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The Status of Biological Control of Weeds in Oregon

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Classical biological control of weeds in Oregon began in 1947 with the introduction of *Chrysolina hyperici* to control St. Johnswort (*Hypericum perforatum*). From 1947-74, 11 species of biological control agents were introduced on 6 species of weeds. In 1975 the Oregon Department of Agriculture (ODA) implemented an intensive program to control tansy ragwort (*Senecio jacobaea*) emphasizing biological control. The ragwort project generated public interest to support other biological control projects. By 1991, 42 species of biological control agents were released against 20 species of noxious weeds. Of the 42 agents, 31 are established, 6 failed to establish, and the status of 5 recently introduced species is unknown. Biological control of *H. perforatum* and *S. jacobaea* has been successful throughout most of Oregon.

Introduction

Classical biological control of weeds in Oregon began in 1947 with the release of *Chrysolina hyperici* (Forster) (Coleoptera: Chrysomelidae) on St. Johnswort (*Hypericum perforatum* L.; Hypericaceae) (Ritcher 1966). In the following year *C. quadrigemina* (Suffrain) (Coleoptera: Chrysomelidae) was also released against *H. perforatum*. By 1952 spectacular results were becoming evident in southwestern Oregon. The beetles were widespread and had achieved regional control by 1965.

Initial releases of biological control agents in Oregon from 1947-74 were through cooperative programs involving the United States Department of Agriculture's Agricultural Research Service (USDA–ARS), Oregon State University (OSU), and OSU County Extension offices. In 1971, the Oregon Department of Agriculture (ODA) began to participate in biological control of weeds. A total of 11 species of biological control agents were released against 6 species of weeds from 1947-74.

In 1975, the Oregon legislature amended *Oregon Revised Statutes 452* to include tansy ragwort (*Senecio jacobaea* L.; Asteraceae) as a target of an intensive statewide control program (Hawkes 1985, Brown 1990). Funding was allocated and the Noxious Weed Control Program of the ODA became involved in an intensive integrated ragwort control program that stressed biological control (Isaacson 1978).

The ODA began intensive collection and redistribution of *Longitarsus jacobaeae* (Waterhouse) (Coleoptera: Chrysomelidae), *Tyria jacobaeae* (L.) (Lepidoptera: Arctiidae), and *Pegohylemyia seneciella* (Hardy) (Diptera: Anthomyiidae), and achieved regional control of ragwort in the 1980s (Brown 1990, McEvoy *et al.* 1991, Coombs *et al.* 1991*a*). During the ragwort control program, the ODA became increasingly involved in other biological control projects and has assumed leadership of cooperative state projects since 1975.

The ODA manages one of the most intensive statewide biological control of weeds programs in the U.S., with primary focus on introduction, collection, and redistribution (Hawkes 1985). Cooperative programs with USDA–ARS and USDA's Animal Plant Health Inspection Service (APHIS) have provided 42 species of biological control agents released against 20 species of noxious weeds (Coombs *et al.* 1991*b*). Research projects on the biology and impacts of biological control agents have been done in cooperation with OSU, USDA–ARS and USDA–APHIS.

Methods and Materials

The introduction process described by Klingman and Coulson (1982) was followed before a new biological control agent was released in Oregon. Environmental assessment reports on possible impacts of biological control projects are also required before new species and some previously established agents are released. Initial releases were similar to the methods used by USDA-ARS scientists; i.e., open, caged, and transplanting infested host plants. Releases were made with agents at various stages of development, depending on the species and the time they were available. Release site selection was an important factor to protect and manage the subsequent nursery colonies. Site monitoring to determine establishment was done by direct observation, sweep nets, vacuum apparatus, dissection of host tissues, Berlese funnel extraction, and rearing out suspect biological agents in a laboratory. Surveys of the number of plants attacked at representative release sites were made by visual inspection and dissection of plant parts. Gross field surveys to determine attack rates were done by estimating the percent of infested target plants. Rates of attack for individual plants, such as the number of seed heads/plant attacked are not included. Attack rate data from multiple locations were pooled and averaged.

When surplus agents became available at nursery sites, they were collected and systematically redistributed to other infested counties, townships, and local areas (Coombs 1991). The ODA has utilized computer data bases and mapping programs, i.e., geographic information system (GIS), to improve the efficiency of redistribution (Isaacson *et al.* 1992). Several accidentally-introduced and native species of insects have also been managed for weed control (Coombs 1991). A major goal of the ODA biological control program was to establish approved agents throughout significant infestations in the state. Interdisciplinary projects involving federal, state, county, and private parties have been developed to accomplish that goal. The primary funding of ODA's biological control program has come from state general funds and contracts with USDA Forest Service, United States Department of the Interior, (USDI) Bureau of Land Management, and the Bonneville Power Administration.

Results and Discussion

The 42 species of biological control agents of noxious weeds released in Oregon include 39 insects, a mite, a nematode, and a pathogen. A total of 31 species are established, 6 failed to establish and the status of 5 species is unknown (Table 1). The ODA has collected and redistributed 25 species of biological control agents. The distribution status of each agent is correlated to the project phase and is grouped into 5 categories: widespread (monitoring phase); limited (redistribution phase); nursery (establishment phase); unknown (introduction); and failed.

Table 1. General status of biological control agents of weeds in Oregon by number of species.

Distribution Status Without Host Range	Number of Species	Attack Rate	Number of Species	Availability for Collection	Number of Species
Widespread	10	Heavy (>50%)	16	Mass	17
Limited	11	Medium (>10%)	5	Limited	8
Nursery	9	Light (<10%)	2	Unavailable[1]	11
Unknown	5	Undetermined[1]	13	–	–
Failed	6	–	–	–	–
Total	42	–	36	–	36

[1] Does not include species that failed to establish.

Table 2. Phases of biological control of weeds projects by year in Oregon.

Biological Control Agent (Order: Family)	Introduced	Established	Redistributed	Monitoring
Agapeta zoegana L. (Lepidoptera: Cochylidae)	1987	1991	–	–
Agrilus hyperici (Creutzer) (Coleoptera: Buprestidae)	1986	1990[a]	–	–
Aplocera plagiata (L.) (Lepidoptera: Geometridae)	1989	[b]	–	–
Aphthona cyparissiae (Koch) (Coleoptera: Chrysomelidae)	1989	1990	1991	–
A. flava Gillebeau (Coleoptera: Chrysomelidae)	1989	1990	1991	–
A. nigriscutis Foudras (Coleoptera: Chrysomelidae)	1989	1990	–	–
Apion fuscirostre F. (Coleoptera: Apionidae)	1983	1984	1986	–
Bangasternus fausti (Reitter) (Coleoptera: Curculionidae)	1989	1990	–	–
B. orientalis (Capiomont) (Coleoptera: Curculionidae)	1985	1986	1989	–
Calophasia lunula (Hufnagel) (Lepidoptera: Noctuidae)	1983	[c]	–	–
Ceutorhynchus litura (F.) (Coleoptera: Curculionidae)	1981 1988[d]	1991	–	–
Chaetorellia australis Hering (Diptera: Tephritidae)	1989	[b]	–	–
Cheilosia corydon (Harris) (Diptera: Syrphidae)	1991	[b]	–	–
Chrysolina hyperici (Forster) (Coleoptera: Chrysomelidae)	1947	1950	1952	1965
C. quadrigemina (Suffrain) (Coleoptera: Chrysomelidae)	1948	1950	1952	1965
Cystiphora scmidti Rübsaamen (Diptera: Cecidomyiidae)	1978	1979	–	–
Eriophyes chondrillae (Canestrini) (Acarina: Eriophyidae)	1978	1979	–	–
Eustenopus villosus (Boheman) (Coleoptera: Curculionidae)	1990	1991	–	–
Exapion ulicis (Forster) (Coleoptera: Apionidae)	1956	1957	1959	1986

Table 2. Continued.

Biological Control Agent (Order: Family)	Introduced	Established	Redistributed	Monitoring
Hyles euphorbiae (L.) (Lepidoptera: Sphingidae)	1980	[c]	–	–
Leucoptera spartifoliella Huebner (Lepidoptera: Lyonetiidae)	1970	[e]	–	–
Longitarsus jacobaeae (Waterhouse) (Coleoptera: Chrysomelidae)	1971	1972	1974	1990
Metzneria paucipunctella Zeller (Lepidoptera: Gelichiidae)	1981	1983	1988	–
Microlarinus lareynii (Jaquelin du Val) (Coleoptera: Curculionidae)	1963 1982[d]	1985	[e]	–
M. lypriformis (Wollaston) (Coleoptera: Curculionidae)	1963 1982[d]	1985	[e]	–
Oberea erythrocephala (Schrank) (Coleoptera: Cerambycidae)	1982	[c]	–	–
Pegohylemyia seneciella (Hardy) (Diptera: Anthomyiidae)	1966 1976	1980	1983	1988
Phrydiuchus spilmani Warner (Coleoptera: Curculionidae)	1969	[c]	–	–
P. tau Warner (Coleoptera: Curculionidae)	1969	1972	1979	1984
Pterolonche inspersa Staudinger (Lepidoptera: Pterolonchidae)	1986	[b]	–	–
Puccinia chondrillina Bubak & Syden. (Fungus: Uredinales)	1978	1979	–	–
Rhinocyllus conicus Froelich (Coleoptera: Curculionidae)	1979	1980	1981	1991
Sphenoptera jugoslavica Obenberger (Coleoptera: Buprestidae)	1980	1981	1984	–
Spurgia esula Gagne (Diptera: Cecidomyiidae)	1988	[b]	–	–
Subanguina picridis Kirjanov & Ivanova (Nematoda: Tylenchidae)	1990	[c]	–	–
Tyria jacobaeae (L.) (Lepidoptera: Arctiidae)	1960	1961	1970	1984
Urophora affinis Frauenfeld (Diptera: Tephritidae)	1975	1977	1979	1986
U. cardui (L.) (Diptera: Tephritidae)	1980	1982	1985	–
U. quadrifasciata (Meigen) (Diptera: Tephritidae)	1979	1981[g]	1982	1986

Table 2. Continued.

Biological Control Agent (Order: Family)	Introduced	Established	Redistributed	Monitoring
U. sirunaseva (Hering) (Diptera: Tephritidae)	1985	1989	1990	–
U. stylata (L.) (Diptera: Tephritidae)	1988	1989	1990	–
Zeuxidiplosis giardi Kieffer (Diptera: Cecidomyiidae)	1981	[c]	–	–

Codes: [a]= Establishment by immigration from Idaho; [b]= Establishment not confirmed, recent release; [c]= Failed to establish; [d]= Re-released after previous failure to establish; [e]= Established prior to introduction; [f]= Population may have died out after severe winter; and [g]= Immigrated from Washington and Idaho via Canada.

There are 4 management phases to each ODA biological control project: introduction; establishment; distribution; and monitoring. In Table 2, biological agents released in Oregon are listed along with the year each project phase was accomplished. An average of 1.6 yrs was required to verify the establishment of a new agent, 4.5 yrs before redistribution of established agents began, and 19.2 yrs for a project to reach the monitoring phase (Table 2). The monitoring phase of a biological control project began when an agent was widespread within its host range and redistribution was done on an as-needed basis.

Results from the successful biological control of *H. perforatum* and later on *S. jacobaea*, provided political and public support for the ODA to expand its biological control of weeds program. Data in Fig. 1 show the steady increase of targeted noxious weeds and the number of species of biological control agents released in Oregon. As a result of the increased number of biological control projects, research and monitoring have decreased. The ODA has worked to increase involvement with county weed control supervisors on well established biological control projects. Table 3 shows the number of Oregon's 36 counties infested with target noxious weeds, the associated species of biological control agents, the number of counties where each agent has been released, and the number of counties where each agent has become established. In Fig. 2, a map of Oregon shows the number of species of classical biological control agents introduced in each county. Counties with larger numbers of biological agents species contain several vegetation zones, which also contain more species of noxious weeds.

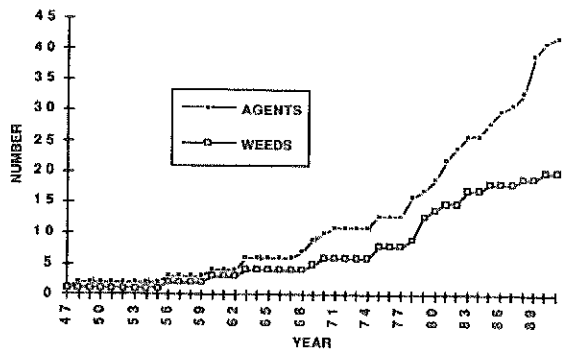

Figure 1. Cumulative number of target weed species and classical biological control agents released in Oregon, 1947-91.

Several species of biological control agents have become reassociated with former hosts which were not primary targets during initial introductions. *Urophora quadrifasciata* (Meigen) (Diptera: Tephritidae), originally introduced against diffuse (*Centaurea diffusa* Lamarck; Asteraceae) and spotted knapweeds (*C. maculosa* Lamarck), has become reassociated with several other *Centaurea* species (Table 3). Data from surveys on yellow starthistle, *C. solstitialis* L. (Asteraceae), in southwestern Oregon showed that it may also be attacked by *U. quadrifasciata* . The thistle seed head weevil, *Rhinocyllus conicus* Froelich (Coleoptera: Curculionidae), has also become reassociated with other several host species (Table 3).

About one-third of the biological control agents released in Oregon are so new that impacts on their target weeds have not yet been determined. Success of each project is measured by rates of establishment, dispersal,

Table 3. Status of biological control of weeds projects by number of counties in Oregon.

Target Weed (Family)	Number of Infested Counties	Biological Control Agent	Number of Counties	
			Released	Established
Acroptilon repens (L.) DC. (Asteraceae)	17	*Subanguina picridis*	1	0
Carduus nutans L. (Asteraceae)	5	*Cheilosia corydon*	1	0
		Rhinocyllus conicus	4	4
C. pycnocephalus L.	5	*R. conicus*	5	5
C. tenuiflorus Curtis	5	*R. conicus*	5	4
Centaurea cyanus L. (Asteraceae)	6	*Chaetorellia australis*	1	0
		Urophora quadrifasciata	0	1
C. diffusa Lamarck	19	*Bangasternus fausti*	1	1
		Pterolonche inspersa	4	0
		Sphenoptera jugoslavica	11	9
		Urophora affinis	19	19
		Urophora quadrifasciata	19	19
C. jacea L.	2	*U. quadrifasciata*	0	1
C. jacea x nigra	14	*U. quadrifasciata*	11	11
C. maculosa Lamarck	16	*Agapeta zoegana*	5	2
		Metzneria paucipunctella	8	3
		U. affinis	18	20
		U. quadrifasciata	18	20
C. solstitialis L.	20	*B. orientalis*	8	2
		C. australis	2	0
		Eustenopus villosus	1	1
		Urophora sirunaseva	7	2
C. virgata Lamarck (Asteraceae)	1	*U. quadrifasciata*	0	1
Chondrilla juncea L. (Asteraceae)	9	*Cystiphora scmidti*	4	2
		Eriophyes chondrillae	4	4
		Puccinia chondrillina	2	2
Cirsium arvense (L.) Scopoli (Asteraceae)	36	*Ceutorhynchus litura*	8	4
		R. conicus	3	2
		Urophora cardui	30	13
C. vulgare (Savi) Tenore	36	*Urophora stylata*	12	4
Cytisus scoparius (L.) Link (Fabaceae)	20	*Apion fuscirostre*	20	11
		Leucoptera spartifoliella	20	19
Euphorbia esula L. (Euphorbiaceae)	9	*Aphthona cyparissiae*	4	1
		Aphthona flava	4	2
		Aphthona nigriscutis	6	2
		Hyles euphorbiae	1	0

Table 3. Continued.

Target Weed (Family)	Number of Infested Counties	Biological Control Agent	Number of Counties	
			Released	Established
		Oberea erythrocephala	1	0
		Spurgia esula	2	0
Hypericum perforatum L. (Hypericaceae)	36	*Agrilus hyperici*	2	1
		Aplocera plagiata	6	0
		Chrysolina hyperici	19	19
		Chrysolina quadrigemina	36	36
		Zeuxidiplosis giardi	1	0
Linaria dalmatica (L.) Miller (Scrophulariaceae)	16	*Calophasia lunula*	1	0
L. vulgaris Miller	10	*C. lunula*	1	0
Salvia aethiopis L. (Lamiaceae)	7	*Phrydiuchus spilmani*	1	0
		Phrydiuchus tau	3	2
Senecio jacobaea L. (Asteraceae)	27	*Longitarsus jacobaeae*	24	19
		Pegohylemyia seneciella	27	27
		Tyria jacobaeae	25	22
Silybum marianum (L.) Gaertner (Asteraceae)	11	*R. conicus*	11	10
Tribulus terrestris L. (Zygophyllaceae)	24	*Microlarinus lareynii*	7	1
		M. lypriformis	7	1
Ulex europaeus L. (Fabaceae)	8	*Exapion ulicis*	6	5

and impact on host plant density (Table 4). We are experimenting at some sites with single *vs.* multiple introductions of agents. We assume that multiple introductions against a single host are not in conflict with the objectives of reducing target weeds below economic and environmental damage thresholds.

The ODA has assisted in testing new candidate agents on gorse (*Ulex europaeus* L.; Fabaceae) in cooperation with scientists in New Zealand and Hawaii. The ODA has also provided cooperative support and funding for the testing of candidate biological control agents for purple loosestrife (*Lythrum salicaria* L.; Lythraceae).

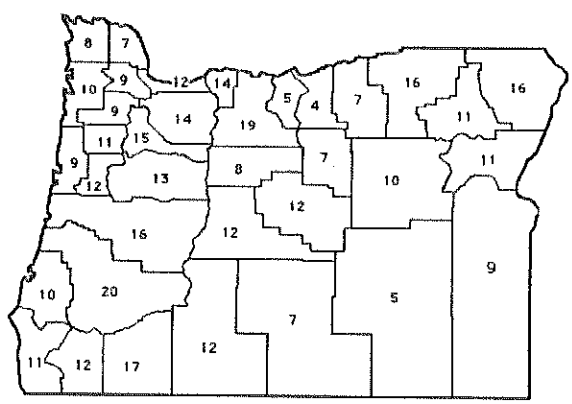

Figure 2. Number of species of classical biological control agents released in Oregon counties, 1947-91.

Table 4. General status of biological control agents of weeds in Oregon.

Agent	Status	Infestation Rate[1]	Availability for Redistribution
Agapeta zoegana	Nursery	Undetermined	Limited
Agrilus hyperici	Limited	Heavy	Limited
Aplocera plagiata	Unknown	Undetermined	Unavailable
Aphthona cyparissiae	Nursery	Undetermined	Limited
A. flava	Nursery	Undetermined	Limited
A. nigriscutis	Nursery	Undetermined	Unavailable
Apion fuscirostre	Limited	Heavy	Mass
Bangasternus fausti	Nursery	Light	Unavailable
Bangasternus orientalis	Limited	Medium	Mass
Calophasia lunula	Failed	–	–
Ceutorhynchus litura	Nursery	Light	Unavailable
Chaetorellia australis	Unknown	Undetermined	Unavailable
Cheilosia corydon	Unknown	Undetermined	Unavailable
Chrysolina hyperici	Widespread	Heavy	Mass
C. quadrigemina	Widespread	Heavy	Mass
Cystiphora scmidti	Limited	Undetermined	Limited
Eriophyes chondrillae	Limited	Heavy	Limited
Eustenopus villosus	Nursery	Undetermined	Unavailable
Exapion ulicis	Widespread	Heavy	Mass
Hyles euphorbiae	Failed	–	–
Leucoptera spartifoliella	Widespread	Heavy	Mass
Longitarsus jacobaeae	Widespread	Heavy	Mass
Metzneria paucipunctella	Limited	Heavy	Mass
Microlarinus lareynii	Nursery	Undetermined	Unavailable
M. lypriformis	Nursery	Undetermined	Unavailable
Oberea erythrocephala	Failed	–	–
Pegohylemyia seneciella	Widespread	Heavy	Mass
Phrydiuchus spilmani	Failed	–	–
P. tau	Widespread	Heavy	Mass
Pterolonche inspersa	Unknown	Undetermined	Unavailable
Puccinia chondrillina	Limited	Medium	Limited
Rhinocyllus conicus	Widespread	Heavy	Mass

Table 4. Continued.

Agent	Status	Infestation Rate[1]	Availability for Redistribution
Sphenoptera jugoslavica	Limited	Heavy	Mass
Spurgia esula	Unknown	Undetermined	Unavailable
Subanguina picridis	Failed	–	–
Tyria jacobaeae	Widespread	Heavy	Mass
Urophora affinis	Widespread	Heavy	Mass
U. cardui	Limited	Medium	Mass
U. quadrifasciata	Widespread	Heavy	Mass
U. sirunaseva	Limited	Medium	Mass
U. stylata	Limited	Medium	Limited
Zeuxidiplosis giardi	Failed	–	–

[1]Rate of infestation: Heavy (>50%); medium (>10%); and light (<10%).

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