



## Risk Analysis: *Euphorbia paralias* – sea spurge



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ISBN No: 978-0-478-40435-7 (online)

**October 2012**

Photos of *E. paralias*: a) upper parts of stems; b) entire plant (DEEDI 2011); c) infestation in Victoria, Australia (CHAH 2011)

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## Executive Summary

*Euphorbia paralias* is a long lived herbaceous coastal plant native to North Africa, western Asia, and Europe and invasive in Australia. Seeds are buoyant and can be spread very large distances by ocean currents. Once established, *E. paralias* develops dense infestations which prevent natural sand movement, altering dune communities, threatening some rare coastal plants, and contributing to the decline of some species of nesting shore birds. *Euphorbia paralias* has been reported as invading pastoral land adjacent to coastal areas in Australia reducing pasture available for stock grazing. Establishment may change coastal sand movement processes which may exacerbate coastal hazards such as erosion. Additionally, the latex sap of *E. paralias* is considered poisonous and causes skin and eye irritation.

*Euphorbia paralias* has been detected at one site near Aotea Heads Scientific Reserve, Waikato, but is not considered to be established in New Zealand. This population is considered to be as a result of seed movement on ocean currents from Australia. Following this detection a risk analysis was requested by the Ministry for Primary Industries Response Manager for *Euphorbia paralias*. This analysis follows the Biosecurity New Zealand Risk Analysis Procedures (MAF 2006) but has been written to support the planned activities, and inform decisions on the management options.

The climate in New Zealand is similar to the climate in native range of *E. paralias* and much of its introduced range in Australia. *Euphorbia paralias* is capable of establishment throughout much of coastal Australia, particularly Tasmania. Given its native and introduced range, it could be expected that climate would be no barrier to establishment throughout coastal New Zealand.

Between the first detection in Australia and the present day, *E. paralias* has spread throughout the entire coastal regions of South Australia, Victoria, southern New South Wales and Tasmania. Given this rate of spread in Australia, the large numbers of seed produced, and the multiple pathways of spread it could be expected that *E. paralias* could spread rapidly to most coastal regions of New Zealand within the next 50 years.

Movement around New Zealand from an established population is highly likely as a result of a combination of coastal currents, bilge and ballast water, and contamination associated with recreational vessels, cruise ships and commercial vessels, and on-shore recreational activities which may transport seeds, plants or root fragments.

While it is not possible to prevent the arrival of seed it is possible to reduce to zero density populations that are detected, thereby mitigating the consequences of establishment.

As there are no management options for stochastic events such as ‘natural dispersal’ of invasive seeds or plants to New Zealand, focus will need to be on management of the current population, and future infestations and populations when they are detected. Furthermore establishment of at least some future populations is likely to be in remote and difficult to access locations and populations may be relatively large before they are detected.

Exclusion (maintain zero density) is recommended as an option as opposed to eradication. The exclusion option recognises that new incursions are likely and therefore the best intervention point is the removal of populations as they are detected. Eradication is unlikely to be achievable as the risk of establishment from new incursions is high. Eradication cannot be achieved if new incursions are likely, as these new incursions would potentially negate the additional effort required of an eradication programme.

Management options to achieve the goal of exclusion include targeted surveillance to identify likely areas of introduction; plant removal and long term monitoring to prevent re-growth of the population from the seed bank; and sand sieving, or sand removal, to prevent germination of seeds within the seed bank or seed movement due to high tide and storm events.

## Risk analysis of *Euphorbia paralias* – sea spurge

**Scientific Name:** *Euphorbia paralias* (Linnaeus 1753) (Malpighiales: Euphorbiaceae)

**Synonyms:** *Esula paralias*, *Euphorbia malacitana*, *Euphorbion paralium*, *Galarhoeus paralias*, *Tithymalus maritimus*, *Tithymalus paralias*

**Common name:** sea spurge

*Euphorbia paralias* is a long lived herbaceous coastal plant usually growing between 20 and 70 cm tall. It is native to North Africa, western Asia, and Europe and invasive in Australia. *Euphorbia paralias* is most commonly found on coastal sand dunes. Seeds are buoyant and can remain viable in sea water for up to six years, and can be spread very large distances by ocean currents. The current detection is considered to be as a result of seeds arriving on ocean currents from Australia. Once established, *E. paralias* develops dense infestations which prevent natural sand movement, altering dune communities, threatening some rare coastal plants, and contributing to the decline of some species of nesting shore birds.

### Purpose of document

A risk analysis was requested by the Ministry for Primary Industries Response Manager for *Euphorbia paralias* to support the planned activities, and inform decisions on the management options, for the recently detected population of *E. paralias*. Also requested was collation and analysis of the information we have to date to ensure we have made correct assumptions about factors such as entry pathway, biosecurity impact, plant life stages, and spread. Information in this analysis may also be used to inform targeted surveillance to detect any other populations that may have established in New Zealand.

### Background

The Ministry for Primary Industries (MPI) received notification on the 13<sup>th</sup> of April 2012 that *E. paralias* was found on the fore-dune near Aotea Heads Scientific Reserve, south of Raglan, Waikato (Fig. 1). The detection site covers approximately 5 x 5 m on the fore-dune, with an additional single plant found approximately 100 m away.

This is the first detection of *E. paralias* in New Zealand but arrival of this weed has been expected by researchers and the Department of Conservation (DoC). Formal validation of the species was received from Trevor James (Senior Scientist, AgResearch) on the 16<sup>th</sup> of May 2012.

All *E. paralias* plants were uprooted during the site visit on the 23<sup>rd</sup> of April. The seed and flower heads were removed from the site, whilst vegetative material was treated with herbicide after hand pulling and allowed to decompose in situ. However, there is likely to be a reservoir of seed in the sand. Plants found at Aotea Head had around 6 – 8 mature stems per plant. As stems die off and are replaced throughout the season there is no way to estimate how many stems were produced by these plants and consequently no reliable estimate of potential seed production.

Information on sea spurge and how to report it was sent to the New Zealand Plant Conservation Network and now appears on its website ([http://www.nzpcn.org.nz/flora\\_details.asp?ID=6748](http://www.nzpcn.org.nz/flora_details.asp?ID=6748)). A fact sheet was distributed to regional councils and DoC on the 28<sup>th</sup> of May 2012. The fact sheet was developed in conjunction with the Waikato Regional Council, DoC, and weed and oceanographic experts.

The MPI exotic pest line (0800 80 99 66) has been instructed to send all reports of *E. paralias* to the Plant Health and Environment Incursion Investigation team.



Figure 1. a) Location of the detection site at Aotea Heads Scenic Reserve (Photo: Crown Copyright: Department of Conservation: *Te Papa Atawhai* (Sieste Bouma 2005)); b) Detail of the detection site (Photo: Sam Stephens, Waikato Regional Council); c) map of the detection site with the initial detection (green triangle) and site survey shown in red and the wider coastline survey shown in orange (Hernando Acosta, Surveillance and Incursion Investigation, Ministry for Primary Industries)



# Hazard Identification

## NEW ZEALAND STATUS

*Euphorbia paralias* has been detected at one site on the Waikato coast. This population is considered to have been present for at least five years; however, despite intensive ground searches 15 km to the north and south of this population, no further populations have been found. Therefore *E. paralias* is considered not to be established in New Zealand.

## CURRENT WORLDWIDE DISTRIBUTION

Native to: **Africa** (Canary Islands, Algeria, Egypt, Libya, Morocco and Tunisia); **Asia** (Cyprus, Sinai, Israel, Jordan, Lebanon, Syria and Georgia); **Europe** (Ireland, United Kingdom, Belgium, Netherlands, Ukraine, Albania, Bulgaria, Former Yugoslavia, Greece [incl. Crete], Italy [incl. Sardinia, Sicily], Romania, France [incl. Corsica], Portugal and Spain [incl. Balears]) (USDA 2012a)

Naturalised in: **Australia** (Western Australia, South Australia, New South Wales, Victoria and Tasmania) (ANBG 2012; USDA 2012a)

There is one historical record of plants being present in Philadelphia, USA, found in low marshland covered with the mud dredged from docks then subsequently covered with ship's ballast (Burk, 1877). The USDA still records it as being present however the only reference for this is an 1899 report in the Annals of the Missouri Botanical Garden (USDA 2012b).

## POTENTIAL FOR ESTABLISHMENT AND IMPACT

The current detection is considered to have been present for around five years; however, this is the only population detected despite intensive ground searches in the area; therefore, *E. paralias* is not considered to be established at this time. *Euphorbia paralias* is capable of establishment throughout much of coastal Australia, particularly Tasmania. Given its native and introduced range, it could be expected that climate would be no barrier to establishment in New Zealand.

Establishment of *E. paralias* throughout New Zealand has the potential to alter dune communities, and contribute to the decline of some species of nesting shore birds.

Furthermore the latex sap of *E. paralias* is considered poisonous and causes skin and eye irritation; on occasion painful temporary blindness can occur if the sap contacts eyes.

Given the reduction in biodiversity in dune communities and the human health impacts of contact with sap, *E. paralias* may have negative impacts on tourism and the socio-cultural value of these dune systems.

*Euphorbia paralias* has been reported as invading pastoral land adjacent to coastal areas in Australia reducing pasture available for stock grazing. Additionally, establishment may change coastal sand movement processes which may exacerbate coastal hazards such as erosion.

## HAZARD IDENTIFICATION CONCLUSION

*Euphorbia paralias* has the potential to establish in New Zealand and cause negative environmental, economic, socio-cultural and human health impacts. Therefore *Euphorbia paralias* is considered a hazard in this risk analysis.



# Risk Assessment

## BIOLOGY

### Summary

*Euphorbia paralias* is a long-lived herbaceous coastal plant with upright or semi-upright stems (Moore 2012; DEEDI 2011; CHAH 2011). It usually grows 20 - 70 cm tall, but may occasionally reach up to 1 m in height (Moore 2012; CHAH 2011; DEEDI 2011; James and Harden 1990). *Euphorbia paralias* has a long taproot with many fibrous roots (Heyligers 2002), which can grow 15 cm within one week of germination (Wilcock and Westbrooke 1999). Stems exude an irritant, sticky, milky sap when damaged (Moore 2012). *Euphorbia paralias* occurs on free draining sandy soils on beaches, around estuaries, through dune fields, in coastal herbfields, grasslands, heaths and shrublands, and may also grow along rocky shorelines and in sand-filled cracks between rocks. However, it is most commonly found on coastal sand dunes (CHAH 2011).

### Stems

The stems are often fleshy and branch from a woody base (Moore 2012; DEEDI 2011). Stem number is influenced by growing conditions; a vigorous three or four year old plant can produce up to 100 stems in a season, with up to eight stems present on the plant at a time, but under unfavourable conditions this number can be less than ten (Heyligers 2002). Side-branches may develop anywhere along the stems, giving *E. paralias* the capacity to grow through accumulating sand (Heyligers 2002). Stems are hairless, bluish-green in colour, and contain a milky white sap (Moore 2012; CHAH 2011; DEEDI 2011).

Stems usually divide into 3 - 5 flowering branches near their tips (James and Harden 1990), which are often further divided (CHAH 2011; DEEDI 2011). Forked flowering branches die off after flowering but may remain on the plant for up to a year (Moore 2012) and are replaced by new shoots from the root crown (Heyligers 2002). Each shoot has the potential to develop a terminal, branched, leafy inflorescence (Heyligers 2002).

### Leaves

The leaves are stalk-less, hairless, alternate, crowded and overlapping along the stems (Moore 2012; DEEDI 2011). They are somewhat fleshy and bluish green in colour but may become yellow or red when the plant is under stress (Moore 2012). Stem leaves are 5 - 30 mm long and 2 - 15 mm wide and vary from being elongated to oblong or oval in outline (Moore 2012; DEEDI 2011). In plants found in New Zealand these leaves have been recorded as 3.8 - 20.1 mm long and 1.03 - 16.2 mm wide (NZPCN 2012). However, the leaves on the flowering branches are usually circular to kidney-shaped and are paler green or yellowish in colour much broader and up to 18 mm wide (Moore 2012; DEEDI 2011; James and Harden 1990). The stems and leaves often turn reddish as they age (DEEDI 2011).

### Flowers

The inflorescence is composed of yellowish-green petal-less flowers in clusters of heads (Moore 2012). The inconspicuous 'flowers' are actually tiny cup-like structures called cyathia (singular cyathium, about 1.5 mm long) each containing several reduced male flowers and one female flower with a very large protruding ovary (Moore 2012; CHAH 2011; DEEDI 2011). Each flower is borne on a separate stalk and the tiny cup-like structure is fringed with four orange crescent-shaped structures that resemble petals, each of which usually has some short projections (CHAH 2011; DEEDI 2011).

Flowering occurs from spring through to early winter (DEEDI 2011). In New South Wales flowering commonly occurs between September to May (Moore 2012; James and Harden 1990) and October to June in Western Australia (Moore 2012; Paczkowska 1996). However, flowering is thought to be more dependent on growing conditions than time of year (Heyligers 2002; Paczkowska 1996). Flowers are insect pollinated and generally require cross fertilisation but can self fertilise (Fitter and Peat 1994), therefore it is possible that a population can arise from a single mature plant.

### **Fruit**

The ovary matures into a capsule 3 - 6 mm long by 4.5 - 6 mm diameter which hangs out of the floral structure and contains three seeds. The seed is explosively propelled up to 2 metres from the capsule at maturity (Moore 2012). Vigorous plants can produce 25 to 80 capsules per stem (Heyligers 2002).

### **Reproduction – Seeds**

The smooth seeds are egg-shaped to round and generally<sup>1</sup> pale grey or whitish in colour and 2.5 - 3.5 mm long (Moore 2012; CHAH 2011; James and Harden 1990). The annual production may be over 20,000 seeds per plant (Heyligers 2002). However, seed production is variable with severely stressed plants producing virtually no seeds (Heyligers 2002). Favourable conditions for growth of *E. paralias* occur where a fresh supply of sand or flotsam enriches the nutrient status of the fore-dunes while a reliable source of fresh water appears to be a contributing factor (Heyligers 2002).

Seeds are buoyant in sea water, most seeds float for at least one and a half years and some stay afloat for more than eight years (Heyligers 2002). Thus seed can be spread very large distances by ocean currents (DEEDI 2011; Heyligers 2002). Seeds have 50% viability in sea water for up to two years after which viability declines, and there is no viable seed after six years (Moore 2012). Seeds that sink are not viable (Heyligers 2007). Dry-stored seeds have a short dormancy period of around six months and after this time have a germination rate of around 40%; this germination rate is maintained for up to 13 years (Heyligers 2007). A closely related species, *Euphorbia esula* (leafy spurge), has around 60 – 80% seed viability (ISSG 2010) and it may be expected that the viability of *E. paralias* would be similar.

### **Reproduction - Root fragments**

Plants can re-grow from root fragments. The root fragments that are moved by wave action or earthmoving may re-establish populations where they are dumped (Moore 2012). However, although the seed can survive immersion in sea water it is unlikely that root fragments could, thus the spread of root fragments by waves is slight (Trevor James pers. comm.).

### **Germination and growth**

*Euphorbia paralias* appears to have very little seed dormancy and plants will not grow under canopy cover (J. Marsden-Smedley pers. comm.). Germination usually occurs after heavy rain (Moore 2012) and in Tasmania mass germination frequently occurs in early spring (Hilton *et al.* 2004). In cold wet sites on the south west coast of Tasmania *E. paralias* takes 12 to 15 months to reach maturity, whereas in eastern Tasmania and on Mainland Australia *E. paralias* takes around six months to reach maturity (J. Marsden-Smedley pers. comm.).

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<sup>1</sup> The seed sample from Aotea Heads in New Zealand was very dark brown; almost black (F. Velvin pers. comm.)

## Roots

After germination the seedling grows rapidly producing a long taproot; the taproot anchors the plant during erosion. The root has a diameter of 2.5 - 3 cm and tapers over a length of 30 - 40 cm to only a millimetre in diameter; this thin root penetrates for a metre or more into the sand. From the tapered section of the root a few lateral roots, about 1 cm thick, grow out horizontally. If it is buried, the plant continues growing until it runs out of nutrients stored in the stem, or reaches the surface to produce new leaves. Plants can cope with being buried up to 30 cm in deep sand by producing new shoots at the latest surface level (Moore 2012; Heyligers 2002).

## Dispersal

Long distance (between countries) spread is considered to be by seed movement between beaches by shipping ballast water; however, spread to New Zealand is considered to have occurred by seed movement on ocean currents from Australia where the weed is widespread. Medium distance (within countries) spread is by seed movement on coastal currents. Local spread (within habitat) is by wind erosion of sand containing seeds and root fragments, explosive release of seed from the parent plant (up to 2 m distance), and seed and root fragments spread along the beach after storms (Moore 2012). Humans can also assist dispersal by spreading seed and root fragments with beach grooming equipment or moving contaminated sand to new areas (CHAH 2011; DEEDI 2011).

## EXAMPLES OF EARLY INTERVENTION IN AUSTRALIA

In 1996 The Breamlea Coast Action Group in Victoria began controlling populations of *E. paralias* by slashing to break the seeding cycle, followed by hand removal of seedlings. By 1998 work was continuing to reduce the density of weeds in infested areas and replant with natives. A control schedule involved two intensive weeding efforts per year to coincide with the plants' flowering cycle, supplemented by regular weeding on an as-needed basis (Horlock 1998).

A study conducted by Wilcock and Westbrooke (1999) in Otway National Park, Victoria, concluded that both hand pulling and herbicide treatment (2,4-D ester) were equally effective in reducing populations of *E. paralias*. However, there was a high degree of replacement indicating that control efforts must be maintained over a number of years to deplete the seed bank and remove seedlings resulting from water borne seeds.

In 2005 and 2006 management plans were developed for the control of *E. paralias* in Henley South, West Beach, Tennyson coastal reserve, Tennyson dune reserve and Semaphore park coastal reserve in Adelaide, South Australia. Staged removal and replacement with native plants was recommended. Plants were controlled by spot spraying with glyphosate and hand weeding, with flowering plants removed from the reserve. Plants were slashed in spring to reduce seed set and controlled with glyphosate (Cordingley and Petherick 2005a; 2005b; 2006a; 2006b).

In 2010 Eurobodalla Shire on the south coast of New South Wales called for the community and local environmental groups to get involved in trying to eradicate *E. paralias* from coastal regions; recognising that *E. paralias* may still be eradicable from some of the beaches in the region on which it had recently become established. Hand pulling or digging was recommended, with plants removed from the site.

In the east coast region of coastal New South Wales *E. paralias* is controlled by herbicide spraying and hand pulling. It is recognised to be in generally low densities on most beaches south of Nowra; however, it is working its way north. *Euphorbia paralias* is recognised to be well dispersed along the coast and the highest priority for control is in those areas where it is

impacting on threatened plant or shorebird protection activities, or where the removal of isolated infestations can limit spread (Office of Environment and Heritage 2011).

SPRATS (sea spurge remote area teams) is a volunteer group in Tasmania which aims to establish and maintain an eradication zone for *E. paralias* along the southwest and southern wilderness coast of Tasmania. Control is achieved by hand pulling of plants, and occasionally digging out deeply rooted plants. Where plants are unable to be removed, stems are cut and painted with glyphosate. This method of control has cleared more than 95% of this coastline of seed producing plants (SPRATS 2010).

## Summary

The key lessons learned from experience in managing the plant in Australia are:

1. Control efforts must be maintained over a number of years to deplete the seed bank and remove seedlings resulting from water borne seeds.
2. Hand pulling and herbicide are equally effective.
3. Once widely established, there is a need to prioritise control efforts – either on the basis of local site values or to slow the invasion front.
4. Control can itself spread seeds and root fragments – good hygiene is essential.

All management plans stress the need for clothing and equipment used for control to be cleaned on site to avoid movement of seed or plant fragments to other locations. If cleaning is not possible on site then clothing and equipment needs to be bagged for cleaning at a location away from suitable germination habitats. These reports do not specify the method of cleaning or whether there is any suitable treatment to render seeds non-viable.

## BIOLOGICAL CONTROL

Scott *et al.* (2010) stated that biological control may be the most sustainable option for long-term control of *E. paralias* in coastal dune systems in Australia. They surveyed arthropods and pathogens that affect *E. paralias* in its native range in France and identified two moth larvae (*Acroclita subsequana* and *Eucrostes indigenata*), a leaf mining fly (*Liriomyza pascuum*), and a rust fungus (*Melampsora euphorbiae*) which were sufficiently damaging to plants to be considered as candidates for biological control.

The rust fungus *Melampsora euphorbiae* is considered as a good candidate biological control agent because it does not have an alternate host and its host range is restricted to a few species of *Euphorbia* (Scott *et al.* 2010). Research is currently underway on the efficacy of *M. euphorbiae* as a biological control agent, including host range testing (RIRDC 2012). As *M. euphorbiae* is present in New Zealand (NZFungi 2012) results of this testing are worth monitoring.

## ENTRY PATHWAY TO NEW ZEALAND

The rapid risk assessment report prepared by Kerry Thomas – Incursion Investigator, Surveillance and Incursion Investigation Plants and Environment (MPI 2012a) states that *E. paralias* was first recorded in Albany, Western Australia in 1927, and since that time has spread to Port Victoria, South Australia (1934), Wilsons Promontory, Victoria (1974), Waterhouse Bay, Tasmania (1980), Loader Beach, New South Wales (1987) and Lord Howe Island in 2001.

## Ballast water

There is an opportunity for spread to New Zealand in ballast or bilge water; however, this is more likely as a result of bilge water in recreational vessels rather than ballast water from commercial shipping. Bilge water is that water which collects in a vessel as a result of rough seas, rain or leaks and is contained below decks within the bilge compartment before being pumped out. Ballast water is taken on board large ships to provide stability and is discharged prior to loading.

Commercial ships commonly exchange ballast water at sea and may discharge this water in ports; therefore, there is a low likelihood of this water containing seeds. Conversely, recreational vessels may take on bilge water close to the Australian coastline where seeds are more likely to be concentrated and discharge this water at any point along the New Zealand coastline. Further information is needed on the movements of recreational vessels to and within New Zealand to better inform an analysis of the entry pathway.

## Ocean Currents

While entry to Australia is suspected to be by transportation in ballast water (Wilcock and Westbrooke 1999); entry to New Zealand was more likely a result of ocean currents from the east coast of Australia. Winkworth *et al.* (2002) state that many plant lineages in New Zealand are recent arrivals and are a result of eastwards transoceanic dispersal events with seeds carried by wind, marine currents or seabirds. Heyligers (2007) speculated that given that *E. paralias* has already spread to Lord Howe Island, it was only a matter of time before it appeared in New Zealand. The evidence for this speculation is the fact that several drift bottles and cards released in Bass Strait were recovered along New Zealand shores and a few plants of *Atriplex cinerea*, an Australian coastal species, have been found along Cook Strait.

*Euphorbia paralias* is well established in coastal mainland Australia and in controlled populations in Tasmania. Control on the mainland is only taking place in new, small, populations with the options for biological control being investigated for well established and widespread populations. Limited control of mainland populations means large numbers of seeds are released into coastal waters which will increase the likelihood of seed spread by ocean currents to New Zealand.

Mapping of ocean currents around Australia indicates that seed is most likely to arrive, and reach a suitable habitat, on currents originating from mainland Australia (primarily New South Wales) rather than Tasmania (Fig 2). The circulation on the West Coast of New Zealand is closely connected with the southwards circulation along the eastern coast of Australia (Heath 1985). This current affects both the east and west coast of New Zealand with flows diverging towards both North Cape (forming the east and west Auckland currents) and Fiordland (feeding into the Southland current) (Fig. 3) (Ridgeway and Dunn 2003). New Zealand coastal currents are likely to be able to transport seeds to northern New Zealand from Cape Egmont around to East Cape; Farewell Spit and into Golden Bay and Southland and Stewart Island (Fig. 4) (W. de Lange pers. comm.).

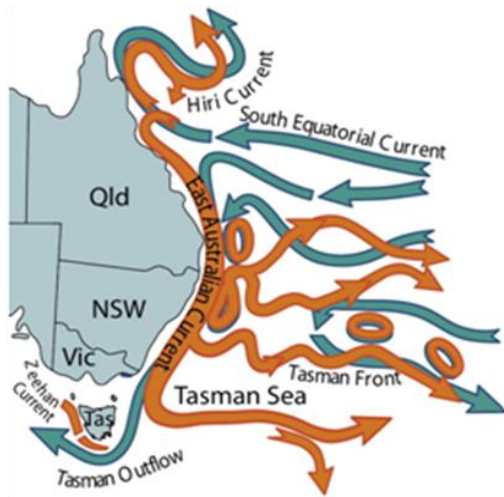


Figure 2. East Australian ocean currents (From CSIRO <http://www.redmap.org.au/resources/tasmanian-marine-environment/currents/>)

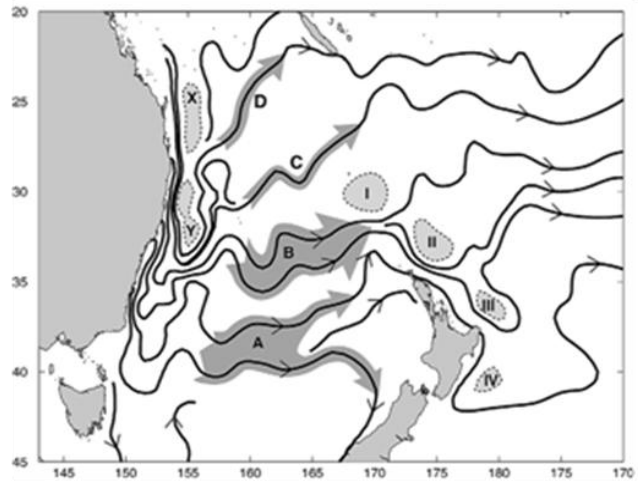


Figure 3. East Australian ocean currents (From Ridgeway and Dunn 2003)

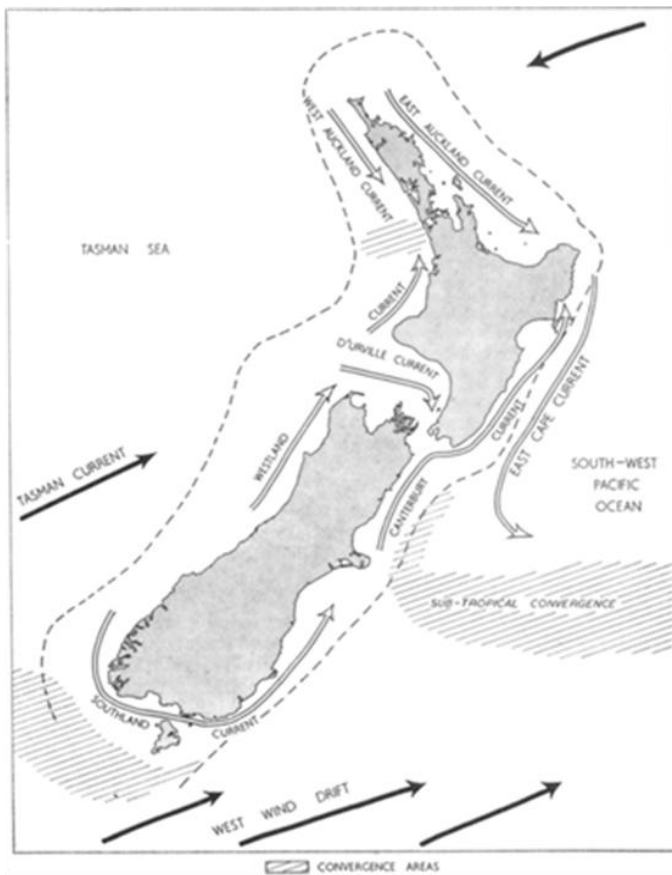


Figure 4. New Zealand coastal currents (From Brodie 1960)

### Personal effects

While entry into New Zealand as seed in the clothing or equipment of beachgoers is possible because seeds are small and remain viable for up to seven years; however, the fact that seeds have no attachment appendages, the relative scale of propagule pressure and the location of the current population of *E. paralias* in New Zealand indicate ocean currents as the more likely entry pathway.



## ESTABLISHMENT IN NEW ZEALAND

The climate in New Zealand is similar to the climate in native range of *E. paralias* and much of its introduced range in Australia. In its native range in the British Isles *E. paralias* requires mean annual temperatures ranging between 5 - 15 °C with a mean annual rainfall of around 1000 mm (Fitter and Peat 1994). *Euphorbia paralias* is capable of establishment throughout much of coastal Australia, particularly Tasmania. Given its native and introduced range, it could be expected that climate would be no barrier to its establishment in New Zealand.

As in New Zealand, the warmest months in Australia are December, January and February; and winter runs from June through to August. Rainfall in Australia is highly variable depending on location. Most areas of coastal New Zealand are climatically similar to coastal Tasmania, South Australia, Victoria and New South Wales. Table 1 shows the climate of coastal Australia (those locations with known populations of *E. paralias*) and that of coastal areas of New Zealand which could receive seeds from Australia on ocean currents.

		Summer temperature (°C)	Winter temperature (°C)	Summer rainfall (mm/month)	Winter rainfall (mm/month)
Known distribution in Australia	Tasmania (east coast)	12 - 20	6 - 14	60	55
	Tasmania (west coast)	10 - 20	5 - 12	90	160
	Victoria (Cape Otway)	13 - 20	8 - 13	45	90
	South Australia (Adelaide)	14 - 28	7 - 15	20	55
	Southern NSW (Eurobodalla)	16 - 23	7 - 16	90	55
	Eastern NSW (Ulladulla)	16 - 24	9 - 16	80	75
Possible initial distribution in New Zealand	Waikato	12 - 23	5 - 14	84	95
	Taranaki	13 - 17	6 - 10	100	120
	Tasman	13 - 17	3 - 8	75	75
	Southland (Milford)	10 - 14	2 - 6	700	550
	Southland (Invercargill)	9 - 14	2 - 6	100	90

Table 1. Average summer and winter temperatures and rainfall (New Zealand data from NIWA 2012; Australian data from BOM 2012)

## SPREAD WITHIN NEW ZEALAND

Movement within New Zealand from an established population is highly likely as a result of a combination of coastal currents, bilge and ballast water, and contamination associated with anchor chains and lockers (internal housing for the anchor) from recreational vessels, cruise ships and commercial vessels, and on-shore recreational activities which may transport seeds, plants or root fragments.

While movement within New Zealand as a result of bilge and ballast water, and contamination associated with anchor chains and lockers from vessels is possible, the likelihood is considered to be extremely low. The most likely pathways of spread within New Zealand are mobilisation of seed by coastal currents and human transport. Of particular concern is the collection of plants by members of the public either for propagation at home, or of flowering heads for dried arrangements.

The rate of spread within New Zealand is dependent on the numbers of seeds produced and the efficiency of the various pathways. Between the first detection in Australia on the southern coast of Western Australia in 1927 and the present day, *E. paralias* has spread throughout the entire coastal regions of South Australia, Victoria, southern New South Wales and Tasmania. In some areas *E. paralias* was present in 100% of plots surveyed and is considered the dominant coastal plant (Wilcock and Westbrooke 1999). Given this rate of spread in Australia, the large numbers of seed produced, and the multiple pathways of spread it could be expected that *E. paralias* could spread rapidly to most coastal regions of New Zealand.

The response brief (MPI 2012b) states that much of the sandy foreshore of the New Zealand coast would provide suitable conditions for establishment. The most likely areas for arrival of seed via ocean currents and establishment of plants include sandy coastal areas of northern New Zealand from Cape Egmont (Taranaki) around to East Cape, Farewell Spit and into Golden Bay and Southland, and Stewart Island. Further information is needed on coastal currents in New Zealand to better predict the likely spread of *E. paralias* throughout New Zealand.

The marine risk analysis group is currently involved in a research project to model the coastal currents around New Zealand to predict the spread of marine organisms (Contact: Dan Kluza, Marine Risk Analysis team). This model should be ready for use within the next year. The results of this project could prove useful for predicting seed movement from initial points of establishment.

## BIOSECURITY IMPACTS IN NEW ZEALAND

There is similarity between dune habitats and the climate (see Table 1) of coastal regions of Australia where *E. paralias* is invasive, and coastal environments in New Zealand that are likely to be colonised. Given these similarities, impacts in New Zealand are likely to be similar to those seen in Australia. The scale of impacts relates to the likely extent and rate of spread; given the extent and rate of spread in Australia *E. paralias* is considered likely to spread to most suitable coastal regions in New Zealand within the next 50 years. The potential environmental, economic, human health and socio-cultural impacts are discussed below.

### Environmental

The response brief summarises the likely environmental impacts of establishments of *E. paralias* as “Primarily an environmental pest that poses a major risk to the coastal environment. Populations are thought to have a significant influence on natural dune building processes, replace native flora species, and reduce suitable sites for ground nesting shorebirds that rely on open areas of sand. This may pose a significant risk to some of New Zealand’s rare shore birds and coastal plants. Once established it is able to rapidly invade the dune ecosystem excluding other plant assemblages and fauna.”

Coastal dunes are widespread in all regions of New Zealand; however they are most extensive along the west coasts of the three main islands, with the largest areas occurring in Manawatu,

Auckland and Northland. The total area of active dunelands<sup>2</sup> in New Zealand is estimated to be around 40,000 hectares having declined by 70% in the twentieth century (Hilton *et al.* 2000). These dunelands are a feature of around 11,000 km of New Zealand's coastline (Auckland Council 2010).

The rapid risk assessment report (MPI 2012a) gives a comprehensive assessment of the potential environmental impacts of establishment of *E. paralias*: "This weed is a pioneer coloniser of the rear of the beach/frontal edge of dunes. This zone includes the nesting sites of ground nesting shore birds such as the northern dotterel (*Charadrius obscurus aquilonius*) and fairy tern (*Sterna nereis*), both considered threatened, and which require open ground for nesting.

Once established sea spurge is able to rapidly invade the dune ecosystem, excluding other plant assemblages and fauna. This includes threatened or at risk plants such as *Atriplex hollowayi*, *Euphorbia glauca*, *Austrofestuca littoralis*, *Ficinia spiralis*, *Pimelea arenaria*, *Pimelea lyallii*, *Atriplex buchananii*, *Tetragonia tetragonoides*, *Libertia peregrinans*, *Atriplex billardierei*, *Pimelea* aff. *arenaria* and *Lachnagrostis ammobia* (NZPCN 2012).

Threatened fauna include the snail *Therapsia* sp. '*chathamensis*', the Lepidoptera *Kiwaia jeanae*, *Kupea electilis*, *Scythris miphozela*, *Ericodesma aerodana*, *Samana acutata*, and *Orocrambus callirrhous*, and the Chatham Islands chestnut weevil (*Thotmus halli*) (possibly extinct) (Hitchmough *et al.* 2007).

Although a pioneer species in the dynamic coastal dune environment, sea spurge is considered to be a poor dune stabiliser. Overseas, where sea spurge has been deliberately planted to stabilise dunes, the resulting sand dunes were steeper and more likely to be undercut."

## Economic

The economic impacts identified in the response brief and the rapid risk assessment report includes impacts on tourism and eco-tourism, agriculture and coastal properties.

The tourist and eco-tourist values of New Zealand's coastal dune environments will be significantly impacted by this weed due both to the toxic sap and the loss of biodiversity. *Euphorbia paralias* has been reported as invading pastoral land adjacent to coastal areas in Australia (M. Hilton pers. comm.). Establishment may change coastal sand movement processes which may exacerbate coastal hazards such as erosion (DPI 2011), which could lead to loss of property or requirements for erosion protection structures.

Few of the documents relating to eradication and control of *E. paralias* in Australia list specific associated costs. Much of the control effort relies on hand weeding by volunteer groups in partnership with local councils. Reports from some larger sites (30,000 plants each) on King Island, Tasmania, indicate that 60 weeding hours were needed every four months for the first year, reducing to 18 hours every four months in the second year, and three and two hours in the third and fourth years respectively. In the Tasmanian wilderness area 80 volunteers contributed around 2,000 days to remove 3 million plants over three years along a 200 km stretch of coastline between Cape Sorell and South East Cape. Additional to this investment of time is the cost of herbicides and equipment for removal of this weed.

## Human health

The latex sap of *E. paralias* is considered poisonous and causes skin and eye irritation; on occasion painful temporary blindness can occur if the sap comes in contact with the eye.

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<sup>2</sup> Characterised by ongoing or very recent movement of sand by wind, in the main they contain significant areas of bare sand or semi-vegetated sand. Vegetation is dominated by grasses, sedges and herbs, many peculiar to the active dune environment.

## Socio-cultural

The response brief and the rapid risk assessment report identifies socio-cultural impacts resulting from the establishment of *E. paralias*: Many coastal dune ecosystems harbour important Maori archaeological sites. Pingao is an important weaving taonga species and loss of this species through competition with sea spurge would have Maori cultural impacts. The visual, structural and amenity value of coastal dunes will be adversely impacted by sea spurge. The formation of dense patches on dune fronts and toxic nature of the sap may also impinge on the beach enjoyment, which is a major part of New Zealand culture.

## Impacts in Australia

An assessment of impacts in Australia, where it has been naturalised for several decades, may help predict likely impacts in New Zealand. In Australia *E. paralias* is an invader of coastal ecosystems and is implicated in the loss of coastal biodiversity and heritage values, and reduction of human enjoyment of beaches due to its toxic sap (Scott 2012).

It is regarded as a significant environmental weed in New South Wales, Victoria, Tasmania, South Australia and Western Australia. It develops dense infestations which prevent natural sand movement, altering dune communities and threatening some rare coastal plants. The decline of some species of nesting shore birds (e.g. the endangered hooded plover, *Thinornis rubricollis*) has been attributed to a loss of habitat as a result of infestations of *E. paralias*. In addition to changing the structure of dune communities, *E. paralias* spreads inland displacing native coastal vegetation and invading adjacent grasslands (CHAH 2011; DEEDI 2011).

An impact assessment conducted by the Department of Primary Industries in Victoria, Australia recognises *E. paralias* as having moderate to high impact on recreation (primarily due to the toxic sap) and moderate to high impact on the environment (due to displacement of native species and habitat loss) (DPI 2011).

## RISK ESTIMATION

*Euphorbia paralias* has the potential to establish and spread in coastal areas of New Zealand and cause negative environmental, economic, socio-cultural and human health impacts; therefore, *E. paralias* is classified as a risk and risk management measures can be justified.

## MANAGEMENT OPTIONS

Surveillance is the only available management option for stochastic events such as ‘natural dispersal’ of invasive seeds or plants to New Zealand, focus will need to be on management of the current population and future infestations and populations when they are detected. Furthermore establishment of at least some future populations is likely to be in remote and difficult to access locations and populations may be relatively large before they are detected.

Management of populations of *E. paralias* in Australia has frequently focussed on removal of plants prior to flowering with ongoing monitoring several times a year to remove newly germinated seedlings. Plants are typically removed by hand weeding and the application of herbicide. Ongoing management and surveillance relies heavily on involvement from local volunteer community groups. It is recognised that effective containment or eradication is problematic, particularly on sections of coastline that are isolated and unpopulated.

The response brief recommended exclusion (maintain zero density) as a desirable outcome as opposed to eradication. The exclusion option recognises that new incursions are likely and therefore the best intervention point is the removal of populations as they are detected. Eradication is unlikely to be achievable in practice as the risk of establishment from new incursions is high. Eradication cannot be achieved if new incursions are likely, as these new

incursions would potentially negate the additional effort required of an eradication programme.

As there is only one known population of *E. paralias* currently in New Zealand, removal of this population to prevent local spread is of fundamental importance. Due to the high reproductive potential and multiple pathways for spread, control rapidly becomes unfeasible once an incursion spreads from one site. There are several options for management, some of which are detailed below (for a full discussion of options, refer to the Options Analysis and Recommendations paper).

### **Targeted surveillance**

Analysis of the most likely pathway of entry (ocean currents) would be useful in order to identify likely areas of future establishments for targeted surveillance. Data on the ocean currents and climate for the past five years affecting the area of the current establishment could help identify conditions suitable for entry of seed. Information about coastal currents combined with recreational boating and shipping patterns could identify those sites which require monitoring.

While pathway analysis is a useful option for identifying sites of future infestations, it is indicative only. Ocean and coastal currents are complex and many factors (e.g. tides, storms, coastal features) will influence where seeds carried on these currents may make landfall. There is potential for seeds to be dispersed throughout New Zealand carried as a contaminant on recreational and commercial boats, and while data on movement patterns of commercial boats is accessible information, movements of recreational boats is much less so. Pathway analysis does not contribute to management of the existing population; rather, it will help predict the likely locations of future populations.

Targeted surveillance could be conducted based on information generated by the pathway analysis identifying the likely areas of introduction. This surveillance is likely to require considerable involvement from volunteer community groups to be effective. Many Australian groups currently use volunteers for targeted surveillance for example the SPRATS (sea spurge remote area team) programme in Tasmania surveys sites annually and those sites which require treatment are further visited for spraying and plant removal.

### **Plant removal and monitoring**

This option involves hand weeding of plants from existing and any new populations and regular monitoring to remove plants that germinate from the seed bank present in the sand.

All identified plants in the existing population have already been removed; therefore, this option would involve frequent visits to the site to remove seedlings germinating from seeds in the seed bank. Given that this population consisted of around 65 mature plants and is estimated to have been at the site for several years there could be approximately one million<sup>3</sup> seeds in the seed bank. This number of seeds presents significant opportunity for reestablishment of a population if not regularly monitored. In Victoria, Australia, a fortnightly weeding effort was required during the flowering period to prevent spread of seed. Based on the phenology of populations in Australia it could be expected that seedlings would take six months to reach maturity and flowering would occur between September and May.

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<sup>3</sup> This figure is a conservative estimate of the number of seeds in the seed bank. Under favourable conditions one mature plant is capable of producing up to 20,000 seeds each year. With 65 mature plants in this site 1.3 million seeds would have been produced in the last growing season. As the population would have been smaller in previous years (and likely to have consisted of only a single plant at its origin) fewer reproductive individuals were likely to be present in previous years.

While plant removal and regular monitoring is a relatively low cost option for control, leaving seeds within the seed bank may enable local dispersal if the sand dune is eroded during storm or high tide events. Erosion and subsequent redistribution of the sand may result in mobilisation of the seed and establishment of local populations throughout this coastline, depending on coastal currents and weather conditions.

### **Sand sieving**

This option involves sieving of the sand in the site of the present infestation (approximately 10 m<sup>2</sup>) to reduce the number of seeds in the seed bank, thus reducing future population numbers and the likelihood of dispersal to new locations. Sieving is unlikely to remove all the seeds therefore ongoing monitoring to remove seedlings will need to continue for a period of around ten years to ensure that any seed remaining in the seed bank does not reinfest this site.

Sieving and appropriate disposal of seeds (by deep burial or incineration) should significantly reduce the number of seeds present at the site, reducing the likelihood of establishment in other nearby sites as a result of sand mobilisation. However, sieving is most easily conducted when the sand is dry (M. Hilton pers. comm.), and given current weather conditions if this option is selected, the sieving may not be able to take place for some months. Delay in starting seed removal provides opportunity for mobilisation of the sand during high tides and storm events increasing the likelihood of further local infestations.

The extent of the seed bank is unknown as is the depth to which seeds may be present in the sand. Cost effectiveness will depend on the extent of the seed bank as the sieving process is time consuming.

### **Sand removal**

This option involves removal of the sand from the site of the present infestation and burial of this sand within a landfill to prevent germination of seeds within the seed bank or their dispersal through high tides and storms. As with the sand sieving option, this may not remove all seeds from the site, therefore ongoing monitoring after sand removal will be required.

Removal of sand could be conducted immediately, reducing the opportunity for further spread of seed. However, as a substantial amount of sand would need to be removed from the site, consideration should be given to the potential for erosion following this control action. The cost of sand removal is likely to be significant. The volume of sand to be removed (approximately 42 m<sup>3</sup>) combined with difficult access would require multiple trips with a helicopter. In addition resource and iwi consent will be needed which may take some time to achieve.

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