Pacific Invasive Species
Battler Series

MANAGE LOW-INCIDENCE PRIORITY WEEDS TO CONSERVE PACIFIC BIODIVERSITY

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Dedication

This Battler volume is dedicated to the memory of the late Dino Mesubed (left) who worked tirelessly in the war on weeds in Palau, pictured here with colleagues Joe Tiobech (centre) and Dr Joel Miles (right). The team from Palau were one of the first teams in the Pacific to adopt these methodologies of weed management planning and implementation following a workshop held in Palau in 2006.

Photo: David Moverley, SPREP

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Our vision: A resilient Pacific environment sustaining our livelihoods and natural heritage in harmony with our cultures.

Cover photo: Preparing to control invasive weeds in Niue. Photo: Bradley Myer, SPREP

Dear Invasive Species Battler

We are a diverse bunch of people in the Pacific region, which spans about one third of the earth's surface and encompasses about half of the global sea surface. We have ~2,000 different languages and ~30,000 islands. The Pacific is so diverse that its ecosystems make up one of the world's biodiversity hotspots, with a large number of species found only in the Pacific and nowhere else. In fact, there are 2,189 single-country endemic species recorded to date. Of these species, 5.8 per cent are already extinct or exist only in captivity. A further 45 per cent are at risk of extinction. We face some of the highest extinction rates in the world.

The largest cause of extinction of single-country endemic species in the Pacific is the impact of invasive species. Invasives also severely impact our economies, ability to trade, sustainable development, health, ecosystem services, and the resilience of our ecosystems to respond to natural disasters.

Fortunately, we can do something about it.

Even in our diverse region, we share many things in common. We are island people, we are self-reliant, and we rely heavily on our environment to support our livelihoods. We also share many common invasive species issues as we are ultimately connected. Sharing what we learn regionally makes us and our families benefit economically, culturally, and in our daily lives.

The "Invasive Species Battler" series has been developed to share what we have learned about common invasive species issues in the region. They are not intended to cover each issue in depth but to provide information and case-studies that can assist you to make a decision about what to do next or where to go for further information.

The SPREP Invasive Species Team aims to provide technical, institutional, and financial support to regional invasive species programmes in coordination with other regional bodies. We coordinate the Pacific Regional Invasive Species Management Support Service (PRISMSS), the Pacific Invasive Learning Network (PILN), a network for invasive species practitioners battling invasive species in Pacific countries and territories, and the Pacific Invasives Partnership (PIP), the umbrella regional coordinating body for agencies working on invasive species in more than one Pacific country.

For knowledge resources, please visit the Pacific Battler Resource Base on the SPREP website: www.sprep.org

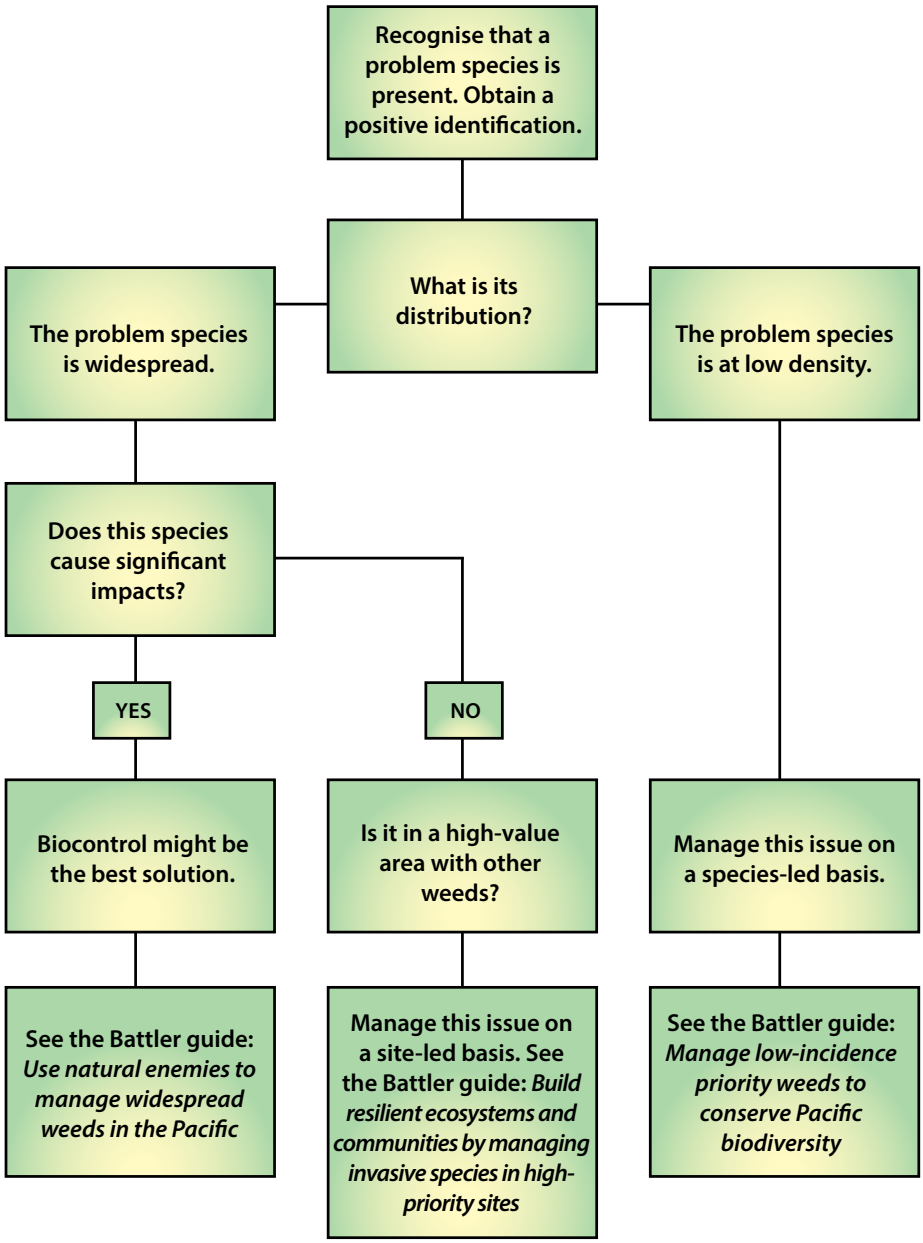
Thank you for your efforts,

SPREP Invasive Species Team

About This Guide

This Battler Series publication, *Manage low-incidence priority weeds to conserve Pacific biodiversity*, is focused on the management of problematic low-distribution ('low-incidence') weed species, as opposed to sites. Site-led management of weeds is covered by the publication *Build resilient ecosystems and communities by managing invasive species in high-priority sites*. Widespread species are covered by the publication *Use natural enemies to manage widespread weeds in the Pacific*. The following flow chart should assist with selection of the appropriate publication for your needs.

Management of priority weeds in the Pacific:
Flow chart for making decisions and assessing resources



What are weeds and why are they a problem?

A weed is any plant that is in the wrong place and requires action to reduce its effect on the economy, environment, human health, or amenity. Weeds are also known as invasive plants.

Plants can become weeds when they are transported to a different place, but not all of them do. Sometimes plants from a very diverse ecosystem have highly adapted physiological functions and processes. These species often tolerate a wide range of conditions, a feature that makes them attractive to gardeners. The term "hardy" is often used to describe a plant with a wide range of environmental tolerances. Most ecological weeds have been introduced by gardeners for amenity purposes. When these plants are relocated into a less-diverse ecosystem, without their natural predators and natural environmental limitations, they may start to behave in an invasive way.

Throughout the Pacific, weeds are spreading faster than they can be controlled, and weed management is consuming an enormous amount of resources. Climate change poses an additional challenge to our ability to manage weeds.

Weeds are among the most serious threats to the natural land environments of the Pacific. Weeds displace native species, contribute significantly to land degradation, and reduce agricultural productivity. Weeds can contribute to soil disturbance, loss of native plant cover, and erosion and can increase the risk of fires.

Invasive species, including weeds, animal pests, and diseases, represent the biggest threat to our Pacific biodiversity after habitat loss. Weed invasions change the natural diversity and balance of ecological communities. These changes threaten the survival of many plants and animals as the weeds compete with native plants for space, nutrients, and sunlight.

A weed can be an exotic species or a native species that colonises and persists in an ecosystem in which it did not previously exist. Weeds can inhabit all environments, from our towns and cities through to our coasts, forests, and uplands. Plants that become weeds typically have highly effective reproductive processes. Weeds are often excellent at colonising and reproducing in disturbed environments.

Weeds typically produce large numbers of seeds, assisting their spread, and rapidly invade disturbed sites. Seeds spread into natural and disturbed environments via wind, waterways, people, vehicles, machinery, birds, and other animals.

Human activities and introduced animals and birds, such as rats, bulbuls, mynas, pigs, and goats, can create good conditions for weed growth and contribute to weed spread. Some weeds thrive where fertilisers and other wastes are washed into bushland, leaving extra nutrients in the soil.

Which weeds are important?

'Weed' is a general term used to describe any plant growing where it is not wanted. The importance of a weed can depend on who you ask. For example, a gardener or farmer would define important weeds as the plants that require control to improve the productivity of crop food or livelihood goods.

Some weeds are of particular concern and have been prioritised for management in National Invasive Species Strategies and Action Plans (NISSAP). Some weeds might already be widely distributed, while others are just beginning to invade and are present in small numbers. Although their impact might be just starting, these low-incidence weeds are a priority target for management and eradication while their populations are still small enough to control more easily.

To manage biodiversity and ecosystems, we need to focus on weeds that have the ability to affect biodiversity or damage ecosystem function. These weeds are known as invasive plants. Invasive plants have the capacity to produce offspring in large numbers, a considerable distance from the parent plant (a distance greater than 100 meters in less than 50 years for seed-producing plants, and greater than six meters in three years for plants spreading by roots, rhizomes, stolons, or creeping stems). There are several obstacles or barriers with which a plant must cope in its new home to become an invasive plant (Box 1).

Box 1: Barriers that exotic plants must overcome to be classified as invasive

- **GEOGRAPHIC** The plant needs to overcome geographic barriers to arrive at a new location. This barrier is easily overcome by people moving plants between countries and islands. Plants that overcome this barrier are known as "Alien" plants. Biosecurity is the best solution to restrict movements of problematic plants through risk analysis and border enforcement.

- **LOCAL ENVIRONMENT** The plant needs to be able to survive in its new environment without assistance. This barrier is determined by a plant's ability to adjust to its new environment. Plants that overcome this barrier are known as "Casual" Alien plants.

- **REPRODUCTIVE** The plant needs to be able to reproduce in its new environment, either by setting viable seeds or spores or by being able to reproduce vegetatively, that is, from fragments of the original plant. Plants that overcome this barrier are known as "Naturalised" Alien plants because they can increase their population naturally without human intervention, although they may or may not be able to disperse un-assisted.

- **DISPERSAL** The plant needs to be able to disperse to other areas so it can spread and increase its total coverage area. The plant must have some form of dispersal vector in its new home, such as wind, water like rivers, gravity, birds and other animals, and humans and their machinery. Plants that overcome this barrier are known as "Naturalised" Alien plants.

- **DISTURBED NATURAL HABITAT ENVIRONMENT** The plant needs to be able to survive in disturbed semi-natural habitats without assistance to impact the regeneration of the ecosystem. Plants that overcome this barrier are known as "Invasive" Alien Plants.

Based on the classification system of Richardson et al. (2000)

Invasive transformers

Some invasive alien plants are also known as "Invasive Transformer" plants. These invasive species change the character, condition, form, or nature of ecosystems over a substantial area relative to the total area of the ecosystem.

Invasive Transformer plants are the highest priority for management to protect biodiversity and ecosystems.

Apia catchment transformed by invasive tamaligi trees. Tamaligi are more prone to storm damage and can cause log jams, damaging infrastructure and increasing flood risks. Photos: *top and centre left* © Stuart Chape, SPREP; *centre right and bottom* Government of Samoa.

Neonative species

Humans have impacted the environment over a very long period of time. These impacts sometimes provide opportunities for native species to expand, upsetting the long-term balance of ecosystems. Native species that behave in an invasive manner due to human-induced environmental changes are known as neonative species (Essl et al. 2019) and have been known in the Pacific as invasive species which are not alien.

An example of a neonative species in the Pacific is the crown of thorns starfish or seastar *Acanthaster planci*, which has had its environment changed by humans overharvesting its key predators, such as the humphead wrasse and giant triton, and by changes in the coastal ecosystem, such as increased sediment loads causing loss of coral resilience. These human-induced changes have increased the impact and population levels of the starfish on coral reefs compared to conditions prior to these human activities.

Another potential neonative is *Merremia peltata*, which appears to have many introductions to the Pacific and could be native in some countries. Whether native or not, this vine has increased its range due to human-induced environmental changes, such as forest clearance, which provide a much larger suitable habitat. This has provided the plant with many more opportunities to subdue forest regeneration in many locations, and therefore, this plant has a greater impact on other species than it did prior to human-induced change.

Merremia peltata appears to be native in Palau based on DNA analysis. Cleared areas, such as the edges of constructed roads, have provided opportunities for this plant to become invasive and dominate newly created forest edges.

Crown of thorns seastar. Photo: SPREP

Merremia peltata. Photo: David Moverley, SPREP

What kinds of plants can be weeds?

Many types of plants are weeds. Some weed examples for Pacific islands are included here, but this list is not comprehensive. National management plans contain specific information for each country and define priority weeds. The Global Biodiversity Information Facility (GBIF) has the most up-to-date country checklists of invasive species found within countries.

Two Battler guides provide advice on finding information online: *Find answers online to common invasive species questions* and *Share Pacific invasive species data using the Global Biodiversity Information Facility*. The Institute of Pacific Islands Forestry via the Pacific Islands Ecosystems at Risk (PIER) project has weed risk assessments relevant to the Pacific to help determine the risk that invasive plant species pose to the environment: see www.hear.org/pier.

Grasses

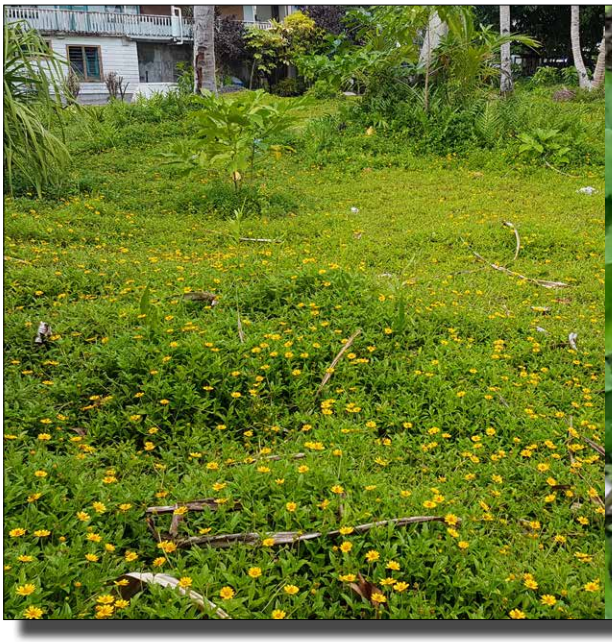
Imperata grass *Imperata cylindrica* is often introduced during airport construction in the Pacific after being dispersed by machinery.

Imperata is a very fast-growing grass, growing in dense stands when not controlled. It is well adapted to fire. Imperata grass is also allelopathic: the plants produce chemicals that inhibit the growth of other plants. This allelopathy results, over time, in mono-specific (one-species, only Imperata) stands, which in some countries cover very large areas and restrict the regeneration of ecosystems. This property also makes Imperata grass a particularly troublesome weed in farms. The underground stems can actually grow through root crops, such as cassava and sweet potatoes. Active management in both the State of Yap (Federated States of Micronesia) and the Republic of Palau has been successful, with Yap declaring the eradication of this plant in 2019. Systematic, herbicide-based control is essential.

Imperata grass invasion in Palau. Photos: David Moverley, SPREP

Ground covers

Wedelia, or Singapore daisy *Sphagneticola trilobata*, is often introduced as an ornamental garden plant and shared among the community. It is also easily dispersed through roadside mowing operations because it can reproduce easily from fragments. Singapore daisy forms a thick, tall mat over the ground, inhibiting ecosystem regeneration and reducing the production of livelihood crops. This weed is particularly damaging to atolls where it can establish on bare limestone. Active management in Niue and Tokelau has been successful. Systematic, herbicide-based control is essential.



Singapore daisy invasion, Tokelau. Photo: Bradley Myer, SPREP

Singapore daisy, Niue. Photo: David Moverley, SPREP

Climbing plants

Taro vine *Epipremnum pinnatum* has been introduced widely in the Pacific as an ornamental plant. Invasive plants might take many years to establish properly in their new environment before people realise that they are spreading and will become a problem.

Taro vine in Niue. Photo: David Moverley, SPREP

Shrubs, palms, and ferns

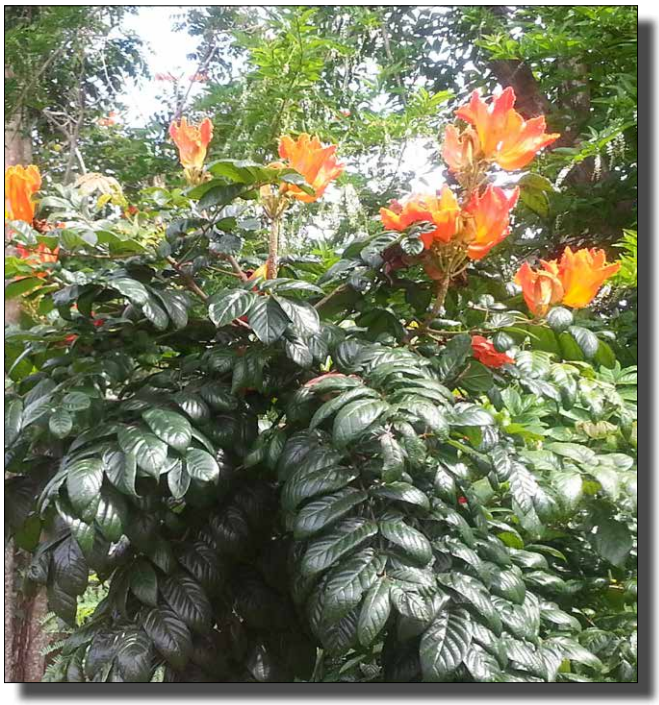
Many shrubs, palms, and ferns are invasive throughout the Pacific. The invasion of these plants can be transformative in Pacific forest ecosystems, with long-lived, slow-growing native species and the essential habitat they create under threat from weedy invasives. Rattan palm *Calamus sp.*, under threat in Malaysia from harvesting for the furniture trade, has proven to be invasive in the Pacific in both Palau and Samoa, where it is under a control programme.

Bronze-leaved Clerodendrum invading forest in Yap.
Photo: David Moverley, SPREP

Mature rattan palms invading forest in Palau.
Photo: David Moverley, SPREP

Trees

African tulip tree *Spathodea campanulata* is found in many Pacific countries. It originates from the lower montane forest of central and west Africa and has been introduced without its natural enemies as an ornamental tree due to its beautiful flowers. In some Pacific islands, such as Niue, Palau and the state of Yap, it is still uncommon and could be controlled within a priority weed-led control programme. In others, including the Cook Islands, Fiji, Samoa, Solomon Islands and Vanuatu, this tree is widespread, occupying whole landscapes. Two natural enemies have been introduced into the Pacific to reduce the vigour of this pervasive plant, but further countries could benefit from the use of these natural enemies. In priority ecological sites, tulip trees will need to be managed within a restoration programme.



African tulip tree, Fiji. Photo: David Moverley, SPREP

What weeds are present?

It is important to know which invasive plants you have, what level of impacts they are likely to have, and how widely distributed they are in order to prioritise for control. Much information is available online through databases and publications that can be collated to assist with discussions with stakeholders. All information will not be available online, particularly where the plants are exactly: the plant distribution within countries or sites. This information needs to be collected on the ground.

A combination of approaches can help you identify and assess weeds.

Online data sets

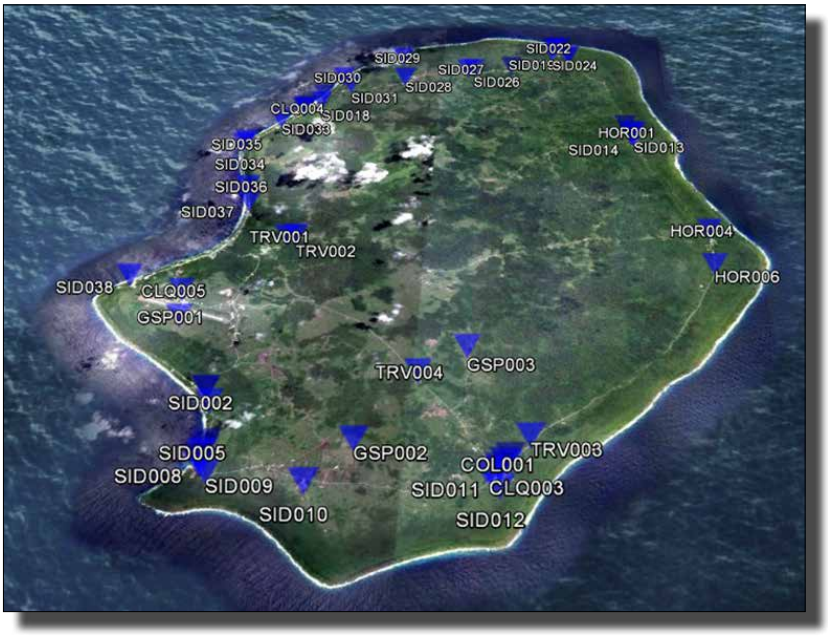
The Pacific Invasive Species Battler Series guides *Find answers online* and *Share invasive species data using the Global Biodiversity Information Facility (GBIF)* will help you locate and use key online databases.

A further step is to summarise all the available information in an Invasive Species and Biodiversity Desktop Study. An example from Federated States of Micronesia is available from SPREP. Desktop reviews are also very useful for stakeholder consultations during National Invasive Species Strategy and Action Plan (NISSAP) creation.

Species surveys

It is impossible to survey every invasive plant within a country because new invasive species arrive often, and the Pacific is home to approximately 30,000 islands. It is important to ensure that invasive species are included in biodiversity surveys, such as Rapid Biodiversity Assessments (BIORAPS; see Vava'u's example), and any other opportunities that involve on-the-ground investigations.

Weeds of low incidence are usually found near where they arrived. Likely spots include gardens, roadsides, wharfs or local boat landing sites, and dump sites—basically anywhere where people go. These are all good places to conduct regular surveys for low-incidence invasive plants. It is not necessary to survey widespread weeds unless they are to be controlled due to their presence in a high-priority area or they are under management using natural enemies.



High-priority weed sites georeferenced in Niue. Image: David Moverley, SPREP

For low-incidence invasive plants, record their geo-referenced locations including species, date, age-class, and coverage. They can then be entered into a geographic information system (GIS) and displayed on a map, then loaded onto a GPS or smartphone to navigate back to their location.

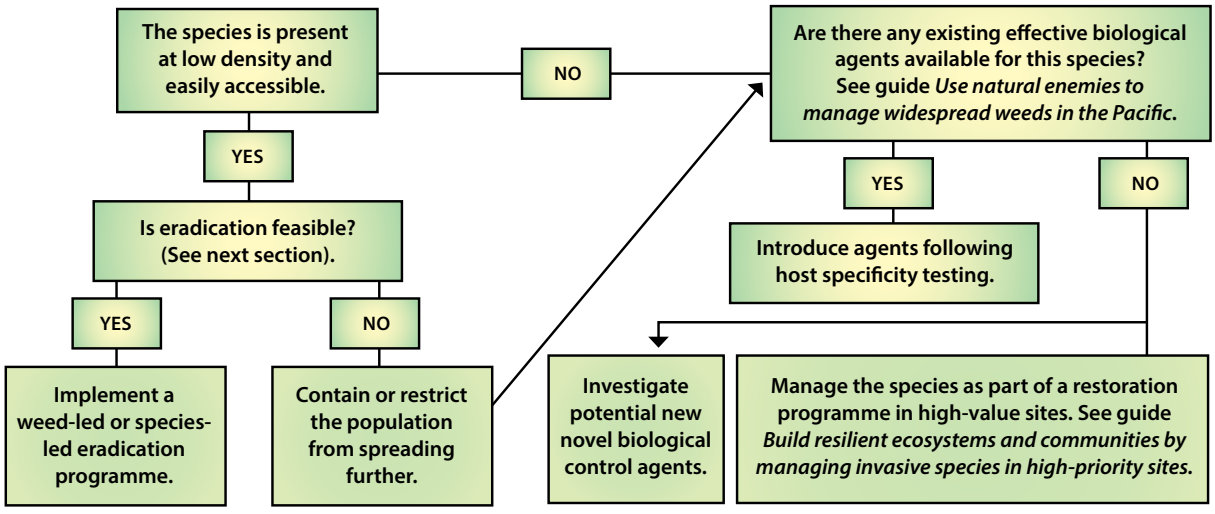
Left: Recording location, date, age class, and coverage of African tulip in the state of Yap, Federated States of Micronesia. *Right*: Roadside surveys provide an accessible and fast method to survey for low-incidence weeds. Invasive management team, Yap. Photos: David Moverley, SPREP

Community detection

Building an informed, aware community connected with invasive species managers is a big advantage for fast, effective response. Encouraging community members to report invasive species or species they do not recognise must be combined with systematic approaches to managing and acting on community reports. Communities can be encouraged to use simple and free phone applications such as iNaturalist (see tutorial here). Incorporating results from community surveys enables the community to participate in a meaningful way and provides extra eyes on the ground. These types of citizen science are great ways to be inclusive of gender and youth.

How should I set priorities and objectives?

Although desirable, it is highly unlikely that you will be able to manage every weed everywhere. Informed decisions need to be made regarding the priority species for management and possible priority sites where they will be managed. This flow-chart can help you select an approach.



What do I need to know about this weed?

Determining your target species and site characteristics and selecting a suitable control methodology is crucial to forming a basic species eradication plan and determining whether or not it can be achieved, how long it is likely to take, and what resources will be required (part of creating a Feasibility and Operational Plan).

In some cases, not all of the information you need will be available from existing knowledge resources. However, efforts to eradicate should not be dismissed; an adaptive management approach can be used with appropriate reviews of the programme and regular requests for expert advice.

The following factors should be considered as you design and implement your plan.

What is the size and location of the infestation(s)?

While there are no fixed rules on which sizes or distributions of a species are manageable, both factors will contribute significantly to the amount of resources (labour, materials, time, and finance) required to succeed in the eradication of the species.

How does the plant disperse/what are the vectors? How far can it disperse by each vector?

Understanding how a plant disperses and the nature of its vectors helps you to understand where you are likely to find it and how far away it could be from your identified location. This allows you to refine your search area. It may also allow you to manage the vectors to reduce dispersal, particularly if dispersal is related to human activities, such as a gardening community which shares plants or machinery used to mow roadside verges.

How long does the plant take to mature?

Plant maturity is the key factor in determining the maximum time allowable between control events if target species are to be repeatedly targeted before they set seed or are able to reproduce. In some cases, plants are always mature because they can be spread by plant fragments being dispersed.

How long is the seed viable?

Seed viability is the key factor in determining how long an eradication programme will take because seeds will continue to germinate after the removal of their parent plants. Some seeds are short-lived, and programmes can be relatively short in duration; this is particularly the case with plants that spread only vegetatively. Other species' seeds may be viable for over 50 years, making an eradication programme unlikely to succeed unless resources were available to cover this time period. For these plants, a better option would be to manage the environment or investigate biological control options.

Are there any natural environmental conditions that increase/decrease the plant's growth or maturity?

Plants respond to environmental conditions differently. For example, some will only grow in full sunlight, some only under the shade of a tree canopy, and some can cope with a variety of light conditions but may grow slower or faster or mature earlier or later. These environmental conditions can be used to help manage an infestation or may help determine which infestation of the plant is best targeted first to reduce the rate of total reproduction and spread.

What time of the year are propagules dispersed?

It is important to know if there is a significant time of the year when plants develop and disperse their seeds or propagules. Plants must be managed prior to this time to eliminate the spread of propagules. If not, the programme will never reach the end goal of eradication because new seeds will be added to the plant's population potential, and the time needed to manage the population to eradication must be reset to the beginning.

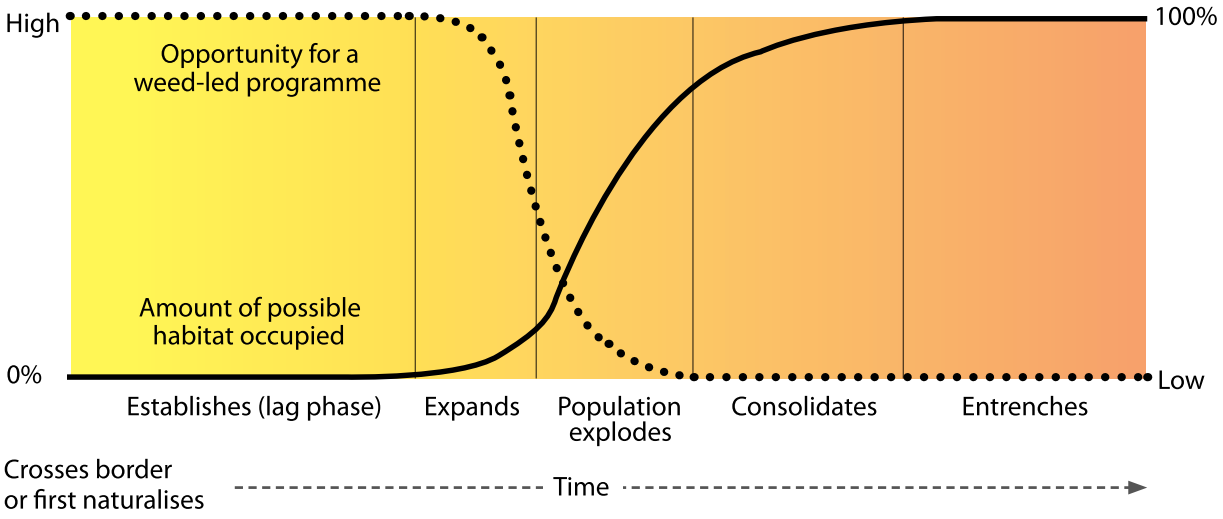
Is there a Best Practice control method?

There needs to be an effective and ideally efficient method to control the species. The method needs to be reliable (preferably with a 100 per cent success rate), achievable (the resources available need to match those required), result in acceptable impacts to the environment, and be safe to use. Consider whether the method requires specific weather conditions or other time- or resource-dependent factors.

Can you control the population faster than it can spread?

Without meeting this criterion, the management programme will fail because the recruitment of new individuals will outnumber those that are controlled. Consider how long, in person/days, it will take to control the sites, expecting that this demand will decline over time as the sites require less control.

Remember, early detection and action is cheaper and more effective.



How do I manage high-risk, low-distribution species?

A species-led approach seeks to minimise the impacts of invasive weeds by managing priority species before they become a major problem.

A species-led approach controls all individuals of a specific pest plant species, wherever they are located, at the same time. This approach seeks to halt the spread of invasive pest species beyond a limited distribution, usually with eradication, or zero population density, as the goal. This approach is often used to target species with an early lag-phase distribution as a cost-effective means of pre-empting major problems.

Weed Management Framework

The Weed Management Framework is a process designed for species-led management. The aim of this Framework for species-led projects is eventual eradication (total removal and no seed or propagules remaining in the soil).

The Framework is designed to provide a clear and coherent process in what is otherwise a complex and obscure situation. The Framework provides accountability and transparency. It is focused on outcomes and therefore is able to provide a timetable for actions but is flexible enough to allow for the unexpected.

In this manner, sites or populations typically progress as follows:

Initial Control Phase

↓

Follow Up Foliar Phase
(if the control method for that target species uses foliar spraying)

↓

Seedbank Control Phase
(management of the seedbank)

↓

Eradication Phase
(declaring the plant eradicated following a period of monitoring with no further plants germinating).

The process can take several years to reach eradication, depending on the seed viability of the pest species and on other variables to a lesser extent.

Further information on how to use a Weed Management Framework can be found in the section "Programming to beat the enemy".

Accuracy, persistence, and timeliness

Three components to a successful weed management programme must be addressed. Failure in any one of these components will lead to failure in achieving the objectives of the programme. Generally, this failure means a lot of wasted time, effort, and money.

Accuracy is vital.

Control methods must be effective on the target while avoiding hazards to human safety and the environment, as much as possible. If you are unsure about which control method to use, seek advice from colleagues and the SPREP Invasives Team via PRISMSS. Often, there is more than one control method that will be effective. The most appropriate method depends on site-specific factors. Attention to detail is needed. A degree of skill, physical capability, and personal motivation are all required to deliver management actions with accuracy. Operators must be able to identify the target and relocate the locations of target seedbanks. This means good data management is vital. Non-target damage must be avoided wherever possible to preserve native vegetation and reduce opportunities for other weed species to invade. The right equipment and control methodology will help to keep the actions accurate.

Persistence is essential.

Some weed species produce seed that is dispersed by birds, wind, or water. Others have seed pods that explode, flinging seed away from the parent plant. Each species has its own means of seed dispersal. Targets that have fruited for more than one season will have deposited seed into the immediate environment and perhaps further afield. The soil seedbank is the natural storage of seeds, often dormant, within the soil. Eradication of a species must include exhaustion of the seedbank. This is done by revisiting a site at critical times to kill the emerged seedlings before the plant becomes mature and reproduces. Some species have a short period of seed viability that may only last one or two years. Other species can produce hard seeds that may remain viable for decades. Some species have a very short period between germination and reproduction; others can take years. Little is known about seed viability for most species. Any attempt at eradication of a plant must consider the need for persistence and plan accordingly.

Timing is critical.

The timing of operations is important to prevent reproduction of further seeds adding to the managed seedbank. If the weeds are allowed to set seed, the eradication programme will need to commence from Year 1 again. This could mean years of wasted effort and resources.

Controlling your target

There are several ways to control your target during a weed-led operation. Whichever method you use, it must be both effective (kill the plant) and an efficient use of resources.

If you do not manage to kill the plant, it will regrow. If the selected method is inefficient, your management programme will be more costly and may result in non-feasible control or fewer resources to address other species-led programmes or areas.

Ineffective and inefficient control leads to lack of engagement by the community and practitioners.

In addition to these two basic requirements, the method chosen needs to minimise the threats to ourselves and the environment.

Manual techniques, including removal

If the number of plants is small, the plants can likely be pulled out by hand. This is easiest done in soft ground where the plant can be completely removed, including the roots. This may be a very labour-intensive option if there are many plants. Be aware that soil disturbance promotes weed growth and be very mindful of where and how you dispose of the vegetation you have removed. This is particularly important if you are controlling plants that may reproduce vegetatively when fragments are moved. Singapore daisy is a good example: this weed is commonly pulled up from gardens and dumped along roadsides or forest edges, where it regrows and forms further infestations.

Traditional methods such as cutting down or stripping the bark around the base of the tree (ring-barking) can be successful with some types of trees; however, most invasive plants recover easily by re-sprouting from the base of the stem, making them more difficult to control effectively and efficiently.

Traditional knowledge may suggest ring-barking, but this practice can fail to kill some tree species. Photo: David Moverley, SPREP

Manipulating the environment

Natural environmental conditions may be used as a control tool where the invasive plant responds negatively to environmental factors. For example, a full tree canopy may reduce sunlight to a level where the invasive plant cannot grow any longer. By encouraging the forest canopy to close through regular tree maintenance, this can be achieved faster.

Regular mowing can often maintain a healthy, thick grass that can reduce woody plants from establishing.

Applying herbicides

Frequently, the use of herbicides (chemicals used to control plants) is required to provide a reliable and efficient method of eliminating a population of invasive plants.

A huge variety of herbicides are available that control plants in different ways and present a range of risks to people and the environment. It is very important to determine which herbicide will meet your control requirements while lowering the hazard that the herbicide provides and requiring the least equipment to lower the exposure, so that the risk is lowest to ensure the safest and most efficient method of herbicide application. This decision process is part of determining Best Practice and should inform both policies and procedures.

Human exposure when mixing the agrichemical is the greatest risk to the users.

Other considerable risks come from poor application procedures causing off-target movement of agrichemicals, commonly called spray drift. Good training of agrichemical users will greatly assist in reducing this risk, especially if users always use the correct nozzles and apply during appropriate weather conditions.

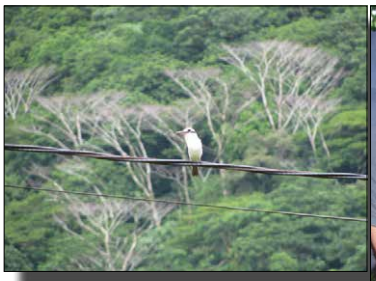
Using the correct herbicide offers the user a cost-effective and environmentally responsible means of control. Herbicides have been used throughout the world since the early 1950s and are now more regulated than most other chemicals. The implementation of the Global Harmonized System (GHS) in most countries identifies and explains the hazards to people and the environment. It is important that the users of agrichemicals understand the hazards and at all times try to use the least-hazardous agrichemical that will effectively do the job.

Mixing glyphosate in backpack spray equipment to control wedelia on Tokelau. The hazard from the glyphosate-based product has been reduced by selecting the herbicide brand that has the lowest hazard rating. The exposure to the hazard has been minimised through the use of gloves, long pants, and shoes. This product is very safe for humans and the environment. Selecting the best practice method based on the lowest hazard also saves resources by requiring little personal protective equipment (safety gear), which is particularly important in the hot environment of the tropical Pacific. Photo: Bradley Myer, SPREP

Common methods of herbicide application are:

Cut stump/frilling/ringbarking

These all require the cutting of woody species and applying a high rate of herbicide directly to the xylem and phloem (the parts of the plant that transport the herbicide to the points which it needs to reach to kill the plant). The herbicide must be applied immediately after cutting, before the plant begins to close off and repair itself.



Killed tamaligi *Falcataria moluccana* standing in American Samoa.

Creating tidy piles of cut vegetation is essential for making the site easy to assess later and provides a refuge for insects and lizards from rats. It is also easily positively identified as being treated and saves time going to check stems that are randomly left leaning against vegetation. Photo:s David Moverley, SPREP

Application of herbicide to a filled trunk of Panama rubber tree *Castilla elastica*, Samoa. Photo: Samoa MNRE

Foliar spray application

Foliar spray application aims to deliver the active ingredient of the herbicide through the leaves of the plant. Although it usually requires a lower concentration of herbicide than methods such as Cut Stump, foliar application does require precision over a larger target area. It is also important to prepare the spray site properly to ensure the target can be accessed easily and thoroughly, so the operation can be completed in one operation and so non-target impacts are minimised. This may require cutting some stems off the target to make the target more compact and to reduce overspray. Vines are best cut above head height so foliar spraying does not need to be targeted at the canopy. For some climbing plants, such as taro vine *Epipremnum pinnatum*, this is not possible because upper parts of the plant actually root into the host tree, so any cutting just creates more individual plants to access. In the case of vines, the part of the cut plant that is still connected to the ground can be placed where possible to apply the foliar spray and cause minimal non-target damage.

Controlling *Praxellis* in Palau. Clearly marking the site makes follow-up operations easier. Using the right equipment including nozzles and the correct pressure increases accuracy. Including the most effective additives, such as penetrants, increases effectiveness and shortens the period of time needed with the correct weather conditions.

Successful treatment of imperata grass in Yap. Flagging tape is used to identify sites on the ground so they are easily found, shortening the time the operation takes and giving confidence to the team that they have found and covered all sites.
Photos: David Moverley, SPREP

Programming to beat the enemy

The most important part of developing a weed-led project is to create a programme that is effective in reaching your objectives and sticking to it. A simple process to use in cases in which the total removal of the target species will not have adverse effects on the environment, such as erosion or landslides, is the Weed Management Framework.

Each species-led project should be planned, using a system such as a Gantt chart, to incorporate the weed management framework and take into consideration important seasons or deadlines. Seasons to consider might include annual weather conditions, such as the wet season, which may impact the operation and site characteristics that may restrict access at certain times of the year, such as heavy wasp times.

Human resources should be specified to match each operation, and equipment needs to be available prior to the operation.

Phase	Definition	Methodology	Phase Duration	Key Performance Indicators
Initial Control	Mature pest plants are killed within the target sites.	Cut stump application of the target woody species or preparation for foliar spraying of the target species.	One control operation is necessary if it is completed thoroughly in all sites.	All mature woody target species are dead or foliar spray targets have been isolated, minimised and placed in position for foliar spraying.
Foliar Control	Target plants requiring foliar spraying have been isolated, minimised and placed in position for foliar spraying to minimise non-target impacts.	Foliar spraying of target species to eliminate mature vines and herbaceous pest plants.	This phase may take two operations if there are mature plants missed during the first application. The operation should take place once the target species have recovered enough from their preparation to take up the foliar herbicide.	No mature target pest plants.
Seedbank Control	All original target pest plants are dead. Seedbanks remain in the soil, resulting in germination events at the target sites.	Foliar spraying or hand pulling of all plants that have germinated from the seedbank prior to maturity.	Depends on seed viability of the species concerned	No target pest plants reaching maturity.
Eradication	All pest plants eliminated and the seedbank exhausted.	Ongoing monitoring of sites to ensure no late germination events occur.	Four to five years	No germination of target species.

Data and information management

Why we record spatial data

Recording spatial data is important for many reasons:

- ***Record keeping*** – Knowledge management to ensure that remnant seedbanks are not forgotten.
- ***Management*** – Often pertinent spatial data will save time and energy when a targeted approach is needed in the management of a particular population.
- ***Communication*** – A consistent spatial dataset provides a standard platform for communicating ideas related to location.
- ***Monitoring*** – Weed populations can be tracked to show progress towards achieving goals.
- ***Transparency*** – Field operators can show where they have been and when they were there.
- ***Accountability*** – Field teams can be made accountable for their actions and service delivery.

The information generated by the various parties involved can be aggregated in a geographic information system (GIS) to provide a powerful platform for land and project management. Alongside the collection of information in the field, this system can be used to disseminate information and maps onto handheld global positioning system (GPS) units for navigation in the field. Aerial images and topographical maps are freely available as background for navigation and recording tracklogs and points.

Field teams delivering weed management, auditors, and monitoring staff should, at minimum, record tracklogs and point data on a handheld GPS-enabled device. Any smartphone can be used in this capacity with the use of certain apps. A range of apps will perform this task, and the most suitable app depends on the type of device being used, varying frequently.

Compared to standard handheld GPS units, smartphones have the added advantage of being able to collect spatial data in applications that are designed to record metadata of any description and in many different formats. These applications are often free or low-cost.

Another advantage of mobile phones is their easy data sharing. Many apps will convert the points to GPX (interchange) format. Then the user can either upload the data to a web- or cloud-based system or email the GPX file to a GIS administrator.

Some apps, such as Fulcrum, allow the administrator to custom design a form for data entry in the field and allow multiple users to sync with a single web-based project. The complete data set can then be downloaded in a range of formats, such as a shapefile for importation to a GIS or CSV for analysis in spreadsheet software.

GPS applications link to the space-based satellite navigation system and are therefore not dependant on active mobile phone coverage during data collection. However, sharing the data involves connecting to a mobile phone network or internet services.

Other useful pieces of information to load onto a device prior to going into the field include previously recorded points, the project area boundary, or a Park boundary. Aerial images, topographical, or custom-designed maps may be cached on the device for offline use.

Methods for recording and using spatial data

Point data should be recorded for all weed species with eradication as the objective. A "point" may represent an area of weed coverage. All points should have a unique identification which includes species identification and a site number. An example of this is in Figure 1 where many original weed points have been grouped into areas to enable simpler operations and data management.

Figure 1. Example mapping of weed control sites. The sites of *Mikania micrantha* are identified with the abbreviation "MIK" and are sequentially numbered. Hence, the first site has the unique ID of MIK001, the second MIK002 and so on.

Point data for each species may be presented over time to illustrate trends in the changes to weed populations as a result of management. This could be as simple as the number of weed stems at each site or the square meters that the target weed covers: if management is working, these numbers should show a reduction in the weed plants over time (Figure 2).

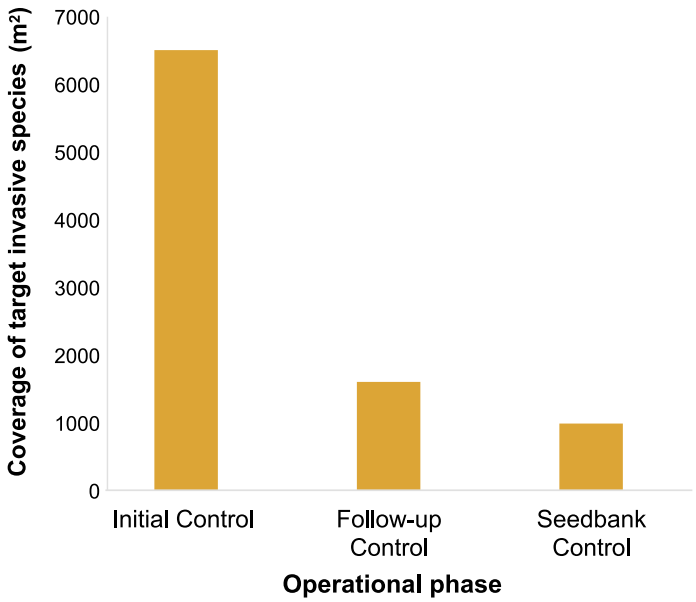


Figure 2. Example of the abundance of the target invasive plant during operational phases.

A bar chart is often the most compelling performance visualisation (Moverley & Floyd 2011). The vertical axis could show square meters or the number of stems, the horizontal axis could show years or the time unit between control operations, and bars should show the abundance of an age class, such as mature, juvenile, or seedlings. In a classic situation, decline in the mature age class should be dramatic in the first year or two, with a slightly more gradual decline in juveniles and a decline in seedlings as seedbanks are exhausted.

For example, the control programme data in Figure 3 show that no mature plants were found following their initial control in the Year 1 season; however, in the Year 3 season, mature plants were found that had re-sprouted following herbicide application. A more effective herbicide that killed 100 per cent of treated plants was selected to use in the control programme to ensure all treated plants were killed and did not re-sprout.

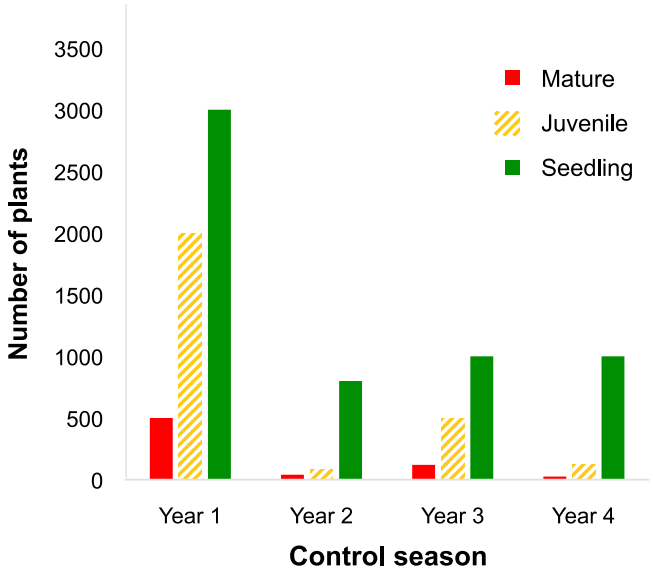


Figure 3. Example of weed control over four field seasons.

The site status categories of extinct (no plants found for a predetermined time period), surveillance (no plants found on this occasion), or active (plants found on this occasion) is a useful measure of programme-wide success. The changes in these categories can be displayed as in Figure 4 where the number of sites in each status can be stacked over time.

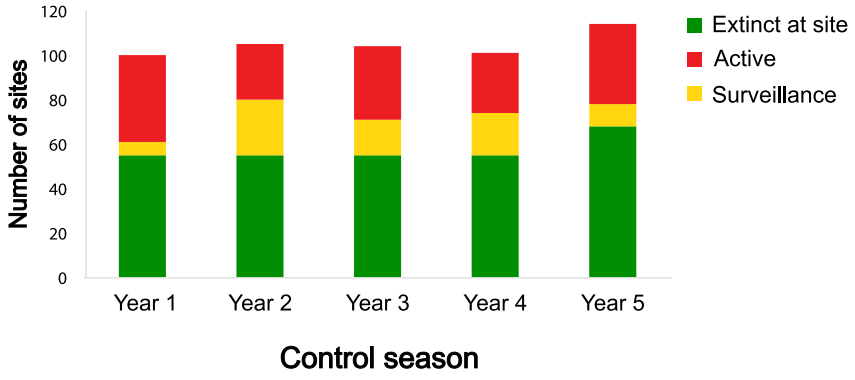


Figure 4. Example of the number of sites in each defined control status over time.

The number of active sites per species is another useful measure which can assist in determining which species are problematic and may require a review of the current programme. Using these measures in our example in Figure 5, kikuyu grass, madeira vine, panic veldt grass, and sweet pea shrub are all problematic species that should initiate a review of the current approach.

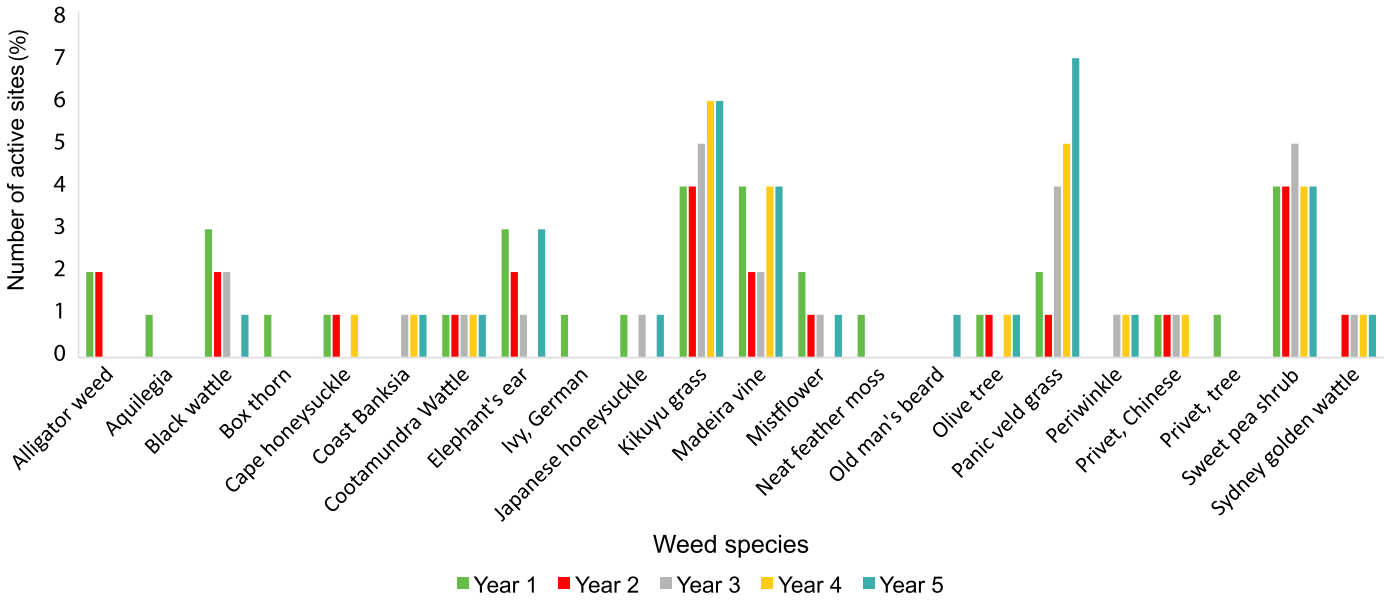


Figure 5. Example measures of the presence of weeds in control sites over time.
Note that species found in more sites or the same large number of sites over time are likely candidates for a different control approach.

The following daily information should be recorded in the field and reported to support the spatial data:

- Hours and times of work;
- Herbicide use;
- Methodology;
- Weather;
- Health and safety incidents;
- Target species;
- Sensitive areas;
- Wildlife noted, or other situational notes;
- Comments and recommendations; and
- Tracklogs of weed management staff, to show where they have searched.

Again, smartphones can be used to record this type of information in the field. This type of information can be entered directly into a spreadsheet.

Who should be involved?

Invasive species are everyone's responsibility.

If you have found something that you suspect is a priority weed, the first step is to obtain a positive identification of the species. There might be specialists within your organisation who can help. Alternatively, you could take a picture and record information about the plant to enable identification by a specialist who is in another location. Simple notes on the locality, habit, stems, leaves, flowers, fruit, and the date collected are all useful pieces of information that will help someone to identify a plant remotely. There are a growing number of online or app-based plant identification systems, such as PlantNet. If you get stuck, you could contact the Invasive Species team at SPREP for assistance.

Once a plant has been identified, you could consult the National Invasive Species Strategy and Action Plan (NISSAP) to determine its status. Bear in mind that the NISSAP is only reviewed and updated periodically, so the plant might not yet be classified.

The local Environment Department should be very interested in new arrivals. Certainly, the SPREP Invasive Species Team will be keen to hear of species turning up in islands where they have not been previously recorded.

A simple control plan can be developed in consultation with the Invasive Species Team at SPREP. The species, its location, and abundance will dictate the best approach. In terms of control, only trained operators should be using herbicides, but anyone can pull weeds out, if it is feasible.

How can I prevent introductions and spread of weeds?

Weeds grow where they are not wanted, and, left unchecked, invasive weeds can threaten native ecosystems and natural areas. Spread by the wind, birds, and water, weed seeds can travel long distances to take root wherever they fall. Weeds can also create havoc in the backyard.

Education

Knowing the importance of native species and the threats posed by weeds can help you make better decisions about plants you grow, weed out, eat, or share. Talking about weeds with your community and advocating for native ecosystems can reduce the cost of weed management for all.

Biosecurity

Early detection and surveillance offer the most strategic and cost-effective form of weed management. Early detection of weeds increases the likelihood that control will be successful and reduces costs because infestations can be treated when they are less extensive. You can help with early detection of weedy plants by knowing what to look for, where to look, when to look, and who to contact. You can share species that you find using free apps like iNaturalist.

Weed hygiene

When you are leaving a field site, plantation, or even after a walk, check your shoes and clothes for seeds. Washing or brushing off the soles of your shoes can help prevent the transport of seeds and pathogens. Cleaning and disinfecting field equipment should be part of standard operating procedure. This might include the tyres and other parts of vehicles used to access sites.

For more information

To find out more about managing invasive species in the Pacific, please contact the Pacific Regional Invasive Species Management Support Service (PRISMSS).

Key references

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Join the Fight

Protect our islands from invasive species