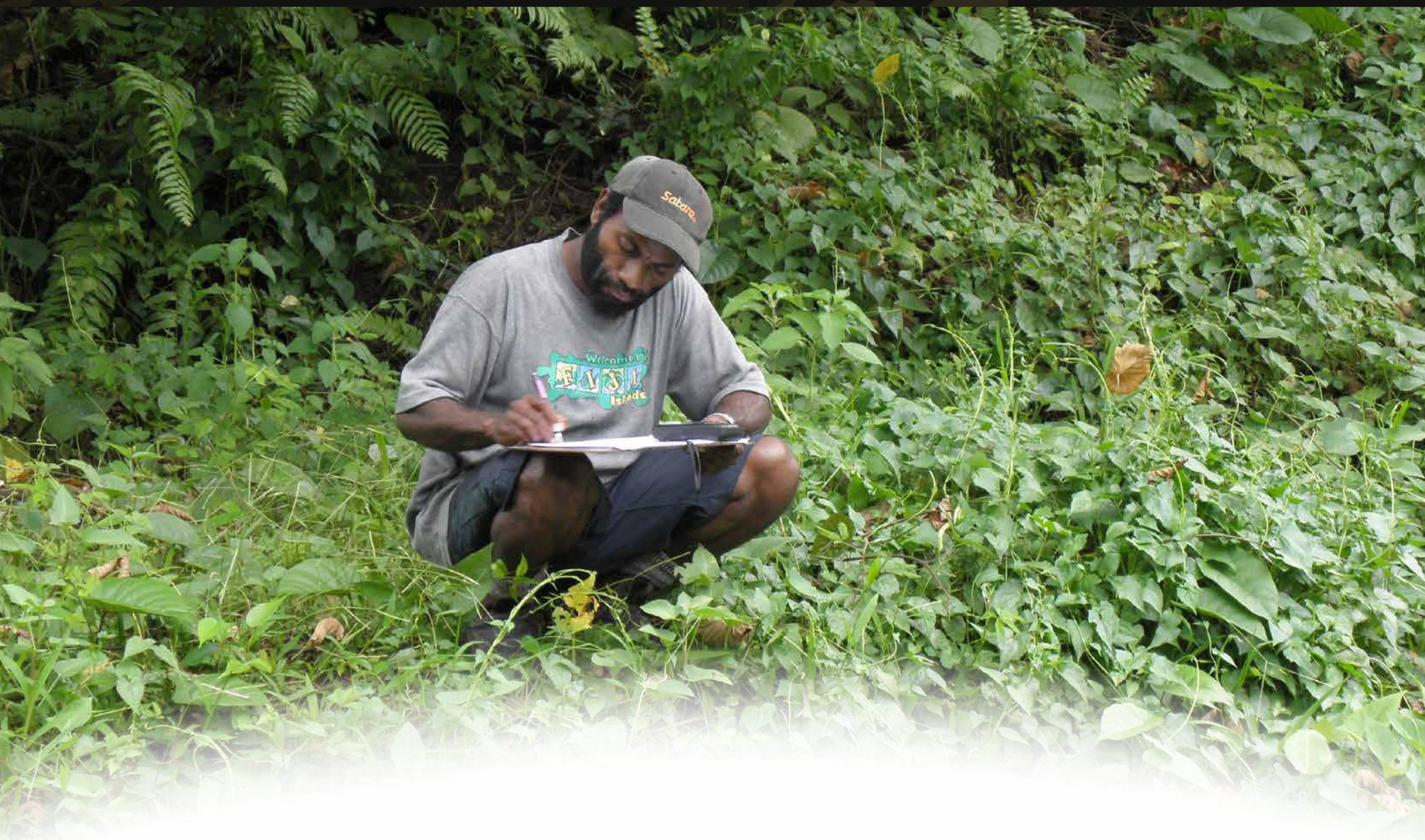
Pacific Invasive Species Battler Series



USE NATURAL ENEMIES TO MANAGE WIDESPREAD WEEDS IN THE PACIFIC

SPREP Secretariat of the Pacific Regional Environment Programme

UN environment programme

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PRISMSS

Manaaki Whenua Landcare Research

Dedication

This Battler volume is dedicated to the memory of the late Sylverio Bule, pictured here in Tanavoli, Santo. Sylverio led great advances in understanding and controlling invasive species in Vanuatu.

Photo: Manaaki Whenua – Landcare Research and Biosecurity Queensland

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

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Cover: The late Sylverio Bule battling invasive species in Tanavoli, Santo, Vanuatu. Photo: Manaaki Whenua – Landcare Research & Biosecurity Queensland

TABLE OF CONTENTS

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 guide explains how natural enemies (typically invertebrates and pathogens from the native home range of the pest) can be used to control serious invasive weeds in the Pacific. We thank our PRISMSS partners Lynley Hayes of Manaaki Whenua – Landcare Research (MWLR), New Zealand for drafting this guide along with Michael Day of Biosecurity Queensland, Australia.

The use of natural enemies is the most cost-effective method of controlling widespread weeds in the Pacific. It is particularly important in the Pacific context where local capacity to manage such widespread problems is limited.

For more information, please contact the Pacific Regional Invasive Species Management Support Service (PRISMSS).

How can natural enemies be used to control weeds?

First, let's define "weed". A weed is a plant that grows too well in the wrong place and therefore becomes a nuisance. Weeds that take over and displace other more desirable plants cause a range of issues. Our ability to grow food and crops and to access water can be reduced. Ecosystem functioning can be disrupted, leading to increased risk of events like fires and floods. If weeds take over landscapes, biodiversity can decrease, and valued species can be lost or threatened. Some weeds can harm animal and human health and reduce our enjoyment of the environment.

Weeds tend to be introduced plants and not native species. These introduced species often grow extremely well because the climate and conditions in their new country are favourable for them, and they have a competitive advantage because their natural enemies are absent.


Hibiscus burr. Photo: MWLR.


Wild peanut. Photo: Biosecurity Queensland

Natural enemies can be used to restore the natural balance between weeds and the environment by introducing the enemies where they are needed. This is also known as biological control or biocontrol. Natural enemies tend to be invertebrates (mostly insects and mites) and fungal plant pathogens that eat, take energy from, or disrupt the function of the plant or the reproductive parts of a plant (like the seeds).

The balance between weeds and the environment can be restored through the use of natural enemies of the weeds. Only natural enemies that will not damage other desirable species or cause any other unwanted problems are used.

Advantages

- Successful use of natural enemies is often highly cost-effective and is an environmentally sustainable method of control for many well-established weeds.
- An initial investment is required to develop a natural enemies programme, but once in place, the on-going costs are almost nil.
- Only the target plants are damaged, a result difficult to achieve by mechanical or chemical means.
- Natural enemies pose no health risk to handlers.
- Weeds are removed gradually, allowing favourable plant species to replace them without exposing large areas of soil to erosion and limiting invasion by other undesirable species.
- Weeds are controlled regardless of land ownership or stewardship.
- Weeds are not usually eradicated but will remain in the environment to a lesser extent than before, so can still be available for any beneficial uses.

Disadvantages

- Using natural enemies is a slow process, taking years to decades for control programmes using them to be put in place and achieve results. Patience and a long-term commitment are required.
- There are no guarantees about how successful natural enemies will be. Some natural enemies may not even establish.
- The level of control can vary from place to place because of differences in climate, soil type, vegetation, management practices, and so on. Natural enemies may only result in slowing the further spread of the invasive weed.
- Weeds will not usually be eradicated, so if eradication is the goal, other control methods may also be required to achieve it.

What's that word?

Weed: a plant growing too well in the wrong place. Often, 'weedy' invasive species grow very quickly and out-compete desired and/or native plants.

Natural enemy: an organism, often a fungus, an insect, or a mite, that is used to control a host weed.

Host: the plant or plant species that is attacked or eaten by a natural enemy.

Host-specific: a specialist natural enemy that can only attack one, or a limited number of closely related, host species.

Pathogen: anything that can cause a disease, such as fungi, bacteria, or viruses.

How the use of natural enemies works

A natural enemies programme typically involves the following steps, described in more detail below:

Step 1: Explore feasibility of a project

Step 2: Survey the weed

Step 3: Select suitable natural enemies

Step 4: Seek permission to introduce new natural enemies

Step 5: Import, rear and release natural enemies

Step 6: Monitor and evaluate the success of the project

Water lettuce weevil and its intended damage. Photo: Biosecurity Queensland.

Step 1: Explore the feasibility of a project

Before embarking on a natural enemies project, it is useful to scope out how feasible the project is likely to be, to ensure it is the best approach and to assist with planning. We ask a series of questions such as:

- What is the desired outcome of the project?
- Are other acceptable control methods available?
- Why might natural enemies be needed? What are the risks of not exploring the use of natural enemies?
- How is the target weed related to other plants? Are there closely related native or economically important species to be considered?
- Are there any known natural enemies that could potentially be used? Have they been used before and to what effect?
- Does the target have any beneficial uses that might result in significant opposition to control?
- Are there any other likely obstacles?
- What is the likelihood of success?
- What work needs to be done? Who would be best to do it and where? How long will it take?
- How much will it cost? Is funding available?
- Will several weeds need to be tackled at the same time to avoid the target weed being replaced with another weed?
- Is this target weed the top priority?

Note that the best weeds to target with natural enemies are usually those that provide the best value for money based on the likely cost and potential for success. Success is easier to estimate for repeat programmes. These are programmes that use natural enemies which have been used and proven effective in other countries. The use of previously tested natural enemies is also cheaper than the use of novel ones where all the development work, such as foreign exploration and host specificity testing, must be conducted. However, more difficult and novel projects should also be tackled when the weeds are serious enough and the

Peltate morning glory. Photo: MWLR

risks of not acting are high. For example, a case in which the weed has the potential to completely and irreversibly change ecosystems (see Figure 1) is a good prospect for targeting in this manner.

The use of natural enemies is usually only considered for introduced plants, not native species. Occasionally native plants can become weedy if, for example, they have been moved outside of their original natural range in-country or because the ecosystem is damaged and disturbed, removing the normal checks and balances on a native plant's growth. Peltate morning glory (*Decalobanthus peltatus*, formerly *Merremia peltata*) is an example of a plant that is a bad weed in some Pacific island countries and territories, although evidence suggests it is also likely to be native to some of those islands. The reasons why peltate morning glory is becoming a serious weed in some Pacific island countries and territories require further research (for example, is it because of additional introduced genotypes of the plant, climate change, increasing disturbance, a combination of these factors, or some other reason).

The best weeds to target with natural enemies are usually those that provide the best value for money based on the likely cost and potential for success, especially when they are also the most serious weeds.

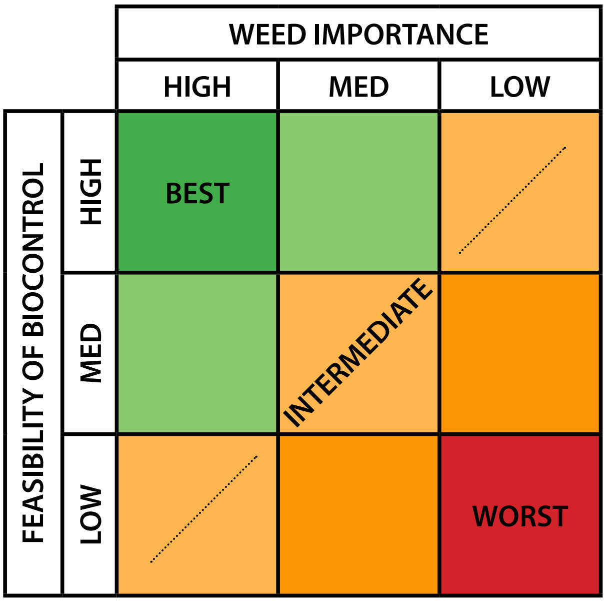


Figure 1: Which weeds make the best targets for control with natural enemies? Here, a highly 'important' weed is one that has, or could have, the most harmful impacts.

Conflicts of interest

It is not unusual for weeds to have some beneficial uses. For example, mile-a-minute (*Mikania micrantha*) is used for medicinal purposes, and African tulip tree (*Spathodea campanulata*) provides shade, shelter, and wood and has attractive flowers. Any beneficial uses of weeds need to be weighed up against their harmful impacts, and an economic analysis can be useful in deciding if control using natural enemies is warranted in these cases. Communication at an early stage with communities is important so all perspectives can be considered and included in any decision-making. It is essential that the community understands why weeds must be managed, how they can play a part in managing weeds, and the opportunity provided by control through the use of natural enemies.

Because natural enemies will not eradicate weeds, there will still be opportunities for people to use the weeds. For example, there would always be some mile-a minute leaves available for medicinal uses. For some weeds, it can also be possible to just use natural enemies that attack the reproductive structures (flowers/ pods/seeds), so the weeds themselves remain but do not continue to spread. This approach has been successfully used against some weedy trees.

Mile-a-minute vine. Photo: MWLR

Any beneficial uses of weeds need to be weighed up against their harmful impacts. Because natural enemies will not eradicate weeds, there will still be opportunities for people to use them.

Step 2: Survey the weed

At an early stage, a survey of the weed should be undertaken in the region where it is invasive, and control with natural enemies is desired, to check the following:

Are any natural enemies already present, possibly through self-introduction?

Are there are likely to be any impediments to the use of natural enemies, such as aggressive predators present on the weed that might harm the natural enemies?

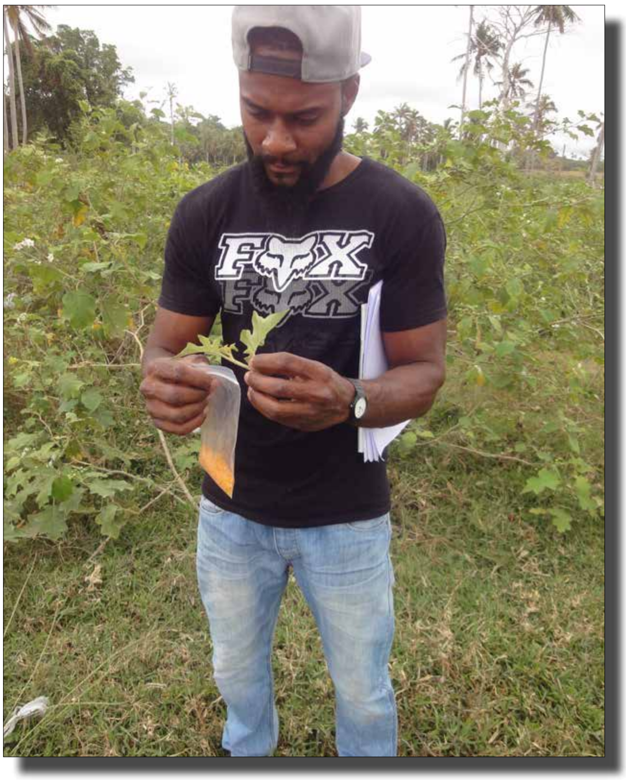
Has the weed been identified correctly? This is important when there are similar-looking species that could be confused (such as *Senna tora* and *Senna obtusifolia*). Molecular studies of the DNA of the plants might be needed to confirm identification or to provide other useful information, such as what genotypes are present (important where natural enemies are specific to only some genotypes, such as occurs with lantana), or when we need to know where in the world the weed came from so appropriate natural enemies can be sought from that place.

An early survey can also be a useful opportunity to gain baseline "before" data about the extent and severity of the weeds, which will be useful later when evaluating the success of a project.

Surveying for hibiscus burr natural enemies in Malaysia. Photo: MWLR

If natural enemies are not well known, then the target weed also needs to be surveyed in its native range. The natural enemies found then need to be identified, and a short-list of the most promising ones to study first must be drawn up. This list should be based on information available in the literature and also on research which has shown that some natural enemies are more likely to be damaging, highly host-specific, and less likely to be affected by parasitoids and predators than others. The life cycle of any promising candidates must then be studied, and methods for rearing them must be developed to enable host-range testing.

Surveys in the native range of the weed might be unnecessary if host-specific and damaging natural enemies have already been identified in cases where a successful control programme has previously been conducted against the target weed in another country.



Collecting plant samples for molecular study. Photo: MWLR

Step 3: Select suitable natural enemies

If natural enemies are already well known, having been used previously, then an assessment is made regarding whether any additional testing is required and from where they can be sourced. Researchers ask questions like: How is the natural enemy related to other species? Are there closely related native or economically important plant species to be considered? In general, redistribution of natural enemies within the Pacific islands requires little to no extra host-specificity testing because plant assemblages are often similar between countries and the host range of these natural enemies is well known. Using tried and proven natural enemies avoids the considerable cost of surveying for and testing the host specificity of new natural enemies, and reduces the likelihood of them not establishing or having minimal impact on the target weeds.

Where testing is required, researchers are rigorous in assessing the risk of damage to non-target plants. Testing to ensure that natural enemies are safe is undertaken following internationally accepted best-practice guidelines. Although not widely appreciated, host-specificity is common in insects and pathogens. Related plants use similar chemicals for defence, and most insects and pathogens can only attack a single plant or groups of closely related plants. Because the plants that are closely related to the target weed are most at risk of non-target attack, they are the first ones to be tested, followed by increasingly more distantly related species until the limits of a prospective natural enemy's host range are established. When there are potentially many related species to test, factors such as plant morphology, biochemistry, and distribution may be used to select the best representative plant species.

Host-specificity is common in invertebrates and pathogens.

Researchers carefully consider a natural enemy's biology and behaviour when deciding on the most appropriate kinds of tests to use. For natural enemies, such as fungi, that disperse passively, 'no-choice tests' (where they are given the option of attacking an alternative host or perishing) are considered appropriate because these natural enemies are continually exposed to no-choice situations in real life. For natural enemies that actively disperse, 'choice tests' (where they are given the option of attacking their host and one or more alternative hosts) are often considered more appropriate because these natural enemies are able to choose in real life.

Multi-choice testing set-up. Photo: Biosecurity Queensland

Natural enemies rarely eradicate their host plants because once a target weed becomes rarer, they find it harder and harder to locate and severely harm every plant. As their host plants become less abundant, the natural enemy populations also decline due to the lack of acceptable food plants. In a successful project, a weed and its natural enemies can eventually become quite rare. If something happens to increase the abundance of a weed again (such as disturbance from a cyclone), the natural enemies will build up again in number. For this reason, some weeds may appear to have a resurgence from time to time but will eventually decline again due to a related resurgence in the number of natural enemies (see Figure 2).

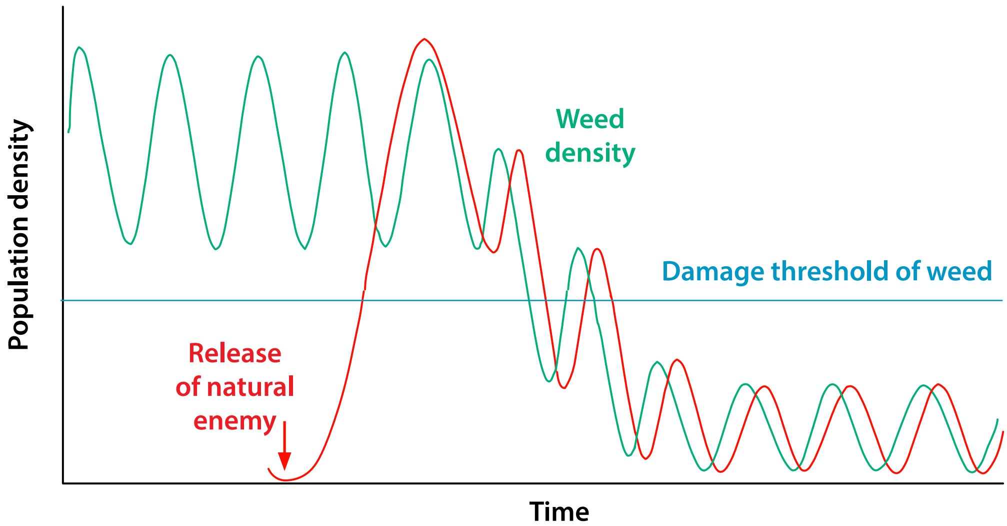


Figure 2: Typical progression of a project to control weeds with natural enemies over time. Density refers to the number of individuals in a given area.

Host-range testing must be done either in the native range of the candidate natural enemy or in a specialised containment facility where they can be studied without risk of escape. At present, Pacific projects largely rely on the use of containment facilities in New Zealand and Australia.

Is it safe?

To some people, the use of natural enemies sounds highly risky. The introduction of natural enemies for weeds is often directly compared with ill-considered introductions of generalist predators, such as cane toads and mongooses, to control invasive pest species, leading to fears of further ecological disasters. However, the need for host-specific natural enemies has always been a requirement for weed programmes due to the risk of damage to crop plants. Consequently, reliable host-specificity testing protocols have been developed, and controlling weeds through the use of natural enemies has an excellent safety record and has provided many benefits.

Safety issues are foremost in the minds of researchers studying the use of natural enemies to control weeds. Only specialist natural enemies are considered that have co-evolved with their host plants over a long period of time and have developed adaptations that allow them to only use that host plant or sometimes close relatives of that plant. This specialisation makes it difficult for these natural enemies to change their host, and the chance of this host-switching has been calculated at between one in ten million and one in one-hundred million. For comparison, that is the same chance as the risk of native species unexpectedly becoming a problem.

Controlling weeds using natural enemies has an excellent safety record and has provided many benefits.

Over the past century, 91 countries have deliberately introduced at least one natural enemy. To date, worldwide, approximately 500 natural enemies (insects, mites, and fungi) have been intentionally released against nearly 200 weeds (see www.ibiocontrol.org). For the vast majority of these natural enemies, no unpredicted host change has occurred. There are only four reports of insects attacking non-target plants that were not predicted by safety testing prior to release. Most of these attacks were only transitory, 'spill-over' attacks, a phenomenon that is occasionally seen when plant-feeding species initially colonise a new habitat, and the attacks have not caused significant harm. This includes natural enemies released when host-range testing methods were not as well developed as they are today. When international best practice methods are followed, non-target attacks are predictable in advance, and we can be confident regarding what plants will be attacked in the field. Researchers continue to further refine best practices, develop more sophisticated tests that more accurately reflect real-life situations, and improve their interpretation of the results obtained. At present, a focus is preventing the unnecessary rejection of suitable natural enemies. Note that it is not unusual for cases of mistaken identity to be reported, where damage to plants is not caused by deliberately introduced natural enemies but by something that looks similar.

Worldwide, approximately 500 natural enemies (insects, mites, and fungi) have been intentionally released against nearly 200 weeds.

As well as direct non-target effects, it is possible that there could be indirect non-target effects on ecosystems if, for example, a natural enemy becomes a food source for another organism. These indirect effects are considered before natural enemies are released but are more difficult to predict given current knowledge about ecosystem functioning. Given that natural enemies will become less abundant as they control their host, such effects, if they occur, are likely to be short-lived.

Evidence to date from a century of using natural enemies to control weeds suggests that the benefits gained from releasing natural enemies far outweighs any harm, and the risk of not controlling weeds is far greater (see the references at the end of this booklet).

Step 4: Seek permission to introduce new natural enemies

Once prospective natural enemies have been deemed to be suitable, permission to release them in-country must be sought using whatever process is required for the approval of new organisms in that country.

Because it is unlikely to be reversible, a decision to release a natural enemy must be made carefully, and ideally, the decision-makers will weigh up all risks, costs, and benefits. If necessary, independent expert advice on release applications can be sought, so regulators are not required to assess evidence themselves if they lack sufficient expertise.

Once permission to release has been granted, a permit to import the natural enemy must also be secured from the relevant agency.

Biosecurity literacy

For fast and effective action against invasive species, we need to create biosecurity literate societies. When people understand the value of native species and the threats from invasive species, they can form part of a fair and consensus-driven fight to protect our island biodiversity, livelihoods, and economies.

The global pandemic of COVID-19 dramatically changed travel and movement of goods. Many biosecurity concepts became part of people's everyday thinking. We can capitalise on this greater understanding of biosecurity to boost the protection of our islands from both invasive species and diseases.

Gaining the support of leaders and partnerships with biosecurity and customs officials relies on a solid understanding of the benefits and risks of using natural enemies to target existing weeds.

Ideally, we want the use of natural enemies to be understood and supported by many: the people determining priorities for projects, regulators issuing permits, customs and biosecurity staff clearing shipments of natural enemies at the border, farmers releasing natural enemies on their land, and communities sharing the battle against invasive weeds.

As an Invasive Species Battler, you are part of this fight to learn and share the best information with your community.

Step 5: Import, rear, and release natural enemies

Importation

Before importation, any shipments of natural enemies to be exported should be held in a secure containment facility (likely in Australia or New Zealand), usually for at least one generation, so their identity can be confirmed and to ensure that the population is free of parasitoids, diseases, and other unwanted contaminants. Natural enemies should never be collected in one country and then directly released in another without this important step. Ideally, new shipments are also received initially into a secure area in-country as an additional safeguard during unpacking.

Because these natural enemies are freed of their own specialist natural enemies, through being kept in containment for a time, they have the potential to be even more damaging in their new homes than in their original homeland.

Mass rearing

Natural enemies will usually need to be mass-reared to provide sufficient numbers for successful establishment in the field. A variety of methods are used to rear natural enemies for release. Many natural enemies can be successfully reared on potted plants in a shade-house or inside mesh cages. The ability to grow and maintain healthy plants, pay close attention to detail, and keep good records are hallmarks of successful rearing of natural enemies. To grow healthy plants, that can support good populations of natural enemies, the right levels of nutrients, light, and water must be provided, and regular checks must be made to ensure the natural enemies are not becoming infested with unwanted pests (such as aphids, mites, or scale insects) which could compromise the rearing. Some natural enemies will need a specific life stage of their host plant to be available, such as new growth, mature stems, flowers, or pods.

Where natural enemies are difficult to mass-rear, an alternative is to set up 1 to 2 field sites from which they can later be harvested and redistributed to new sites.

Left to right: Rearing cat's claw creeper lacebug. Photo: MWLR; Rearing water hyacinth weevils. Photo: MWLR; Shadehouse for rearing plants and natural enemies. Photo: MWLR

Release

Release methods can vary among natural enemies and may require experimentation for those that have never been used before. It is always important to release a starter colony of sufficient size and to release colonies at more than one site. Releasing natural enemies at many sites increases the chances they will find suitable conditions for establishment and minimises the chances that all will be lost if the site is accidentally destroyed. What constitutes a sufficient starter colony will vary between species, and guidance can be given based on previous experience with a particular natural enemy or other similar species.

Choosing safe and suitable release sites is also important. Suitable release sites should be selected well in advance based on the following criteria:

- The weed population is of a sufficient size, not just a handful of plants, and the plants are healthy.
- The site is warm and sheltered and is not prone to flooding, slipping, or other physical disturbance.
- There is a co-operative owner who will not undertake weed control at the release site.
- The site is not intensively managed, to ensure the site is less likely to be disturbed.

Starter colonies should always be released promptly. Take the colony to the field inside an appropriate container (such as a plastic container or paper bag), stored inside a polystyrene box with a freezer pad if there is a risk of them overheating. Insects should never be left inside plastic containers in full sun, or in a car, because they can quickly overheat and die. Delay making releases if the weather forecast is bad because natural enemies need time to settle in before a disturbance.

It is important to keep good records about what natural enemies are released, when, and where, so that in future others can follow up. It is also useful to collect information about the amount and severity of the weed infestation at the time of the release, including photos, to provide baseline data so that changes as a result of the control project can be assessed over time.

Releasing mile-a-minute rust. Photo: MWLR

Harvesting and redistribution

All natural enemies can disperse on their own, but the speed of this dispersal can vary from metres to hundreds of kilometres per year, depending on the type of natural enemy. For natural enemies that spread slowly (such as large beetles and scale insects), it is helpful to harvest them from established field sites and release them at sites some distance away.

For natural enemies that spread rapidly (such as fungal pathogens and some flies and mites), little or no redistribution may be required. Natural enemies collected from field sites for redistribution should be treated in the same manner as those produced for releases through mass-rearing.

The ability to grow and maintain healthy plants, pay close attention to detail, and keep good records are hallmarks of successful rearing of natural enemies. It is important to keep good records about what natural enemies are released, when, and where, to assess and follow-up.

Step 6: Monitor and evaluate the success of a project

Agree on the desired outcomes and approach

Studies to assess the impact of natural enemies can be extremely complex if data is required for publication in science journals. However, simple assessment approaches can also be used where the aim is to measure large changes rather than small, subtle ones, and these will generally be most appropriate for Pacific projects. If these simple approaches are done well, they can yield useful data. To avoid wasting resources, a hierarchical approach to assessment can be undertaken (see Figure 3). It is important to determine at the outset what the goal (desired outcome) is to be able to assess progress towards achieving it. Often, that goal will be to reduce the harmful impacts of weeds, although for some species, an appropriate goal might be to reduce further spread or prevent a weed from establishing in new areas.

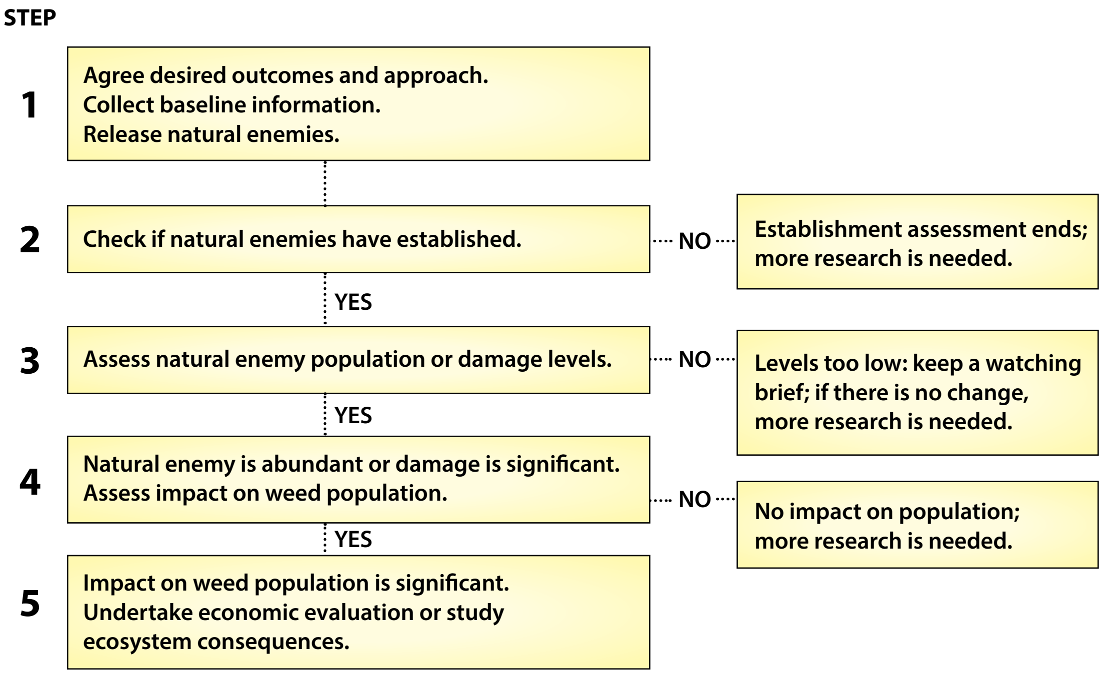


Figure 3: Hierarchical approach to assessment

Collect baseline data

Baseline data about weeds (such as their extent, percentage cover, and height for some species) should be collected at the release time, if not before. Photos should also be taken, some of which may be suitable for analysis with digital software, but even "before and after" shots provide a useful visual record.

Check for establishment

After a natural enemy is released, the release sites should be checked regularly to see if the natural enemy population is establishing. If the natural enemy is not establishing, then efforts may need to go into making more releases or trying different release techniques or natural enemies, rather than assessment activities. The time to wait before assessing a site will depend on the natural enemy involved. Some natural enemies will be difficult to find in the field for the first year or two following their release, when they are still rare. However, some natural enemies in the tropics can build up damaging populations quickly, and for these species, follow-up checks should be made at least every 3 to 6 months.

Checking for natural enemy establishment is usually done by visual inspection, although beating plants can also be useful for small natural enemies. To do this, beat plants at the release point with a stick over a white plastic tray, sheet of material, or piece of cardboard and examine what has been dislodged. A hand lens or magnifying glass is useful to help identify what you find. Be sure to check natural enemies at the appropriate time of the year or day. Some natural enemies might hide away at certain times of the year or day to avoid adverse conditions or might only be present as cryptic (hard to see) life stages, such as tiny eggs, at certain times of the year.

Assess population/damage levels

Once establishment has been confirmed, the next step is to assess if the natural enemy population is building up to damaging levels or not. If the population is growing well, it is then appropriate to assess the impact it is having on its host plant. However, if the natural enemy is only persisting at low levels, then patience might be required or studies might be needed to determine why it is not flourishing and what should be done next.

Assessing population levels can be achieved by counting the number of individuals present or assessing their damage levels. Counting is appropriate where it is easy to collect/count individuals, for example, in cases where a researcher can beat plants for a set number of times or for a set period of time and count the beetles that were dislodged. Assessing the level of damage is appropriate for pathogens and where insect population assessments will be difficult. Categories of abundance or infestation can be used, such as occasional, patchy, heavy, or severe.

Clockwise from top left: Looking for lantana natural enemies. Photo: MWLR; Lantana natural enemies. Photo: MWLR;

Assessing mile-a-minute rust establishment. Photo: Biosecurity Queensland; Severe balloon vine rust infestation. Photo: MWLR.

Non-target damage

Once natural enemies are well established and abundant, it is good practice to check for non-target damage, even when none is expected. If closely related plants co-exist at the release site, check them for any signs of attack by the released natural enemy and record what is found.

Keep gathering data

Visits to release sites should continue to be made on a regular basis (as often as 3 months if control is progressing rapidly or as long as 12 months if it is happening slowly), to gather information about the extent, percentage cover, and, if appropriate, height of weeds and to take photos. As weeds begin to decline, photos may clearly demonstrate what species have replaced them, or this data may also need to be collected if desired. It can also be useful to undertake an economic evaluation to determine financial, and other, benefits arising from the projects. Economic analyses that have been undertaken for weed control projects that have used natural enemies worldwide typically show extremely positive returns on investment, with benefit to cost ratios ranging from 10:1 to 4000:1.

Economic analyses for weed control projects that have used natural enemies worldwide typically show extremely positive returns on investment, with benefit to cost ratios ranging from 10:1 to 4000:1.

How successful is control using natural enemies?

Some people are sceptical that weeds can be controlled by using natural enemies. However, evidence from a century of such activity worldwide indicates that one third of programmes are so successful that no other control is required, half are partially successful (the chosen natural enemies are effective in some habitats but not in others), and only one sixth are unsuccessful (have no impact). A leading cause of failure is that funding ends before a project is completed. Research is continuing to improve safety, success, and cost-effectiveness all the time. Success rates can also be much higher when tried and proven natural enemies can be used.

For control using natural enemies to be successful, usually more than one natural enemy is required. Most programmes will develop a range of natural enemies that complement each other by attacking the plant in different ways or through being best suited to slightly different conditions.

One third of programmes are so successful that no other control is required.
For control to be successful, more than one natural enemy is usually required.

Pacific case studies

African tulip tree

African tulip mite one week after release in the Cook Islands. Photo: MWLR

African tulip tree (*Spathodea campanulata*) is a major invasive weed throughout the Pacific Region, for which control using natural enemies is predicted to have a medium feasibility. Surveys for natural enemies were undertaken in Ghana where this tree is native. The surveys identified two potential natural enemies that were subsequently tested by Rhodes University (South Africa) and found to only attack African tulip tree. One is an eriophyid mite (*Colomerus spathodea*), which forms hairy galls (erinea) on the leaves and shoots of the plant, resulting in deformations. The other is a flea beetle (*Paradibolia coerulea*) which mines the leaves as larvae and feeds on the leaves externally as an adult. The mite was released in Rarotonga (Cook Islands) in January 2017 with establishment confirmed later that year. By November 2018, the mite was becoming abundant and widespread and was showing promise as a useful natural enemy. There are plans to release the mite in Vanuatu and the beetle in Rarotonga in the near future. Other Pacific island countries and territories are now able to benefit from these natural enemies if desired.

Broomweed

Broomweed (*Sida acuta*) is a small herbaceous shrub growing to approximately 1 to 2 metres high. It is found in all 22 Pacific island countries and territories. It is particularly a problem in pastures, where it can outcompete preferred grass species. It is generally unpalatable to cattle. A leaf-feeding beetle (*Calligrapha pantherina*) was introduced into Australia to control the weed there. Following its success in Australia, it was released into Fiji, Vanuatu and Papua New Guinea (PNG). In all three countries, the beetle has reduced populations of broomweed to levels where it is no longer considered a problem. The beetle was introduced into Samoa but it is not thought to have established there. However, the beetle is now found in New Caledonia, having probably spread naturally from Vanuatu. This beetle would be suitable for any country in the Pacific that considers broomweed a major problem.

Left to right: African tulip mite one week after release in the Cook Islands. Photo: MWLR; Broomweed infestation in Vanuatu before broomweed beetle was released. Photo: Biosecurity Queensland; The same broomweed infestation after control by the broomweed beetle. Photo: Biosecurity Queensland

Mile-a-minute

Heavy mile-a-minute rust infection. Photo: MWLR

Mile-a-minute (*Mikania micrantha*) is a fast-growing vine, capable of growing up and smothering other vegetation. Apart from being able to kill other smaller plants, such as taro, it can reduce yields of bananas, cocoa, coconuts, and papaya. Mile-a-minute is found in 21 of the Pacific island countries and territories. A rust fungus (*Puccinia spegazzinii*) was first released in India in 2006 and later in China and Taiwan, following extensive host-specificity testing in these countries and by CABI (www.cabi.org). Following the testing of approximately 11 additional species, the rust was released in Fiji and PNG and then later into Vanuatu and the Cook Islands. The rust was also introduced into Palau and Guam, albeit unsuccessfully. Detailed monitoring has not occurred in any country to date, but anecdotal information suggests that field populations of mile-a-minute are decreasing. The rust has already been tested against 287 species and would be suitable to introduce into any country that considers mile-a-minute a problem.

Lantana

Lantana (*Lantana camara*) is a shrub found in 21 Pacific island countries and territories. It infests pastures, plantations, disused lands, and open forests. Lantana has been the target of control using natural enemies for over 100 years, and many natural enemies have been released throughout the world, including 31 in Australia. Collectively, 20 natural enemies have been introduced into 15 countries, with nine establishing across the 15 countries. Of the natural enemies that have established, a sap-sucking bug (*Teleonemia scrupulosa*) and a beetle (*Uroplata girardi*) are the most damaging, but these natural enemies have established in only 13 countries each. These natural enemies could be moved to other countries if warranted. In addition, there are other natural enemies present in Australia that could also be considered for Pacific introduction if lantana is considered problematic in any country.

Water lettuce

Water lettuce (*Pistia stratiotes*) is also an aquatic weed from South America and has been reported in 10 Pacific island countries and territories. Water lettuce has the ability to double its biomass in a short period of time. The small weevil *Neohydronomus affinis* has been released in only PNG and Vanuatu, where it is controlling the weed in most places where the weevil has established. The weevil could be considered for introduction in those countries where water lettuce is a problem and cannot be managed by conventional means.

Top: Before and after biological control of water lettuce at Avue Beach, Vanuatu, January and August 2017. Photos: Biosecurity Queensland. Bottom left: Water lettuce weevil and its intended damage. Photo: Biosecurity Queensland. Right: Growing on water lettuce to rear a natural enemy. Photo: MWLR

Nail grass

Nail grass psyllid. Photo: Biosecurity Queensland

Nail grass (*Mimosa diplotricha invisa*) is a small spiny shrub found in 16 of the 22 Pacific island countries and territories (PICTs). It infests grazing lands, outcompeting preferred pastures, and can interfere with mustering due to its dense growth habits. A small sap-sucking psyllid (*Heteropsylla spinulosa*) was first introduced into Australia. This psyllid has since been introduced into 13 PICTs, establishing in 12 PICTs. In countries such as PNG, nail grass is now considered under control in most areas where the psyllid has established. Nail grass is confirmed in another three countries, so there is scope for the psyllid to be moved to a few more countries if populations of nail grass warrant this action.

Water hyacinth

Water hyacinth (*Eichhornia crassipes*) is an aquatic weed from South America and is now found in 15 Pacific island countries and territories. It can double its biomass in 10 days and can completely cover lakes, ponds, and rivers, disrupting water flow, access to water, and fishing. Two beetles (*Neochetina bruchi* and *Neochetina eichhorniae)* have been released in two and five Pacific island countries and territories, respectively. In PNG and Vanuatu, where both beetles have been released, there has been substantial control of water hyacinth in the areas where the beetles have established. Introducing both beetles into countries where water hyacinth is problematic could be considered. Two moths have also been released in PNG, but neither species has established.

Before and after water hyacinth control in Tambali Lagoon, PNG. Photo: CSIRO

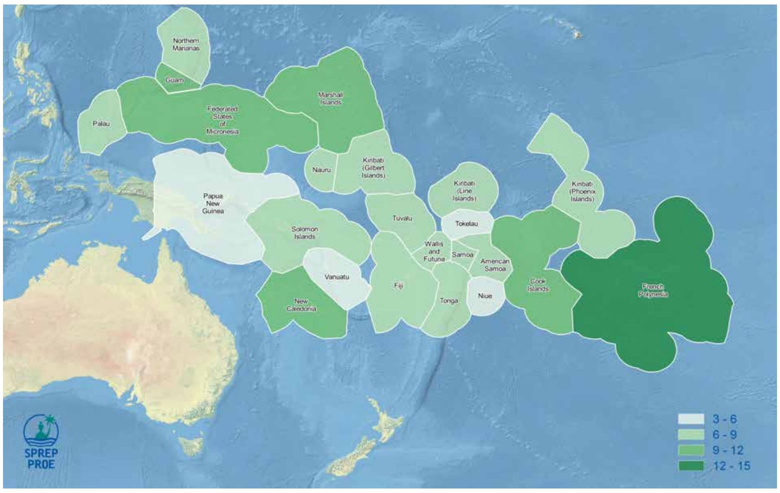
Before and after water hyacinth control in Waigani, PNG. Photo: CSIRO

Before and after water hyacinth control in Vanuatu. Photo: Warea Orapa

Future opportunities for the Pacific

Existing natural enemies

In the Pacific, since 1911, 68 natural enemies have been released to control 27 weed species in 17 countries (Day & Winston 2016). Some natural enemies have also self-introduced. Many natural enemies which typically have medium to high impact have not been released in all Pacific island countries and territories where their respective target weed has been recorded. For example, the broom weed beetle (*Calligrapha pantherina*) has proven very effective against *Sida acuta* and *S. rhombifolia* in three countries and could potentially be introduced into as many as 18 additional countries.



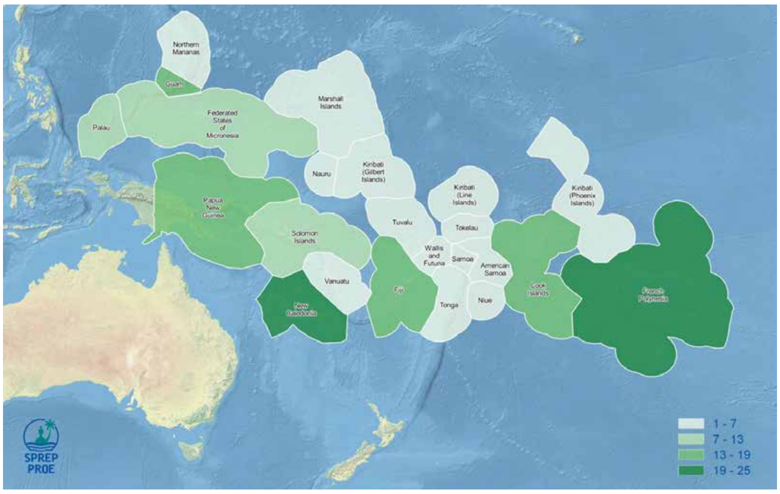
Opportunities to use natural enemies already present in the Pacific islands region as of 2016. Adapted by SPREP from Day & Winston (2016).

There is considerable potential to make better use of existing natural enemies already in the Pacific.

Red postman (***Heliconius***) butterfly for red passionfruit. Photo: MWLR

Potential opportunities

There are also opportunities to introduce natural enemies that have been introduced outside the Pacific island countries and territories, provided the target weed densities are sufficiently high to warrant this introduction. These include natural enemies for weeds such as air potato (*Dioscorea bulbiflora*), Honolulu rose (*Clerodendrum chinesis*), Madeira vine (*Anredera cordifolia*) and yellow bells (*Tecoma stans*), as well as additional natural enemies for cat's claw creeper (*Dolichandra unguis-cati*), lantana (*Lantana*), and parthenium (*Parthenium hysterophorus*).



Opportunities to use natural enemies already present outside the Pacific islands region as of 2016. Adapted by SPREP from Day & Winston (2016)."

Natural enemies continue to be developed for weeds. Within the next 5 years, natural enemies may also be available in the Pacific region for devil's fig/turkey berry (*Solanum torvum*), hibiscus burr (*Urena lobata*), wild peanut (*Senna obtusifolia, S. tora*), and albizzia (*Falcataria moluccana*).

Pasture weeds in Vanuatu. Photo: MWLR

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).

Online resources

www.ibiocontrol.org/

www.landcareresearch.co.nz/science/plants-animals-fungi/plants/weeds/biocontrol

Key references

Day MD, Witt ABR (2019) Weed biological control: challenges and opportunities. Journal of Asian-Pacific Weed Science Society 1(2):34–44

Day MD, Winston RL (2016) Biological control of weeds in the 22 Pacific island countries and territories: current status and future prospects. In: Daehler CC, van Kleunen M, Pyšek P, Richardson DM (Eds) Proceedings of 13th International EMAPi conference, Waikoloa, Hawaii. NeoBiota 30: 167–192. doi: 10.3897/neobiota.30.7113

Hinz HL, Winston RL, Schwarzlander M (2019) How safe is weed biocontrol control? A global review of direct nontarget attack. The Quarterly Review of Biology 94:1–27

Suckling DM, Sforza RFH (2014) What magnitude are observed non-target impacts from weed biocontrol? PLOS ONE 9:e84847 doi: 10.1371/journal.pne.0084847

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