a short period.
No response detected	Total native cover and/or richness remained constant over time. Where possible, this was determined through statistical tests.
Negative response	Total native cover and/or richness decreased over time.

Thirty-eight of 64 (59%) sites had insufficient data to detect a response, mostly due to poor plot replication and/or a short duration of monitoring. This category also included sites where too few native species were sampled to determine an overall biodiversity response (though often, sampled flora had responded positively). A positive biodiversity response occurred at 13 of 64 (20%) sites. This category included sites where: 1) data were sufficient (long-term and gathered from several plots) to perform valid statistical tests that showed total native cover and/or richness had increased over time; 2) long-term and well replicated photopoint monitoring indicated an increase in native cover; and 3) cover classes were used to estimate abundance of native species and sufficient plots and species were monitored for a positive change of native cover classes to occur. Nine of 64 (14%) sites had sufficient data but no change in native biodiversity was detected. Often there were positive trends but these were not statistically significant. Case studies have been prepared to provide further explanation of these results (see below).

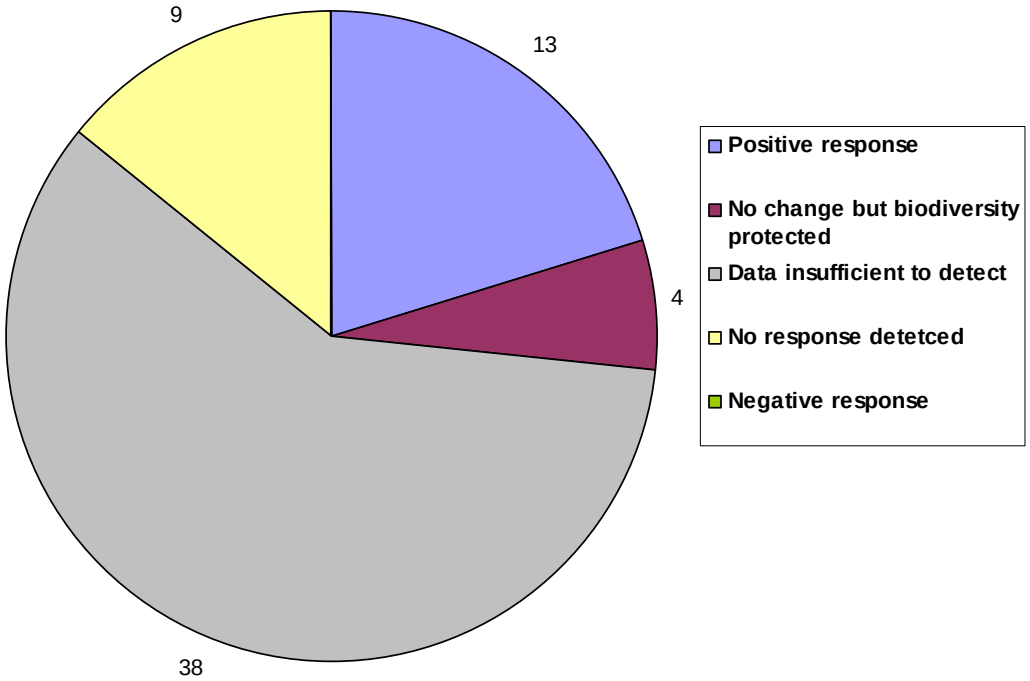


Figure 5: The response of native biodiversity at TAP sites, as determined by analysis of native species abundance and/or richness

Note: See Table 7 for explanation of categories. N=64 sites (includes one site where monitoring ceased in 2006). No sites recorded a negative response.

Additional studies have also been published evaluating the effectiveness of bitou bush control programs. Compared to other WoNS, a relatively large number of papers were published on bitou bush management. Reid *et al.* (2009a) reported that only seven of the 20 WoNS had publications on the response of native species following weed management, with only 20 papers in total published for all WoNS; seven relating to bitou bush. Mason and French (2007) established that intensive bitou bush management such as hand pulling and hand spraying on foredunes provided better biodiversity outcomes in terms of native species richness and composition when compared to extensive management (aerial spraying); however, intensive methods also resulted in an increase in the number of other exotic species. This is supported by Reid *et al.* (2009b), who surveyed site managers and found that following management at 86 sites, 33% of sites had native species replace WoNS, but 52% had the WoNS replaced by native and other weed species. These results indicate that continued follow-up control of all weeds is essential.

Area managed and cost

The site manager survey provided data for 101 sites which showed that the total area managed across these sites was 4700 ha, or an average of 46.5 ha per site. Expenditure at these sites (including cash and in-kind but excluding monitoring) is reported below (Table 8). The average approximate expenditure at a site was $17,827 per year. There was also a large input from volunteers and community groups (see Action 4.1 below). Two significant rounds of funding from the Australian Government assisted with on-ground management, NHT funding awarded in 2006 and CfoC in 2009.

Table 8: Approximate expenditure for on-ground management at a subset of TAP sites between 2006 and 2011 (from the site manager survey)

Expenditure type	Total reported expenditure	No. of sites reporting	Average site expenditure
External	$3,455,781	109	$31,704
Internal	$1,790,064	104	$17,212
In-kind	$3,820,871	95	$40,220
Total	**$9,066,716**		**$89,136**

Case studies

In addition to the general site biodiversity responses above, a series of case studies were prepared for three TAP sites and for three high priority species and two endangered ecological communities (EECs).

TAP site case studies

NR29 Cape Byron State Conservation Area

Photos: Mark Hamilton

Site information

Cape Byron State Conservation Area (SCA) covers 98 ha and is managed by Cape Byron Trust, a collaborative partnership of the local Arakwal Aboriginal people, NPWS and the local community. The site is situated in the far north of NSW, 55 km south of the NSW–Queensland border. It consists of Cape Byron Headland, the most easterly point on mainland Australia; Cosy Corner, at the northern end of Tallow Beach; and the eastern section of Clarkes Beach. In the 1960s, prior to the land being reserved for conservation, dune areas of the current SCA and adjoining lands were planted with bitou bush for land stabilisation following mining. Bitou bush and other weeds became widespread throughout the SCA and began to impact a range of threatened plant species and ecological communities.

Cape Byron SCA is the second highest priority site in the TAP. A site management plan was prepared by the NPWS site manager in 2007. It divided the site into five control zones and detailed an integrated approach to control, combining aerial and ground spray treatment, along with hand removal. Due to the relatively small site size, high natural resilience, and secure funding, the site managers opted for a rapid and broad-scale approach to control. Though initial attempts to control bitou bush and other coastal weeds began in 2005, the reserve was aerially sprayed in 2008 and 2009 using metsulfuron methyl, a selective herbicide which has a limited effect on native plants when applied at the given rate in winter. Aerial spraying allowed cost-effective control, with large areas treated in a short space of time, including difficult to access steep cliffs and headlands. Extensive ground control of bitou bush and other weeds was also undertaken between and after aerial sprays.

Figure 6: Map of the NR29 Cape Byron State Conservation Area TAP site showing broad monitoring sites (white text) and the Cape Byron Headland monitoring site (red circle)

Biodiversity at risk

The region where the site is located is floristically diverse, with subtropical and temperate flora present. The TAP lists 17 native plant species and two communities at risk from bitou bush at the site. Littoral rainforest and Themeda grassland EECs, as well as Plectranthus cremnus are the high priority entities listed. In addition, many of the other TAP species present are threatened and include Acronychia littoralis, Cryptocarya foetida and Xylosma terra-reginae. Themeda grassland is present in the north-eastern sections of the reserve. Littoral rainforest stands dominate the reserve and are present in most areas outside the grassland, cliff face and foredune habitats.

Plectranthus cremnus at Cape Byron Headland
Photo: Mark Hamilton

Monitoring and results

The site is situated in an area where the local community has concerns regarding the use of herbicides to manage weed invasions. To address these concerns and to determine the response of the native vegetation communities to weed management, a monitoring program was established in 2008 with the specific aims of determining: 1) the response of bitou bush infestations to control; and 2) the response of native species to ongoing weed control.

Monitoring sites were established in February 2008 at three of the five control zones: 1) Cape Byron Headland, 2) Clarkes Beach, and 3) Cosy Corner, Tallows Beach (Figure 6). Monitoring was consistent with the advanced monitoring techniques of the monitoring manual. Each control zone was sampled using different methods that provided a representative sample of each zone. Species richness and plant species crown cover were recorded at each control zone. Sampling was conducted prior to bitou bush control in February 2008 and again in November 2008, August 2009, September 2010 and September 2011. Monitoring at these locations is ongoing. Bitou bush control occurred prior to the TAP and initiation of monitoring at Clarkes Beach and Cosy Corner. For this reason, the main results presented here relate to the Cape Byron Headland.

The Cape Byron Headland differs from the other two monitoring sites in that it is not a sand dune community. Five 20 m line-intercept transects were randomly established on the headland (Figure 7) and the intercepts of all shrubs were recorded. Initially this consisted of only bitou bush but later native shrubs established and were measured. Gaps between canopies of less than 10 cm along the tape were considered continuous cover. Three quadrats (1 m x 1 m) were placed at the 5, 10 and 15 m mark along each transect (Figure 7). The quadrats were established to record the native species found growing under the bitou canopy. Abundance of each species identified in the quadrats was estimated using the Braun Blanquet scale. Two transects could not be located in 2010, as stakes delineating these were removed by vandals; consequently these were not monitored past 2009.

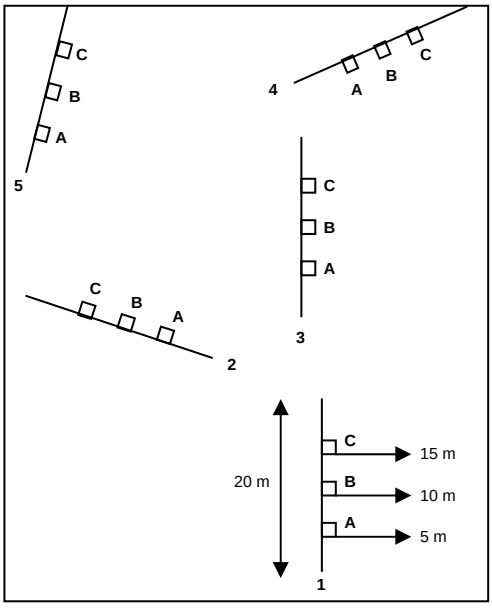


Figure 7: Layout of transects and quadrats at the Cape Byron Headland monitoring site
Note: Not to scale.

The cover of bitou bush was reduced from an average of 79.9% in 2008 to 0% by 2010 (Figures 8 and 11), and maintained at this level to 2011. The site manager observed that reduction in bitou bush cover was more rapid than in adjacent sand dune communities. Bitou bush seedlings are still occasionally detected in the quadrats but no bitou canopy remains. A total of 45 native species and 11 exotic species have been recorded in this zone over time. The high priority species, *Lepturus repens*, was recorded at the site for the first time in 2009, with the next closest records being at Coffs Harbour or south-eastern Queensland. Anecdotal observations indicate that another high priority species, *Plectranthus cremnus*, increased up to tenfold in the first two years of bitou bush control. At the Clarkes and Cosy Corner zones, two other high priority species, *Ischaemum triticeum* and *Vigna marina*, were also discovered as part of the monitoring.

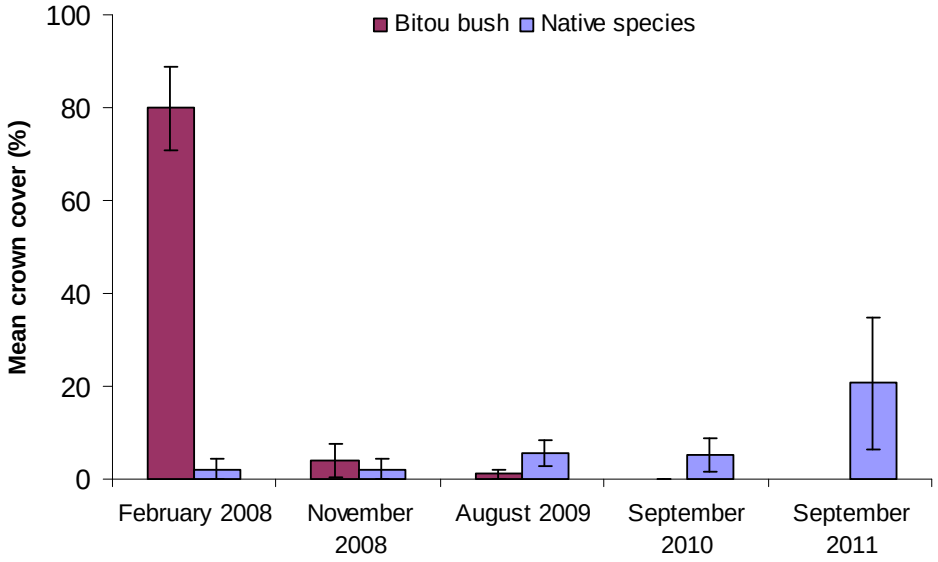


Figure 8: Average cover of canopy species (±1 standard error) along transects at Cape Byron Headland

Note: Aerial spraying occurred in winter 2008 and 2009, and ground control occurred throughout.

More broadly, from 2008 to 2011, there was a significant increase in the number of native species ($p<0.0001$) at Cape Byron Headland, with steady increases since initial control (Figure 9). The median native cover class increased from <5% (<3 individuals) to <5% (8–15 individuals) between 2008 and 2011 (Figure 10). There was a significant interaction with exotic and native richness over time ($p<0.0001$). That is, the proportion of native to exotic species increased with control (Figure 9).

Results at Cosy Corner and Clarkes Beach were not as conclusive as Cape Byron Headland due to extensive control occurring prior to the initial monitoring. Nevertheless, the median bitou bush crown cover in these zones in 2011 was <5% and all mature bitou bush plants had been removed from the three monitoring zones (e.g. see Figure 11). Both zones had no significant difference in the mean number of native species over time (Cosy $p=0.13$, Clarkes $p=0.24$), though there was a trend of increasing native species richness, and native species significantly outnumbered exotics ($p<0.0001$ at Cosy and Clarkes).

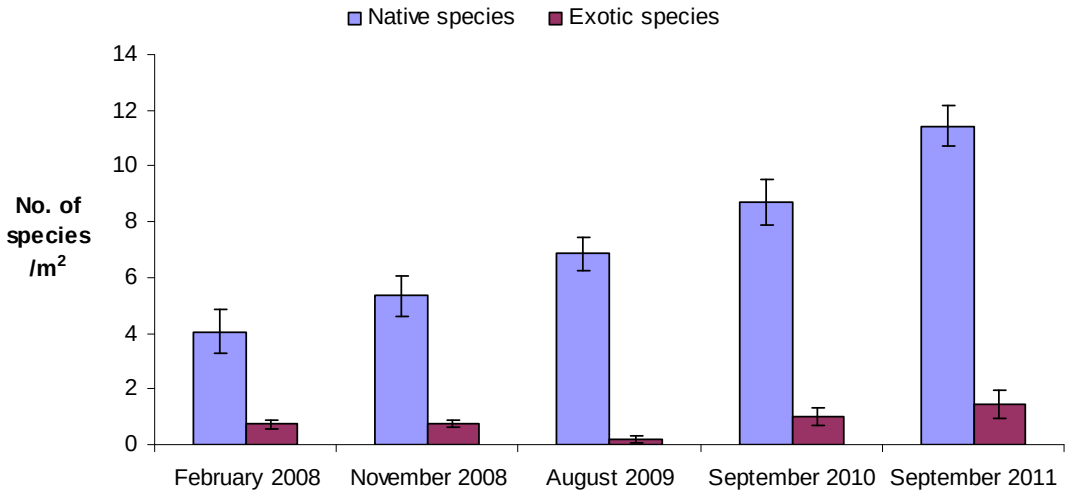


Figure 9: Number of native and exotic groundcover species per m^2 (±1 standard error) at Cape Byron Headland

Note: Aerial spraying occurred in winter 2008 and 2009, and ground control occurred throughout.

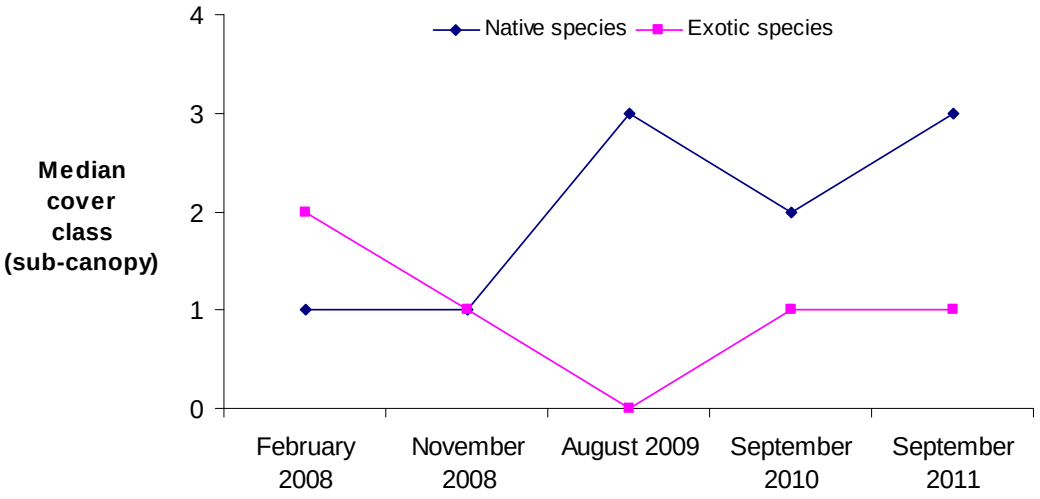


Figure 10: Median cover class of groundcover plant species at Cape Byron Headland

Note: Aerial spraying occurred in winter 2008 and 2009, ground control occurred throughout. Cover class 3 = <5% cover (common), 2 = <5% cover (uncommon), 1 = <5% cover (one/few individuals), 0 = absent.

Summary

At Cape Byron Headland, bitou bush was reduced to insignificant levels after three years of control and native species richness has increased significantly since weed management began. These results have occurred despite dense bitou bush infestations at the outset and high public usage of the reserve. A dedicated bush regenerator and rapid and broad-scale control coupled with repeated follow-up control, made possible by consistent funding, likely contributed substantially to these results. The comprehensive monitoring program also contributed to the detection of these outcomes, which may be occurring at other sites but may not be detected due to lower levels of monitoring.

February 2008		**November 2008**	
August 2009		**November 2010**	
September 2011			

Figure 11: Photopoint images from Cape Byron Headland at Cape Byron State Conservation Area NR29 TAP site

Note: Weed management commenced in June 2008. Photos: Mark Hamilton

The reduction in bitou bush abundance has alleviated the threat of bitou bush to nearby Littoral rainforest and Themeda grassland stands. Prior to control on the headland, dense bitou bush provided no indication of the pre-invasion ecological community, hence the target community was unknown. It was thought Themeda grassland would establish following bitou bush control but this has not occurred to date. Other native and exotic grasses and herbs have colonised the site, and a mixture of *Banksia integrifolia* and Littoral rainforest species form the canopy. Despite decreases in bitou bush and increases in native species richness and cover, the community is still structurally poor (Figure 11). Wallaby grazing is likely to be significantly limiting plant growth on the headland, but continued growth of existing shrubs and trees should eventually change this community from the present open woodland with severely grazed understorey. For this reason, monitoring should continue.

Due to the rock crevice habitat of *Plectranthus cremnus*, the large anecdotal increase in abundance was unable to be captured in the sampling due to safety issues with sampling too close to cliff edges. The headland site is steep and dangerous along the cliff, which plunges into the ocean tens of metres below. Monitoring of species in such locations may be performed with photopoints as per the standard monitoring techniques.

Similar to several other TAP sites, monitoring plots at Cosy Corner and Clarkes Beach were established after initial control occurred. It is preferable to set up monitoring when prior to control to better show the changes that management can produce and to provide a baseline of exotic and native species present.

The monitoring program described in this case study is consistent with the monitoring manual advanced monitoring techniques. Set up time was five days and sampling required three people, three days to sample the three zones (72 person hours per year). This case study illustrates the importance of site managers choosing a range of methods to better sample their site. At the headland zone, a combination of line-intercept transects and small quadrats were used to sample shrubs and groundcover species respectively. The design of the monitoring program, including random location of plots and sufficient replication, allowed the detection of the bitou bush decline and native species response, even with loss of plots due to vandalism. A biodiversity response has been detected and the control zones are at a maintenance stage, with little mature bitou bush in the immediate area. However, monitoring is still required due to the threat of secondary weeds. Therefore, it is recommended that after 2012, monitoring frequency be reduced to intervals of two years. Due to the reduced control effort and the reduced monitoring frequency, the cost of control and monitoring at this site will be reduced over time.

NR63, 64 and 67 Bundjalung National Park

Photos: Andrew Fay

Site information

The three TAP sites are situated in Bundjalung National Park (NP), a coastal reserve covering over 20,326 ha on the North Coast of NSW (Figure 12). Within the reserve an area of 10,655 ha is gazetted as wilderness under the NSW *Wilderness Act 1987* and the Commonwealth Department of Defence (DoD) utilises an area within the park known as the Evans Head Defence Air Weapons Range. The reserve stretches 35 km from south of Evans Head village south to the Clarence River. Prior to being gazetted as a national park, between the 1930s and early 1980s, large areas of heathland and dunes were mined for mineral extraction. Post-mining rehabilitation involved planting of a limited number of native plant species, including *Acacia longifolia* ssp. *sophorae*, *Banksia integrifolia* and *Spinifex sericeus*. However, mapping of bitou bush in 2000 revealed that 680 ha of the weed occurred in the reserve, almost half of which was >40% crown cover.

In the summer of 2001–02 an intense wildfire burnt approximately two thirds of the reserve (south of Jerusalem Creek, see Figure 12), including the coastal sand dunes. This followed a large fire that burnt the northern section of the park the previous year. Intense fire is known to kill bitou bush but promote germination from soil and canopy seedbanks that can rapidly out-compete native vegetation. With this in mind, the fire was viewed as an opportunity to begin a long-term bitou bush control program that consisted of aerial spraying of low volume glyphosate, supplemented with ground-based spraying and some manual control. The DoD agreed to participate in the program and provide funding for control and monitoring activities. Aerial spraying has occurred in winter from 2002 to 2011 (over time the spray area was steadily decreased and aerial spot spraying was increasingly employed to target difficult to access infestations), and 104 ha was excluded from the spray zone due to the presence of glyphosate sensitive species or species with unknown sensitivity.

The TAP identified six sites in the reserve; sites NR63, NR64 and NR67 are covered here and included in the spray program. All sites are control category 1, the highest priority for control. A site management plan for the reserve was prepared in 2006. It divided the park up into TAP sites and work zones. Prior to the TAP, control was focused on protecting and regenerating the dunal communities. Since the TAP, the control program has shifted focus to protecting priority species.

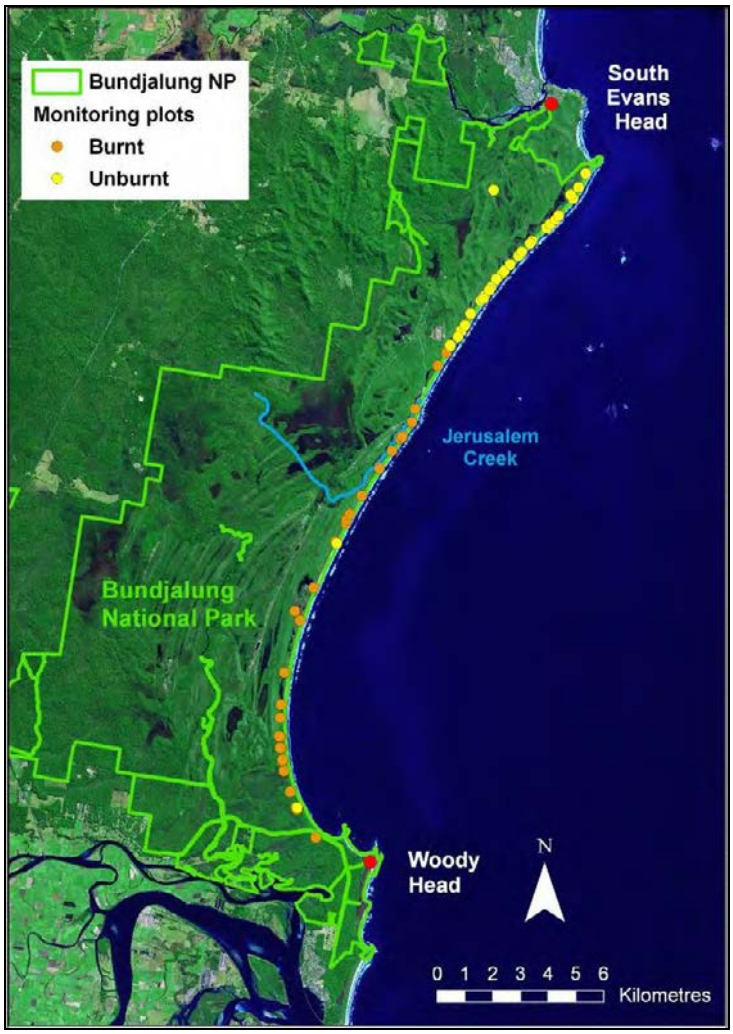


Figure 12: Map of Bundjalung National Park that contains NR63, NR64 and NR67 TAP sites

Note: Location of monitoring plots and whether they were burnt in a 2001 fire are indicated.

Biodiversity at risk

The park is home to a diverse range of vegetation types, from subtropical communities at the southern end of their range, to coastal communities, as well as many temperate species. Vegetation present within the TAP sites includes Littoral rainforest, Coastal Banksia Woodland and shrubland and grassland dominated by *Spinifex sericeus* and *Acacia longifolia* ssp. *sophorae*. Eleven species and five ecological communities were identified in the TAP for these sites, this included the high priority *Gleichenia mendellii*, *Ischaemum triticeum*, *Stackhousia spathulata*, *Vigna marina*, and Littoral rainforest EEC.

A site assessment revealed that bitou bush was having a medium to high impact on the high priority species and communities, but most were still capable of regeneration if bitou bush were removed. Due to the high likelihood of successful control at these sites, they were ranked high priority in the TAP.

Monitoring and results

A monitoring program was established with the overall objective of determining whether native vegetation and individual plant species were adversely impacted by aerial spraying of herbicide. The focus of this case study is on the response of bitou bush and changes in richness and abundance of native species in response to control efforts in the reserve. However, this case study may also be instructive to site managers with respect to the long-term nature of control and associated monitoring programs.

Monitoring plots were established in May 2002, prior to the first control but following the 2001–02 fire. Plots were sampled pre and post aerial spray to September 2005 and then only pre spray (annually). Plots were measured post spray to determine off-target effects of the herbicide spray, and prior to control to determine the effectiveness of the control in reducing bitou bush. Interim results were published in 2006 (Thomas *et al.* 2006).

Monitoring was conducted in 66 permanent quadrats that were systematically located 0.5–1 km apart. Quadrat dimensions were 4 x 4 m, which was considered sufficient to capture 50–75% of plant species at each site, whilst being small enough to accurately count seedlings. Cover abundance and seedling density data were collected for all species in each quadrat. Cover abundance was estimated visually and observer inconsistency and bias were reduced by the same observer conducting the monitoring. As multiple vegetation strata were measured, overlapping canopies (e.g. shrub cover underneath tree canopy) were counted individually – leading to cover greater than 100% (e.g. see Figure 14).

The cover of bitou bush generally decreased steadily in the first four years, or approximately 50 months, since control began (Figure 13), irrespective of whether plots were burnt or unburnt in 2001. The cover of bitou bush was reduced significantly over time (burnt and unburnt $p<0.00001$). More specifically, in unburnt plots the first pre-spray measurement to be significantly different to the baseline measurement was March 2003, seven months after the first aerial spray. Perhaps a more meaningful reduction was observed at September 2004 (34 months in Figure 13), where mean bitou bush cover was less than 1%. Mean crown cover only increased substantially following a fire in September 2007 in the northern section of the reserve. This fire stimulated bitou bush seed germination, and rapid seedling growth was responsible for the spike in bitou bush cover in 2008 (77 months since the 2001 fire). In burnt plots, the first pre-spray measurement to be significantly different to the baseline measurement was May 2005 or almost three years since the first aerial spray.

The cover of native species differed significantly over the monitoring period (burnt and unburnt $p<0.00001$). Across unburnt and burnt plots, the increase in native and decrease in exotic species abundance is apparent in Figure 14. The native to exotic species cover ratio also differed significantly over the monitoring period ($p<0.00001$). More specifically,

in unburnt plots it was not until September 2005 that native cover increased significantly from the baseline measurement, more than three years after the first control. In burnt plots, the first measurement to increase significantly from the baseline was September 2004, more than two years after the first control.

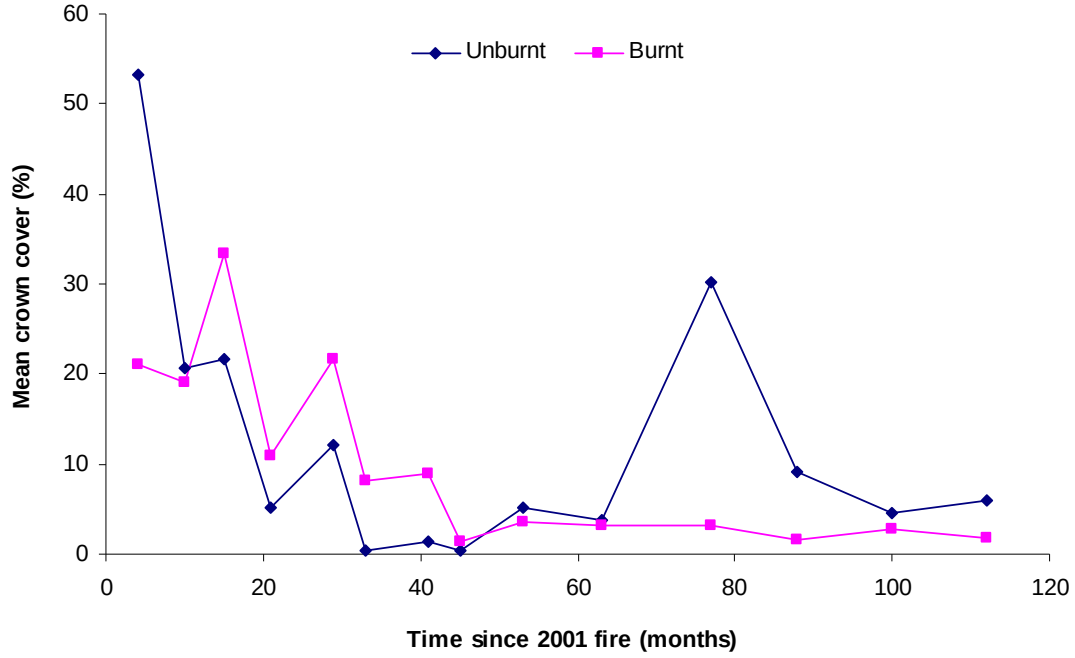


Figure 13: Changes in the mean cover of bitou bush in burnt and unburnt areas of Bundjalung National Park TAP sites (NR63, 64 and 67)

Note: Aerial spraying of glyphosate occurred annually in the winter, and ground control occurred throughout.

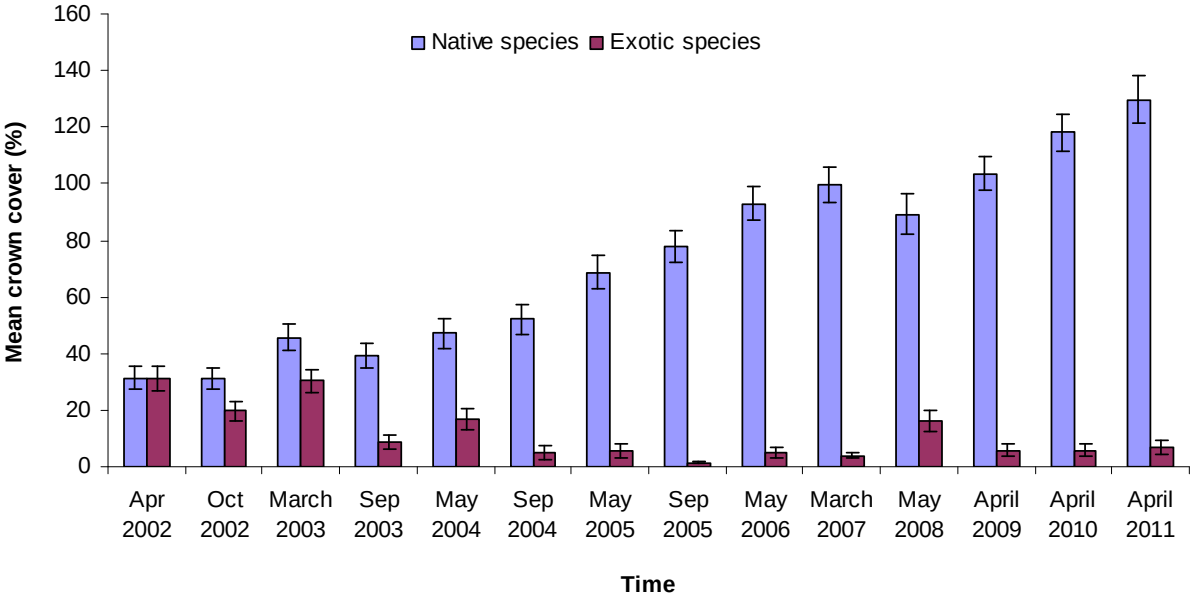


Figure 14: Change in mean crown cover of exotic (incl. bitou bush) and native species (±1 standard error) at Bundjalung National Park NR63, 64 and 67 TAP sites

Note: Burnt and unburnt data are combined.

Across unburnt and burnt plots, native species richness ranged from 6.5 to 8.2 species per 16 m^2 and did not differ significantly over the monitoring period (p=0.71). Exotic species richness was much lower and ranged from 0.7 to 1.5 species per 16 m^2. The only significant difference (p=0.001) in exotic species richness occurred between September 2003 and September 2004. The reasons for this are unknown and unimportant given the low exotic species density.

Summary

Over a large and remote coastal park, bitou bush was effectively controlled and reduced to an insignificant abundance in less than three years using a combination of aerial and ground spraying, and manual control. While above ground bitou bush abundance was clearly reduced, it is important to remember bitou bush propagules exist in the seedbank and are a ready source of regeneration post fire or disturbance. Following the 2001 fire, reduction in bitou bush abundance in fire-affected areas was slower. After the 2007 fire, bitou bush abundance increased markedly, due to fire-stimulated germination and subsequent rapid growth. Site managers should be mindful of the potential for such rapid reinvasion, especially where infestations are old and substantial seedbanks may exist.

The cover of native species increased significantly at 2.5–3 years after the initial control (and only with repeated follow-up). Note, this pattern was observed in dune landscapes and may differ on the heavier soils of headlands. The trend of increasing native abundance continued over the course of monitoring and does not seem to be halting (Figure 14). Notwithstanding this trend, the structure of the ecological communities is likely still developing and recovery may take much longer. In light of this, many control and monitoring programs are funded by grants, which rarely exceed three years in duration. This case study demonstrates that over such short time periods, a bitou bush reduction and native species response may occur, but with lower spatial and temporal replication, may not be detected. In addition, as this case study shows, bitou bush infestations can recover rapidly following disturbance events such as wildfire. This highlights the need for continued follow-up long after initial control and grant funding has ceased.

Increases in native species richness at Bundjalung NP could not be detected. This may be due to the small plot sizes. The 4 x 4 m plot dimensions were specifically chosen to allow accurate counts of seedlings to be made, and thus may not have been large enough to be representative of species richness (i.e. to include the majority of species). Though exotic species richness did increase between two samples in 2003–04, exotic richness was low and most likely consisted primarily of bitou bush.

The importance of collecting baseline data prior to initiating control is paramount. Many monitoring programs are set up after the initial control event, with the pre-invasion state of the infestation and native species being unknown. A before and after control comparison is used as the experimental design for this monitoring program, as at most other TAP sites. It is essential that the ‘before’ data is collected when the infestation is untreated and when the native flora is assumed to be impacted. Similarly, if resources allow sampling only once per year, the ‘after’ measurement should be collected just prior to the next control event, when the inter-control period is longest and the effects of previous control on the target weed/s are less pronounced.

The monitoring effort in this case study exceeds what is required or expected of TAP site managers, in terms of the number of quadrats and the frequency of sampling. The placement of 66 quadrats that were sampled annually for nine years (biannually for the first four years), and the employment of a consultant ecologist to set up and undertake the monitoring, represents a significant time and money investment, though importantly, this investment was across three large TAP sites. The frequency of sampling conducted at Bundjalung NP may not be required at other TAP sites; however, with any monitoring program, data analysis should occur regularly to ascertain the response of weeds and natives and to determine if a reduction in sampling frequency is feasible.

While the control of bitou bush at Bundjalung NP began prior to the completion of the TAP, this case study provides an indication of the intensity and duration of management required to achieve threat abatement and a positive response of native species, as well as the need for long-term monitoring to detect these changes. The level of plot replication at this site exceeds that required for the advanced techniques in the monitoring manual and the monitoring also contains aspects of the research-level techniques. However, a research-level study as defined in the monitoring manual, would require an experimental control (untreated quadrats) and/or reference sites (quadrats in uninvaded natural sites).

NR148 Sea Acres National Park (demonstration site)

Photo: Cathy Mardell

Site information

Sea Acres NP (formerly Sea Acres Nature Reserve) is located on the mid north coast of NSW, approximately 400 km north of Sydney. It covers an area of approximately 76 ha within the town of Port Macquarie. The TAP site NR148 in this park is a control category 1 site and contains *Sophora tomentosa, Acronychia littoralis*, *Cynanchum elegans, Zieria smithii* (low growing form), and Littoral rainforest and Themeda grassland EECs.

A demonstration site was established north of Miners Beach to trial the effectiveness of various bitou bush control measures. Sampling occurred from April 2001 to April 2007. Although this site was established prior to the TAP publication, it demonstrates the use of photopoints and transects to measure general biodiversity response following weed management.

The original purpose of the demonstration site was to trial bitou bush management practices, monitor the results, promote bitou bush management and restore native vegetation. Three management zones were established, including: spray with glyphosate, spray with metsulfuron methyl and hand removal with cut and paint. All other weeds were also treated at the site. Although a variety of management techniques were trialled in the zones, results presented below concentrate on the objective of restoring native vegetation, regardless of the method used to remove bitou bush and other weeds.

Monitoring and results

The demonstration area is on a headland with shallow soils derived from serpentinite and basalt. The original vegetation prior to bitou bush invasion was a rainforest/banksia woodland ecotone with Themeda grassland on the most exposed areas.

Three 50 m transects were established, one in each of three zones. The line-intercept method was used to record all plant species and their cover abundance. Photos were also taken along each transect.

The first treatment of bitou bush occurred in April 2001. Each transect received different management techniques, but all were used as individual replicates to show the general vegetation response to management.

The cover of bitou bush was reduced from 83% in April 2001 to <1% by November 2002 and maintained at this level to June 2006, when sampling of transects ceased ($p<0.0001$, Figure 15). Photopoints from April 2007 also confirm that bitou bush suppression was maintained (for example see Figure 17).

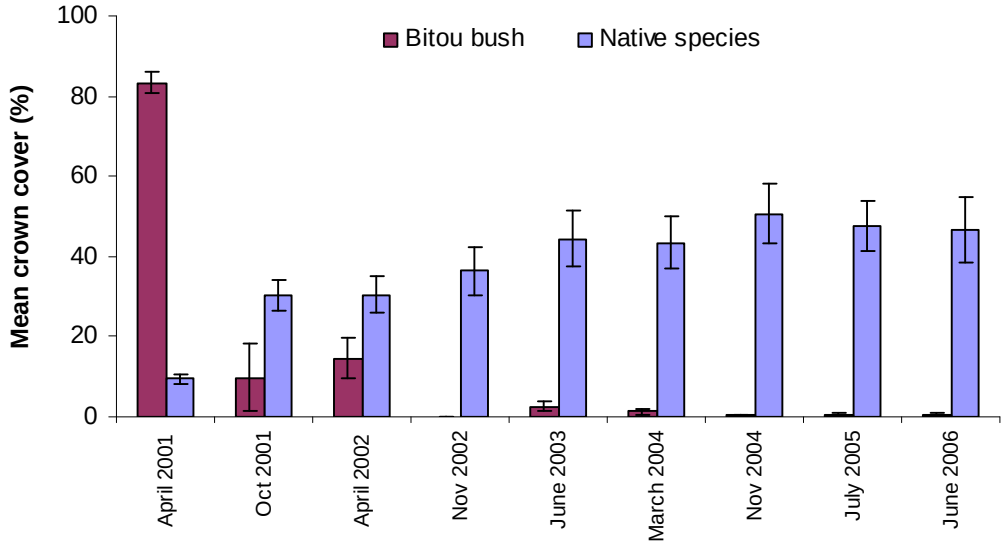


Figure 15: Mean crown cover of bitou bush and all native plant species (±1 standard error) across three transects at Sea Acres demonstration site

Note: Weed management commenced in April 2001 and occurred throughout.

The cover of native species increased over the monitoring period ($p<0.0001$, Figure 15). The number of native species also increased, while the number of exotic species remained at a low level ($p=0.02$, Figure 16).

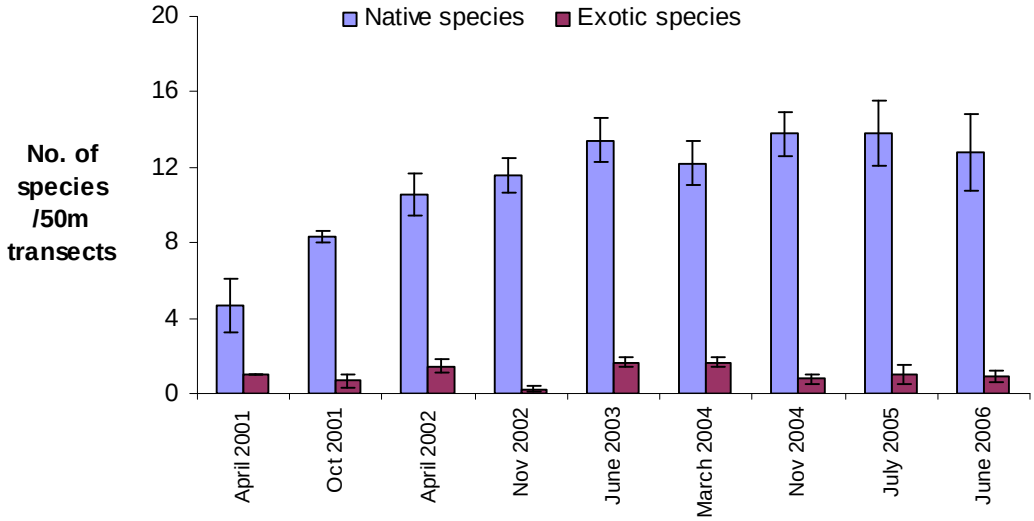


Figure 16. Mean number of native and exotic species (±1 standard error) across three transects at Sea Acres demonstration site

Note: Weed management commenced in April 2001 and occurred throughout.

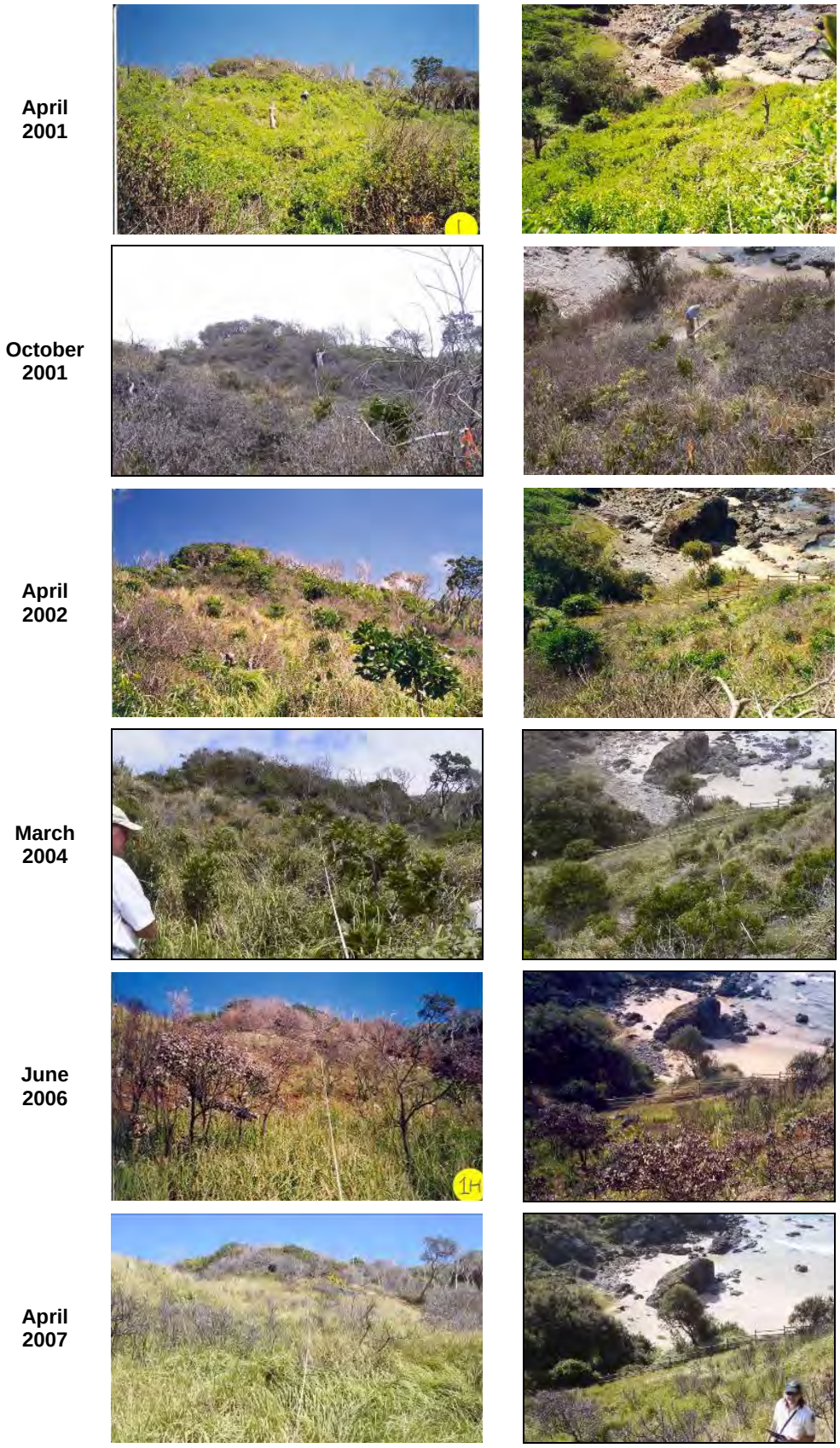


Figure 17: Photopoint images from Sea Acres demonstration site

Note: Weed management commenced in April 2001 and occurred throughout. Photos: Jeff Thomas

Summary

Bitou bush was reduced to insignificant levels after 19 months of intense control and native species richness and abundance has increased since weed management began. Bitou bush and other weeds were still present at the site, so follow-up and maintenance would be needed.

The monitoring program described above is consistent with the monitoring manual advanced monitoring techniques. At this site, the response of native vegetation was able to be detected due to the replication (both temporal and spatial) of the monitoring. The photopoints also visually support the quantitative results from transects. Given this was a demonstration site, it was appropriate to cease monitoring in April 2007. This is due to the minimal changes in biodiversity over the final three years. However, at other high priority sites, it would be appropriate to resample such a site, but less frequently. For example, provided that ongoing maintenance control occurred, resampling could occur every three years.

The average year that management commenced at TAP sites was in 2002, four years before the TAP was released. Unfortunately, many TAP sites had management commence before the TAP was published, but monitoring programs were not established until TAP implementation post 2006. At this demonstration site the native vegetation response was detected in the first two years. This could also be the situation for many of the bitou bush managed high priority TAP sites if monitoring was set up prior to control and sampling was sufficient. If such an approach was followed at the demonstration site, that is, monitoring established post control, the site manager may not have been able to detect a change in biodiversity. Therefore, where possible, monitoring should be established prior to control.

Species case studies

The TAP identified 158 native plant species at risk from bitou bush in NSW. This was later revised to 157 in Hamilton *et al.* (2008) due to an orchid species being no longer considered a distinct species. Nineteen of the 157 species were determined to be at the highest risk from bitou bush invasion. This risk was determined by considering habitat susceptibility, distribution of the species relative to bitou bush, individual species' susceptibility to invasion, and species' ability to persist.

In the TAP, 152 occurrences of high priority species were documented at control category 1 sites. Many of these high priority sites had more than one high priority species present (Table 9). Through implementation of the TAP, involving site-specific management plan preparation, monitoring, progress reporting and annual scientific licence reporting, a further 56 occurrences of high priority species at control category 1 sites were identified. An occurrence is defined as a species' presence at a site. Some of these new reports represented a significant expansion in range or new localities for species. This result illustrates the heightened awareness of these at-risk species and the possible recolonisation of habitats vacated where bitou bush was controlled.

Of the 208 occurrences of high priority species at control category 1 sites, 181 were at managed sites, but only 38 were captured within formal monitoring programs. Where formal monitoring did not occur, a further 46 occurrences of high priority species were observed, photographed, or location details were provided to the TAP Coordinator.

In total, 108 control category 1 sites had records of high priority species being present. Two high priority species, *Fontainea oraria* and *Poa poiformis*, did not occur at any sites (control category 1 or otherwise) where the TAP was implemented, though bitou bush control occurred at the TAP sites where these species are present but not under an approved site management plan. Twelve of the 19 high priority species were captured in

monitoring programs. Species abundance was monitored and, for one species, mapping the extent of the population was undertaken. Four of the 12 monitored species had only been sampled once (mostly prior to control, with post-control monitoring to occur following this review). For the remaining eight species, most monitoring at the sites was not specifically targeted at the high priority species, with monitoring mostly being undertaken to measure the overall biodiversity response and the response of bitou bush to management. Therefore, monitoring of high priority species was mostly incidental or there was insufficient replication at the site level to be representative of the population at the site. However, six species were monitored at two or more sites prior to and following control. Of these, monitoring results for *Chamaesyce psammogeton*, *Stackhousia spathulata* and *Westringia fruticosa* are detailed below as case studies.

Table 9: Occurrence of high priority species at control category 1 sites listed in the TAP

Note: An occurrence is defined as a species' presence at a site. Note, often multiple high priority species were present at a site so number of occurrences is not equal to number of sites.

Species	Rank	Number of occurrences		
		2006 (TAP)	New occurrences	All
*Acianthus exiguus**	4	4	0	4
Actites megalocarpus	14	3	3	6
Calystegia soldanella	4	1	3	4
Chamaecrista maritima	4	2	2	4
*Chamaesyce psammogeton**	3	21	3	24
*Diuris praecox**	17	6	1	7
*Fontainea oraria**	17	2	0	2
Gleichenia mendellii	14	8	1	9
Ischaemum triticeum	4	10	8	18
Lepturus repens	4	1	4	5
*Plectranthus cremnus**	1	13	5	18
Poa poiformis	14	2	0	2
*Pultenaea maritima**	4	12	6	18
*Senecio spathulatus**	4	7	1	8
*Sophora tomentosa**	4	10	2	12
Stackhousia spathulata	4	24	3	27
Vigna marina	4	8	6	15
Westringia fruticosa	19	15	8	22
*Zieria prostrata**	2	3	0	3
Total		**152**	**56**	**208**

*species listed under the TSC Act, Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, or as a Rare or Threatened Australian Plant (Briggs & Leigh 1995).

Chamaesyce psammogeton

Sand spurge

EUPHORBIACEAE

Photo: Jeff Thomas

Photo: Ian Hutton

Photo: Mark Hamilton

Background information

Chamaesyce psammogeton is a prostrate perennial herb that forms mats to 1 m in diameter. Flowering occurs in summer and is followed by small capsules that are water dispersed. It grows on sand dunes and exposed headlands on the coast, with favoured habitat being open sand areas such as incipient foredunes and sparsely vegetated dunes close to the sea. It is endemic to Lord Howe Island and the eastern seaboard of Australia, occurring sporadically from Jervis Bay, NSW, to Mackay, Queensland. The species was listed as endangered under the TSC Act due to noted declines in distribution and threats from disturbance to the foredune habitat and overgrowth by bitou bush.

Priority sites

The TAP identified 26 sites where bitou bush was threatening *C. psammogeton*, including 21 control category 1 sites, two category 2 sites, and three sites that were not modelled due to insufficient information. Through site management plan preparation, monitoring or site assessments, a further three control category 1 sites were identified for this species. In total, 17 sites were managed for bitou bush within the last five years (Figure 18), all control category 1 sites.

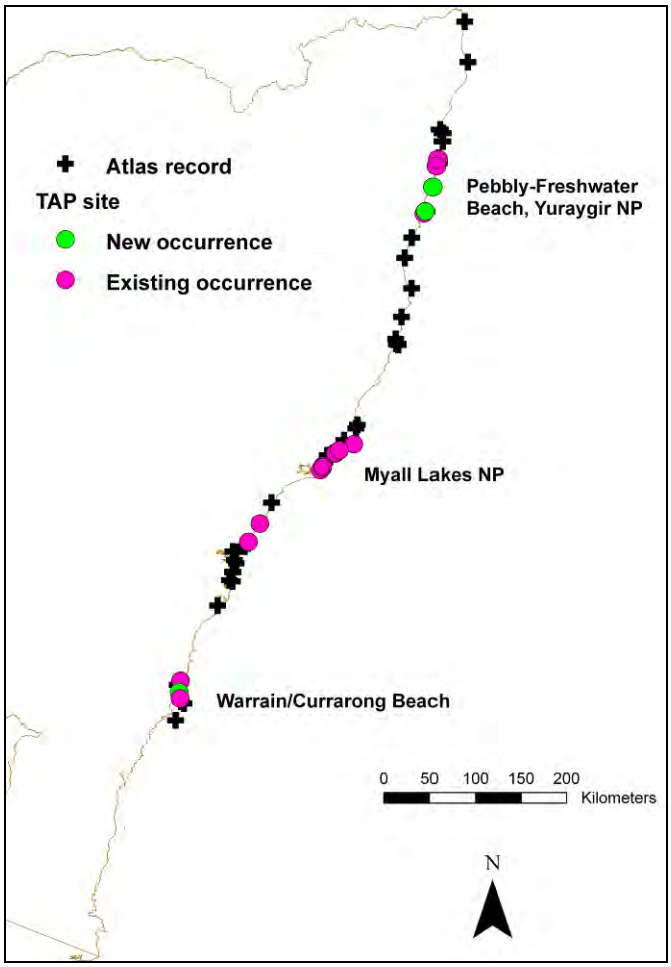


Figure 18: Distribution of *Chamaesyce psammogeton* and the managed priority sites for the species under the TAP

Note: The three labelled sites indicate where monitoring of this native species occurred. Existing sites were those identified in the TAP, new sites were identified as part of the TAP implementation. Species records were sourced from the OEH's Atlas of NSW Wildlife, which holds data from a number of custodians. Data obtained 23/11/2011.

Monitoring

Bitou bush

Bitou bush cover abundance was monitored at five *C. psammogeton* priority sites and density was measured at a further one site (Table 10). Due to management and monitoring beginning at sites at different times this data could not be reported as an aggregate. However, when taking the median value of cover classes prior to and at the last monitoring event, all five sites reported reductions in bitou bush cover. Where density was measured at the additional priority site, bitou bush was managed prior to monitoring but was kept low.

Species at risk

Site managers at six sites recorded observations of the effect control techniques had on *C. psammogeton*, as per the *Best Practice Guidelines for Aerial Spraying of Bitou Bush in NSW* (Broese van Groenou & Downey 2006). All reported that there was 'no damage' to the species as a result of their control techniques.

Table 10: Overview of monitoring programs and changes in bitou bush abundance at *Chamaesyce psammogeton* priority sites identified in the TAP

Site no. and name	Sampling unit	Data collected	No. of sampling units	Years monitored	Result
HCR41 Yagon Gibber, Myall Lakes NP	Quadrat	Braun Blanquet cover abundance	2	2009–2011	Decreased from a median 51–75% to 6–25% cover
HCR42 Coastline from Big Gibber to Banksia Green	Quadrat	Braun Blanquet cover abundance	2	2009–2011	Decreased from a median 26–50% to 6–25% cover
	Line-intercept transect	Cover (distance)	5	2007–2009	Decreased from a mean 35% to 7%
HCR46 Bennetts Beach	Radial plot	Braun Blanquet cover abundance	2	2009–2011	Decreased from a median 51–75% to 26–50% cover
HCR48 Yacaaba Peninsula	Radial plot	Braun Blanquet cover abundance	1	2009–2011	Decreased from a median 76–100% to 26–50% cover
HCR108 Wamberal Lagoon NR	Quadrat	Braun Blanquet cover abundance	2	2007–2010	Decreased from a median 76–100% to <5% cover
SR16 Warrain Beach / Currarong Beach	Quadrat	Plant density	6	2007–2011	Decreased from 17.5 to 4 individuals per 400 m^2

Monitoring the response of the species to weed management occurred at three TAP sites, including at Myall Lakes NP (HCR42) in Great Lakes LGA, at Warrain/Currarong Beach (SR16) in Shoalhaven LGA, and in Yuraygir NP (NR87) in Clarence Valley LGA. At Yuraygir NP, formal monitoring only began in 2010 and post-control sampling has not yet occurred. Previously at this site, two populations of the species were recorded in 2001; both disappeared following vegetation changes after bitou bush control, with infilling of open spaces by spinifex and coastal wattle. At the remaining two sites monitoring techniques varied thus site results are reported separately here.

At the Warrain/Currarong Beach site, the population of *C. psammogeton* was monitored in a 20 x 20 m permanent quadrat. The number of adult and juvenile *C. psammogeton* and bitou bush individuals were counted. Evidence of rabbit or wallaby grazing was observed and the site manager placed wire guards around adult specimens. The threat from bitou bush and other weeds was kept low but it was not until four years after management commenced that there was a large increase in *C. psammogeton* density (Figure 19).

At the Big Gibber to Banksia Green, Myall Lakes NP site, *C. psammogeton* was monitored through two programs, one not specifically targeted to the species and the other targeted to determine the effects of aerial spraying. The first employed five 20 m transects and measured plant cover by intercept length along the transect. *C. psammogeton* cover was captured along one transect and showed negligible change from 2007 to 2009 (from 0.25% cover in 2007, 1.6% in 2008, and 0.16% in 2009), whilst all native species cover increased from 11% to 22% (in a sparsely vegetated dune).

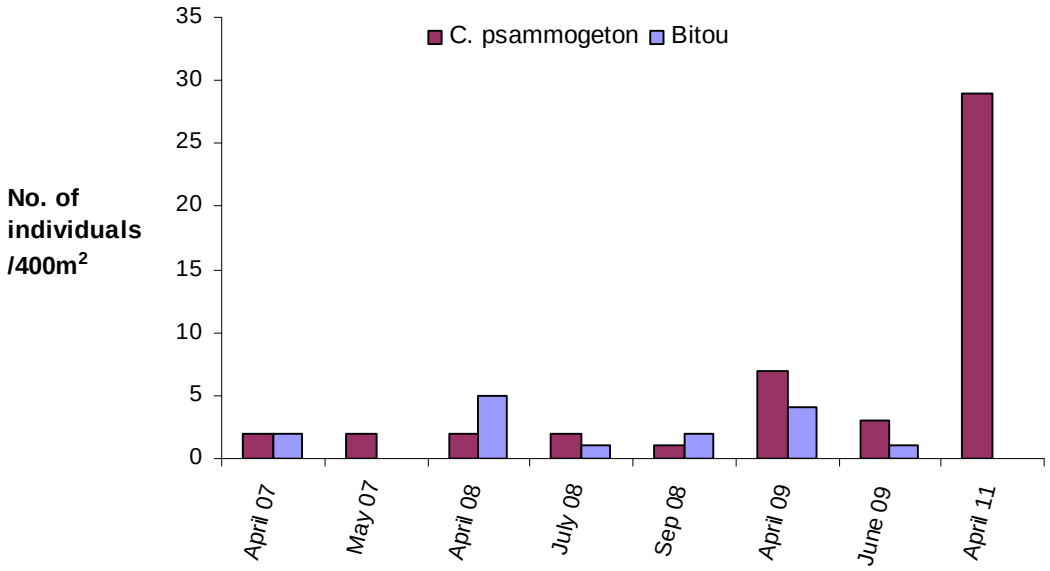


Figure 19: Change in the number of individuals of bitou bush and *Chamaesyce psammogeton* in response to bitou bush management at Warrain/Currarong Beach priority site (SR16)

Note: Density encompassed all age classes.

The second monitoring program monitored the response of *C. psammogeton* and *Senecio spathulatus* to aerial spraying of metsulfuron methyl (30g/ha). Fourteen 2 x 10 m plots were established in the habitat of the two species, seven located in a spray area and seven in a no-spray area. Plots were sampled one month prior to the aerial spray, and three and nine months following the spray. Species cover was measured by dividing plots into 1 m^2 grids and measuring cover abundance.

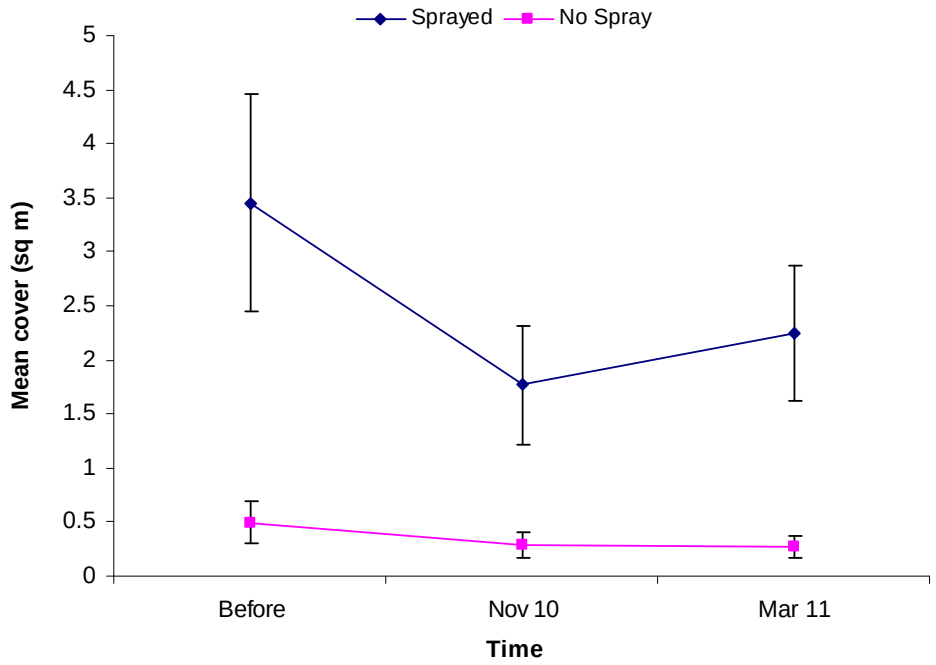


Figure 20: Mean cover of *Chamaesyce psammogeton* (±1 standard error) at the Myall Lakes priority site (HCR42) in response to aerial spraying of metsulfuron methyl (30g/ha)

Note: Aerial spraying occurred in June 2010.

Aerial spraying had no significant effect on the cover of *C. psammogeton.* Although cover differed significantly between spray and no-spray plots (p=0.0000), cover did not change significantly before and after spraying (Figure 20) (p=0.2045). When taking into account spray/no-spray and sampling period, cover was also not significantly different (p=0.3909).

Discussion

General reduction in bitou bush and other weeds at priority sites has likely been beneficial to *C. psammogeton*; however, targeted and formal monitoring of *C. psammogeton* was not performed extensively at priority sites. Species-specific monitoring undertaken is mostly inconclusive regarding the response of *C. psammogeton* to weed management. Monitoring at the Warrain/Currarong Beach site consisted of one plot, precluding statistical analysis, but showed a large increase in the density of *C. psammogeton* in the final year of monitoring, following a germination event. Whether this is representative of the site is unknown. Results may also suggest that even in the absence of weed impact, considerable time may be required for a measurable increase in abundance to occur. In addition, this response may have only occurred in conjunction with other recovery actions, e.g. preventing herbivore grazing.

Monitoring of bitou bush at the six monitored *C. psammogeton* priority sites was not standardised or undertaken at similar times or periods. Therefore site results could not be collated, analysed and reported collectively. The monitoring manual (Hughes *et al.* 2009) outlines standardised methods for site managers but most of the monitoring for this species was initiated prior to the manual's release in 2009. In addition, replication of plots within sites was low, which reduced the validity of performing statistical analysis within sites and the ability to monitor whole populations. Recommendations are made within the monitoring manual regarding the number of plots to establish.

Monitoring at the Myall Lakes NP site is only short-term but no statistical impact was detected from aerial spraying. These results also suggest there may be seasonal fluctuations in cover that may confound assessment of this species' response if experimental control plots are not monitored.

Though the response of the species to control was not determined, it is clear there are difficulties in monitoring this species. Aside from its small and unremarkable habit, specific difficulties include: the species' propensity to grow in transient habitats vulnerable to coastal erosion (populations have been lost due to storm events); the apparent seasonal fluctuations in abundance; and the successional changes in the ecological community that may alter the species' preferred open sand habitat. Other issues, which are common to several high priority species, include: the delicate nature of the species and its habitat, which may discourage repeated monitoring; and the extremely small population sizes, which requires the whole population to be sampled. These difficulties highlight the limited suitability of permanent plots (as recommended in the monitoring manual) for monitoring such species after weed control. For example, there is the possibility of storm damage and vandalism of permanent plots on the relatively open foredune and incipient dune. However, where permanent plots can be re-sampled the monitored individuals may apparently 'disappear' from the plots only for the population to appear in another part of the site outside of monitoring plots. Similarly, in the absence of non-treatment plots, reductions in abundance may be attributed to off-target impacts from weed control when seasonal fluctuations in abundance may be responsible. Both situations could lead to the false conclusion of species decline due to weed control. For this and other hard-to-monitor species there may need to be a case-by-case assessment made as to the feasibility of monitoring such species and, if feasible, the monitoring technique to utilise.

Further monitoring recommendations for high priority species are detailed below in the discussion section of the review.

Stackhousia spathulata
STACKHOUSIACEAE

Photo: Mark Hamilton

Photo: Glenn Leiper

Photo: © Bush Restoration Services

Background information

Stackhousia spathulata is a perennial, spreading herb growing to 50 cm high. It grows in heath and dry sclerophyll forest in sandy regions, often near beaches or lagoons. Observation of the species suggests that in NSW it prefers open sand habitats on the incipient and foredune. It has a wide distribution from Port Augusta, South Australia to Hervey Bay, Queensland and although widespread in coastal districts, in NSW it occurs only sporadically.

Priority sites

A total of 24 priority sites were identified in the TAP for this species, all control category 1 sites. Since the release of the TAP, the species was found at a further three control category 1 sites following site management and monitoring. Twenty-four of the 27 sites (89%) were managed for bitou bush (Figure 21), but five sites did not have approved site management plans.

Monitoring

Bitou bush

Bitou bush cover abundance was monitored at 11 *S. spathulata* priority sites, for one of which only baseline data were available. Due to management and monitoring beginning at sites at different times this data could not be reported collectively. However, when taking the median value of cover classes prior to and at the last monitoring event, nine of the ten sites recorded a reduction in bitou bush cover (six to <5% cover), and no change was recorded at another site (due to extensive control prior to the TAP and infestations being kept low). Density of bitou bush was measured at a further five sites and was reduced from an average of 12.8 plants per 400 m^2 in 2007 to 1.9 in 2011 (Figure 22), but was not significantly different between years (p=0.45).

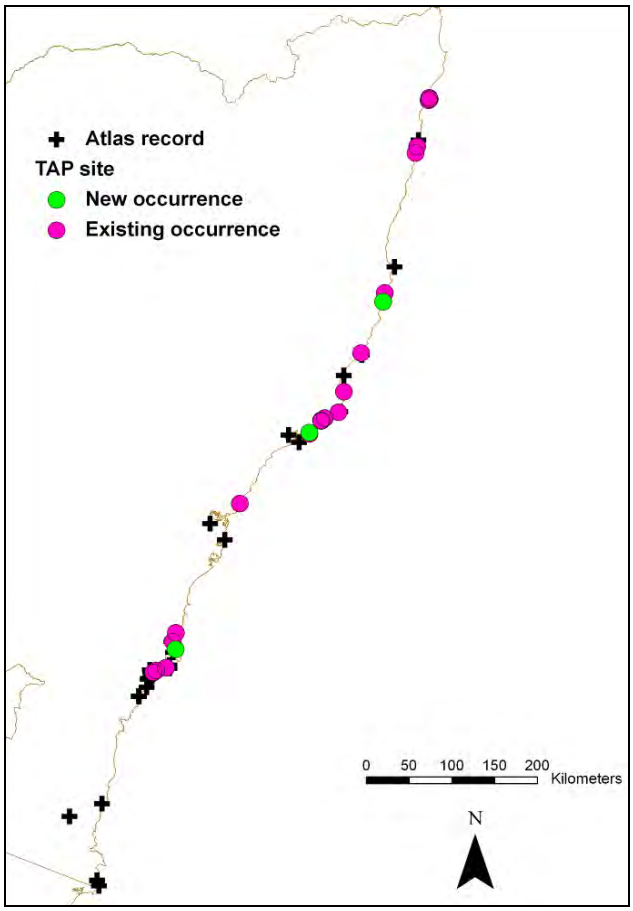


Figure 21: Distribution of *Stackhousia spathulata* and the managed priority sites for the species under the TAP

Note: Existing sites were those identified in the TAP; new sites were identified as part of the TAP implementation. Species records were sourced from the OEH's Atlas of NSW Wildlife, which holds data from a number of custodians. Data obtained 23/11/2011.

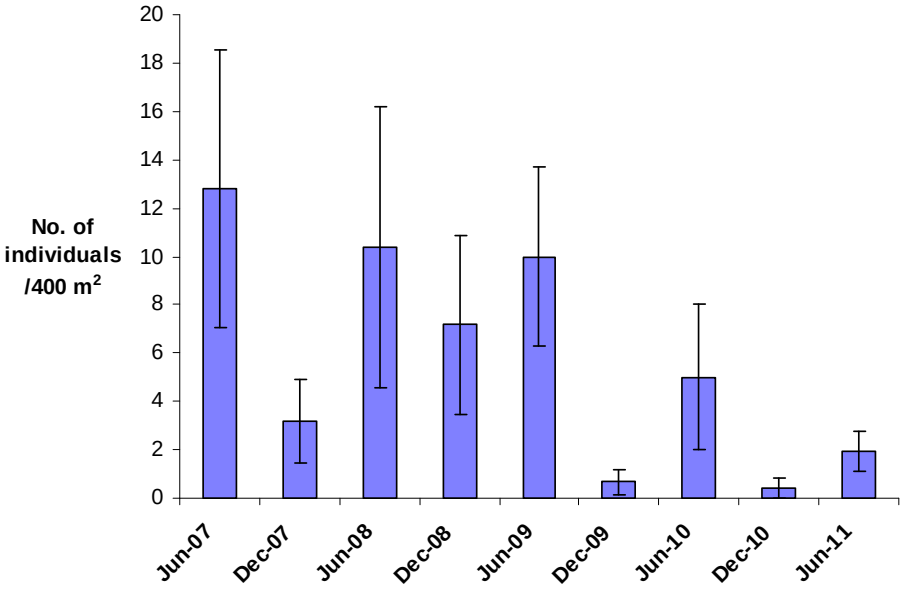


Figure 22: Mean bitou bush density across years at five *Stackhousia spathulata* priority sites where the TAP was implemented

Note: Density encompassed all age classes.

Species at risk

S. spathulata was monitored at eight priority sites, five in Southern Rivers CMA and three in Hunter-Central Rivers CMA. The former involved targeted and standardised monitoring of the species via counting individuals in six 20 x 20 m plots. Results from the Southern Rivers CMA sites are illustrated in Figure 23. There is no significant difference in the number of individuals over time (p=0.56). The large increase in number of individuals in 2011 is due to a large germination event in one of the six plots.

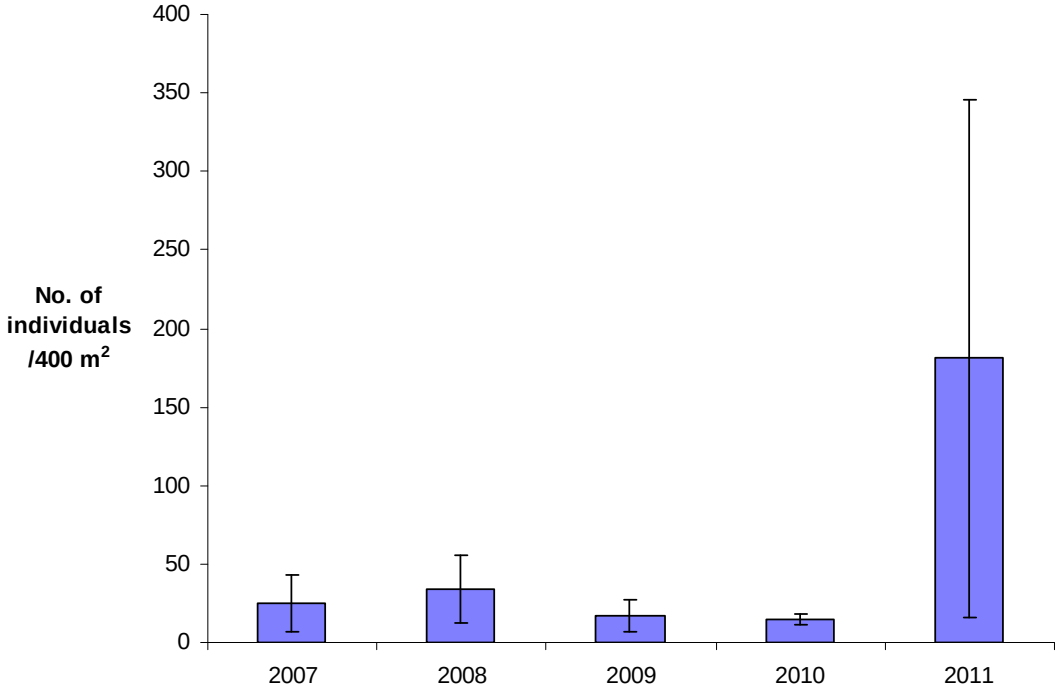


Figure 23: Mean plant density of *Stackhousia spathulata* across years at five priority sites in Southern Rivers CMA in response to weed control

Note: Density encompassed all age classes.

Monitoring at the Hunter-Central Rivers sites was not standardised across sites and consisted of transects and quadrats that had low replication (both spatially and temporally). Cover abundance was measured or estimated and results are inconclusive as regards response of the species. However, in brief, one site reported low abundance for two years and then absence in the third and final year of monitoring; another reported no change in abundance over 2 years; and the last reported the species colonising the sole plot but at low abundance (<5% cover).

In addition to the above monitoring, this species was observed and informally monitored at a further five priority sites, two noting anecdotal increases in populations and three noting the continued presence of populations. Site managers also reported the species' response to control (as per the *Best Practice Guidelines for Aerial Spraying of Bitou Bush in NSW* (Broese van Groenou & Downey 2006)) on six occasions at five sites. Five observations were 'no damage' and one was 'moderate dead', a case of mistaken identity by a contractor.

At other TAP sites within Yuraygir NP (in Northern Rivers CMA), the site manager has observed major changes in populations as a result of bitou bush control and landscape changes. Six populations were recorded in 2004, and have since disappeared or diminished due to ongoing coastal erosion removing habitat. However, control of bitou

bush infestations in extensive coffee rock areas has resulted in hundreds of new individuals being observed in these areas. Maximum numbers seem to be attained 1–2 years after initial control, when dead bitou bush frames are still evident and colonisation of other species has not occurred to any degree.

Discussion

Management of sites where this species and bitou bush are present was comprehensive, with 24 of the total 27 priority sites with this species receiving management. Priority sites were managed across almost the entire weed-affected distribution of the species in NSW, likely alleviating the threat of weeds to many of the species' populations in NSW. However, monitoring of bitou bush and native species across sites was not standardised or performed at the same time. Nevertheless, analysis of monitoring on a site-by-site basis revealed that bitou bush abundance at most monitored sites decreased when taking the median cover class prior to control and at the last monitoring event.

Monitoring of the species at risk was mostly inconclusive, even amongst sites with standardised monitoring. Replication within sites was insufficient to detect changes in populations of *S. spathulata* and methods across sites differed, which precluded a thorough analysis of the species' response across priority sites. At the Southern Rivers CMA priority sites, variability in the data led to a result of no significant change in the species' abundance over time, even when the threat of weeds was kept at a minimum. Though a positive change in abundance was not detected, there was a continued presence of the species at most sites and a likely positive trend in abundance. Also, management had no off-target impacts, except in one instance of misidentification.

Similar to *C. psammogeton*, it is likely that abundance of this species is dictated by a variety of factors, only one of which is impacts from weeds. Hence monitoring programs with differing methods, inadequate spatial and temporal replication, and conducted with limited resources are unlikely to yield statistically valid results.

S. spathulata grows in a similar habitat to *C. psammogeton*, and the species often co-occur. Many of the limitations in monitoring *C. psammogeton* are evident for this species, including the species' sporadic occurrence, habitat that often includes the incipient and foredune, and the delicate habit and habitat of the species.

Monitoring of this species at priority sites should continue in order to better determine its response to bitou bush and weed control. However, incidental or low frequency monitoring will not suffice to determine the species' response to control. It is recommended that the rare species methods and datasheets in the monitoring manual be used at sites where populations are still at risk from weeds and where the aim of monitoring is to show a population change following weed management. It is advised to monitor complete populations or distinct sub-populations of species at sites. The rare species methods do not record abundance (only number of individuals). Where this is required, plot-based sampling should occur. Randomly placing plots across a site is unlikely to adequately sample populations. Monitoring all individuals or randomly placing plots within the area over which the population exists is recommended. For this, plot replication needs to be high, and will invariably have to be balanced with available resources. Other possible methods include the T-Square methods and variations of this that involve long transects.

Westringia fruticosa

Coastal rosemary

LAMIACEAE

Photo: Paul Downey

Photo: Jaime Plaza

Background information

Westringia fruticosa is a perennial compact shrub growing 1−2 m high. It grows near the sea and estuary foreshores, often on exposed cliffs and headlands. It has a distribution spanning from Scotts Head in the north to the Victorian border in the south. Much of the species' range is encompassed by that of bitou bush. *Westringia fruticosa* is a component of Themeda grassland on seacliffs and coastal headlands, an EEC. It is extensively planted as an ornamental for its hardy nature and small white flowers.

Priority sites

The TAP identified 17 sites where bitou bush was threatening *W. fruticosa*, this included 15 control category 1 and two category 2 sites. Through site management plan preparation, monitoring or site assessments, a further eight category 1 sites were identified for this species. In total, 16 sites were managed for bitou bush within the last five years (Figure 24), all control category 1 sites.

Monitoring

Bitou bush

Bitou bush abundance was measured at 11 priority sites for the species. Bitou bush density was measured at three sites, cover at seven sites, and the area of bitou bush was mapped at one site. Bitou bush was monitored at a further site using photopoints. Due to management and monitoring beginning at sites at different times this data could not be reported collectively. However, when taking the median value of cover classes prior to and at the last monitoring event, all seven sites where cover abundance was measured showed substantial reduction in bitou bush cover, most to around 5% cover, the highest final cover was 14%. The average density of bitou bush at the three sites where density was measured showed good reductions, from an average of 11.3 plants per 400 m^2 in 2007 to 1.9 in 2011. The area of bitou bush at the remaining site where bitou bush was mapped showed a reduction from 31 ha in 2009 to 2 ha in 2011.

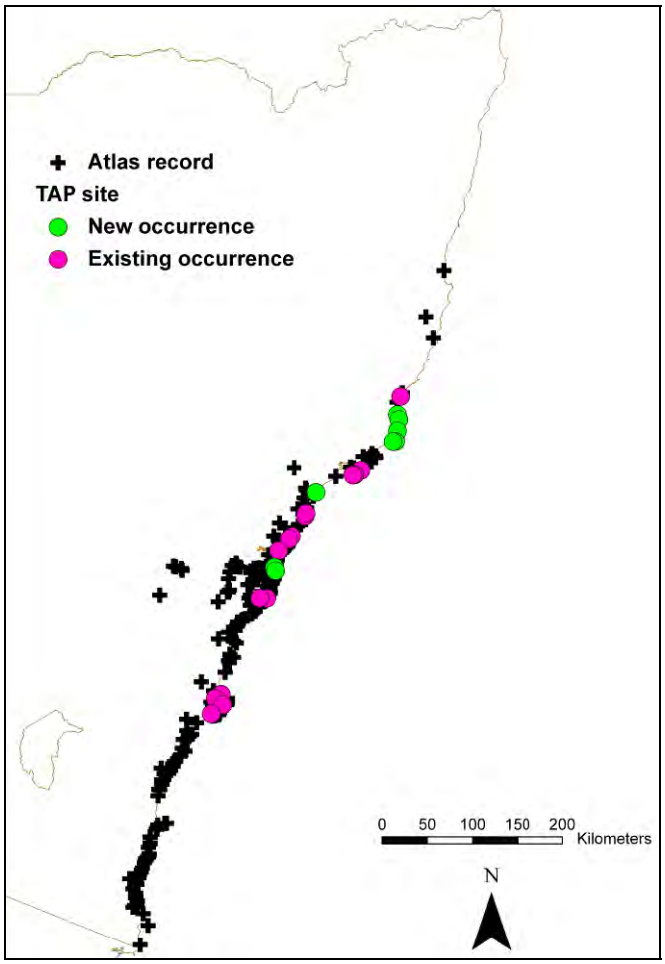


Figure 24: Distribution of *Westringia fruticosa* and the managed priority sites for the species under the TAP

Note: Existing sites were those identified in the TAP, new sites were identified as part of the TAP implementation. Species records sourced from the NSW Office of Environment and Heritage's Atlas of NSW Wildlife, which holds data from a number of custodians. Data obtained 23/11/2011.

Species at risk

The species was monitored at eight priority sites, for one of which only baseline data were available, and another where management did not occur between monitoring events. At the remaining six sites, species abundance was measured along transects and in quadrats and radial plots. There was insufficient data to perform statistical analysis for site monitoring programs. Table 11 illustrates the details of the monitoring programs at priority sites and results as regards the response of *W. fruticosa* to weed management. Though spatial and temporal replication is insufficient, all but one site show a positive trend in the species increasing in abundance.

Site managers also reported the species' response to control (as per the *Best Practice Guidelines for Aerial Spraying of Bitou Bush in NSW* (Broese van Groenou & Downey 2006)) on six occasions at five sites. All observations were 'no damage', indicating no off-target impacts to the species.

Table 11: Overview of monitoring programs and results of bitou bush changes at *Westringia fruticosa* priority sites identified in the TAP

Site no. and name	Sampling unit	Data collected	No. of sampling units	Years monitored	Result
HCR49 Yagon Gibber, Myall Lakes NP	Quadrat	Braun Blanquet cover abundance	1	2009–2011	Increased from <5% to 6–25% cover
HCR59 Boat Harbour	Line-intercept transect	Cover (distance)	1	2006–2008	Increased from 9 to 16% cover
HCR96 Munmorah SCA	Line-intercept transect	Cover (distance)	2	2007–2009	Increased from 7.5 to 11.6% cover
SM1 Narrabeen Headland	Radial plot	Braun Blanquet cover abundance	1	2009–2010	Decreased from 6–25% to <5%
SR17 Callala Bay & Beach (Miola Peninsula)	Quadrat	Plant density	1	2007–2011	Increased from 4 to 5 individuals
SR20 Bherwerre Peninsula Booderee NP	Quadrat	Plant density	1	2007–2011	Increased from 1 to 14 individuals

Discussion

Management of *W. fruticosa* priority sites was comprehensive across the bitou bush-affected distribution of this species. Though monitoring was not standardised across sites, monitoring programs at each site show good reductions in bitou bush abundance.

Monitoring of the species at risk was mostly inconclusive due to insufficient spatial and temporal replication. Table 11 illustrates that monitoring did not occur over a meaningful (long) period or encompass enough plots (to be representative of sites) to reliably detect a change in abundance. The monitoring manual makes recommendations on the size and minimum number of plots required to adequately sample a population at a site, as well as providing advice on the duration of monitoring. Despite the monitoring shortfalls, it can be gleaned that, at a minimum, the species persists at priority sites and has likely increased in abundance with weed management.

Unlike *C. psammogeton* and *S. spathulata*, *W. fruticosa* is a relatively common plant that is easily recognisable and a key component of the communities it occurs in. As such, the limitations of monitoring mentioned for the previous two species above do not wholly apply here. The species often inhabits steep and rocky headlands which may have inhibited monitoring due to safety issues; this was the case at one site, where monitoring was discontinued due to the steep terrain and safety concerns. Also, as with many species, little is known of the species' ecology or the impacts bitou bush has on it. Therefore, even if monitoring was sufficient, it is not certain a positive response would have been detected due to other factors that influence abundance.

In consideration of the above, there seem to be few difficulties in monitoring this species that cannot be overcome by methods outlined in the monitoring manual. The species is relatively abundant where it is present and is easy to identify, so monitoring as per the standard and advanced monitoring techniques is recommended for site managers. In determining which species to monitor, site managers who have identified this species in their site-specific management plans should consider monitoring this species where it is at risk from bitou bush.

Ecological community case studies

The TAP identified 26 priority ecological communities at risk from bitou bush in NSW. During development of the *Native plant species at risk from bitou bush invasion: a field guide for New South Wales* (Hamilton *et al.* 2008), this number was revised to 24 communities due to overlaps with other communities. Fifteen are listed as EECs under the TSC Act. The remaining ecological communities were not systematically determined through vegetation survey and classification. Hamilton *et al*. (2008) sought to define these ecological communities to improve identification and monitoring. Overall, seven communities were determined high priorities.

Ecological communities are inherently harder to identify than individual plant species as knowledge of multiple species and their relative abundance, and vegetation structure is required (as a minimum). Species composition can vary between sites, leading to site managers not identifying the community or using general terms such as 'foredune'. In addition to identification, monitoring of multi-species entities is also inherently difficult as site managers are unsure of the number of species and which species to monitor. The monitoring manual recommends performing full floristic surveys or monitoring the community's characteristic species in each life form category.

Here, case studies of two of the highest ranked ecological communities are detailed. Littoral rainforest in the South East Corner, Sydney Basin and NSW North Coast bioregions and Themeda grassland on Seacliffs and Coastal Headlands in the NSW North Coast, Sydney Basin and South East Corner bioregions are EECs that are broadly distributed in NSW and easy to identify. The difficulties and lessons learnt from the below case studies are likely applicable across all ecological communities.

Littoral rainforest

Photo: Shane Ruming

Photo: Mark Hamilton

Background information

Littoral rainforest is a closed forest community present in close proximity to the ocean (mostly within 2 km). The community can be found on coastal headlands, coastal sand dunes, on soils derived from bedrock, and around coastal estuaries, north from Bega in southern NSW. The structure and species composition is strongly influenced by proximity to the ocean and latitude. Vegetation structure can vary from low closed forest in exposed situations to tall closed forest in more protected areas. Characteristic plant species are typically rainforest species with evergreen, leathery leaves, often with vines being a major component of the canopy. For further detail on characteristic species see the profile on the OEH threatened species page: (www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10867).

Littoral rainforest was listed as an EEC under the TSC Act in 2004 and 'Littoral Rainforest and Coastal Vine Thickets of Eastern Australia', a community that encompasses the NSW-defined community, was listed as critically endangered in 2008 under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Invasion by weeds is likely to be the greatest threat to the community (especially if stands are protected from clearing), with bitou bush being high amongst these species.

Prior to threatened listings, in 1988, Littoral rainforests were recognised and protected under State Environmental Planning Policy (SEPP) No. 26 – Littoral Rainforests. The policy provided mapping of Littoral rainforest stands and aims to provide a mechanism by which the ecological community will be considered during land-use planning.

Priority sites

The SEPP 26 mapping, though not exhaustive, likely led to the numerous site nominations for this community during the TAP development. Outside of this mapping, many more sites were identified due to the relative ease of identification of this community (rainforests in close proximity to the ocean). Coupled with bitou bush mapping or knowledge, this mapping allowed land managers to identify the asset to be protected in relation to the bitou bush infestations. In other instances little or no mapping is available for ecological communities and hence this spatial relationship is not obvious.

A total of 113 sites were identified for Littoral rainforest in the TAP. Site prioritisation led to 78 control category 1, 31 category 2 and four category 3 sites. A further 22 sites were identified through site management plan preparation leading to total of 135 Littoral rainforest sites. Seventy-five sites where the TAP was implemented had Littoral rainforest present, many having this community as the sole or main biodiversity being protected.

Monitoring

Bitou bush

Bitou bush was monitored at a total of 49 priority sites where Littoral rainforest is present. Plots were not necessarily located in the ecological community, for example some plots were situated in the foredune that abuts a Littoral rainforest stand. Thirty-nine sites had bitou bush measured quantitatively and two sites had photopoints. At eight sites only baseline data were available or bitou bush was not measured separately from other weeds. Results show a reduction in bitou bush abundance at 34 sites and three reported no change due to extensive works prior to the TAP and bitou bush being kept at a low level. For another four sites the data were insufficient to determine a response, but at two of these sites substantial reductions in bitou bush abundance was observed prior to 2006.

Of the 49 sites mentioned above, 17 had plots situated in Littoral rainforest stands. An analysis of these plots at the 17 sites was performed. Many of the plots were situated in degraded Littoral rainforest stands as intact stands were less likely to be impacted from bitou bush. Of the 17 monitored sites, 12 reported reduction in bitou bush cover, most to less than 5% cover; and the remaining five had insufficient data, no baseline data (but cover remained low), or cover was reduced prior to 2006 with no monitoring occurring during TAP implementation.

Community at risk

Native plants were monitored within the Littoral rainforest community at 17 priority sites. However, for most sites monitoring was short-term and/or data were only collected from one plot, for a subset of species, or only presence/absence data were collected. In addition, data could not be analysed collectively due to the variation in methods, time of monitoring and management history. For each site, analysis of native species richness and cover was performed to determine the response of all native species.

Of the 17 sites, a positive response of native species was only detected at three sites, with no change at another three sites. One of the sites where a change was detected had

significant control and monitoring prior to the TAP but no monitoring between 2006 and 2011. However, native species richness increased significantly between 2003 and 2006 (p=0.04), whilst native cover was not significantly different (p=0.28) but increased from 29% to 37.8%.

There were four sites where all plant species were monitored. Collectively, Littoral rainforest species richness generally increased, though not significant statistically, and the proportion of Littoral rainforest species composing the community also did not change significantly. The proportion of Littoral rainforest species' cover could not be calculated, as cover classes or presence/absence data were used.

Site example – NR21 Billinudgel Nature Reserve

At this site, three 5 x 5 m plots were situated in areas to be aerially sprayed, two in a degraded Littoral rainforest community and one on a dune crest close to Littoral rainforest. Monitoring was consistent with the advanced monitoring techniques of the monitoring manual. Cover, density, age dynamics and plant height were measured prior to control and approximately every three to four months over a 26 month period. Native cover and species richness were the most useful data to analyse in the short term. In the two plots formerly Littoral rainforest, native species richness increased from an average of 15 to 21.5 per 25 m^2 (p=0.010) (Figure 25) but no change was observed in the low number of exotics (p=0.63). Bitou bush cover changed from a median cover of 51–75% to <5% cover. Median cover classes for native species remained constant over time. Species richness of Littoral rainforest species increased from 6.5 to 10 per 25 m^2, but the proportion of rainforest species remained fairly constant at 39.1% to 41.4% (both changes are not statistically significant).

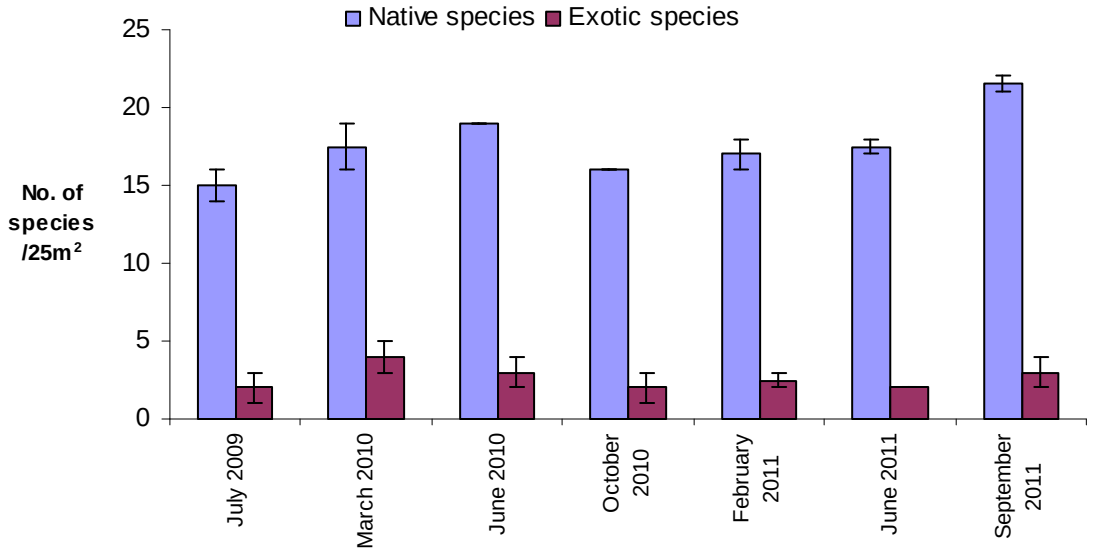


Figure 25: Changes in species richness at Billinudgel Nature Reserve TAP site in response to bitou bush management

Note: Data are from plots situated in degraded Littoral rainforest.

Discussion

Identification of Littoral rainforest priority sites was comprehensive in the TAP and as a result of TAP implementation. This is likely to be the result of the SEPP 26 mapping of the community, the relative ease of identification, the wide distribution, and the community's prominence achieved through listing as an EEC. Management at Littoral rainforest sites was widespread, with 75 of 135, or 56% of TAP sites managed.

At monitored sites, bitou bush abundance was reduced substantially or remained low (following control prior to the TAP). Hence, the impact and threat of bitou bush to Littoral rainforest has been reduced at monitored sites, with a similar reduction likely at sites that were managed but not monitored. Data were mostly insufficient to determine a response of native species at Littoral rainforest sites. Most monitoring was set up prior to the monitoring manual and hence was not standardised. Invariably, average abundance and richness of native species increased but poor plot replication led to highly variable data that prevented statistical analyses detecting a species response. The length of monitoring was also insufficient. Though bitou bush abundance was often decreased to <5% cover, the restoration of ecological communities is a long-term process which invasion by secondary weeds can further delay. Monitoring is required to continue if a response of this community is to be detected.

It is important to consider that bitou bush, in most instances, only invades Littoral rainforest canopy gaps or on rainforest ecotones. Most plots were set up in ecotonal areas or where Littoral rainforest species were recolonising areas after sandmining. These areas are, according to the identification guidelines for Littoral rainforest (DECC 2008), considered part of the EEC. Some plots were situated in closed-canopy stands unaffected by weeds (reference plots), or in areas little affected by weeds, and few changes were observed.

Monitoring conducted at Billinudgel NR, for example, is more advanced than most at priority sites, but despite significant time investment in monitoring, it has only been able to detect short-term changes in native species richness. Monitoring should continue for many years hence, albeit at a lower frequency, and more plots would be required to adequately sample the site. As observed at Billinudgel NR, the median cover of native species, in lieu of calculating total native species cover, often decreases over time. This is a result of species richness increasing (with weed control and associated disturbance) and most of this increase is from species only present as seedlings (with low abundance).

Themeda grassland on seacliffs and coastal headlands

Photos: Mark Hamilton

Background information

Themeda grassland is a closed tussock grassland community dominated by a prostrate and glaucous form of kangaroo grass, *Themeda australis*. Scattered shrubs occur in many stands resulting in an open shrubland or open heath interspersed with grassy patches.

The community is found on a range of substrates though it is more commonly found on basalt headlands and old sand dunes above cliffs. Individual stands of the community can range from a few square metres to whole headlands covering tens of hectares, as for example at Moonee Beach Nature Reserve. Overall, the community has a geographic distribution in coastal NSW comprising small, but widely scattered patches.

The community is relatively species poor but harbours a distinct assemblage of species, often with different growth forms of more common species being present. Several high priority TAP species such as *Chamaecrista maritima*, *Plectranthus cremnus*, *Pultenaea maritima* and *Westringia fruticosa* are present in this community.

Themeda grassland on seacliffs and coastal headlands was listed as an EEC under the TSC Act in 2005. Coastal development, changed fire and grazing regimes, and invasion by woody weeds, especially bitou bush, are listed as the main threats to the community's survival.

Priority sites

Forty priority sites were identified for Themeda grassland in the TAP, including 29 control category 1 sites, nine category 2 sites and two sites that were not modelled. A further 20 sites were identified for this community through site management plan preparation and monitoring, leading to a total of 60 TAP sites for Themeda grassland. Forty-seven TAP sites were managed for weeds throughout the first five years of the TAP, 44 of which were under approved site management plans.

Monitoring

Bitou bush

Bitou bush was monitored at 26 priority sites where the Themeda grassland community is present. Plots were not necessarily located in the ecological community, e.g. plots may be situated in the foredune below a headland Themeda grassland community. At four sites bitou bush was measured only once, with post-control monitoring yet to occur. Of the remaining 22 sites, bitou bush was measured quantitatively at 18, aerially surveyed and mapped at one, and monitored at three sites using photopoints. A reduction in bitou bush abundance was observed at 20 sites, at one site no monitoring was performed throughout the TAP though good reductions were observed prior to 2006, and for another site no observable change was detected from the photopoint images.

At 12 of the above 26 priority sites, bitou bush was monitored in plots that were situated in the Themeda grassland community, the results of which are detailed in Table 12. Only one plot was monitored in this community at most sites however.

Table 12: Response of bitou bush to management in Themeda grassland plots at TAP sites

No. of sites	Response of bitou bush
6	Abundance reduced during the TAP
2	Abundance reduced prior to the TAP
1	Not detected from photopoint images
3	Not detected – only baseline data were collected

Community at risk

Plots were situated in Themeda grassland at 11 priority sites. At most sites, only one plot was located in the community, a subset of species was measured, and/or monitoring data were short-term. Data were not analysed collectively due to variations in methods, the period of monitoring and management history. Of the 11 sites, only baseline data were collected at three (with post-control monitoring yet to occur), insufficient data were available to detect a native species response at seven, and a positive response (determined by native species richness and cover) was detected at one site (though statistical analysis was not possible).

At two sites there was more than one plot located in Themeda grassland. However, plots were sampled at different times and the type of data collected was not consistent (e.g. presence/absence data were collected, then abundance was measured later in the program), precluding a thorough analysis of all plots. Both sites had extensive control prior to the TAP (since 1997), although with few plots and infrequent monitoring, analysis for this community was not possible.

At the seven sites where pre- and post-control data were collected, characteristic Themeda grassland species were identified and their collective response determined. The proportion of Themeda grassland species cover could not be calculated as cover classes were mostly used. However, the cover of Themeda grassland species increased over time at five sites, being primarily *T. australis* cover. Cover at the remaining two sites remained constant. Where observations on all species were recorded (three sites), Themeda grassland species richness remained constant during TAP implementation, while the proportion of Themeda grassland species composing the community decreased. Neither result was tested statistically due to lack of replication.

Site example – NR133 Hat Head National Park

At this site, a series of belt transects were located in areas to be aerially sprayed, as part of a regional NPWS initiative to monitor the response of native species to aerial spraying of bitou bush. Three of these transects were located in Themeda grassland, two set up in 1997 and a third in 2006. The 2006 plot was sampled at different times and frequencies from the 1997 plots. Initially species presence or absence along the belt transects was recorded, but later the cover abundance of species was estimated. The following results are from the two plots set up in 1997. Native species richness increased from an average of 9.8 per 50 m^2 in 2001 to 25.3 in 2010. Exotic species increased from 0.9 per 50 m^2 to 3.25 over the same period. Over the period 2003 to 2010, average total native cover increased from 57.8 to 88%, with exotic cover increasing from 1.5 to 4.7%. From 2001 to 2010, species richness of Themeda grassland species increased from 3.8 to 5.1 per 50 m^2. The proportion of Themeda grassland species decreased from 39% to 20%, but the proportion of Themeda grassland species cover increased from 17% to 70.7%. All changes are not statistically significant due to insufficient replication.

Discussion

As with Littoral rainforest, identification of Themeda grassland priority sites was comprehensive in the TAP and as a result of TAP implementation. A full 50% more sites were identified as a result of site management plan preparation and monitoring at TAP sites. No statewide mapping for this community exists but the relative ease of identification (grasslands dominated by *T. australis* in close proximity to the ocean) and the listing under the TSC Act has likely contributed to this comprehensiveness.

At 20 of the 22 sites with pre- and post-control data, bitou bush abundance was reduced. The impact and threat of bitou bush to Themeda grassland has been reduced at most monitored sites, a pattern that is likely at the 18 other sites that were managed but not

monitored. For monitoring within the ecological community, seven of nine pre- and post-control monitored sites showed a bitou bush reduction or a reduction prior to the TAP, that was maintained. For native species, data were mostly insufficient to determine a response at Themeda grassland sites. Insufficient plot replication, inconsistent sampling, and short-term monitoring hindered a reliable determination of this community's response to weed management. At sites where monitoring was long-term and across more plots, the purpose of the monitoring was not to determine a response to weed management but to determine the response of native biota to aerial application of herbicides to bitou bush. Few plots were located in Themeda grassland (as many communities were monitored), or were sampled at the same time, leading to data being unable to be grouped and analysed.

Cover of Themeda grassland species mostly increased over time. Where this did not occur the cover remained stable, probably due to monitoring only occurring over a short time period post control rather than a poor response to control. The proportion of Themeda grassland species in plots decreased, which is likely due to increases in the total number of species (at low abundance) due to associated weed control.

The monitoring conducted at Hat Head NP, though set up for a different purpose, highlights the significant time invested in monitoring and the need for long-term monitoring. Three of 12 plots set up in various communities were located in Themeda grassland in the reserve. This dispersion of effort across multiple community types is likely symptomatic of the time and resource limitations on site managers. However, over a nine year period in two plots, the community moved from having 17% cover of Themeda grassland species to 71%. Without more plots and plots sampled at the same time, it is unknown whether this pattern is consistent across the site however.

Action 2.2 performance criteria

- *Establish experiments to determine the effects of herbicides, as used for bitou bush control, on priority species (including seedlings).*
- *Collect data where possible during the tier one monitoring programs.*

In the standard and advanced monitoring techniques, the response of target weeds and native biota to weed control was recorded. Site managers recorded the control technique and the response of species using seven categories (as per the *Best Practice Guidelines for Aerial Spraying of Bitou Bush in NSW* – Broese van Groenou & Downey (2006) – Table 13).

Table 13: The seven categories for vegetation response to weed control

Category	Description
No damage	There has been no damage to target plant population due to control
L (low damage)	≤25% of target plant population has been damaged, with no dead
M (moderate damage)	>25% of target plant population has been damaged, with no dead
LD (low dead)	≤25% of target plant population is dead
MD (moderate dead)	>25% of target plant population is dead
AD (all dead)	All individuals of target plant population are dead
Unsure	You are unsure of the damage to your target plant population; detail the reasons why you are unsure

Since 2009, 672 observations of species' response to control were recorded at 36 sites across NSW, 442 for native plant species and 220 for weed species (the remainder being unidentified species). The percentage of observations from each response category for all native plant species, all weeds, bitou bush, and priority TAP species are illustrated in Table 14 below. Off-target damage to native plant species was negligible, with 91% of observations showing no impact from control techniques. This pattern was reinforced for the priority TAP plant species (listed in the TAP as under threat from bitou bush invasion), with only 3% of observations indicating plant death.

Table 14: Response of plant species to weed control at TAP sites

	% of observations			
Category	**All native plant species**	**All weed species**	**Bitou bush**	**Priority TAP species**
No damage	91.2	15.5	6.7	97.4
L (low damage)	4.8	1.8	0.0	0.0
M (moderate damage)	0.7	2.3	1.0	0.0
LD (low dead)	1.6	1.8	1.0	0.0
MD (moderate dead)	0.5	29.1	29.8	0.9
AD (all dead)	0.9	49.5	61.5	1.7
Unsure	0.5	0.0	0.0	0.0

For all weed species, 50% of observations indicated complete plant death (AD), 31% some plant death (LD and MD), and 16% no damage. The latter seems mostly due to the broad-scale aerial spraying technique that does not target all weed plants (e.g. some weed species may have been under canopy or were not sprayed due to no nearby bitou bush), leading to some weed species that were likely not 'controlled'. Given this, follow-up of secondary weeds will be needed. For bitou bush, 62% of observations indicated complete death and a further 31% some plant death. In general, site managers were largely successful in controlling bitou bush and avoiding off-target impacts to native species.

The above result is supported by Turner (2009) who determined the direct and indirect impacts of aerial boom application of glyphosate on foredune vegetation communities within Crowdy Bay NP (including TAP sites). The direct aerial application of glyphosate between 24 April and 3 May 2009 caused significant death of bitou bush, whilst causing minor or no damage to most of the native species present. An increase in native species cover was also observed less than four months after the aerial spray in 2009 (Turner 2009). Although minor or no damage was noted against most of the native species present, the areas sampled had been aerial sprayed on at least four prior occasions (between 2002 and 2008), and so any susceptible native species may no longer be present in the sampled area. However, Toth *et al.* (1996) recorded that whilst bitou bush was susceptible to winter applications of glyphosate, many native genera such as Acacia, Banksia, Leptospermum and Lomandra could tolerate levels of this herbicide applied in winter.

Not all plant species react similarly when exposed to herbicide. Thomas *et al.* (2006) found that while most native species showed no observable effects to winter applications of glyphosate, some species often associated with bitou bush were damaged, including bracken (*Pteridium esculentum*), dusky coral pea (*Kennedia rubicunda*), scrambling lily (*Geitonoplesium cymosum*) and native senecio (*Senecio pinnatifolius* var. *pinnatifolius*). The endangered native shrub *Pimelea spicata*, growing within bitou bush areas, has also been reported to be damaged by glyphosate when applied in winter (Matarczyk *et al.* 2002).

At the HCR42 TAP site in Myall Lakes NP the response of *C. psammogeton* and *Senecio spathulatus* to aerial spraying of metsulfuron methyl (30 g/ha) was monitored (see *C. psammogeton* species case study). Both species are threatened and the spraying was conducted under a licence issued under the NPW Act. Aerial spraying was found to have no significant effect on the cover of *C. psammogeton*. Cover did not change significantly before and after spraying. When taking into account spray/no-spray and sampling period, cover was also not significantly different (p= 0.3909). Importantly, cover did change in no-spray plots, indicating that the species cover fluctuates with season. For *S. spathulatus*, when taking into account spray/no-spray and sampling period, cover did not differ significantly over time (p=0.5089), though a trend of seasonal fluctuation in cover seems to be evident (as observed in no-spray plots).

Action 2.3 performance criteria

- *Re-survey the NSW coastline (including offshore islands) to determine the extent of bitou bush and boneseed in NSW in the final year of the TAP.*
- *Special attention to be given to areas free of bitou bush and boneseed during the last survey.*

The NSW Department of Primary Industries (DPI) completed mapping in 2010. However, the DPI did not differentiate boneseed from bitou bush (www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/339049/Chrysanthemoides-monilifera.pdf). However, as discussed above, in 2008, bitou bush was remapped by NPWS and compared to 2001 mapping data (Thomas 2002). Analysis specific to areas free of bitou bush and boneseed was conducted.

In 2008 bitou bush infestations covered 43,588 ha in NSW. Bitou bush was recorded as absent from 4620 ha that were previously occupied by bitou bush in 2001 and there was a 43% reduction in infestations with greater than 40% cover. In addition, the area of bitou bush on NPWS estate decreased by 21% (between 2001 and 2008), including a 56% decrease in infestations with greater than 40% cover (Hamilton *et al.* 2012).

Hamilton *et al.* (2012) also determined bitou bush contraction and spread between 2001 and 2008, by overlaying the complete 2008 distribution on the 2001 distribution. Areas with bitou bush mapped in 2001 but not 2008 represented bitou bush contraction, while those with bitou bush in 2008 but not 2001 represented bitou bush spread. The area of bitou bush spread amounted to 20,446 ha. Conversely, the area of bitou bush contraction amounted to 13,265 ha. This resulted in the net increase (spread) of 7180 ha, or 20% since 2001; however, 83% of the increase consisted of infestations with less than 10% cover. Some of the overall increase in area may be attributed to a more comprehensive survey methodology, as the 2008 study may have captured sparse infestations that were not recorded in previous surveys (Hamilton *et al.* 2012). The distribution of bitou bush was found to be highly coastal in nature, with 90.3% of bitou bush within 2.5 km of the coastline. The majority of the increase in area of bitou bush was captured within the core infestation, being infilling within 4 km of the coast (Hamilton *et al.* 2012).

In relation to boneseed, the Southern Councils Group (local governments in the Illawarra and the South Coast of NSW), in conjunction with other regional weed groups in the Riverina and east Victoria, are coordinating a CfoC-funded project to map the distribution and density of boneseed throughout NSW and eastern Victoria. The whole of NSW will be surveyed to determine the distribution and density of boneseed by June 2013. The project also aims to coordinate the eradication of 50 known infestations of boneseed across nine NRM regions in southern and western NSW and East Gippsland in Victoria. This project covers all known boneseed infested areas in NSW, with the exception of the Hawkesbury Nepean CMA, which has an existing boneseed control project in place.

Action 2.4 performance criterion

- *Establish management objectives for boneseed following the completion of mapping.*

Management objectives for boneseed were established under the *Weeds of National Significance Bitou Bush and Boneseed Strategic Plan 2012–2017*. Under this, the management action for boneseed in NSW is eradication (see www.weeds.org.au/WoNS/bitoubush/docs/Map_2.4.20_Boneseed_MgtActions_10_Feb_2011.pdf).

This action is supported by recent changes to the NSW *Noxious Weeds Act 1993*, which have elevated boneseed to a Class 2 Noxious Weed ['the plant must be eradicated from the land and the land must be kept free of the plant'] in all but two Local Control Authorities (LCAs) in NSW. While boneseed is listed as a Class 4 Noxious Weed in Hawkesbury River County Council and Wentworth Shire, these LCAs have requested a change in classification to Class 2. Thus, all NSW LCAs are committed to eradication.

3.3 Objective 3

Evaluate the ways in which bitou bush causes the decline of native plant species

Action 3.1 performance criteria

- *Establish experiments to determine the ways in which bitou bush causes a decline in native plant species.*
- *Collect data where possible during the monitoring programs (tier one only).*

PEMU established a long-term experiment at Tomaree NP in 2006 to determine the impacts of bitou bush invasion on native plants. This site continues to be sampled and the results will be presented upon further data collection. Future results from this will supplement previous research that has been undertaken. For example, Weiss and Noble (1984) previously established that bitou bush can out-compete and totally replace native vegetation, drastically altering native ecosystems.

Previous research has indicated that the effects of bitou bush invasion are expressed at the recruitment stage (germination or seedling growth) in the life histories of a number of native species (Vranjic *et al.* 2000; Ens & French 2008; French *et al.* 2008). Bitou bush exudes chemicals or changes soil processes that influence the growth of seedlings (French *et al.* 2008). Vranjic *et al.* (2000) found the presence of litter or soil from beneath bitou bush could influence growth of the dominant shrub *Acacia longifolia* ssp. *sophorae*, which suggests chemical interference within the soil/litter layers that may facilitate invasion by bitou bush. Research extending these findings found that bitou bush actively inhibits the seedling growth of a range of species, apparently through releasing toxic compounds from its roots into the soil (Ens 2007). While extracts from *A. longifolia* ssp. *sophorae* roots and soil near roots also inhibited the growth of other native seedlings, the novelty of the chemicals exuded by bitou bush appeared to affect a wider range of native species (Ens 2007). The reduced establishment of native plants via allelopathy is likely to create space and contribute to the invasion of bitou bush (Ens *et al.* 2009). Seedlings of *A. longifolia* ssp. *sophorae* were also affected by this interference mechanism, potentially providing an effective mechanism to enhance invasion of coastal habitats (French *et al.* 2008). Furthermore, even under climate change, Mason *et al.* (submitted) suggest that bitou bush will remain a competitive dominant in coastal dune communities.

Bitou bush invaded habitat is also darker, cooler and moister than non-invaded habitat at ground level (Lindsay & French 2004a, Ens 2007). The leaf litter layer is reduced as a result of faster decomposition of bitou bush leaves (Lindsay & French 2004a) and a lower biomass of leaves falling in invaded habitats (Lindsay & French 2005). Consequently, nutrients are released into the soil more quickly in invaded habitats, resulting in fewer nutrients being stored in the litter layer (Lindsay & French 2005).

Reported ecological effects of bitou bush include reduced native plant species diversity and vegetation structural complexity (Mason & French 2008) and ecosystem transformation effects (Lindsay & French 2005). Seed banks of native trees may also be affected with species richness significantly higher in sparsely-invaded hind dunes compared to hind dune sites heavily invaded by bitou bush (Mason *et al.* 2007). To overcome some of these impacts, French (2010) has prepared a guide to restoring invaded coastal foredune scrub and Littoral rainforest.

Habitats dominated by bitou bush have substantially different patterns of fleshy fruit production compared to uninvaded ecosystems, as bitou bush produces large quantities of fruit during early winter when native fruits are scarce (Gosper 2004a). At least 18 species of birds consume bitou bush fruits, most of which are likely to disperse the seeds (Gosper 2004b). While it would be predicted that bitou bush infestations would affect dispersal of native fruits, Gosper *et al.* (2006) showed that native fruit removal by birds is unaffected by either invasion or broad-scale spraying of bitou bush.

3.4 Objective 4

Ensure that all stakeholders are involved/participate at each of the priority sites

Action 4.1 performance criteria

- *Source training providers and develop training courses/programs.*
- *Maintain accredited training programs throughout the five year duration of the TAP, to accommodate new volunteers and offer updates and refresher courses.*

A major reason for the criterion relating to sourcing training providers and developing courses was to assist community groups in implementing the TAP. However, this was not required as the majority of volunteer training was conducted by site managers and CMA partners. From the site manager survey, managers reported that they trained 52 community groups in bush regeneration techniques, and 39 groups also receiving training in herbicide use. Other training also included first aid, OH&S and plant identification. In addition to training at TAP sites, in 2010 the Northern Rivers CMA contracted consultants EnviTE Environment, to undertake training for the monitoring and evaluation of coastal vegetation management projects as part of a CfoC-funded coastal community engagement project. An outcome of this project was for representatives of community organisations, public land managers and CMA staff (involved in delivery of the project) to be trained in the use of standard monitoring techniques outlined in the monitoring manual (Hughes *et al.* 2009).

Monitoring workshops were held across the five coastal CMA regions and workshops were attended by 158 people. A broad range of organisations and sectors of the community were represented. This included various regional offices of NPWS, branch offices of NRCMA, branch offices of HCRCMA, NSW Maritime, local government (e.g. Tweed, Ballina, Richmond Valley, Port Macquarie, Hornsby and Hawkesbury), tertiary institutions such as Richmond Windsor TAFE, NGOs (Wetland Care Australia, EnviTE, Conservation Volunteers Australia), Indigenous organisations (Green Team Alliance, Nyambaga Green Team, Madhima Gulgan Community Association and Yarrawarra Aboriginal Cultural Centre) plus a broad range of community groups, e.g. Brunswick Heads Dunecare, Nambucca Valley Landcare, Friends of Coffs Creek, Port Macquarie Landcare, Mangrove Creek Landcare, Dangar Island Bushcare, Somersby Landcare. PEMU supported the project by senior staff attendance at two workshops and provision of hard copies of the monitoring manual (Hughes *et al.* 2009), identification guide (Hamilton *et al.* 2008), and bitou bush management manuals (Winkler *et al.* 2008).

Other external projects assisted in the training of community groups. For example, the ‘Community Implementation of Biological Control across SE Australia’ engaged

community members, local governments and school students in distributing biological control agents for bitou bush. The project involved supporting community groups and local government to establish biocontrol nurseries and to rear and release the Tortrix leaf roller moth on dense bitou bush infestations. Over 10 nurseries are now established along the NSW coast. Also, workshops were held by University of Wollongong, PEMU and the bitou bush WoNS program to work with community groups to develop restoration guidelines for coastal habitats following weed management. These guidelines are now available to assist community groups to restore native habitat following bitou bush control. Publications produced include *A Community Guide to Implementing Biological Control* (Jenner *et al.* 2010) and *A Framework to Guide Ecological Restoration: Coastal Foredune Scrub and Temperate Littoral Rainforest, South Coast* (French 2010).

A key obstacle to implementing the TAP was the identification and hence protection of the biodiversity at risk from bitou bush. Feedback from site managers was that such information was vital to protect the priority native species in the field. In 2007, the NHT project steering committee (see Action 5.1 below), decided that rather than fund the training of a limited number of stakeholders in plant identification, it would be more effective and sustainable to develop an identification guide to the native species, populations and ecological communities at risk from bitou bush invasion. The guide was released in May 2008 (Hamilton *et al.* 2008) and approximately 5000 copies have been distributed to community groups and land managers. The guide has been well received by stakeholders and strong demand resulted in most copies being handed out.

Aside from the identification guide, PEMU developed multiple other resources, with funding from the Australian Government. These were distributed (free of charge) to site managers and include:

- *Monitoring Manual for Bitou Bush Control and Native Plant Recovery* (Hughes *et al.* 2009)
- *Bitou Bush Management Manual: Current Management and Control Options for Bitou Bush (*Chrysanthemoides monilifera *ssp.* rotundata*) in Australia* (Winkler *et al.* 2008)
- *Boneseed Management Manual: Current Management and Control Options for Boneseed (*Chrysanthemoides monilifera *ssp.* monilifera*) in Australia* (Brougham *et al.* 2006)
- *Best practice guidelines for aerial spraying of bitou bush in New South Wales* (Broese van Groenou & Downey 2006).

Three hundred copies of the monitoring manual, 3500 of the Bitou Bush Management Manual, 2000 of the Boneseed Management Manual, and 30,000 bitou bush information flyers were printed and distributed to stakeholders. In addition, all documents are available on the OEH website for download and printing, and hard copies of the management manuals (and flyers) continue to be available through the WoNS program.

Action 4.1 performance criteria

- *Establish a database of those who are working/volunteering at high priority sites, and monitor their progress at regular intervals during the life of the TAP.*

From the site manager survey responses and details in site management plans, approximately 120 community groups were noted as undertaking management at TAP sites. This included Bushcare, Dunecare, Landcare and Coastcare groups, schools, TAFE, Community Development Employment Projects groups, National Parks Association volunteers, and many other non-aligned volunteer groups. Furthermore, Strehling *et al.* (2011) reports management at TAP sites was complemented by the efforts of over 50 coastal community volunteer groups within Northern Rivers CMA alone.

In relation to the criterion to establish a database, the engagement and collaboration with community groups has primarily been with site managers and a centralised database was

not deemed necessary. Local government site managers maintain bush regeneration record sheets for council managed projects. These are monitored by local government (usually weekly), detailing stakeholder involvement and training. Also in 2011, NPWS introduced a centralised database for pests and weed management on their estate which records staff, volunteer and contractor involvement at TAP sites.

Action 4.2 performance criteria

- *Establish a poster, fact sheet and webpage for the TAP and place signage at selected control category 1 sites.*
- *Establish a program to report significant events in bitou bush management to the general public, or provide for regular updates, especially at control category 1 sites.*

The performance criteria for Action 4.2 have been achieved. Since 2006, the TAP website has been maintained and updated regularly (www.environment.nsw.gov.au/bitouTAP/index.htm). The 'What's new?' and 'Bitou TAP case studies' webpages have been the most regularly updated. The former reports significant new events such as current external funding opportunities and new resources; the latter provides information on the management of control category 1 sites.

Promotional materials including banners, bookmarks, stickers and magnets have also been produced. These have been distributed to stakeholders and given out at field days and conferences. In addition, 140 interpretive signs were produced and placed at 60 TAP sites (Figure 26 is an example of the signage). Signs explain the threat bitou bush poses to native biodiversity, detail what is being done to abate this threat, and provide contact information for those interested in becoming involved. Four types of banners were also produced; a general TAP banner, banners for the identification guide and monitoring manual, and a fourth that detailed the tools available for management of sites. These banners are held by PEMU and the coastal CMAs in NSW and have been displayed at conferences, forums and workshops.

Figure 26: Signage at a TAP site
Photo: Mark Hamilton

Significant events such as the release of the identification guide or the bitou bush management manual were reported to the media through media releases and launches that the media attended. Site managers and coastal CMAs released numerous media releases to report the successes at TAP sites and to raise awareness. Most funding for TAP sites from CMAs involved requirements to issue media releases promoting the project and raising awareness of the threat to native plant species. Site managers also published their experience with the TAP. For example, Wellman (2011) published an article entitled 'A collaborative pathway to Working on Country – the Northern Rivers journey', which provides a case study of Indigenous involvement at the Cape Byron TAP site (NR29).

In 2009, the TAP received recognition when the Global Restoration Network undertook a search for the Top 25 Australasian Ecological Restoration Projects. Although not in the Top 25, the TAP was recognised as a 'Highly Commended' project amongst 17 other projects in Australia and New Zealand (www.globalrestorationnetwork.org/countries/australianew-zealand/).

3.5 Objective 5

Ensure implementation and administration of the TAP is undertaken

Action 5.1 performance criteria

- *A position is established, following the approval of the TAP, to coordinate its implementation.*
- *Progress reports are provided on a regular basis.*
- *The coordinator reviews the current TAP and prepares a second plan five years after the date of commencement of this TAP.*

PEMU established a dedicated position (Project Officer – Weed Monitoring) to coordinate the TAP. The TAP Coordinator worked full-time on the TAP implementation from May 2006 until July 2009. A half-time position (Project Officer – Weed TAPs) also assisted with TAP implementation from March 2007 to July 2009 and was then full-time on the TAP to January 2010. These were externally funded positions, with funding provided by the Australian Government under the NHT and CfoC. From January 2010 to the present the coordination/administration of the TAP was conducted by staff funded by NPWS, with the TAP implementation being only part of their roles.

In 2006, a TAP project steering committee was established following NHT funding for the initial implementation of the TAP. The committee consisted of representatives from the five coastal CMAs and the then DEC (now OEH). Coordination and implementation of the TAP has been further supported by staff in the coastal CMAs. Staff from the five coastal CMAs administered contracts to fund TAP sites, liaised extensively with site managers and PEMU staff, conducted site visits, participated in the NHT project steering committee, and applied for and received funding for TAP sites. The Bitou Bush/Boneseed WoNS Coordinator and various staff from local governments and regional weed committees have also assisted in coordination and implementation.

Numerous progress reports have been prepared over the last 5 years. For example, reports were provided to the Southern Rivers CMA, who coordinated the NHT funding. The NHT project steering committee also met as part of this funding. In addition, reporting against the 2009 CfoC project to implement the TAP was provided to Northern Rivers CMA. Each CMA conducted internal reports and reporting to the lead CMA that received grants. The WoNS program has also reported on the TAP to the Australian Weeds Committee and the Australian Government.

Progress on the implementation of the TAP was also presented at various weed/ecological conferences or published in scientific journals. These include:

- Hamilton *et al.* (2011) and Strehling *et al.* (2011) – 16th NSW Weeds Conference, Coffs Harbour
- Hamilton *et al.* (2010) – 17th Australasian Weeds Conference, Christchurch New Zealand
- Downey *et al.* (2009a) – 10th International Congress of Ecology, Brisbane
- Downey *et al.* (2009b) – journal article in *Ecological Management and Restoration*
- Downey *et al.* (2008a) – Australian Network for Plant Conservation Inc 7th National Conference, Sydney
- Strehling *et al.* (2008), Sinden *et al.* (2008) and King & Downey (2008) – *Plant Protection Quarterly*
- Burley *et al.* (2008) – 16th Australian Weeds Conference, Cairns
- King *et al.* (2007) – 9th International Conference on the Ecology and Management of Alien Plant Invasions, Perth.

See the Discussion for consideration of the requirement to prepare a second TAP.

3.6 Objective 6

Determine the effects of bitou bush invasions on fauna

Action 6.1 performance criteria

- *Establish a system to prioritise fauna species (or groups of species, e.g. waders) that are at risk from bitou bush invasions.*
- *Develop research projects on the effects of bitou bush invasions on priority fauna species.*
- *Initiate these research projects during the TAP. The results of these works could then inform subsequent TAPs.*

Although it has been reported that bitou bush infestations are associated with changes to the diversity of birds and ground-dwelling insects (French *et al.* 2008), a system to prioritise fauna species at risk from bitou bush has not been used. Such a system was established during the development of the *Plan to Protect Environmental Assets from Lantana* (Biosecurity Queensland 2010).

Research projects have been conducted on bitou bush impacts for some fauna. For example, those birds that rely most heavily on plant material for food resources, such as some nectarivores and frugivores, are less abundant in bitou bush invaded habitats, suggesting that these habitats provide inadequate resources for such birds (French & Zubovic 1997, Gosper 2004b). However, for canopy foraging species and some insectivores, few changes were evident (French & Zubovic 1997, Gosper 2004b). French and Eardley (1997) also found no difference in overall invertebrate species richness between coastal heath and bitou bush infestations; however, they reported that seed dispersing ants were less abundant in infested areas.

Unpublished data from PEMU indicates that 27 bird species consume bitou bush fruits (Table 15). Birds that dispersed bitou bush also dispersed 135 other plant species (105 native and 30 exotic) that were either threatened by bitou bush (native species listed in the TAP or part of a TAP community) or were co-occurring exotics. These bird species, on average, fed on 17.5 ± 3.4 plant species, comprising 11.8 ± 2.8 native plant species threatened by bitou bush and 5.8 ± 0.8 co-occurring exotic plant species. This does not determine the effects of invasion but suggests that birds may play an indirect role in native species decline by dispersing alien plants while foraging on native species at risk.

In addition to the above studies, during the development of the TAP, a suite of threatened fauna thought to be at risk from bitou bush were identified. These included 16 bird species (primarily shore birds), 10 mammal species (primarily bats) and one invertebrate species (for further detail see Table 5.2 in DEC 2006). Bitou bush invasions do not always have negative impacts on native animals. For example, little penguins (*Eudyptula minor*) use bitou bush as protection in the absence of other native vegetation in foreshore areas (Winkler *et al.* 2008).

3.7 Objective 7

Determine the effects of bitou bush control on fauna

Action 7.1 performance criteria

- *Establish a system to prioritise fauna species (or groups of species, e.g. waders) that are at risk from bitou bush control.*
- *Establish sites where studies can be undertaken to determine the effects of bitou bush control on fauna.*
- *Develop research projects on the effects of bitou bush control on fauna.*
- *Initiate these research projects during the TAP. The results of these works could then inform subsequent TAPs.*

Table 15: Bird species that consume fruits of bitou bush and plant species threatened by bitou bush, or co-occurring alien plants

Common name	Number of plant species' fruit consumed		
	Native plant species	Exotic plant species	Total
Yellow-faced honeyeater	2	4	6
Lewin's honeyeater	49	10	59
White-cheeked honeyeater	0	0	0
Little wattlebird	1	3	4
Red wattlebird	4	2	6
Noisy miner	4	3	7
Silvereye	22	14	36
Regent bowerbird	49	11	60
Satin bowerbird	53	11	64
Olive-backed oriole	25	7	32
Figbird	37	6	43
Common koel	9	2	11
Emu	2	6	8
Pied currawong	31	12	43
Grey currawong	0	0	0
Black-faced cuckoo-shrike	6	5	11
Mistletoebird	4	2	6
Red-whiskered bulbul	14	13	27
Australia raven	3	6	9
Forest raven	1	0	1
Common blackbird	1	7	8
House sparrow	1	6	7
Common starling	1	6	7
Crimson rosella	16	10	26
Eastern rosella	5	6	11
Silver gull	0	3	3
Superb fairy-wren	4	3	7

A system to prioritise fauna species at risk from bitou bush control has not been used. However, while it could be predicted that bitou bush management would affect fauna, Lindsay and French (2004b) did not detect any change in abundance and composition of leaf litter invertebrates following control of bitou bush with glyphosate at invaded coastal dune sites. Similarly, no difference in the abundance, taxonomic richness and composition of litter invertebrates was found within four months of bitou bush control with the herbicide metsulfuron methyl (French & Buckley 2008). Gosper *et al.* (2006) also showed that removal of native plant species' fruit by birds was unaffected by either bitou bush invasion or broad-scale spraying of bitou bush. However, management of bitou bush with herbicide reduced the removal (and subsequent dispersal) of bitou bush fruits, leading Gosper *et al.* (2006) to suggest that dense bitou bush infestations should be targeted to limit its spread.

PEMU developed the bitou bush monitoring manual to monitor native plant recovery after control. It did not detail methods for fauna monitoring due to the extra complexities involved; however, under the Weeds of National Significance Bitou Bush and Boneseed Strategic Plan 2012–2017 (Australian Weeds Committee 2012), a high priority action (3.1.2) is to 'evaluate new and existing control applications and promote further research and improvement, including impacts on native flora and fauna…'. Therefore, this research remains a national priority, but would be best undertaken by researchers rather than land managers.

A staged approach to weed management has been adopted under the TAP (see Section 7.4 of the TAP) and is incorporated into site management plans. The staged approach should minimise many adverse effects on native animals that may occur from bitou bush removal. In addition, the management manual (Winkler *et al.* 2008) suggests the inclusion of information about native fauna at the site in the planning and pre-control considerations, regardless of whether the native animals are listed as threatened. Undertaking these actions should ensure weed managers are aware of and manage the impacts of bitou bush control on native animals (both positive and negative) at a site level.

3.8 Objective 8

Establish guidelines for future control programs and research projects based on the outcomes of this TAP

Action 8.1 performance criterion

- *Re-evaluated management plans and control strategies based on data collected in Actions 6.1 (fauna and bitou bush), 7.1 (fauna and control), 3.1 (decline of native plants), 2.1 (monitoring of control programs) and 2.2 (herbicide impacts), as well as any other data available, during the final year of the TAP.*

This review of the TAP began five years after its release. The outcomes and recommendations of this review will result in the site management plan template being amended, continued cross-tenure coordination, and greater guidance and advice on biological monitoring for site managers. In addition, the management manual was prepared in 2008 and is still current and applicable. For further information on the recommendations of this review refer to the discussion.

Action 8.2 performance criterion

- *Determine future research objectives based on data collected in Actions 6.1 (fauna and bitou bush), 7.1 (fauna and control), 3.1 (decline of native plants), 2.1 (monitoring of control programs) and 2.2 (herbicide impacts), as well as any other data available, during the final year of the TAP or the development of subsequent TAPs.*

Other than research into the decline of native plants due to bitou bush and monitoring the effectiveness of bitou bush control, the extensive research proposed under Objectives 6, 7 and parts of 2 has not been conducted. As such, these research objectives are still valid but site managers and researchers have indicated these are not a high priority. As mentioned previously, bitou bush has been one of the most researched WoNS. Any additional research priorities have been determined, prioritised and detailed in the Weeds of National Significance Bitou Bush and Boneseed Strategic Plan 2012–2017 (Australian Weeds Committee 2012).

3.9 Summary of evaluation against objectives

Table 16 summarises the evaluation of the TAP implementation against the objectives and actions. Five of the eight objectives were achieved and the remaining three objectives were partially met or not achieved. Objective 1 had most actions achieved but as of 2011, 67% (or 114 sites) of high priority sites were managed, falling just shy of the 75% (or 127 sites) performance criterion under Action 1.1. Although 73% of all managed sites were high priority, indicating site prioritisation was followed. Objectives 6 and 7, relating to the impacts on fauna, were not achieved as much of the research required was not undertaken. For other objectives, often the intention of the objective had been achieved by maintaining relationships with other stakeholders e.g. ‘Action 3.1 DEC will foster research into the decline in native species as a result of bitou bush invasions’ was achieved by researchers mainly at the University of Wollongong, with whom PEMU maintains a good working relationship.

Table 16: Summary of evaluation of performance against the objectives and actions of the TAP, 2006–2011

Actions	To what extent has the action been implemented?	Summary of key achievements	Future priority
Objective 1. Ensure that bitou bush (and boneseed) control is undertaken in areas where the benefits to threatened species, populations and ecological communities are greatest			
1.1 DEC and the Department of Lands (DoL) will undertake bitou bush control programs at high priority (control category 1) sites on their estate.	Majority achieved	Control programs established at 67% (114 of 169) of high priority sites. Site prioritisation successful, with 73% of all managed sites being high priority sites. The average year that management commenced at TAP sites was 2002, the earliest being 1989 and latest in 2010. Bitou bush control programs in existence at commencement of TAP (2006) continued.	Maintain commitment at high priority sites. Additional bitou bush sites to be determined and existing TAP site nominations to be updated (if required) through BPWW (DPI & OEH 2011).
1.2 At control category 1 sites, DEC and DoL will help to develop and implement site-specific management plans for bitou bush control programs, based on currently available best practice guidelines. DEC will work with councils and private landholders that agree to Action 1.1, to develop site-specific management plans.	Partially achieved	57% of all high priority sites were covered by an approved site plan. 73% (115 of the 157) of managed sites (between 2006 and 2011) were covered by an approved site management plan. For the 114 high priority sites where management occurred, 97 (85%) of these had approved site management plans. Control was occurring at sites without an approved site plan. Most site managers found site management plans useful but 49% did not update their plans when conditions or circumstances changed.	Site management plan template to be amended and simplified. Site management plans prepared for new sites and updated for existing sites as required.
1.3 Indigenous communities will be encouraged to assist with the development of site-specific management plans.	Achieved	Of the 124 sites covered by an approved site management plan, consultation with Indigenous people took place for 107 sites. As per the site management plans, 63 sites had Aboriginal significance and a further 50 indicated no or no known significance. However, ten of the 124 site management plans did not answer the question relating to Aboriginal cultural heritage present at the site.	Liaison with Indigenous communities to continue during development, updating and, if appropriate, implementation of site management plans.

Actions	To what extent has the action been implemented?	Summary of key achievements	Future priority
1.4 Control of bitou bush is to continue at both the northern and southern containment zones in NSW.	Achieved	Extensive and well-funded programs were in place at both containment zones. Mapping performed in 2008 shows large reductions in bitou bush density in the southern and northern containment zones. The southern containment line progressed 105 km north and the northern line 35 km south.	Continue control at national containment zones. Containment lines to be reviewed as per the WoNS strategy.
Objective 2. Evaluate the effectiveness of control programs with respect to the response of priority species, populations and ecological communities			
2.1 DEC will coordinate the monitoring/ measurement of bitou bush control programs at control category 1 sites	Achieved	Monitoring manual developed in 2009 that outlines monitoring objectives, methods and data collection instructions. Experiments established at some priority sites. Most monitoring programs do not include non-treatment areas, instead a before–after experimental design was used. Median bitou bush cover was 26–50% cover in 2007, 6–26% cover in 2009, and 0–5% cover in 2011. Monitoring mostly insufficient to detect biodiversity response. Overall biodiversity response at sites as well as case studies presented in this document.	Site managers to be assisted with monitoring. Requirement for monitoring to be determined in conjunction with TAP Coordinator. An overarching monitoring strategy is required to ensure biological monitoring is efficient, targeted and meaningful.
2.2 DEC will foster research into the effects of herbicide on priority species.	Achieved	Experiments established and other research performed to determine effects of herbicide on native plant species. Data were also collected as per monitoring manual datasheets. 91% of responses indicated that weed control caused ‘no damage’ to native plant species.	Monitoring of the effect of herbicide on native plant species to continue as per the monitoring manual.
2.3 DEC will coordinate a statewide (NSW) survey of bitou bush and boneseed infestations (including offshore islands).	Achieved	NPWS coordinated a statewide bitou bush survey in 2008 in collaboration with land managers. In 2008, bitou bush infestations covered 43,588 ha in NSW, a 20% increase. However, the density of infestations decreased markedly and some of the overall increase in area may be attributed to a more comprehensive survey methodology, as the 2008 study may have captured sparse infestations that were not recorded in previous surveys. Bitou bush was recorded as absent from 4620 ha that were previously occupied by bitou bush in 2001.	Further mapping on NPWS estate to occur as part of Pest and Weed Information System (PWIS), though this does not supplement systematic mapping across tenure. In addition, a national weed mapping and information portal is available which can be used to maintain distribution information for WoNS.

Actions	To what extent has the action been implemented?	Summary of key achievements	Future priority
2.4 DEC and other stakeholders will determine the distribution of boneseed in NSW and develop a containment/eradication strategy.	Achieved	The NSW Department of Primary Industries completed mapping in 2010. A boneseed eradication management objective was established under the Weeds of National Significance Bitou Bush and Boneseed Strategic Plan 2012–2017.	Future boneseed management objective is eradication in NSW as determined by the WoNS strategy (Australian Weeds Committee 2012).
Objective 3. Evaluate the ways in which bitou bush causes the decline of native plant species			
3.1 DEC will foster research into the decline in native species as a result of bitou bush invasions.	Achieved	Long-term monitoring experiment established at Tomaree NP to determine impacts of bitou bush invasion on native plant species. Large body of research published on the impacts of bitou bush, particularly by researchers at the University of Wollongong.	Continue long-term experiments and publish results.
Objective 4. Ensure that all stakeholders are involved/participate at each of the priority sites			
4.1 DEC and other agencies will coordinate and contribute to training volunteers (and other stakeholders) who wish to participate in control programs at control category 1 sites.	Achieved	Approximately 120 community groups undertook management at TAP sites. The bitou bush management manual, native plant identification guide, and monitoring manual provided to stakeholders to increase their capacity to undertake control and monitoring. Training of volunteers conducted by site managers where required. Monitoring workshops for stakeholders were also held in 2010 by Northern Rivers CMA. Future volunteer involvement on NPWS estate will be captured in PWIS.	Site managers to continue engaging with community groups.
4.2 DEC and other agencies will undertake public awareness programs on the impacts of bitou bush, especially on biodiversity, and the importance of its control.	Achieved	TAP webpages established and regularly updated; educational materials such as banners, bookmarks, stickers and magnets were produced and distributed. 140 interpretive signs were produced and placed at 60 TAP sites. Excellent promotion of project through media releases and events.	Webpages to be maintained.

Actions	To what extent has the action been implemented?	Summary of key achievements	Future priority
Objective 5. Ensure implementation and administration of the TAP is undertaken			
5.1 DEC will support a position to coordinate the implementation of the TAP.	Achieved	NPWS TAP Coordinator position established from May 2006 to January 2010. From then to the present the coordination of the TAP was conducted by NPWS staff, with the TAP implementation being only part of their roles.	Coordination continues focusing on assisting site managers to prepare/ update site management plans and assisting with biological monitoring.
Objective 6. Determine the effects of bitou bush invasions on fauna			
6.1 DEC will foster research into the effects of bitou bush invasions on fauna.	Not achieved	A system to prioritise fauna species was developed under the Plan to Protect Environmental Assets from Lantana but not applied to fauna at risk from bitou bush. Minimal research undertaken on the effects of bitou bush invasions on fauna.	Not a high priority, dependent on available funding.
Objective 7. Determine the effects of bitou bush control on fauna			
7.1 DEC will foster research into the effects of bitou bush control on fauna.	Not achieved	A system to prioritise fauna species at risk from bitou bush control was not developed. The staged approach to control advocated in the TAP somewhat mitigates the effects of control on fauna species. Otherwise, minimal research was undertaken.	Not a high priority, dependent on available funding.
Objective 8. Establish guidelines for future control programs and research projects based on the outcomes of this TAP			
8.1 DEC and other stake-holders will examine new data and integrate it into future control/ management strategies and best practice guidelines for bitou bush.	Achieved	As a result of this review the site management plan template will be amended, cross-tenure coordination will continue, and greater guidance and advice in biological monitoring will be provided to site managers. The bitou bush management manual was developed in 2008. It incorporated the cumulative knowledge of researchers, site managers, bush regenerators, etc. at that point in time.	TAP coordination to continue as per this review.
8.2 DEC and other stakeholders will examine new data and establish future priorities for bitou bush research.	Achieved	Other than research into the decline of native plants due to bitou bush and monitoring the effectiveness of bitou bush control, the extensive research proposed under Objectives 6, 7 and parts of 2 has not been conducted.	The research objectives are still valid but site managers and researchers indicate they are not a high priority. Current research priorities determined by the WoNS strategy (Australian Weeds Committee 2012).

4 Discussion

Since the release of the TAP, strategic management of bitou bush has occurred at many sites across NSW. Most bitou bush management occurred at the highest priority TAP sites and in containment zones (determined by the WoNS strategy). The TAP has been a successful tool to ensure bitou bush control occurs at sites where the biodiversity benefit is greatest.

There was a reduction in bitou bush abundance at most high priority sites. However, the priority biodiversity may still be threatened by secondary weed invasion. Therefore, a future priority should be to address the threat from secondary weeds. This is supported by French *et al*. (2008), who, after reviewing current research on impacts and management of bitou bush, suggested that programs should include long-term management of secondary weeds that are at risk of invading after bitou bush management.

Implementation of the TAP required extensive cooperation between agencies. The TAP attracted a significant amount of external funding from a variety of sources, which illustrates a further benefit of the TAP. However, ongoing effort is required to ensure that: 1) weed management is targeted towards the conservation of high priority biodiversity as opposed to general weed management; 2) future management at priority sites is holistic, incorporating the long-term follow-up of secondary weed invasion; and 3) momentum is maintained at sites such that bitou bush or other weed reinvasion does not occur. Future investment and coordination in the implementation of the TAP is required. This would not require a major directional shift in the TAP objectives. Any future investment in bitou bush management is to be guided by this review, the current legislative context, new arrangements for managing widespread weeds that impact biodiversity, and the direction set under the WoNS program.

A number of tools, strategies, research and reviews were undertaken as part of, or occurring in concert with, the TAP. These have and will continue to assist implementation of the TAP. These include the bitou bush management manual, native plants at risk from bitou bush invasion identification guide, monitoring manual for bitou bush control and native plant recovery, the comprehensive Bitou TAP web pages (www.environment.nsw.gov.au/bitoutap/), revised national strategy for bitou bush/ boneseed 2012–17, research such as that from the bitou bush/boneseed forum in 2007 (Plant Protection Quarterly Vol. 23, No. 1) and the University of Wollongong; and the BPWW (DPI & OEH 2011). These tools were produced relatively recently and remain useful to site managers.

4.1 Legislative context – Threat Abatement Plans

The invasion of native plant communities by *Chrysanthemoides monilifera* (bitou bush and boneseed) was the first KTP for a weed species listed under the TSC Act in 1999 (www.environment.nsw.gov.au/determinations/BitouBushBoneseedKTPListing.htm). Formerly, the Act required OEH to prepare a TAP which identified the actions needed to abate, ameliorate or eliminate the adverse effects of the KTP on native biodiversity, including threatened species, populations and ecological communities. As such, the first weed TAP, the Bitou TAP, was published in 2006.

Under the Act, the Director-General of OEH is to review the TAP by the date published in the TAP, which was at the end of the first five years of implementation. Further to this, if the Director-General considers that any change (other than a minor change) should be made to the TAP, the Director-General is to prepare a new TAP.

Since the KTP listing, several other weeds or groups of weeds have been listed as KTPs under the Act, for example the invasion and establishment of exotic vines and scramblers,

and the invasion, establishment and spread of *Lantana camara*. The Director-General may prepare a TAP for each KTP or a TAP may contain provisions relevant to more than one KTP. However, as a result of changes to the TSC Act in 2004, the preparation of TAPs is now at the discretion of the Director-General. In deciding whether to develop a TAP for a KTP, the Director-General may consider such factors as: the significance of the impact on biodiversity (including whether it is the main threat to many species); whether impact varies with location; whether management of the threat requires coordination and commitment from several public authorities and stakeholders; and whether cost-effective management is available. Notwithstanding the threat of bitou bush, the invasion of many weeds meets most of these criteria. Weeds have significant impacts on a broad suite of native biodiversity and they remain the main threat to the survival of many threatened species in NSW. Weed impacts vary across species and location. Cost-effective control is available for most weeds, but requires significant and ongoing commitment and coordination across land tenures.

4.2 Biodiversity Priorities for Widespread Weeds and future bitou bush site priorities

In August 2007, a national bitou bush/boneseed forum was held summarising the latest research and management. A priority action was determined that management of these weeds should be part of a more holistic approach to the management of multiple weed species (Downey *et al.* 2008b). Where the management goal is asset protection, priorities for control should consider more than a single weed species. This focus was evident in the subsequent development of the bitou bush management manual (Winkler *et al.* 2008), where it was emphasised that it was essential to develop site management plans that included other weeds.

Between 2008 and 2011, the TAP approach was adapted in the BPWW (DPI & OEH 2011) to identify and prioritise all widespread weeds impacting on native biodiversity, and sites for weed control. Because most weeds listed as KTPs in NSW are widespread and thus unlikely to be eradicated, the focus was on reducing the current impacts to biological assets (including threatened biodiversity), rather than actions associated with prevention, eradication, and reducing spread. Thus the BPWW helps address impacts of all weeds listed under KTPs in NSW. The BPWW has identified priorities for the management of widespread weeds for biodiversity conservation in each of the 13 CMA regions in NSW. High priority sites have been identified where targeted weed control is likely to have the greatest benefits for biodiversity.

The BPWW reports were released in 2011 and can be downloaded here: www.environment.nsw.gov.au/cmaweeds/index.htm. As the BPWW framework was applicable to all widespread weeds impacting on biodiversity, sites that were previously included in the TAP were incorporated into the BPWW. In addition, the BPWW project assessed additional sites where bitou bush was having an impact on biodiversity, and in 2011 there were 488 bitou bush sites identified. Given this, the BPWW process has identified additional site-based priorities for bitou bush as well as for other weeds (Table 17).

The BPWW has also identified additional sites where weeds are impacting threatened species. For example, *Fontainea oraria* is a high priority and threatened species in the TAP (see species case studies section). The *Fontainea oraria* draft recovery plan (DEC 2004) reports that this species is one of Australia's rarest rainforest trees, known from four small sub-populations in two remnants at Lennox Head, NSW. As discussed under the species profiles, the TAP identified two sites where this species occurs. The BPWW identified another site, where *Lantana camara* was identified as the major weed impacting.

Table 17: Current number of TAP sites and BPWW sites across the coastal NRM regions

NRM region	Total number of sites in TAP	No. of control category 1 sites in BPWW*	Total number of sites in BPWW
Northern Rivers	136	228	603
Hunter-Central Rivers	103	147	470
Southern Rivers	64	84	244
Hawkesbury Nepean	11	223	517
Sydney Metro	37	81	257
Total	**351**	**763**	**2,091**

*Control category 1 sites are the highest priority for widespread weed management.

Unlike the TAP, the BPWW site rankings can be changed as new information becomes available. In addition, new sites can be added and assessed into the future. Therefore, additional and existing bitou bush sites can be assessed or reassessed respectively to determine future site priorities.

4.3 National strategic plan for bitou bush/boneseed 2012–2017

In conjunction with the TAP, the 2000 national bitou bush/boneseed strategy set goals and objectives to ensure strategic management of these weeds. National coordination has facilitated significant progress towards achieving those objectives; however, national coordination will cease in July 2013 and, while there remains a legacy of national action, effort is still needed for management of these weeds.

A revised national strategic plan (2012–2017) has been prepared (Australian Weeds Committee 2012). It provides information and guidance to assist site managers and the community in taking strategic action to reduce the impact of bitou bush and boneseed on Australia's native biodiversity. The revised strategy sets future directions, including actions relevant to NSW, and re-confirms many of the objectives in the TAP, such as:

- support the northern and southern national bitou bush containment lines in NSW (see Figure 27) and develop buffer zones where appropriate to support movement of containment lines
- continue implementation of the TAP and other identified asset priorities for bitou bush and monitor progress and communicate results
- monitor post-control native recovery and undertake restoration where impacts have occurred, to ensure biodiversity conservation
- disseminate the bitou bush monitoring manual and encourage its use and training of end users.

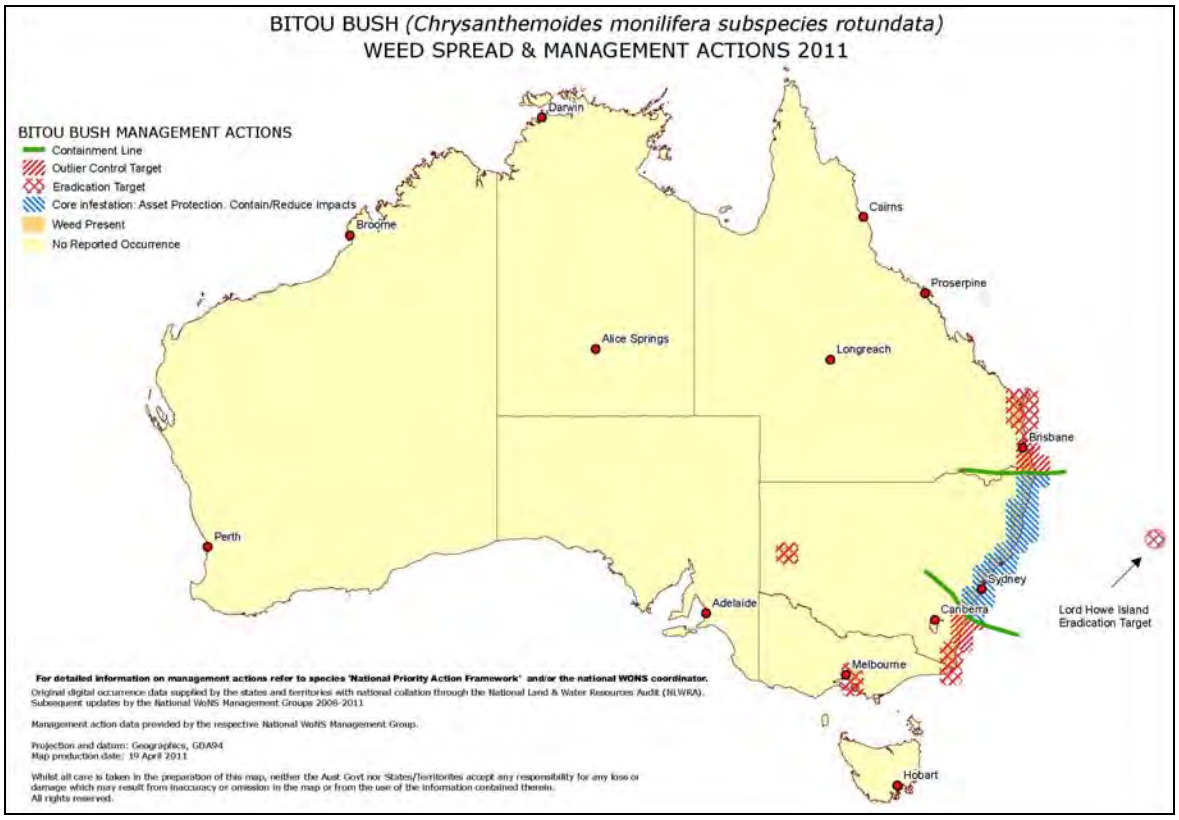


Figure 27: Management actions for bitou bush in 2011 as determined under the Weeds of National Significance Program

5 Recommendations for future implementation of the Bitou TAP

This review has identified a number of issues regarding the implementation of the TAP that need to be addressed for improved implementation. These issues are also applicable to the implementation of other weed threat abatement strategies. They relate to:

- maintaining long-term commitment at priority sites where management has occurred, including follow-up management of bitou bush and secondary weeds
- the useability of site management plans, the need to update them and a review of when a site management plan is actually required
- continued coordination (especially in regards to site plans and monitoring) across tenures and with all stakeholders
- training of and consultation with field staff in relation to monitoring
- nomination and assessment of additional bitou bush sites and updating existing site nominations
- data collation and management, and
- maintenance and assessment of containment lines.

The above issues are supported by the site manager survey. Site managers were asked to provide comment on improvements that could be made to the TAP. Twenty-six site managers suggested the improvements detailed in Table 18.

Table 18: Suggested improvements to implementation of the TAP from a survey of site managers

Suggested improvements	No. of responses
A need for consistency in long-term funding	12
Monitoring and/or reporting were either too complex or onerous, therefore needed to be simplified or assistance was required	7
Secondary weeds needed to be targeted and/or restoration of areas was now needed	6
On-ground support and training with further assistance with identification of threatened species were needed	3

5.1 Strategic approach to bitou bush management

Bitou bush site priorities may be outdated following five years of TAP implementation; however, the existing Bitou TAP sites were incorporated into the BPWW and new bitou bush sites were nominated. Updating of some Bitou TAP sites may be required. The BPWW is an ideal tool to update and/or add new bitou bush sites and prioritise them based on the biodiversity at risk and the likelihood of successful control. The BPWW also considers the threat of all weeds to at-risk biodiversity, an issue that has been highlighted in this review (e.g. see Table 18). It is recommended that, where required, existing Bitou TAP sites are updated and new bitou bush sites are nominated through the BPWW. Note, where little or no bitou bush remains at a TAP site but secondary weeds are a threat to biodiversity, the site is still considered a TAP site and the at-risk biodiversity requires protection.

The BPWW has a review date of 2015. This is also the due date for the invasive species reporting under the NSW State Plan, which is October 2015. Therefore, it is recommended that the TAP be extended to 2015.

5.2 Site management

One of the main issues identified in the site manager survey and in discussion with the working group is the need for the site management plan to be amended. Most site managers thought the plan worthwhile but almost half did not update the plan when circumstances changed, and there appeared to be little reference to the plans after their initial approval. In addition, there has been little ownership of site management plans and control was occurring at many sites without an approved site management plan. From the site manager survey, it was generally thought the site management plans provided a good starting point. Regarding the usefulness of the site management plan, two responses representing two diverse opinions were: 1) '*marginal additional benefit to the standard site planning we do for all our reserves. However, it provided a large reporting burden on Council which was not commensurate to the funding provided*'; and 2) the '*Site plan allowed for guidance and referencing progress against the proposed timetable. It also assisted in identifying the most appropriate management technique required for the level of bitou infestation and stage of control. It identified other weed issues and generally assisted in implementing the control program*'.

The purpose of the site management plan is to detail the proposed control and monitoring actions to best protect identified biodiversity and mitigate off-target impacts. In particular, the site management plan is important to:

- spatially define sites
- clearly outline the conservation objectives of weed management
- propose the extent, frequency and methods of control
- outline monitoring methods and responsibilities for data collection and storage, and
- provide information on sites (e.g. for this review).

Further, as the TAP and BPWW are focused on protecting environmental assets, it provides a mechanism to clearly identify the locations of priority assets (on which the sites have been prioritised) and weed/s, for planning purposes. Implementation of site management plans has also assisted in discovering new records of threatened species (as detailed in the species case studies section).

Currently the site management plans are completed for a five-year period. Based on this review, the duration of site management plans should be reduced to a maximum of three years. Further, based on the issues and requirements detailed above, the site management plan template should be amended and simplified to increase useability. This should include more detail surrounding who collects, collates and analyses monitoring data. Lastly, considering the importance of long-term control, it is particularly important that site managers who obtain short-term funding prepare site management plans, to document commitment to manage all weeds at a site over the long term, after the received funds cease.

In relation to the staged approach to control (as advocated in the TAP and in the site management plan), there were 35 responses relevant to this issue in the site manager survey. Only two respondents suggested they did not follow the staged approach, five indicated they only followed it in part, and eight indicated they followed the staged approach but tied this to broader landscape management of bitou bush, usually aerial spraying. However, four respondents indicated that the staged approach had to be modified due to external funding (e.g. one grant required the whole site to be managed in a short timeframe). At smaller sites, the staged approach to control is not as vital (as funds may be available to treat the whole site at each event), but at larger sites this approach should be utilised around priority biodiversity. Implementing the staged approach is often frustrated by poor knowledge of the location of biodiversity at risk. For this reason, a thorough search of the site by the site manager, botanist, TAP Coordinator, or qualified individual is recommended prior to control commencing. Results of this should then be incorporated in the site management plan map.

5.3 Monitoring

The primary objective of controlling weeds under the TAP was to trigger a positive response from the targeted native biodiversity. This response has not been detected at the majority of sites and for the majority of biota. Monitoring was unable to detect a response in many instances, especially due to low replication or insufficient time to detect a biodiversity response. Therefore, training of and consultation with field staff remains a priority. It is worth noting, from the data presented above, that there is a time lag between the control of the weed and response of biodiversity. This is thought to be approximately three years at least.

A substantial amount of monitoring was undertaken, but guidance and direction is required. Most monitoring is short-term and this review shows monitoring needs to be long-term to detect a biodiversity response. It also shows that monitoring of rare or difficult-to-monitor species may not be feasible unless substantial time and expertise is committed. In some cases, monitoring frequency could be reduced, more plots are required or new plot establishment should be restrained if this will affect existing monitoring. An overarching monitoring strategy may be required to ensure biological monitoring is efficient, targeted and meaningful.

For sites on NPWS estate, control and monitoring actions should now be detailed and scheduled in the new PWIS. This will help NPWS site managers report on the implementation of actions in site management plans. Spatial data collected on control actions and weed extent will also be collated in a spatially-enabled database that is a component of the system. This new system will also allow sites to be spatially defined.

Monitoring native species

It is evident that monitoring of the native species at greatest risk from bitou bush was insufficient to reliably determine their response to weed management. However, the long-term nature of recovery is well documented and expectations of recovery in a five-year timeframe are likely unrealistic. Equally, long-term monitoring programs are required to detect recovery of many native species. Despite the monitoring shortfalls, it can be gleaned that, at a minimum, high priority species persist at priority sites, weed management had very limited off-target damage and bitou bush abundance has been reduced.

The high priority species detailed as case studies present many difficulties for site managers with limited time, resources and monitoring skills. In many instances bitou bush was not impacting populations of priority species, rather it was a threat that was avoided when bitou bush was controlled. Hence a priority species' response would not be expected. Other such monitoring difficulties may include:

- species' rarity and sporadic occurrence in the landscape
- steep and rocky habitats or transient dunes vulnerable to coastal erosion
- delicate species' habit and habitat
- species identification difficulties
- seasonal fluctuations in species' abundance, and
- species' life history traits that may reduce the likelihood of a species' response.

In addition, knowledge of the biology and ecology of the species at risk is often poor, as are the mechanisms of weed impact on native species. Designing a program that isolates the effects of weed control from life history factors and background population trends is difficult. For example, weed control may alleviate one impact on a species but other threats such as altered fire regime may reduce the likelihood of a species' response.

In consideration of the above difficulties and the potential implications they have on site managers attempting to monitor, it is likely that adequate monitoring of high priority species requires effort that is beyond the budgets and/or skill sets of many site managers. However, monitoring of the most at-risk species should continue in order to better determine their response to weed management. In light of this, where sufficient skill and resources are available, site managers should observe the following:

- Incidental or low frequency monitoring is not sufficient to determine species' response to control, and random placement of a limited number of plots across a site is unlikely to adequately sample populations. Monitoring should be targeted.
- Monitoring should occur over long periods. This increases the likelihood that a response will be observed and ensures the weed impact is reduced.
- The monitoring manual details rare plant species monitoring methods. With these, it is advised to monitor entire species' populations or distinct sub-populations at sites. Where populations are large or dispersed, monitoring all individuals is not feasible. To adequately sample the population, random placement of small plots (likely more than the minimum recommended in the monitoring manual) or a long linear plot within the area over which the population exists is recommended.
- Where monitoring has been initiated, ensure it continues until some assessment of the data is undertaken, and before other monitoring plots/programs in different areas of the site are established.
- Efforts should be made to ensure the time of year at which monitoring is undertaken is kept approximately consistent. Interpretation of results should also consider this.
- For threatened biota, databases such as the Priorities Action Statement should be consulted by site managers to determine if any other recovery actions, in addition to weed control, may need to be performed to protect the species at risk.
- For difficult-to-monitor species, a case-by-case assessment by PEMU may need to occur to establish the feasibility of monitoring a species at a site, based on the resources needed to measure a change in the species' population. Where feasible, monitoring techniques and requirements can be recommended. Additionally, there may be a need for specialised monitoring personnel who utilise the monitoring manual. A reduced number of sites could then be selected and such personnel undertake a more intense form of monitoring.

Monitoring ecological communities

From the ecological community case study results, the following recommendations have been deduced and should be followed when monitoring ecological communities:

- Where the objective is to determine the response of an ecological community to control, monitoring should occur over the long term and not aim to simply show short-term weed reduction in numerous parts of a site.
- It is preferable to use more advanced monitoring techniques such that all species are monitored (full floristic survey method) and native species richness and total cover can be calculated. Selecting a subset of target species (as per the standard monitoring techniques), even if they are characteristic of the community, reduces the likelihood of the correct species being monitored, prevents thorough data analysis being performed, and prevents species richness being calculated. If all species are to be monitored, site managers may require assistance with plant identification.
- If monitoring all species is not feasible, ensure monitored species are characteristic of the community (e.g. consult EEC determination) and ensure the same species are monitored across plots, e.g. *T. australis* in Themeda grassland, as it is a defining component.

- Assessing abundance by assigning Braun Blanquet cover abundance classes prevents the calculation of total cover of native species, as classes cannot be added. It is suggested that if cover classes are used, multivariate analyses be performed to determine if a community is becoming more similar to the target ecological community. For this, reference plots in the target ecological community may also need to be sampled, with weed managed plots being compared to these.
- Use of cover classes can limit the detection of small abundance changes, so where possible, estimating actual cover is advisable. This is uncomplicated when the 2 x 10 m plot size (as recommended in the monitoring manual) is used, as one square metre is 5% of the plot.
- For determination of any cover subjectively, multiple persons should be involved in deciding on the class (to reduce observer error).
- If using the standard monitoring techniques, use the recommended minimum of 3−5 plots in locations representative of the site, though more plots are beneficial.
- Ensure plots are sampled at the same time and at consistent frequencies.
- If time or resources are limiting, it is better to collect high quality data from fewer plots over time than to collect low quality or infrequent data from many plots. However, if using the standard monitoring techniques, a minimum of 3−5 plots is required.
- It is important to identify the ecological community where plots are located, even where individual species or a handful of species are being monitored.
- Additional monitoring plots should only be set up if commitment is maintained at existing plots. Set up of plots or photopoints in newly managed areas of sites disperses monitoring effort and prevents quality long-term data being collected.
- Ensure details of control activities are recorded as these influence the results.
- When interpreting results, consider that other factors such as altered historic fire and grazing regimes may affect results.

5.4 Summary of recommended priority actions

Table 19: Summary of the issues and recommended priority actions for implementation of the Bitou TAP to 2015

Issue	Priority action 2012–2015	Importance
The threat of bitou bush reinvasion or secondary weed invasion at TAP sites.	Coordination of the Bitou TAP to continue across tenure. Ensuring management continues to occur at the highest priority sites as determined by the Bitou TAP and BPWW.	High
	Management of all weeds to be a focus in the site management plan and in any new/updated site nominations.	High
Most monitoring is insufficient to detect a biodiversity response.	At monitored sites, ensure the minimum number of plots are sampled as per the monitoring manual, and the frequency and duration of sampling is sufficient. Monitoring requirements need to be balanced with available resources. For specific recommendations, consider those made for species and communities in this review.	High
	Where possible, PEMU to assist site managers with data analysis.	High
	PEMU to report results of site monitoring data from 2006–11 to site managers to increase awareness of the value of monitoring.	High

Table 19, continued.

Issue	Priority action 2012–2015	Importance
Site management plan not updated by many site managers and poor site manager ownership.	Site management plan duration to be reduced to three years and amendments to be made in consultation with site managers to increase useability and reduce preparation time.	High
Staged approach to control may be frustrated by poor spatial data for priority biodiversity.	To protect priority biodiversity, a thorough search of sites should be performed to locate priority biota and their location included in the site management plan.	High
Continued community engagement.	PEMU to produce a concise document outlining the key points of the Bitou TAP Review for distribution to the public/community groups.	High
Continued maintenance of containment lines.	Support given at containment lines as defined under the Bitou Bush WoNS Strategy.	High
Site information used to rank sites may be outdated and more sites may need to be nominated.	Nominate new and update existing sites (if required) under the BPWW. The BPWW site priorities are not static like those printed in the TAP.	Medium
Difficulties in monitoring certain species.	Site managers monitoring individual species, to consider the monitoring recommendations for native species.	Medium
	For rare species monitoring, PEMU is to make a case by case assessment to decide if monitoring a species at a site is feasible, based on the resources needed to measure a change in the species' population.	Medium
	To consider the need for specialised monitoring personnel.	Medium
Monitoring has occurred mostly on an ad-hoc basis.	The PEMU to prepare an overarching monitoring strategy to ensure efficient, targeted and meaningful monitoring data is collected.	Medium
Minimal research into the effect of bitou bush invasions and control on fauna.	Research objectives are still valid but are not considered a high priority. Progress research projects where funds are available.	Low
Managed sites and site management plan performance criteria were not reached (as per Objective 1).	Not significant. No priority action. A large number of sites were managed and most resources went to control category 1 sites. These targets were funding dependant. External funding was available to fund many of the high priority sites where management could occur.	N/A

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