CHARLES STURT
UNIVERSITY

THE JOHNSTONE CENTRE
REPORT Nº 120

Nathan Cobb's Laboratory
Conservation & Interpretation Project

The spread of Olives (*Olea* sp.) on Wagga Wagga Campus

III. Impact on heritage resources and eradication

by
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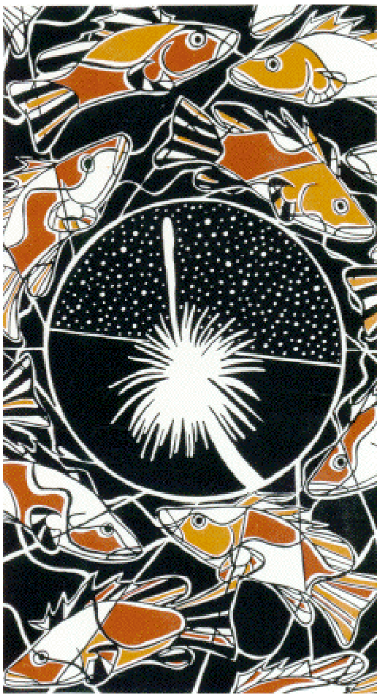

Albury Australia
1998

CIP

Spennemann, Dirk H.R. 1958—
Nathan Cobb's Laboratory Conservation & Interpretation Project.
The spread of Olives (Olea sp) on Wagga Wagga Campus.: volume
III. Impact on heritage resources and eradication-by Dirk H.R. Spennemann
Albury, NSW: Charles Sturt University, The Johnstone Centre, 1998.
1 v., - (Report / Johnstone Centre of Parks, Recreation & Heritage, no. 120)

DDC 583.87099448
1. Agriculture--Wagga Wagga Experimental Farm (NSW)
2. Olive--History--Australia--Wagga Wagga (NSW).
3.
4.
I. Charles Sturt University. Johnstone Centre of Parks, Recreation & Heritage. II. Title. III. Series.

Contents

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Introduction

Two olive species occur on the Australian mainland and offshore islands. Australia, two introduced varieties of the same species and one native. Introduced are *Olea europaea* ssp. *europaea* and *Olea europaea* ssp. *africana*, while *Olea paniculata* is deemed native to Australia. The European native olive, *Olea europaea* ssp. *sylvestris* was never transplanted to this continent. *Olea* are evergreen shrubs or trees. The leaves are opposite, simple in form, with non-serrated margins. The lower surface of the leaves usually shows a dense covering of scale.

In their habitat *Olea* ssp. occur in semi-arid to subhumid warm-temperate regions, with dry and hot summers and winter-dominant rainfall. In South Australia the 500mm annual rainfall isohyet seems to be defining the boundary of its distribution (Parsons & Cuthbertson 1992, p. 523). *Olea* can occur on a wide range of soils.

Olives as weeds

The drupes of olives (*Olea europaea*) are sought after food for several native and exotic frugivorous birds, as well as for ground dwelling mammals. Often animals feeding on olives in the orchards take the drupe (and seed) to cover in a remnant bushland situation (Spennemann and Allen 1997). Once established, *Olea europaea* forms a dense and permanent canopy under which olive seedlings can grow, but native trees cannot regenerate. This characteristic was not only observed in South Australia (Cooke 1991), but also in South Africa (Manders and Richardson 1992). In South Australia *Olea europaea* was declared a community pest species for three areas 1980, which was extended other areas in 1990 (SAAPCC 1990; Cooke n.d.). Consequently, the olive has been classified in South Australia as a noxious weed, class 5, unless planted for domestic or commercial use (Parsons & Cuthbertson 1992, p. 552). In Victoria too it is considered to be an environmental weed (Carr *et al* 1992, p. 51).

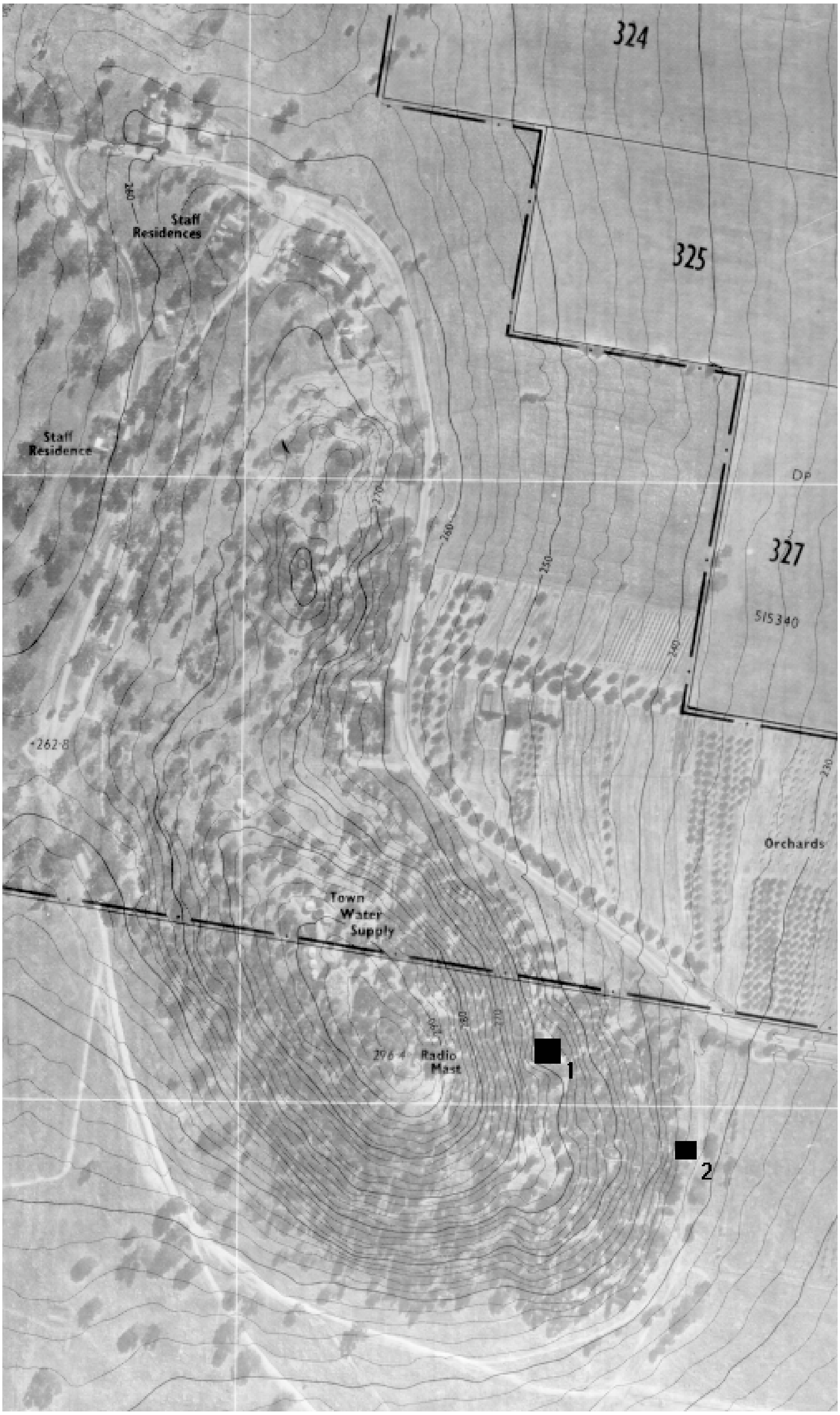

Figure 1.1. Aerial Photography showing the study site on Wagga Wagga Campus of Charles Sturt University. Scale approx. 1: 6000. Date: 1972. (Source: Orthophotomap 1:4000 Wagga Agricultural College 2717-VIII).

In Sydney Harbour National Park *Olea europaea* ssp. *africana* is found scattered throughout the area and recognised as a plant pest potentially capable of creating a much greater problem (Smith 1984). In the Camden area of NSW olives have invaded remnant bushland (Dellow *et al.* 1987) and pose a major problem in Mt. Annan Botanical Garden (Cuneo 1997). Eradication was conducted on Norfolk Island (Hermes 1987; Stevenson 1997). Likewise, in South Australia a number of weed eradication programs were conducted in natural environments (cf. Hawkins 1994; Stafford and Venning 1984; Robertson 1984).

The importance of olives as a woody weed is increasingly recognised. It is, for example, not included in Lamp and Collet's *Field guide to weeds in Australia* (1976; 1989), but treated extensively in Parsons and Cuthbertson (1992, p. 522ff.).

The study area

The predecessor institution of Charles Sturt University, Wagga Wagga Campus, the Wagga Wagga Agricultural College, celebrated its centenary in 1996. As part of these celebrations it had been planned to adequately manage and interpret the ruins of a laboratory building, commonly known as "Farrer's Lab", but more accurately to be addressed as Nathan Cobb's Laboratory, as well as the associated concrete base of a granary. A draft conservation management plan of the resource had been developed which recommended *inter alia* that the extent and nature of an infestation with olives (*Olea* ssp.) be investigated (Spennemann 1997). Observation had shown that olive trees were contributing to the decay of the sites.

This document represents the findings of this research, including an assessment of the damage caused by the olives; and a review of possible mitigation options.

2
Impact of olives on sites

Trees, especially those with a broad and deep root network have been responsible for much damage in archaeological and historical sites. Roots tend to grow through crevices between masonry units, and through growth and thickening of the root widen the existing crevices and cracks, ultimately dislodging and uplifting stones and the like. The examples for this range from raised and cracked pavements to the spectacular images of the temple of Angkor Vat (Cambodia), entangled in rainforest trees.

In addition, root networks of trees withdraw moisture from the ground, which in times of moisture shortages in summer can lead to ground shrinkage (especially in clayey soils) and subsequent settling of foundations (Feilden 1982, p. 131; Weaver 1993, pp. 242-243).

Common mitigation options are to cut the plants and to poison the stumps to prevent regrowth—if it has been established that the plants are not part of the culturally significant fabric. Consideration must also be given to the voids left behind by decaying wood, which may lead to sudden settling of foundations.

In archaeological sites the root growth of plants can lead to disturbances of the soil column and subsequent mixing of the stratigraphy and to the destruction of soft artefacts and human remains. Further, decayed roots can leave behind voids which could result in the movement of artefacts and/or microstratigraphic collapse.

Impact of olives of foundations

Olive trees will produce two types of roots, those that are short-lived (frequently only a few months) and those that develop secondary enlargement (Connell and Catlin 1994). A tree grown from seed will have a long and strong taproot and, commonly, a straight stem, while trees propagated from layers or truncheons will have a shallower root network and will be more susceptible to wind impact (Thompson 1891; Marvin 1888, p. 60).

The root network of olives is governed by the depth of the soil. But even in deep soils olives have a shallower root system that extends far, but rarely goes below 1.2m. Self-seeded or seed-grown olives tend to have a deeper root system than olives that have been grown vegetatively from truncheons of cuttings (Connell and Catlin 1994).. Olives tend to have about 60% of their root system in the top 0.6m of the soil profile.

Normally the extent of the of the root network of a tree is equivalent to the spread of the canopy. Among olives, however, the spread of the root network can be up to three times that of the canopy (figure 2.1)—a reason why olives can survive in relatively dry conditions.

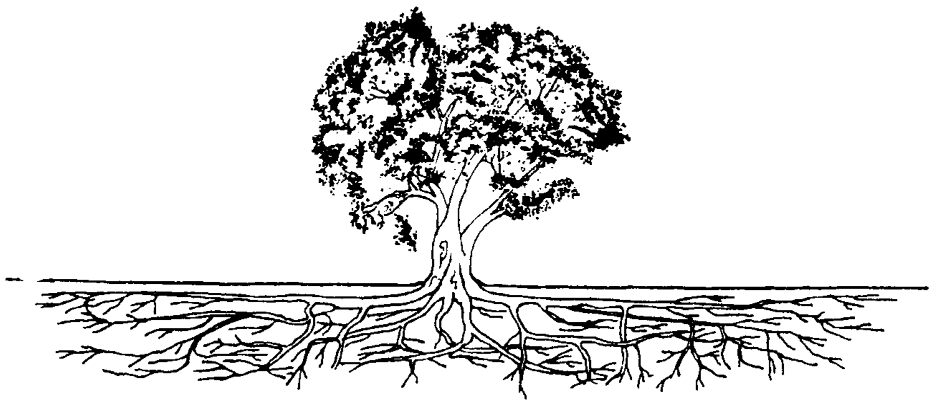

*Figure 2.1.Example of the root distribution of a mature olive tree (*Olea europaea*) in an olive grove (after Connell and Catlin 1994)*

Severe pruning tends to stimulate vigorous shoot growth and suppresses root development in spring. This is compensated later in the season and increased root growth is likely to follow.

Fire hazard

A side effect of an olive infestation of a site or its environs is that olives are highly inflammable plant species. Increased infestation creates an exponentially greater fire hazard, with a greater fuel production (Cooke 1991).

Substantial growth of olives, however, increases leaf litter generation and fire risk (Parsons & Cuthbertson 1992, p. 523). The main hazard of feral olives stems from the high proportion of dead and dry fruitwood in the canopy. This wood is predominately very thin (ø ≤ 10mm) and well aerated, leading to increased combustibility (Brian Lord pers comm.).

3

Case study

Foundations of the granary

The infestation with olives of the foundations of Cobb's granary can be used to exemplify the problems brought about by the olive roots.

The ruins are located at the bottom of the eastern side of the hill, bordering a dirt track that leads from the winery to the entrance of CSU Wagga Wagga Campus. Since the erection of the granary the area would have been at the margin between the developed orchards and experimental fields and the remnant bushland on the hill. The area, therefore, was well suited for the dispersal of olive seeds by a variety of birds, as well as mammals, such as foxes.

Figure 3.1 shows the plot of all olive plants on and near the granary foundations. Observation sin November 1997 have shown that the olives growing on the granary platform are of different varieties as not all were in flower at the time.

Table 3.1 Girth (at 50 cm) and characteristics of the olives growing on and at the granary platform.

Olive	Girth (cm)	Comments
B1	16	multiple stems
B2	55	multiple stems, two are dominant
B3	68	
B4	11	
B5	72	
B6	19	multiple stems
B7	58	
B8	15	
B12	46	

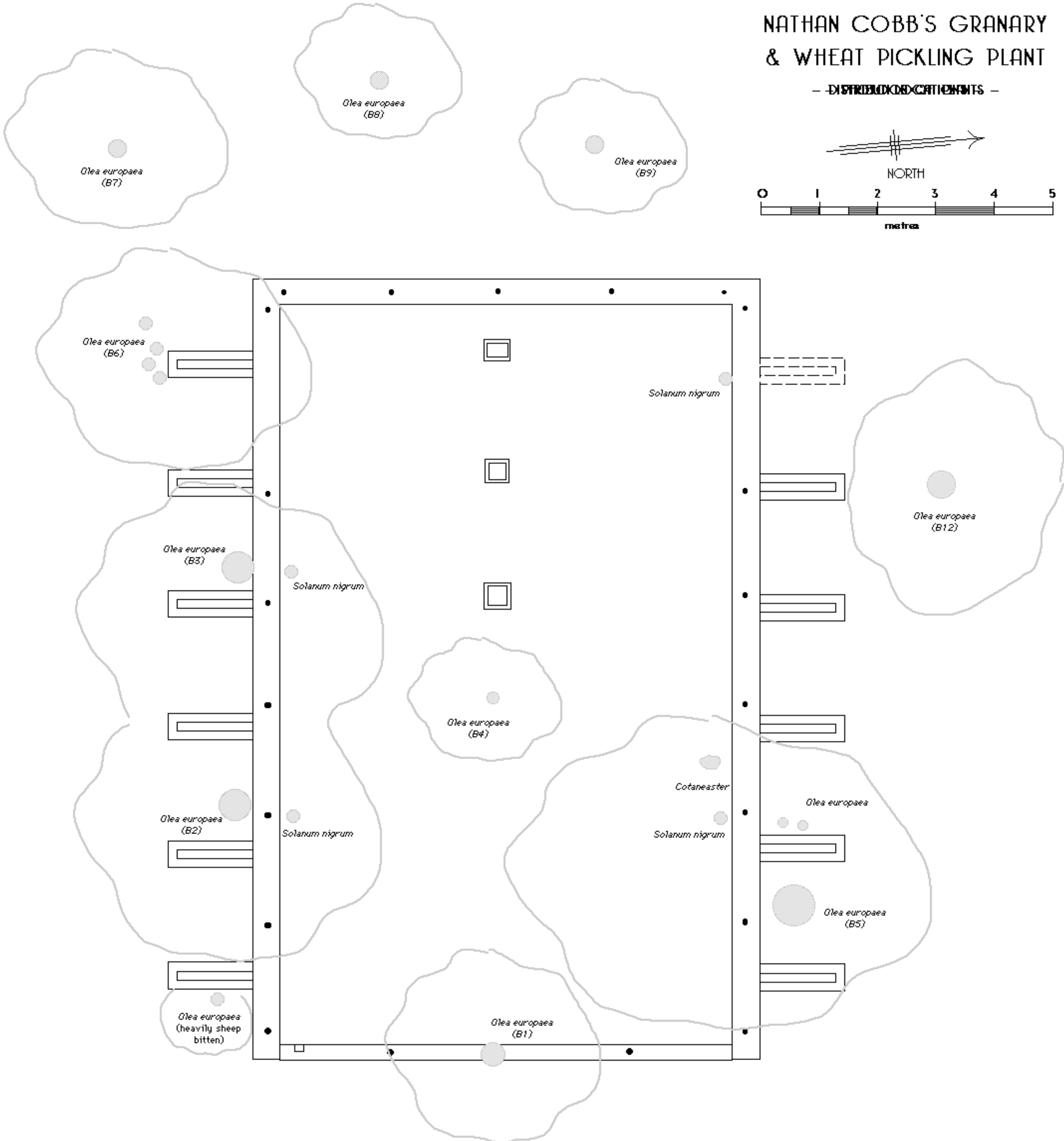

Figure 3.1 Plot of the granary ruins, showing the distribution of olives.

Figure 3.2. View of the interior of the granary platform.

Figure 3.3. Example of a mature feral olive pushing apart the foundation of a buttress.

Above:

Figure 3.4. Infestation of feral olives between foundations of buttresses.

Left:

Figure 3.5. Young feral olive growing up from foundations.

4
Eradication of olives

Containment of olives

It appears that high grazing pressure is able to contain the spread of olives. Dellow *et al* (1987) state that olives have established themselves in the late 1970s and early 1980s as a major woody weed in the Camden/Campbelltown districts. The authors suggest that this establishment was caused by bird dispersal of seeds and facilitated by changes in grazing regimes. The Adelaide hills are very infested with olives, which spread following the removal of grazing livestock. Reintroduction of stock, however, could contain the spread (Stafford & Venning 1984).

While this appears to suggest that stock can contain the spread of olives, the experience at Wagga has shown that occasional agistment of stock not necessarily achieves this aim. The success of the containment depends on the feeding pressure exerted by the livestock on the olive seedlings. If the olive seedling has enough time to firmly establish itself before being bitten back by livestock, then the plant will produce only small leaves near the stem which are not grazed upon, ensuring the survival of the plant for a while.

In addition, the livestock also feed on ripe olive drupes that fell from the tree. Studies in the Mediterranean have shown that sheep and goats feed on olives and are thus also dispersal agents that need to be considered.

Observations in Spain have shown that fallen olives are also picked up and eaten by rabbits (*Oryctolagus cuniculus*), goats (*Capra hircus*) and deer (*Cervus* sp.), but that the seeds are regurgitated undamaged (Jordano 1987). Bigler and Delucchi (1981) observed in Western Crete (Greece) that sheep (*Ovis aries)* and goats (*Capra hircus*), grazing in orchards as well as shrubland around orchards, sought out olive trees (inc. *Olea europaea* spp. *sylvestris*) and fed on fallen olives. Chapman (1896) comments that in Tuscany sheep were sent into olive groves after the harvest to graze upon grass and fruit.

Eradication of olives

A number of eradication options exist, which are discussed below in terms of success ratio for the successful removal of the plant and its potential impact on cultural resources. Published experiences come from Hawai'i , New South Wales and South Australia

Hawai'ii

In Hawai'i the feral "Russian olive" (*Olea europaea* ssp. *africana*) is controlled by the application of 10% Garlon 3a ("Redeem"), an amine formulation of Triclopyr, on the basal bark. It works well if it is sprayed close to run off and as close to the ground as possible (pers. comm. Tunison 1997).

New South Wales

Dellow *et al.* (1987) conducted a study comparing the effectiveness of various commercial herbicides and herbicide concentrations in a parkland/remnant bushland setting at Camden near Sydney. Tested were the herbicide application at the basal bark, as well as an application on a cut stump. The result are set out in table 4.1. As shown, merely cutting off the olive will has no effect at all, and Dellow *et al.* comment that the regrowth was between 1 and 2 m tall after 20 months. The use of glycophosphate ('Round-up®") was not very successful. Despite a higher concentration the cut stumps still regrew, even though the regrowth was stunted and deformed.

Table 4.1 Success of poisoning with herbicides based on four replications per treatment (Data after Dellow et al. *1987)*

Herbicide	Concentration	Method	% Kill rate after 13 months	20months
Roundup® + Water	1:2	cut stump	41	13
		basal bark	55	68
	1:10	cut stump	0	0
		basal bark	15	13
Garlon® + Distillate	1:10	cut stump	100	100
		basal bark	100	98
Control (untreated)		cut stump	0	0
		basal bark	0	0

Parsons and Cuthbertson (1992, p. 524) recommend the use of the cut stump technique with an immediate application of undiluted picloram and triclopyr, triclopyr, or ester 2,4-D immediately after cutting. The bark of the stump should be peeled back and the entire stump swabbed. With the basal bark technique triclopyr diluted in distillate should be applied for the first 50-60cm of the trunk, wetting the bark to the point of run-off.

Table 4.2. Treatment of olive infestation recommended by the SA Animal and Plant Control Commission (Cooke 1991)

Age of plant	Method	Herbicide	Concentration	Dilution	Dilutant
Seedling	spot spray	Comkil Non-residual Systemic Herbicide®	100/l	36ml/L	
≤6 months		Glypho Weedkiller (Chemspray)®	100/l	36ml/L	
		Tumbleweeb Weedkiller Concenrate®	100/l	36ml/L	
		Wipeout Total Weedkiller®	100/l	36ml/L	
		Zero Weedspray®	100/l	36ml/L	
		Glyphosate 360 Herbicide®	360h/L	10ml/L	
		Roundup Herbicide®	360h/L	10ml/L	
		Glyphosate 450 Herbicide®	450g/L	8mlL	*)
		Glyphosate CT Broadacre Herbicide®	450g/L	8mlL	*)
		Roundup CT Broadcare Herbicide®	450g/L	8mlL	*)
Plant	spot spray	Garlon 600®	600g/L	1.6ml/L	
≤2 years		Garden King Treekil®	120g/L	8ml/L	
Mature Tree	swab cut &	Garlon 600®	600g/L	undiluted	—
	frilled stump	Garden King Treekil®	120g/L	undiluted	—
		Axe-It Blackberry and Tree Killer®	50g/L	undiluted	—
		Hortico Blackberry and Tree Killer®	50g/L	undiluted	—
		Defender Blackberry Plus Tree Killer®	50g/L	undiluted	—
		Cherec Tree Killer®	50g/L	undiluted	—
Shoot from cut stump	spot spray	Garlon 600®	600g/L	1:30	Diesel

*) plus 1.25 ml organo-silicon surfactant

South Australia

In the Adelaide Hills Stafford and Venning (1983) cut off *Olea europaea* ssp. *europaea* at the base and painted the stump with a 1:20 solution of Roundup and neat Amitol (Vorox). Kangaroo grass (*Themeda australis*), direct seeded to regenerate the area, grew in the Vorox applications but not where round-up had been used. In a parkland/bushland setting the recolonisation by olives can be controlled by burning, which will destroy all olive seedlings.

In the Watiparinga Reserve olives were hand pulled or cut and swabbed with 2,4,5-T. Very young olives could be hand pulled in winter or early spring when the soil was moist. Older trees were cut off at ground level and the surface liberally swabbed with a 1:20 solution of 2,4,5-T ester in distillate. Frilling at the root stem junction is described as essential (Robertson 1984). Control is described as most effective in late spring or summer. Large olives with multiple stems were fond to be the most difficult to eradicate, with follow up work in subsequent years being necessary.

The SA Animal and Plant Control Commission recommends to give priority to the removal of seedlings from sites with no established olives, as seedlings up to six month old will not regrow after spot-spraying with glycophosphate. This work needs to be carried out repeatedly, however, as seedlings from old -dispersed may germinate. Older plants (up to two years should be spot sprayed with triclopyr, while mature olives need to be cut and the stump with sections of frilled back bark be treated with undiluted triclopyr (Cooke 1991). Table 4.2 sets out the recommended treatment and concentrations.

An evaluation of eradication options

A number of eradication and management methods are discussed below w.r.t. their effectiveness in terminating growth and their impacts on cultural resources:

- Option 1 : No action alternative
- Option 2 : Pruning of trees after flowering
- Option 3 : Hand-pulling of trees
- Option 4 : Cutting down of trees
- Option 5 : Cutting down of trees and grubbing of stump and roots
- Option 6 : Cutting down of trees and poisoning of stump
- Option 7 : Poisoning of basal bark
- Option 8 : Cutting down of trees and agistment of stock
- Option 9 : Fire

Option 1 : No action alternative

Application:	n/a
Ideal time:	n/a
Success to terminate growth:	None.
Long-term prospects:	None.
Impact on cultural resources:	Continued decay of the fabric of the site. Increased risk that retaining walls of the cellar will collapse. The foundations of the granary will continue to be split.
Long-term implications	Over time the foundation walls of the granary will be pushed out of alignment. As a result the significance and interpretability of the site will suffer. The olive plants will self-seed additional small olive trees which will exacerbate the decay problem.
Approx cost per plant	n/a

Option 2 : Pruning of trees after flowering

Application:	Cutting off the remains of the small inflorescences to remove the developing fruiting bodies, thereby reducing the chance of further dispersal of ripe drupes.
Ideal time:	November-December each year
Success to terminate growth:	It has been shown that heavy pruning encourages the growth of suckers. Root growth is likely to continue.
Long-term prospects:	Nil. Unless the pruning regime is kept up, the tree will continue to fruit and grow.
Impact on cultural resources:	While the tree height is maintained, the continued pruning will lead to increased root development. The subsurface damage to the sites will continue. Intensified root growth and sucker development will lead to the widening of the stem base, thus threatening the foundation walls.
Long-term implications	Ongoing maintenance and cost of pruning. Not very viable method.
Approx cost per plant	$100/ year

Option 3 : Hand-pulling of trees

Application:	Manual extraction (pulling up) of seedlings and saplings from the ground.
Ideal time:	winter to late spring
Success to terminate growth:	The method is only possible if the trees/ seedlings are small. The method should be carried out when the soil is moist to facillitate removal.
Long-term prospects:	If the small plant was established, it may regrow from root sections if some of the root matter has been left in the ground.
Impact on cultural resources:	The impact on cultural resources depends on the size and spread of the root system. Deeper roots being pulled are likely to disturb the stratigraphy of the site. The method appears suitable for clearing the perimeter of a site where archaeological subsurface features are not expected. Suitable for site maintenance to remove the developing small seedlings grown from bird dispersed endocarps.
Long-term implications	Reasonably good.
Approx cost per plant	$5-20 (depending on thickness of the plant)

Option 4 : Cutting down of trees

Application:	Cutting down the tree in small sections to prevent heavy logs from falling onto the site damaging site components of surface and subsurface deposits.
Ideal time:	At any time, preferably before fruiting to reduce the likelihood for seed spread.
Success to terminate growth:	The cut stump would resprout, leading to a coppicing effect. Further, suckers would grow from the roots, exacerbating the infestation problem. It has been shown that heavy pruning encourages the growth of suckers.
Long-term prospects:	The tree will regrow if the cutting down is not accompanied by additional measures.
Impact on cultural resources:	Provided that the tree is cut down in sections and these are roped/lowered down without damaging the surface, the cutting down itself would not cause any damage to the heritage site. Increased sucker growth, however, would cause a spreading of the olive plant and would encourage additional root growth, thereby threatening larger areas.
Approx cost per plant	$80-200 (depending on size of plant)

Option 5 : Cutting down of trees and grubbing of stump and roots

Application:	Cutting down the tree in small sections to prevent heavy logs from falling onto the site damaging site components of surface and subsurface deposits. Manual excavation of the stump and major root network.
Ideal time:	At any time, preferably before fruiting to reduce the likelihood for seed spread.
Success to terminate growth:	This process usually results in a heavy seedling generation, as those seeds resting on and embedded in the surface will be firmly embedded in the soil
Long-term prospects:	Good if followed up by hand pulling or poisoning of seedlings and sucker regrowth. If some larger root sections are left in the ground the olive will resprout from these, usually leading to a proliferation of small plants that cannot be hand pulled.
Impact on cultural resources:	The grubbing of the roots would exacerbate any damage cultural sites may already have sustained, and would impair the integrity of any subsurface features that might be present.
Long-term implications	The loosening of the topsoil may result in increased wind and water erosion of the surface, exposing archaeological subsurface components of the site.
Approx cost per plant	$100-250 (depending on size of plant)

Option 6 : Cutting down of trees and poisoning of stump

Application:	Cutting down the tree in small sections to prevent heavy logs from falling onto the site damaging site components of surface and subsurface deposits. Application of triclopyr herbicide (such as Garlon®600) to poisoning the freshly cut stump.
Ideal time:	At any time, preferably before fruiting to reduce the likelihood for seed spread.
Success to terminate growth:	Good
Long-term prospects:	unknown
Impact on cultural resources:	Provided that the tree is cut down in sections and these are roped/lowered down without damaging the surface, the cutting down itself would not cause any damage to the heritage site.
Approx cost per plant	$80-200 (depending on size of plant)

Option 7 : Poisoning of basal bark

Application:	Stripping part of the bark, and painting with tryclopyr
Ideal time:	At any time, ideally during spring during increased plant development.
Success to terminate growth:	Unclear
Long-term prospects:	Unknown
Impact on cultural resources:	Provided that the dead tree is cut down in sections and these are roped/lowered down without damaging the surface, the cutting down itself would not cause any damage to the heritage site. The risk is that the dead tree is left standing and will eventually collapse
Long-term implications	Unknown
Approx cost per plant	$5-20

Option 8 : Cutting down of trees and agistment of stock

Application:	Cutting down the tree in small sections to prevent heavy logs from falling onto the site damaging site components of surface and subsurface deposits. Followed by the agistment of stock, such as sheep, goats or cattle.
Ideal time:	At any time, preferably before fruiting to reduce the likelihood for seed spread.
Success to terminate growth:	Continual agistment of sheep or cattle is likely to keep the growth of olives in check. However, doe not prevent infesttaion
Long-term prospects:	Infestation will continue once agistment stops
Impact on cultural resources:	Provided that the tree is cut down in sections and these are roped/lowered down without damaging the surface, the cutting down itself would not cause any damage to the heritage site.
Approx cost per plant	$80-200 (depending on size of plant) partially offset by agistment income

Option 9 : Fire

Application:	Spray foliage and stem with combustible material, ignite
Ideal time:	Late spring or early autumn
Success to terminate growth:	Olive seedlings and small plants are very susceptible to the impact of fire and are easily destroyed. Large plants will regrow from the root stocks.
Long-term prospects:	While flammable, due to the thin and well aerated branch network, mature olives cannot be destroyed by fire. W. Frogatt mentions an example from Crete, where mature olive orchards had been burnt in a civil feud. For practical purposes the trees appeared to be dead. yet they grew new shoots and suckers the following year (Frogatt quoted in Beverly 1935).
Impact on cultural resources:	The fire could impair the cultural resource affected by the plant growth, either by the destruction of remnant combustible materials or by the emitted radiant heat that could lead to differential expansion of worked surfaces and thus spalling. The calcium-based (lime) mortar of the cellar walls would most likely decay very rapidly under the fire regime.
Long-term implications	Unlikely to kill the major and well established plants
Approx cost per plant	$5-10

Recommended Options

In view of the previous discussion, the only method for containment that can be recommended from a cultural heritage perspective is a combination of options 6 and 3.

In the first instance, cut down all established plants (preferably before fruiting to reduce the likelihood for seed spread) in small sections to prevent heavy logs from falling onto the site damaging site components of surface and subsurface deposits. An application of triclopyr herbicide (such as Garlon®600) to poison the freshly cut stump shall follow immediately. The surrounds need to be cleared of any fallen fruit making sure that any archaeological surface deposits are not impacted.

In the following years systematic follow up needs to be carried out to hand pull all merging seedlings, as well as to patrol the bases of any perch trees where birds might drop seed.

Acknowledgments & Bibliography

Acknowledgments

The study reported here was made possible by a number people through their assistance in the field and laboratory, as well as through the provision of data and information. Their contribution is gratefully acknowledged: David Cooke (Animal and Plant Control Commission, South Australia, Adelaide); Jim Dellow (NSW Dept of Agriculture, Orange); Brian Lord (SESI, CSU); Tim Tunison (U.S. National Park Service, Hawai'i);

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