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Review Article

Community involvement in the distribution and evaluation of biological control agents: Landcare and similar groups in Australia

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ABSTRACT

A key element for achieving a successful outcome to a biological control programme is the effective redistribution of agents throughout the range of infestation of the target weed. Australian biological control workers have enjoyed a good reputation for scientifically based and systematic studies leading to the selection, release and establishment of control agents. However, in the past, redistribution of agents following establishment has been done in a fairly piecemeal fashion. A recent social phenomenon in Australia has been the development of community groups that have become concerned with, and actively involved in, the remediation of a wide range of environmental problems. Weed biological control practitioners are using these groups more and more frequently to develop control agent release networks, ensuring a more systematic redistribution of agents and more rapid delivery of biological control to the end-user. Examples of this, in particular those involving the Landcare Program, are given to illustrate how the harnessing of community interest can provide a valuable resource for the classical biological control of weeds, both for the redistribution of agents and for their subsequent evaluation.

INTRODUCTION

Weed infestations affect all members of the community, either directly or indirectly (Darby & McLaren, 1993). They increase agricultural production costs by lowering yields and/or contaminating produce, leading to higher commodity prices. Invasion of national parks and native vegetation by alien plants reduces local biodiversity and affects the aesthetics of our natural landscape. Secondary problems can occur through the overuse or misuse of chemicals and consequent contamination of soil and waterways.

Biological control is an important management tool that can be used to help control weeds in many situations, but one which has been the domain of government and which has traditionally followed the linear model of technology transfer; from researcher to extension officer to land manager. This tends to reinforce community perceptions that biological control is a panacea for their weed problems, and frequently leads to disillusionment with the technology when the effects are not quickly apparent. Despite the impression given by a few high-profile success stories, such as *Cactoblastis cactorum* (Berg) (Pyralidae) controlling prickly pear cactus (*Opuntia* spp.; Cactaceae) over 20 million hectares of south-west to central Queensland, most biological control projects (particularly those involving terrestrial weeds) are long-term solutions and will form one part of an overall management strategy. Most people fail to realize that even the spectacular success of the prickly pear programme involved the introduction of 51 biological control agents over a 22-year period (1913-1935) and that once *C. cactorum* had been introduced in 1925, it took a further seven years to control most infestations (Wilson, 1960).

More appropriate means are required to transfer biological control technology effectively to the wider community. In recent years there has been an increasing focus on the development of effective extension systems for the release and redistribution of biological control agents of weeds (Brown, 1990; Darby & McLaren, 1993; Syrett *et al.*, 1993; Grindell, 1995; Jupp, 1996). This key phase has often been the weak link in biological control programmes, and attention to it should not only reduce the high rates of failure of agents to establish following release (see Crawley, 1989) but also speed up delivery of the effects of biological control to client groups (Briese *et al.*, 1996a). In Australia, the need to prioritize the development of efficient redistribution procedures for biological control agents has

Table 1. Community groups in Australia available for biological control of weed technology transfer activities.

	Community group	No. of groups	No. of members
Landcare movement	Landcare groups Dunecare groups Bushcare groups Urban Landcare groups	2500	74000
National Park supporters	Friends of National Parks Australian Trust for Conservation Volunteers	>1000	unknown but likely to be several thousand.
Schools	Rural High Schools Double Helix Science Clubs	380	24000

been recognized by both research workers, as illustrated by the recommendations of a recent workshop on thistle management (Briese *et al*., 1996b), and funding bodies, such as the Meat Research Corporation (MRC), the International Wool Secretariat (IWS) and the Dairy Research and Development Corporation (DRDC), which are supporting such projects (Conley, 1993). A common feature of these redistribution programmes is that they involve, to varying extents, the active participation of the end-users, i.e. members of the community.

Participation by community members in biological control has many advantages (Andrews *et al*., 1992). It not only reinforces their ownership of the problem, but provides them with ownership of the solution. It also provides a structure for education about biological control, its benefits, limitations and management requirements. As pointed out by Andrews *et al.* (1992), if community involvement is to aid biological control, the community must understand it, believe in it and want to use it. Direct interaction between researcher and client enables the researchers to become more aware of the precise needs of their clients and to tailor the biological control projects accordingly. Finally, community groups provide a potentially powerful source for the monitoring and evaluation of the success of established control agents. Ultimately it is the community which will assess the success of biological control.

Participation of the community in research and extension projects depends greatly on the structures that exist within a particular society and varies greatly between regions and countries. In this paper, we discuss the types of community structures which exist in Australia and how they are being harnessed to improve the delivery of biological control. In particular, we will look at the involvement of the Landcare movement (Campbell, 1994), a highly successful model of community action that evolved to reverse land and water degradation and move toward more sustainable resource use (Curtis, 1995).

STRUCTURE OF COMMUNITY GROUPS

In recent years in Australia, there has been a dramatic upsurge of formalized community groups concerned with environmental monitoring and rehabilitation. A recent directory (Alexandra *et al*., 1996) lists some 200 examples of such groups, 75% of which had formed since 1990. The prime example of this type of community involvement is the Landcare movement. The origins of this movement (summarized in Campbell, 1994) stem from a broad community realization of need for sustainability in land-use practices and the desire of individuals to take responsibility for their own problems. The essence of Landcare is local groups tackling local problems in their own way (Alexander, 1995). Based on small neighbourhood or regional groups, with an average membership of close to 30, there has been enormous growth from fewer than 100 groups in 1985 to about 2500 currently, as local communities band together to tackle the particular problems that they have in common. These presently comprise about 30% of rural landholders in Australia, and a considerably higher proportion in some regions (Alexander, 1995). While groups were initially concerned with rural land problems, more recently some groups have been formed to tackle specific concerns in coastal regions and the rehabilitation of native vegetation affected by urban encroachment (Rees & Smith, 1996) (Table 1). This rapid growth in the Landcare movement has been facilitated by a partnership between the government and the community. While the formation and expansion of Landcare groups is a bottom-up process, driven by local needs, it is supported by government-funded infrastructure (the national and state Landcare Programs) aimed at providing a degree of coordination and a system of small grants designed to catalyse group activities.

The value of Landcare for the extension of agricultural research was recognized quite early (Curtis, 1995). Moreover, the strong ethic of sustainability makes the Landcare movement highly sympathetic towards biological control as a management tool. Surveys have indicated that weeds are the most important issue to Landcare groups in all states (Alexander, 1995; Curtis, 1996), and weed control comprises the highest number of activities undertaken by these groups (see Curtis, 1996). Possession of a shared understanding of the importance of controlling weeds in a sustainable way and a willingness to act, makes the Landcare movement a powerful resource for researchers to improve the transfer of biological control technology to the Landcare group.

Friends of National Parks groups exist in all states and are formed by volunteers who assist in maintenance activities in various parks and conservation areas. These groups are involved in flora and fauna surveys, public education, fund-raising, the upkeep of walking trails, and revegetation and weed control. While there is usually a coordination of ‘Friends of ...’ groups through state conservation agencies, the groups are autonomous and operate in close contact with the managers of the particular reserves in which they have an interest. With more than 200 such groups operating in Victoria alone (Victorian National Parks Association) it is likely that in excess of 1000 groups would be operating Australia-wide (Table 1). Few areas of conserved native vegetation would not have an associated Friends group, and they therefore provide an as yet untapped resource for biological control programmes involving environmental weeds such as bridal creeper, *Asparagus asparagoides* (Asparagaceae), and Scotch / English broom, *Cytisus* spp. (Fabaceae).

Probably the most widely distributed and the greatest potential source of community participation for biology-based extension and monitoring projects is the education system, in particular rural schools. A good example of a school-based project is BIOSCAN, which is designed to involve science students in the monitoring of dung beetle distribution and abundance, and assessment of their impact on bushfly populations (Allen *et al*., 1995). A well-designed

Table 2. Biological control project and agents that have been redistributed by release networks including local community groups.

Target weed	Agents		Overseeing agencies#	Groups involved	Years of redistribution
Echium plantagineum	*Dialectica scalariella*	Lepidoptera	CSIRO, DNRE, NSW Agric,	Landcare	1989-92
	Mogulones larvatus	Coleoptera	Agric WA, SARDI		1994-96
	M. geographicus	Coleoptera			1995-96
Hypericum perforatum	*Aculus hyperici*	Acarini	CSIRO, DNRE, NSW Agric	Landcare	1994-96
Carduus nutans	*Trichosirocalus horridus*	Coleoptera	CSIRO, NSW Agric	Landcare	1995-96
	Urophora solstitialis	Diptera			1995-96
Carduus pycnocephalus	*Puccinia cardui-pycnocephali*	Fungus	DNRE	Landcare	1995-96
Cirsium vulgare	*Rhinocyllus conicus*	Coleoptera	DNRE	Landcare	1994-96
	Urophora stylata	Diptera	DNRE	Landcare	1995-96
Silybum marianum	*Rhinocyllus conicus*	Coleoptera	DNRE		1996
Onopordum spp.	*Larinus latus*	Coleoptera	CSIRO, NSW Agric	Landcare	1994-96
	Lixus cardui	Coleoptera			1995-96
Senecio jacobaea	*Cochylis atricapitana*	Lepidoptera	DNRE, Tas DPIF	Schools/Landcare	1992-96
	Tyria jacobaeae	Lepidoptera	DNRE, Tas DPIF		1995-96
	Longitarsus flavicornis	Coleoptera	Tas DPIF		1994-96
Eichhornia crassipes	*Neochetina bruchi*	Coleoptera	CSIRO	Double Helix	1995
Chrysanthemoides monilifera	*Cosmostolopsis germana*	Lepidoptera	NSW Agric	Dunecare	1994-96
subsp. *rotunda*	*Chrysolina* sp. A	Coleoptera			1996
subsp. *monilifera*	*Chrysolina* sp. B	Coleoptera	DNRE	Schools	1995-96
	Chrysolina picturata	Coleoptera	DNRE	Schools	1996
Rumex spp.	*Chamaesphecia doryliformis*	Lepidoptera	Agric WA	Landcare	1996
			DNRE	Landcare	1996
Parthenium hysterophorus	*Bucculatrix parthenica*	Lepidoptera	QDNR, QDPI	Parthenium Action	1995-96
	Epiblema strenuana	Lepidoptera		Group/Landcare	1995-96
	Zygogramma bicolorata	Coleoptera			1995-96
	Listronotus setosipennis	Coleoptera			1995-96
	Smicronyx lutulentus	Coleoptera			1995-96
	Puccinia abrupta	Fungus			1996
Heliotropium europaeum	*Uromyces heliotropii*	Fungus (Uredinales)	CSIRO	Landcare	1995-96

CSIRO: Commonwealth Scientific and Industrial Research Organisation, Division of Entomology; DNRE: Victorian Dept. of Natural Resources and Environment; NSW Agric: New South Wales Agriculture; QDNR: Queensland Dept. of Natural Resources; QDPI: Queensland Dept. of Primary Industries; SARDI: South Australian Research and Development Institute; Tas DPIF: Tasmanian Dept. of Primary Industry and Fisheries; Agric WA: Agriculture Western Australia.

project such as BIOSCAN will in return serve as an educational resource for biology studies, so that both researcher and teacher/student benefit from the activity. In fact, BIOSCAN has recently been adopted as part of the school curriculum in Tasmania (I. Dadour, pers. comm.). Harnessing the resources of the school system has been greatly facilitated in Australia since the formation of the Double Helix Science Club, a CSIRO-sponsored initiative to promote science in schools. This club has 24,000 members in 380 school groups and annually runs a national experiment involving club members Australia-wide, usually comprising a monitoring exercise for a research project of national importance. To date, three major projects have been successfully carried out – ‘The Great Dung Beetle Crusade’, ‘Earthworms Down Under’ and ‘Termite Tally’ – and have provided very large sets of data on the distribution and abundance of different species of these economically important groups. Club officials are available to help coordinate smaller-scale projects where there is mutual benefit to researcher and student.

EXAMPLES OF COMMUNITY NETWORKS AS A RESOURCE FOR BIOLOGICAL CONTROL PROJECTS

Biological control projects in Australia which have made use of community groups to aid the release and redistribution phase are shown in Table 2, together with the agents involved and the organizations that have overseen the programmes. These projects cover about 40% of the target weeds for which there are established control agents. The following brief outlines describe individual projects of varying complexity and formalization, and draw out particular aspects of community involvement which are important for the success of biological control.

Paterson’s curse

Paterson’s curse, *Echium plantagineum* (Boraginaceae), is one of the most serious broadleaf annual weeds of grazing lands throughout southern Australia, occupying more than six million hectares of Australia. This created a need for coordination across the infested states to ensure an efficient distribution of biological control agents. As a consequence, an *Echium* biological control workshop was set up in Canberra in 1988, involving research officers from CSIRO (Commonwealth Scientific and Industrial Research Organisation), DNRE Victoria (Victorian Department of Natural Resources and Environment), NSW Agriculture (New South Wales Agriculture), Agriculture WA (Agriculture Western Australia) and SARDI (South Australian Research and Development Institute) as well as industry representatives from MRC and IWS. This led to the first Australia-wide network for cooperation on biological control agent releases.

The Paterson’s curse leaf miner, *Dialectica scalariella* (Zeller), was the initial biological control agent used in this network. *Dialectica scalariella* is a small gracillariid moth that causes

Box 1. Release kits concerning the redistribution of biological control agents may be pitched to different audiences (e.g. individual landholders, Landcare coordinators), but generally contain the following minimal information:

- **Identification and management of the weed**
  - common names, origin, significance, description of weed and its life cycle
  - current control methods (e.g. chemical, pasture management, cultivation, slashing)
- **The life cycle and identification of the biological control agent**
  - description of agent and its life cycle
  - description of damage caused by the agent
- **How biological control fits in as part of local weed management plans**
  - overview of what biological control hopes to achieve, stressing its long-term nature
  - how biological control should be viewed as part of an overall weed management plan that integrates it with other control options
  - details of the biological control strategy for the particular target weed
- **Factors to consider when selecting and looking after release sites of biological control agents**
  - sites that are suitable for the release of biological control agents are those which:
    have a dense and chronic weed infestation
    have a long time frame for control
    have a low priority for control by other methods
    are inaccessible to other control methods
    are preferably connected to neighbouring infestations to enable spread of the agent
  - sites should be managed for up to five years following release, and:
    may need to be fenced to exclude stock
    no insecticides or herbicides should be used within 100 m of the site
    should not be burnt, slashed or cultivated, but should be managed to maintain the infestation
- **Management of the biological control agents and harvesting for further redistribution**
  - detailed instructions on how to release particular agents, including a description of cages and their erection (if used), the timing of releases and the numbers of each agent required, and subsequent maintenance of the release site
  - detailed instructions on how and when to harvest agents from the release cages or sites and make further distributions
  - a diagrammatic calendar showing the month / season, weed life cycle, biological control agent life cycle, nursery site activities and signs of agent damage to clarify the timetable for each activity
- **Monitoring the release site for establishment of the agents**
  - reply-paid forms to ensure that release information is recorded and can be entered on an appropriate database
  - instructions on how to recognize damage caused by the agents and simple sampling methods to measure this
  - simple monitoring forms to record presence of agent and estimate of numbers and / or impact

blister-like mines on the surface of *Echium* leaves. Severe attack may cause premature defoliation and reduced flowering. From 1989-1990 starter colonies were supplied to collaborators and over 1000 releases were made over all states. Establishment of the agent has been recorded in parts of Victoria (Shepherd, 1990), New South Wales, South Australia, Queensland and Western Australia (Dodd, 1990). However, nationally there was inconsistency in the effectiveness of these release programmes, chiefly owing to physical and financial constraints. As a consequence, a joint industry- (MRC and IWS) and government-funded programme was set up to accelerate the establishment and distribution of *Echium* biological control agents. This was to be done by researchers setting up community networks and establishing biological control ‘nursery sites’ from where affiliated regional groups, including Landcare groups and other land managers, could help collect and redistribute the agents.

It was also at this time that DNRE and the Victorian Farmers Federation launched a programme to increase public awareness of the threat posed by Paterson’s curse. ‘Operation Blue Hills’, as the programme was called, provided a network of advice, information and assistance to landholders with Paterson’s curse infestations, aimed at long-term reduction and management of the weed. As part of this programme, Landcare groups from affected areas liaised with DNRE area staff to formulate plans for the release of biological control agents in suitable areas over a five- to 10-year period.

This community involvement was the catalyst for the development of biological control information kits designed to inform participants better about the nature and aims of biological control and to help them play an effective role in the establishment of control agents. While different kits may be pitched at different levels (e.g. individual landholder, group coordinator, local government officer), they contain detailed information on the weed, the agent, release methodology and agent redistribution (see Box 1).

Two agents were initially targeted for this community ‘nursery site’ release network, the *Echium* weevils, *Mogulones larvatus* (Schultze) and *M. geographicus* (Goetze). *Mogulones larvatus* attacks the crowns of *Echium* species while *M. geographicus* attacks the roots. Both of these species are univoltine making it imperative that the most efficient and effective establishment and redistribution programmes be put in place. Government departments in all states received starter colonies for mass-rearing and information on rearing methods was quickly shared. The mass-rearing programme has resulted in a total of 360 releases of the Paterson’s curse crown weevils since 1994. An example of the Victorian network is shown in Figure 1.

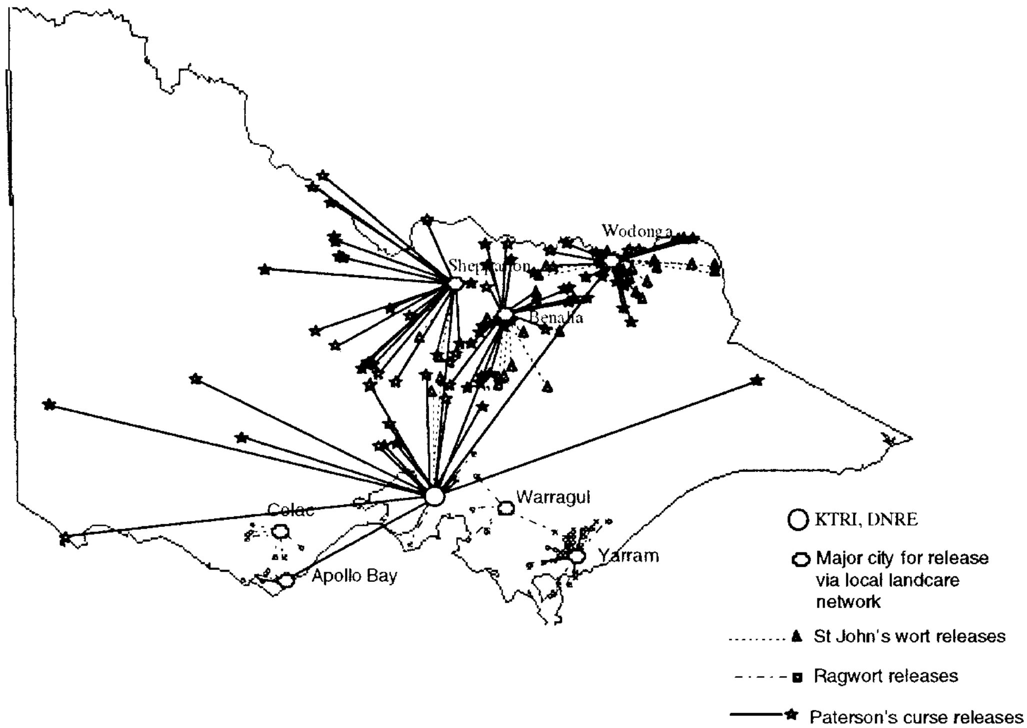

Figure 1. Examples of some biological control agent distribution networks in Victoria.

Each nursery site has been supplied with a release cage (4 × 2 × 2 m) with detailed instructions on how the cage can be utilized to optimize weevil establishment and requirements for management of the site (Morley *et al.*, 1996). These cages also enable containment of weevils so they can be collected for re-release at new sites. Landcare groups have been enthusiastic about their involvement in biological control and already 133 new sites have been set up through agent redistribution from nursery sites Australia-wide.

Ragwort

Ragwort, *Senecio jacobaea* (Asteraceae), is a plant of European origin that has become a major economic weed in disturbed, high-rainfall areas of Australia, North America, New Zealand, South Africa and Argentina. There are currently biological control programmes against ragwort in Australia (Field, 1990), the USA (McEvoy *et al.*, 1991), Canada (Harris *et al.*, 1984) and New Zealand (Syrett, 1989).

In Australia, some ragwort biological control agents either have failed to establish (the ragwort seed fly, *Botanophila seneciella* (Meade); Anthomyiidae) (Wilson, 1960), have established intermittently (ragwort flea beetles, *Longitarsus* spp.; Chrysomelidae) (Field, 1990) or are still being evaluated for establishment (cinnabar moth, *Tyria jacobaeae* (L.); Arctiidae). The ragwort flea beetle, *L. flavicornis* (Stephens), has established well and is controlling ragwort in Tasmania (J. Ireson, pers. comm.). In Victoria, the ragwort crown boring moth, *Cochylis atricapitana* (Stephens) (Tortricidae), is establishing well and increasing its populations (McLaren, 1992). As a consequence, a mass-rearing and release programme funded by DRDC was initiated in 1995. This enabled the setting up of a network of Victoria and Tasmania government agencies, producer groups and agribusinesses to establish 60 nursery sites of the crown boring moth and to field-collect and redistribute flea beetles to 30 new release sites each year (Victorian distribution – Figure 1). An important concomitant of this community involvement is the provision of detailed information on all aspects of the biological control programme (Newnham *et al.*, 1995, 1996) (see Box 1). Community groups receive regular updates on the progress of biological control (quarterly biological control newsletters) and also sign an agreement outlining their obligations to look after and maintain the nursery sites. This agreement is important as it ensures that the land manager takes full responsibility for the nursery site. Such agreements reduce the risk of site destruction through spraying or over-grazing. In addition, a ragwort management handbook has been recently published (McLaren & Mickan, 1997) which provides detailed information on how biological control can be integrated into an overall ragwort management strategy.

In 1992, an educational project on biological control of ragwort was set up. School children in areas where ragwort infestations are a problem were invited to rear the ragwort crown boring moth, on potted ragwort plants in screened cages. The moths produced by the students were released at particular locations where the students could monitor their establishment and effects. However, the moth is relatively inconspicuous and larvae bore into ragwort not to be seen again until emergence. In 1994, the cinnabar moth which has large brightly coloured larvae that feed externally on ragwort foliage was reared by the schools instead. This resulted in greater interest and more day-to-day participation by students while also attracting increased media attention. Schools now compete against each other to see who can produce the most larvae, and field trips are organized where several schools meet at a particular site to release large numbers of cinnabar moth larvae. In 1995, students reared and released 11,900 cinnabar moth caterpillars at eight sites. Many schools are now self-sufficient and collect and store pupae for the following year's biological control programme. Companies and businesses were approached for sponsorship of the 'Ragwort School Biological Control Project' and, as a result, 19 schools have received equipment enabling them to participate in the programme. Each school has received screen cages, lights, a timer switch and research notes and has been given introductory talks outlining the background and scope of the project. Teachers and students are enthusiastic about the programme as it gives the students practical information that they can use themselves or pass on to their family and friends. They learn that biological

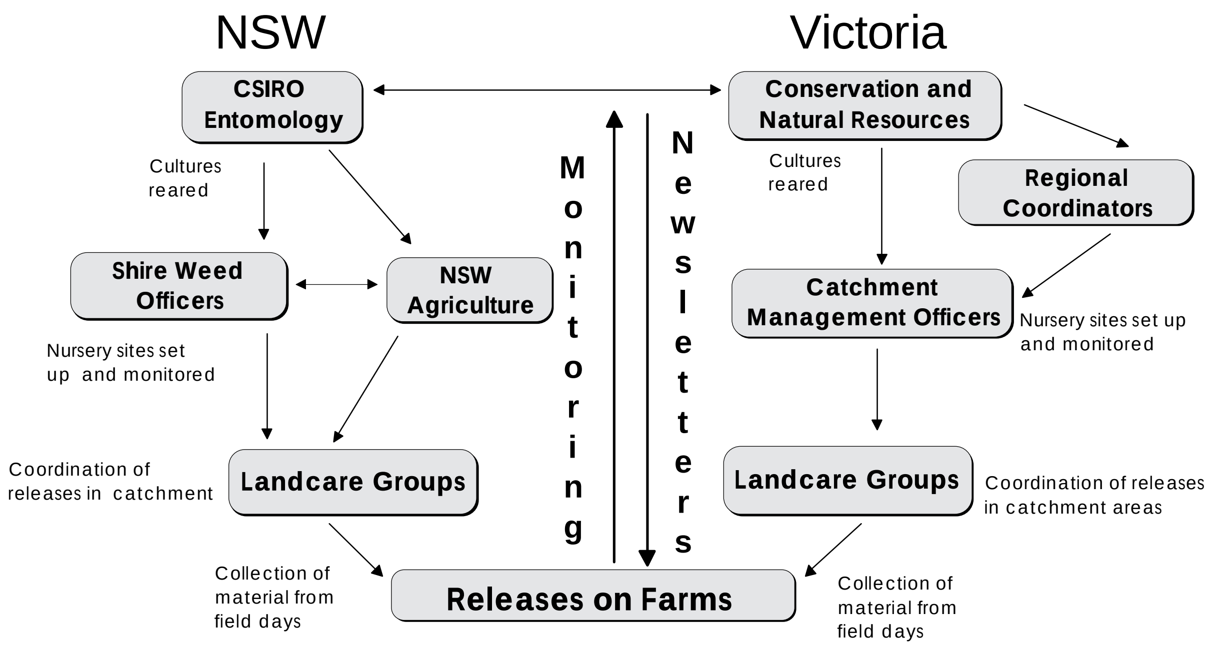

Figure 2. Structure of the redistribution network for St John's wort, showing differences in linkages within different states (after Jupp 1995).

control takes a long time to become effective and that it may not work in all situations. They also learn that biological control is only a part of a broad range of management tools required to control weeds.

St John's wort

St John's wort, *Hypericum perforatum* (Clusiaceae), is a perennial noxious weed of European origin that was introduced into Australia in the late 1800s and has since become a major problem in farmland and native bushland. It is a particular problem in New South Wales and Victoria where its combined distribution has been estimated at 350,000 ha (Campbell *et al.*, 1995). Previous biological control attempts in the 1930s and 1940s have led to partial successes through the leaf-feeding beetle, *Chrysolina quadrigemina* (Suffrian) (Chrysomelidae), but have not stopped the spread of this weed. Moreover, the beetles are ineffective on infestations of the weed shaded by trees, and these form the bulk of currently infested areas. Recently, an eriophyid mite, *Aculus hyperici* (Liro), was introduced in an attempt to improve biological control in all infested areas (see Briese, 1997).

The mite had been released at a number of sites in south-eastern Australia between 1992 and 1994 and began to exert some control on the weed. Consequently, MRC funded a 12-month redistribution programme, carried out jointly by CSIRO, NSW Agriculture and DNRE Victoria during 1994-95, and designed to ensure the systematic redistribution of the control agent throughout all weed infested areas. Sixty nursery sites were set up in both New South Wales and Victoria (see Jupp, 1996). These nursery sites are currently being managed by Landcare groups under the general oversight of local or state government officers for the further redistribution of mites. Considerable effort went into preparing the ground for establishment of nursery sites. Field days were organized for participants and land managers, a release information kit was produced (Jupp, 1995) and a slide kit was developed as a visual aid. The organization of this programme is shown in Figure 2 and is typical of the links which occur in release networks.

Because of the high rate of reproduction of the mite (several generations per year), this particular network was able to be set up rapidly and to be highly effective in promoting the spread of the mite. These agents are now widespread in areas of southern and central New South Wales where they are starting to have an impact on weed density and vigour (Mahr *et al.*, 1997). It is planned that the Landcare groups involved with the setting up of nursery sites will be able to help provide the essential quantification of this impact through simple monitoring protocols that are provided with the release information kits.

The Cooperative Research Centre (CRC) for Weed Management Systems has recently provided funding for the appointment of a technical officer to facilitate this monitoring and ensure that the network continues to spread the mite throughout the Australian distribution of the weed.

Thistles

Several species of thistle (Asteraceae) have become serious weeds in south-eastern Australian pastures. These include annuals such as slender thistles (*Carduus pycnocephalus* and *C. tenuiflorus*), variegated thistle (*Silybum marianum*), and those with a more biennial life history, including Scotch and Illyrian thistles (*Onopordum* spp.), nodding thistle (*C. nutans*) and spear thistle (*Cirsium vulgare*). Biological control programmes are currently underway against all these weedy thistles (see Woodburn *et al.*, 1996).

Funding from IWS and MRC has also permitted a joint programme to be set up by CSIRO and NSW Agriculture, aimed at the redistribution of biological control agents of both *Carduus* and *Onopordum* thistles in south-eastern Australia. Funding from IWS to DNRE has permitted programmes on variegated thistles and spear thistles to be undertaken in Victoria. In the case of *Onopordum* spp., networks of collaborators have been set up, based on up to 20 release sites per Landcare or other regional group. Where formal Landcare groups did not exist, networks were developed *de novo*, with the local government weeds officer organizing the cooperating landholders. Grouping together to combat a common problem, in this case thistles, is typical of the genesis of the Landcare movement.

The collaborating landholders in each network are selected by the group coordinator, on the basis of the suitability of their infestations and the ability of the person to manage a site. Local knowledge of the weed problem also enables the planning of more efficient patterns of release sites. For example, the Harden-Murrumburrah Landcare group members placed the release sites at strategic positions along a creek system which formed the main infestation corridor for *Onopordum* thistles. In both *Carduus* and *Onopordum* thistle redistribution networks, the initial releases in a region have been accompanied by field days to demonstrate procedures, and the provision of a release information kit (e.g. Briese *et al.*, 1995) is considered essential.

The method of redistribution for the *Onopordum* stem-boring weevil, *Lixus cardui* Olivier (Curculionidae), is based on the use of cages to establish one site of the agent per community region. Then, by harvesting and dividing the progeny to establish new release sites, there is a multiplication of sites over two to three years to provide up to 20 foci, from which the agents can disperse to all weed-infested areas in each local region (see Briese *et al.*, 1996a). This has enabled the number of release sites for the weevil to increase from six to 20 to 65 over the three years to 1995, with an expectation of about 200 release sites in 1996. The method is effective for speeding up the redistribution of an agent that does not have a rapid rate of increase (i.e. univoltine with a relatively low fecundity). Experience has shown that it is less suitable for the seed weevil, *Larinus latus* Herbst (Curculionidae). Particular aspects of an agent's biology may predispose it to different methods of release and redistribution. This is reflected in the release networks for *Carduus* thistles, where cages have been found to be unnecessary for the establishment of both the seed fly, *Urophora solstitialis* (L.) (Tephritidae), and the crown weevil, *Trichosirocalus horridus* (Panzer) (Curculionidae). Redistribution of these agents is effected by harvesting nursery sites and making subsequent free releases of critical numbers into the field (T. Woodburn, pers. comm.).

Participants in the *Onopordum* release networks were requested to complete a survey questionnaire on the problems caused by the thistle infestations, the effectiveness of control procedures and their cost (see Briese, 1996). This survey was intended to serve as a complementary assessment method to detect whether there were any changes in management practices once agents become well-established. Quantitative measures of agent impact are important, but if control efforts and costs are not reduced, biological control will be of little relevance.

The Victorian DNRE thistle projects are involved in releasing a receptacle weevil, *Rhinocyllus conicus* (Fröhlich) (Curculionidae), that attacks the seed head and reduces seed production of variegated thistle, *S. marianum*, and spear thistle, *Cirsium vulgare*, and a thistle gall fly, *Urophora stylata* (F.) (Tephritidae), that attacks the seed head of spear thistle. Two strains of rust fungus, *Puccinia cardui-pycnocephali* (Uredinales), that attacks the leaves of slender thistles, *Carduus pycnocephalus* and *C. tenuiflorus*, have also been released. Releasing, monitoring and redistribution of these agents are all conducted through government-community networks with three tiers of involvement.

Government officers:

- rear agents for distribution to regional coordinators
- produce information kits on the release of biological control agents as part of local weed management plans, the management of nursery sites and the monitoring of agents (Bruzzese *et al.*, 1996a, b, c)
- conduct workshops to train regional coordinators
- help regional coordinators conduct training days for Landcare groups and other nursery site managers
- provide information and updates on programme progress through a quarterly newsletter
- provide media releases to help publicize the programme

The regional coordinators (who are usually field-based DNRE weeds officers):

- identify suitable biocontrol agent release sites as part of local, integrated weed management
- locate Landcare groups or other suitable nursery site managers and provide training
- coordinate releases and monitor establishment progress
- enter all data on site details, releases and establishment on the DNRE pest management information system

The third tier of the network comprises the nursery site managers, the Landcare groups/farmers/land managers who actually ensure the day-to-day survival and operation of the nursery site.

Bitou bush and boneseed

Bitou bush, *Chrysanthemoides monilifera* subsp. *rotunda* (Asteraceae), is a South African shrub that has become naturalized in coastal dunes of eastern Australia. It was accidentally introduced, probably in ballast, but then deliberately planted to reduce dune erosion. However, it is now recognized as a serious environmental weed, as it rapidly displaces native vegetation and reduces floral diversity. The first biological control agents for bitou bush were released in Australia in 1989.

One particular subset of Landcare groups has specifically formed to look after areas of coastal Australia. These Dunecare groups have been utilized in management strategies for the control of *C. monilifera* subsp. *rotunda.* Groups have been involved in the release of the bitou tip moth, *Cosmostolopsis germana* Prout (Geometridae), at 30 sites and the black boneseed beetle, *Chrysolina* sp. A, at one site in coastal New South Wales. Once releases have been made, the groups provide information on establishment and dispersal, either as presence/absence data or, in some cases, as quantitative data along transects. Many of the groups are now redistributing the moth from the original release sites to other areas of infestation. While the numbers actively involved at any one time may fluctuate, there are currently about 15 groups actively involved, and interest levels are rekindled each time that information updates are sent to the participating groups (R. Holtkamp, pers. comm.).

In Victoria, a school biological control programme was set up in 1995 to rear the blotched boneseed beetle, *Chrysolina* sp. B, and the painted boneseed beetle, *C. picturata* (Clark), in 1996. Ten schools have been involved in the project where the students feed and look after the beetle larvae until they emerge as adults. The students then release the beetles at nearby boneseed, *Chrysanthemoides monilifera* subsp. *monilifera*, infestations with supervision from DNRE officers. Both primary and secondary schools are involved and are enthusiastic about being involved in an environmentally safe programme that could lead to reducing *C. monilifera*'s dominance in the local bushland.

Docks

Four species of docks, *Rumex* spp. (Polygonaceae), have been declared targets for biological control in Australia. These perennial weeds of pastures are important in areas of Australia with Mediterranean-type climates.

Research by Agriculture WA, supported by the MRC over the past decade, has resulted in the importation and release of the clearwing moth, *Chamaesphecia doryliformis* (Ochsenheimer) (Sesiidae), for control of dock (Fisher, 1992; Strickland & Fogliani, 1995). There have been over 150 releases in the south-west of Western Australia since 1989 with more than 50% of sites establishing (Strickland & Fogliani, 1996). Techniques have been developed enabling producers/Landcare groups to assist with spread and distribution of *C. doryliformis* by placing 'egg-sticks' onto dock plants in the field during summer. In 1994, a Victorian Landcare group, the St Helen's Shelterbelters, took the initiative to obtain MRC funding for a project of local releases. Agents and release information were supplied by Agriculture WA and minimal supervision was provided by Agriculture Victoria. Data are also being collected annually on presence or absence of the moth larvae in root samples.

The programme is now being further extended in Victoria with the MRC funding DNRE to set up a clearwing moth release network that will assist cooperators in the identification of suitable release sites, distribute information kits and train site coordinators on selection and management of nursery sites, and supervise the preparation and releases at five demonstration nursery sites in cooperation with landholders, Landcare groups and local DNRE staff.

Parthenium

Parthenium, *Parthenium hysterophorus* (Asteraceae), is a widespread weed throughout the tropical and subtropical regions of the world. It arrived in Australia in the late 1950s as a contaminant of pasture seed and has spread throughout pastoral areas in Queensland. In addition it can provoke serious allergenic responses in susceptible humans. Biological control of this weed commenced in Australia in 1980, with five agents released in the first four years (CRC for Tropical Pest Management, 1996). Two, the tip-galling moth, *Epiblema strenuana* (Walker) (Tortricidae), and the leaf-mining moth, *Bucculatrix parthenica* Bradley (Bucculatrigidae), are now widespread, while numbers of the defoliating beetle, *Zygogramma bicolorata* Pallister (Zygogrammatidae), have recently increased in the southern part of the weed's range. The stem-boring weevil, *Listronotus setosipennis* (Hustache), and the seed weevil, *Smicronyx lutulentus* Dietz (both Curculionidae), have also established. The rust fungus, *Puccinia abrupta* (Uredinales), was released more recently in 1992 and has become established (CRC for Tropical Pest Management, 1996).

In 1994, parthenium weed was identified as the major Landcare concern in the Rolleston district of central Queensland at a workshop organized by the Rolleston Landcare group. As a result, the Parthenium Action Group was formed, involving representatives of landholders, local government and the State Government Departments of Natural Resources and Primary Industries (DNR and DPI). The aims of the group were to eradicate where possible or contain the weed, promote field-based research and improve communication between researcher and landholder, educate landholders in best management practices and promote community awareness of the weed problem to prevent its spread. Biological control forms a major part in the strategy of the group and, in 1995, funding was obtained from the Drought Landcare Program to appoint a project officer / coordinator (S. Dearden, pers. comm.).

The project officer works in collaboration with researchers from the DNR laboratories in Brisbane and Charters Towers to ensure the supply and redistribution of the six agents. As this region is relatively isolated from the research centres, it has proved highly beneficial to have a person operating in the field who can develop methods for the collection and release of the agents that are suited to local practices and conditions. More importantly, it improves the efficiency of redistribution of agents that have short time periods in which they are collectable, or whose activity periods are triggered by unpredictable events, such as rainfall (e.g. *Z. bicolorata*). Distribution methods have centred on *Z. bicolorata*, which first became abundant in the area in 1993. However, it was realized that, by taking whole bushes (rootstock included) when collecting these beetles, the other four rarer insect agents could at times also be collected and re-released. This method is particularly effective for the stem-boring weevil, *L. setosipennis*, which pupates on the outside of the root crown. Although the project is only in its second year, there have already been over 300 releases throughout 16 local government shires and 20 Landcare groups (S. Dearden, pers. comm.). Currently, efforts are concentrating on redistribution of the rust fungus, with Landcare groups growing potted parthenium plants for infection from a nursery site for redistribution to release sites. Redistributions are organized through groups of neighbouring landholders, rather than individuals, to promote control efforts on a regional basis. Information and agent redistribution are conducted through the provision of management packages and field days. The management packages include monitoring forms which are aimed at providing information on the establishment and fate of the releases.

This is the first example of a community group taking the initiative to organize the distribution of control agents and demonstrates how effective community mobilization can be in speeding up the impact of biological control.

Lantana

Lantana, *Lantana camara* (Verbenaceae), is a toxic shrub, introduced as a garden plant from Central America. It escaped to invade both pasture lands and native vegetation in tropical and subtropical Australia. The biological control of lantana has been investigated in various phases since 1914, and over 30 insects have been introduced. Four species are now widely abundant, including two leaf-feeding beetles.

The beetles, *Uroplata girardi* Pic and *Octotoma scabripennis* Guérin-Méneville (both Chrysomelidae), are considered to be effective control agents for lantana in northern and south-eastern Queensland, but seem to be limited by cooler climates. In order to obtain information on the current distribution and densities of lantana beetles throughout Queensland, Broughton (1996) developed a school programme, 'Beetle Watch', which was made available to primary schools throughout coastal and sub-coastal Queensland in 1995. A booklet which included information on biological control and the mechanisms involved, identification keys and instructions on sampling procedures was made available to schools, all pitched at the appropriate level. These booklets were included in kits, along with photographs of the beetles and data sheets. Invitations to participate were sent directly to schools and through the CSIRO Double Helix Science Club. Fifty schools became actively involved and sent in data sheets. The exercise provided valuable information on the current distribution and abundance of the two main lantana beetles, and even located one rare species, *U. fulvopustulata* (Baly) (Broughton, 1996), but the programme as a whole was relatively time-consuming to develop and implement. The results of a questionnaire to schools seeking feedback on perceptions of the project indicate that it did serve the secondary purpose of educating teachers and students about the aims and technology of biological control (Broughton, 1996).

Water hyacinth

Water hyacinth, *Eichhornia crassipes* (Pontederiaceae), is one of the worst aquatic weeds in tropical regions of the world, and infests many waterways in northern Australia. Biological control has been implemented since 1975, relying mainly on the weevil, *Neochetina eichhorniae* Warner (Curculionidae). While this agent has been attributed with some success, it is less effective in cooler regions and a congeneric species, *N. bruchi* Hustache, was introduced in 1990 with the hope of achieving wider control.

The Double Helix Science Club has also been used for a biological control of weeds project, involving the release and early monitoring of the water hyacinth weevil

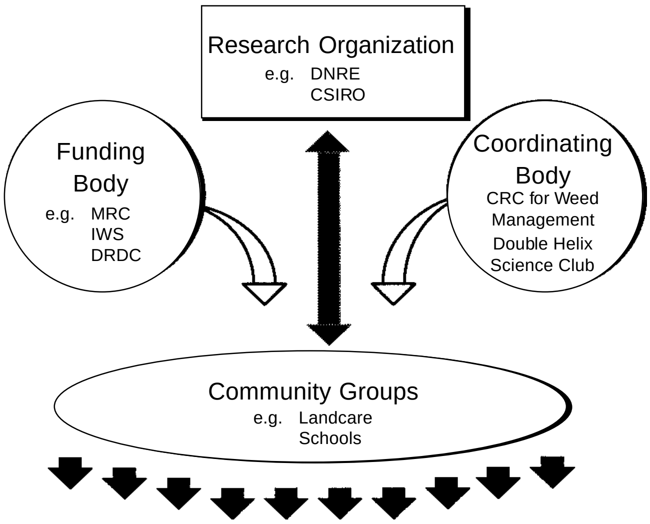

Figure 3. Relationship between partner organizations in a redistribution network. The research organization initially supplies the agents and expertise required to manage them, as well as the overall strategy for biological control and evaluation of the releases. The coordinating body establishes and maintains the network and facilitates a two-way flow of information between community group and researcher (in some cases research and coordination may be undertaken by the same organization). The funding body (which in Australia is often based around particular rural industries) provides the financial support needed for these operations.

N. bruchi at eight coastal sites between north Queensland (Townsville) and central New South Wales (Sydney) (A. Wright, pers. comm.). The school clubs involved were selected by the CSIRO Science Education Centre, which also coordinated transfer of agents and information kits between researchers and cooperating students. While the exercise enabled releases to be made, and served as a means of educating students about biological control, there was a problem in maintaining interest because the establishment phase of the weevils was quite slow (A. Wright, pers. comm.). This highlights one problem in working with particular groups who have no direct interest in the outcomes of biological control.

DISCUSSION

The rearing of biological control agents is an extremely costly and labour intensive process. The examples reported here demonstrate that harnessing community groups to help with the rearing and monitoring of agents not only can speed up the delivery of biological control, but can provide a resource for evaluation of the impact of agents.

In Australia, the development of such a community-based system has been greatly facilitated by the genesis of the Landcare movement and a general recognition that communities must be involved in finding solutions to the problems that affect them. The cases described here illustrate that, for community involvement to be of benefit to biological control, there needs to be a partnership between researchers, funding bodies, a coordinating body and the community groups (Figure 3). To date, this has been largely driven by the researchers, but there are now cases where the community has initiated the project, as illustrated in the case of the parthenium and dock weed projects, or attracted corporate sponsorship rather than responding to researcher-driven initiatives. Some funding bodies, such as MRC and IWS, are planning to support community initiatives from industry-linked groups (e.g. meat producers and woolgrowers in a region) for projects of benefit to the industry. Such PIRDs (Producer Initiated Research and Development groups) as they are known, could further stimulate client-led development of networks for the redistribution of biological control agents.

To maintain such networks, however, requires a high degree of coordination and two-way information flow (Figure 3), and the development of information packages and educational infrastructure has been a feature of many of the networks described here. It is also essential for release networks to cover the weed-infested areas in a systematic and appropriate way. Without some form of centralized coordination there is a risk that the process will become haphazard and inefficient, and the importance of this role cannot be overemphasized. Without it, conflicting interests, competing commitments and burn-out of initial enthusiasm by participants can easily lead to the foundering of networks. This is a general problem of any form of voluntary participatory activity (see Curtis, 1995). A recent feature on the Australian scientific landscape has been the creation of Cooperative Research Centres (CRCs), which promote links between research and industry. The CRC for Weed Management Systems was formed in 1995 to develop integrated strategies for reducing weed problems. It has a subprogramme, Delivering Biological Control, which has provided resources to employ technical coordinators, whose job is to facilitate redistribution of agents via release networks and ensure that there is effective monitoring and subsequent feedback, both to and from the researchers.

The role of release networks in evaluating the success of biological control should not be overlooked. Most of the redistribution networks described in this paper have planned monitoring roles, though it is too early to comment on their effectiveness. While it is probably unrealistic to expect detailed analyses of releases made through the networks, simple monitoring forms can be designed that will give a picture of agent establishment and impact over a much broader geographic region than was previously possible (see Briese (1985) for an example with St John’s wort). Such monitoring would complement the more detailed evaluation of plant-agent interactions that is carried out at a limited number of sites. It would, however, require appropriate and uniform databasing and mapping facilities. Effective coordination is even more critical for the evaluation of biological control, as the interest of some participants may wane once they have assisted in the establishment of control agents.

While teachers and schools are often enthusiastic about participating in monitoring or release exercises their agendas are often quite different from that of the researcher. Long-term school-based projects require continual monitoring and input from the researcher to maintain enthusiasm and ensure that data are regularly collected (I. Dadour & S. Broughton, pers. comm.). One way of overcoming this problem may be for the project to be incorporated into the school curriculum, as has happened in Tasmania with the BIOSCAN project developed by Allen *et al.* (1995) to monitor dung beetle populations and their impact on bushflies. In general, though, it would be unrealistic to expect on-going evaluation by schools (Broughton, 1996) and projects using schools as resources are best limited to one-off monitoring exercises over a large geographic area, where the extent and volume of data collected compensate for the organizational effort required. The involvement of schools in releases needs to be considered carefully, and restricted to agents with good prospects for establishment. Failures of releases would not only quickly extinguish enthusiasm but could give negative messages about the value of biological control. It would also seem prudent to limit school involvement to agents that are attractive or easy to rear (e.g. cinnabar moth on ragwort) to generate the enthusiasm needed for the success of the exercise. The educational value of involving schools in biological control projects is self-evident.

The most effective redistribution networks remain those in which the participants are land managers who are directly affected by the weed problem and are strongly motivated to be part of solution. Landcare, in its commitment to whole farm planning, further provides a resource for efforts to integrate biological control with other control options, such as herbicides and grazing management, to produce weed management strategies appropriate to particular situations.

If students and land managers become aware of biological control, they will pass this information on to their parents or neighbours which will further facilitate community involvement and utilization. Once established, release networks become important vehicles for raising community awareness about biological control, ensuring that the expectations of the landholders concerning the speed and success of biological control are realistic. They can also facilitate the provision of other information on weed management, with an emphasis on biocontrol as one of a range of measures in overall regional and on-farm management plans. A greater understanding of the processes and long-term nature of biological control are essential for its long-term acceptance and implementation by the community, and to create a political climate favouring support for biological control from governments and funding bodies. Involving the community in these processes at the research and development level of a project is an excellent way to achieve this.

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