AQUATIC PLANT CONTROL RESEARCH PROGRAM

INSTRUCTION REPORT A-81-1

THE USE OF INSECTS TO MANAGE ALLIGATORWEED

By Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
PO Box 631, Vicksburg, Miss. 39180

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The purpose of this manual is to help field personnel identify and assess alligatorweed problems and manage them with specialized insects that feed on the plant. This manual is intended as an instructional guide for understanding alligatorweed as a problem and methods available for managing the weed by using biological agents.

Three insects are available for the management of alligatorweed: alligatorweed flea beetle, alligatorweed thrips, and alligatorweed stem borer. → cont (Continued)

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20. ABSTRACT (Continued)

Factors such as climate, flooding, and pesticide use must be considered when selecting the agent to be used.

Instructions are given on determining the number of agents needed, how to obtain the insects, how to collect and pack insects for shipment, and how to release the insects and later check for population establishment.

PREFACE

The Corps of Engineers Aquatic Plant Control Research Program, (APCRP) provides funds to the U. S. Department of Agriculture, Science and Education Administration (USDA-SEA), to conduct the exploration and quarantine evaluation of insects that may have potential for the management of problem levels of certain aquatic plant species. This work, conducted under an interagency agreement, must prove that the insects are host specific before any insects can be released from quarantine for additional evaluation. One such insect that has proved to be effective on a large scale throughout the southeastern United States is the flea beetle, *Agasicles hygrophila* Selman and Vogt. Released in the proper manner, and at the proper time, this insect can be used to successfully manage the problem aquatic plant alligatorweed. Through this same research and testing, two other insects, *Amynothrips andersonii* O'Neill and *Vogtia malloi* Pastrana were subsequently released to provide added pressure to the alligatorweed population.

While these insects were tested, released, and proven successful during the 1970's, no attempt was made at that time to provide guidance for its future use and thus complete the transfer of technology to an operational level. This manual is an attempt to provide that guidance and is expected to be revised periodically if and when necessary.

Many persons contributed to the contents of this manual and should be recognized:

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Mr. Neal Spencer
Ms. Winifred M. H. Cahill
Mr. Franklin D. King
Dr. Donald Maddox for the photos of *Amynothrips*
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CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
inches	25.4	millimetres
square feet	0.0929	square metres

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9) (F - 32). To obtain Kelvin (K) readings, use K = (5/9) (F - 32) + 273.15.

THE USE OF INSECTS TO MANAGE ALLIGATORWEED

PART I: INTRODUCTION

Background

Alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb.) was introduced into the United States in 1897 and rapidly became a problem aquatic plant in the southeastern United States. By the early 1960's, the problem had become so severe that efforts were intensified to develop more effective methods for the management of alligatorweed. With funds provided through the Corps' Aquatic Plant Control Research Program, U. S. Department of Agriculture scientists conducted overseas searches for insects that had potential for controlling alligatorweed. By 1971, three species of insects had been released in the United States for the management of alligatorweed.

Purpose

The purpose of this manual is to help field personnel identify and assess alligatorweed problems and manage them with specialized insects that feed on the plant. This manual is intended to be used as an instructional guide for understanding alligatorweed as a problem and as a source of available methods for biological management of the weed.

Scope

Information in this manual has been prepared for the field worker who has little prior knowledge of or experience with biological management methods. It defines problem aquatic plants and provides general methods for their management, alligatorweed and methods for its management, available alligatorweed insect agents, the typical damage they produce, and steps involved in the selection and application of the insect agents. Also included are some references to previous work on management of alligatorweed by insect agents. The information is presented in an informal style, and common names of aquatic weeds are used instead of the scientific names. Photographs and illustrations are included to help the reader identify waterweeds, insect agents, and damage caused by the agents.

PART II: AQUATIC PLANTS AND GENERAL METHODS FOR THEIR MANAGEMENT

Classification of Aquatic Plants

For the purpose of this manual, aquatic plants are divided into five groups, based on their growth habit and the places where they are found.

Algae. Algae include plants ranging in size from microscopic to more than 1 m in length. They are found in highly alkaline or acidic waters or waters with high nutrient levels. Some varieties grow year-round while other species appear (or bloom) only during certain months. They can be observed free-floating or semiattached to foreign objects and may appear as a pea green soup or a scum on the water surface, or they may resemble submerged vegetation. Example: chara (Figure 1).

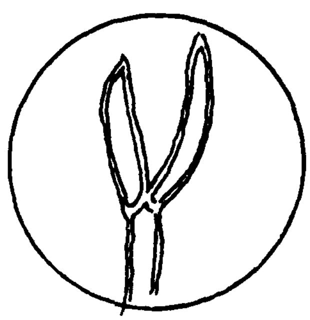


FIGURE 1

Floating aquatics. Floating aquatic plants include those species that live on the water surface and have no attachment to the lake or river bottom. Example: waterhyacinth (Figure 2).

FIGURE 2

Emergent aquatics. These plants are rooted in the soil below the water surface with stems, most leaves, and flowers extending above the surface of the water. Example: alligatorweed (Figure 3).

FIGURE 3

Submersed aquatics. These plants are rooted in the soil below the water surface. The entire plant, except the flowering stems, remains below the surface of the water during the plant's life. Example: Eurasian watermilfoil (Figure 4).

FIGURE 4

Aquatic grasses. These plants include grasses and sedges and usually have thin, *highly defined* blades and stem systems. They are usually fast-growing and thrive in the moist soil at the water's edge and along the shoreline. Examples: maidencane (Figure 5) and giant cutgrass (Figure 6).

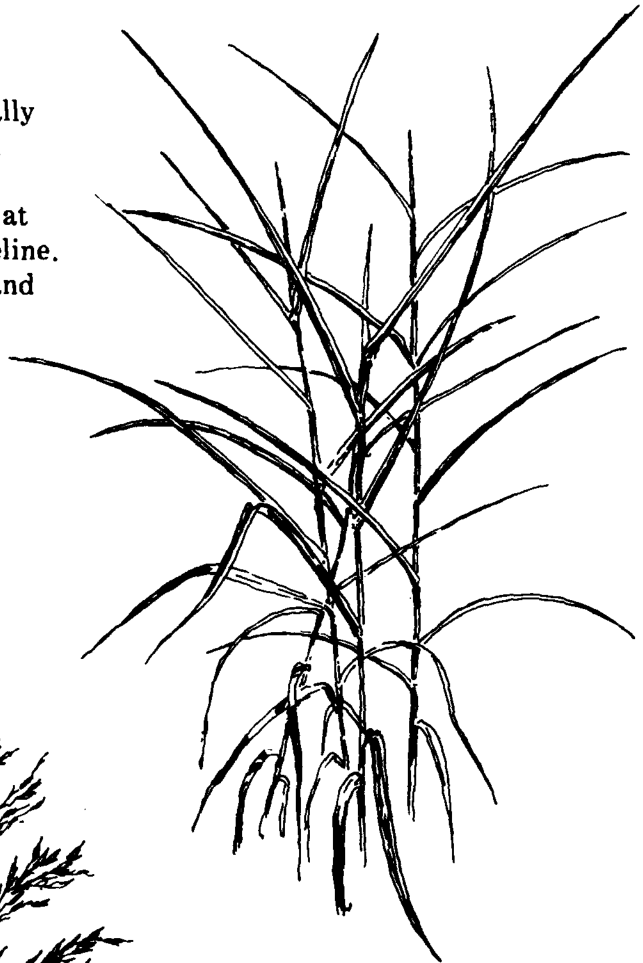


FIGURE 5

FIGURE 6

Identification of Aquatic Plants

Because methods to be used for the management of problem aquatic plants vary according to species, it is important that positive identification of the problem species be made. When questions arise about the identity of the species, samples should be collected and sent to experts for identification prior to the initiation of management operations. Readily available sources for obtaining species identification include personnel of State fish and game departments and plant taxonomists at nearby universities.

Waterweeds

The presence of aquatic plants may or may not be a problem. Aquatic plants fill important roles in the food and shelter needs of many types of aquatic lifeforms and assist in the natural process of stabilizing and balancing the nutrient content of water.

What then are waterweeds? A large number of aquatic plant species are capable of growing in a wide range of climatic conditions throughout the world. While there are hundreds of species presently growing throughout the United States, only a few species are considered to cause serious problems in our water areas, and are thus considered to be "waterweeds." This term will be used in this manual to describe aquatic plants that have become problems. Waterweeds include vegetation that may be either submerged, emergent, or floating.

Recognizing waterweed problems. Aquatic plants can proliferate to the point that they limit utilization of water resources. Historically, waterhyacinth has impeded navigation in rivers and lakes of the southern United States and even threatened the passage of ships through the Panama Canal. Waterhyacinth commonly restricts the free movement of water in irrigation and flood control systems. For example, submersed aquatic species significantly limit the flow of water in the All-American Canal in southern California and in the vast irrigation and flood control system in southern Florida. Aquatic plants significantly impact recreational uses of waterways. Swimming, boating, and fishing areas have been eliminated by massive infestations of submersed or floating problem aquatic plant species. Fisheries management problems often result from heavy waterweed infestations. In addition, severe infestations of aquatic plants around marinas, launching ramps, and private camps have precluded access to uninfested areas of lakes and rivers throughout the country. Aesthetics and commercial value of shoreline properties have been reduced in many areas by the presence of large infestations of problem aquatic plants. In all of these cases, aquatic plants are deemed to be a problem, and management measures must be implemented to provide relief.

Waterweed management methods. After a waterweed problem has been identified, it is essential that field personnel be familiar with the basic categories of treatment methods used to manage waterweeds. The selection of any particular method must be done on a case-by-case basis, considering local requirements.These include:

Mechanical methods — The use of any method that physically detaches alligatorweed from its environment. A wide variety of mechanical methods are now available, ranging from hand harvesting to the use of heavy equipment such as draglines.

Chemical methods — The use of manufactured chemical agents to manage the growth of waterweeds, including herbicides, growth regulators, and fertilizers.

Biological methods — The use of organisms, including insects, fish, other animals, and pathogens, to manage the growth of waterweeds.

Environmental manipulation methods—The use of any method that alters the normal environment of the waterweed, exclusive of methods described above. These include dewatering, flooding, shading, dyes, etc.

Integrated management methods — The use of any combination of the above four categories of methods as a management technique is called integrated management.

Selecting management methods. Seven principal factors must be considered when selecting the particular method to be used in the management of a waterweed problem:

- The species of waterweed to to be managed.
- The level of desired or required management.
- The probable short- and long-term effects of each method on water quality.
- The effects of each method on nontarget organisms.
- The effect of each method on the water body usage.
- The effects of climate on the level of management that can be achieved.
- The cost of each method.

The order in which these are considered will, to a large degree, depend upon the local situation.

PART III: ALLIGATORWEED AND METHODS FOR ITS MANAGEMENT

Alligatorweed (Figure 7) thrives in many habitats. It is just as much at home growing in the soil along streams and lake shores as it is floating on mats of decaying vegetation. Alligatorweed grows best in relatively flat areas and in water that has little or no wave action. Under normal conditions, its most rapid growth is in the spring. The ability to grow both on land and in water gives alligatorweed an advantage over plants that are limited to a narrow range of habitats. When rooted in the soil or mud, it has a solid stem typical of terrestrial plants. With its roots anchored on the shore, it can extend into and onto the water for 50 ft* or more. As it begins to grow outward across the water surface, its structure changes. Small roots extend from nearly every *node* (the point where the leaf joins the stem). These small roots are aquatic roots and are designed to take nutrients directly from the water. Stems growing in water are characteristically hollow with thick walls. Air is captured in the hollow stem allowing the alligatorweed to float on the surface of the water. As these parts die off and stems fall over, thick mats of old, floating vegetation are formed. These mats provide additional anchors and nutrition for the alligatorweed roots.

Alligatorweed usually produces small, white flowers in heads from June through October. However, the resulting seeds are not viable, and reproduction is therefore limited to asexual means. Alligatorweed reproduces by growth from existing mats or from fragments that break off and float to a new area, where the fragments become anchored and produce new stems from buds located at the junction of the leaf base and main stem.

FIGURE 7

Low temperatures can have a serious adverse effect on alligatorweed. In areas where freezing temperatures occur, all of the exposed parts above the surface of

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 4.

the water quickly freeze and die. However, in early spring, the underwater mass, or that part that did not freeze, will send up new stems from each node and the plant resumes its normal growth.

Importance of Alligatorweed

Beneficial uses. Alligatorweed has some beneficial uses. Cattlemen use alligatorweed as a forage plant for their herds. They obtain the plants from waterways and sometimes grow them in their pastures. Some fishermen have cited the importance of alligatorweed as bedding material for crawfish, a sizeable industry in Louisiana. It is also believed to provide shelter for young fish and for small fishes (e.g. mosquitofish) that consume mosquito larvae. Several types of waterfowl feed upon insects and seeds found in growths of alligatorweed. Nutria, which are large, brown aquatic rodents important to the fur industry, feed directly on alligatorweed.

Detrimental effects. At problem levels, alligatorweed can produce detrimental effects on aquatic ecosystems and their use by man by restricting the free movement of water, impairing recreation, impeding navigation, inhibiting the flow in irrigation and drainage systems, and reducing the aesthetic and commercial value of waterfront properties. It can also kill desirable species of submerged plants by reducing the amount of sunlight available to the plants. If unchecked, alligatorweed can crowd out other types of vegetation. Generally, alligatorweed is most often found growing with other competitive waterweeds such as waterprimrose and waterhyacinths. Alligatorweed mats also provide favorable breeding grounds for several species of mosquitoes.

When Is Alligatorweed a Problem?

The physical presence of alligatorweed does not necessarily mean there is a problem. Whether or not a problem exists depends on the environment and conditions in which the alligatorweed is found in relation to the desired use of the water system. A small mat or mats of plants growing in front of someone's boat dock or in a high use water area may be a problem, while a large thick mat of alligatorweed in a low use or uninhabited area may not be a problem. Alligatorweed growing in a marsh habitat, for instance, is not usually considered to be a problem because it is not interfering with man's use of the area. If, however, a stream filled with alligatorweed is meandering through that marsh, it might be considered to be a problem. The reasoning here is that streams are the natural drainage channels of an area. Alligatorweed that impedes or blocks normal water flow could cause upstream flooding. The major point to remember is to always first consider the environment where alligatorweed is growing, and then determine whether it constitutes an existing or a potential problem.

Once a determination has been made that an alligatorweed problem exists and action needs to be taken to manage an infestation, consideration must then be given to the management methods to be used.

Methods for Managing Alligatorweed

Alligatorweed can be effectively managed by mechanical, chemical, or biological methods (see definitions on page 12). However, none of these treatment methods provide for eradication of alligatorweed, and each method has certain advantages and disadvantages (Table 1). To select the treatment method best suited to the local situation, these advantages and disadvantages must be considered in relation to the seven factors listed on page 12.

If the decision is made to use insect agents for the management of alligatorweed, consideration must then be given to the insect agents available for use.

Table 1
Advantages and Disadvantages of Using Mechanical, Chemical, and Biological Treatment Methods

Treatment Method	Specific Methods	Advantages	Disadvantages
Mechanical	Dragline	Physically removes plants	Creates disposal problems
	Back-hoe	Provides immediate relief from the problem	Provides no long-term management
	Harvester	Environmentally compatible	Produces fragmentation of plants that may contribute to increased rate of spread
Chemical	2,4-D	Provides a predictable level of management	May adversely affect nontarget species
	Diquat	Provides desired level of management in a short period of time	May adversely impact man's use of the resource
		Ease of application	Requires repeated applications
Biological	Flea beetle	Provides long-term management	Desired level of management cannot be achieved in a short period of time
	Thrips	Provides management of much larger area than application site	Degree of management that can be achieved is unpredictable
	Stem borer	Produces no harmful side effects	Use in some areas is limited

PART IV: INSECT AGENTS AND THEIR DAMAGE CHARACTERISTICS

Biocontrol Agents

Three species of insects are available for the management of alligatorweed:

- Alligatorweed flea beetle.
- Alligatorweed thrips.
- Alligatorweed stem borer.

Alligatorweed flea beetle. The alligatorweed flea beetle, *Agasicles hygrophila* Selman and Vogt (Coleoptera:Chrysomelidae), was brought into the United States in 1964 from Argentina. After intensive quarantine testing, it was determined that the alligatorweed flea beetle is host specific to alligatorweed. Being host specific means the insect uses alligatorweed as its only food source and depends on alligatorweed to complete its life cycle. All attempts to entice the alligatorweed flea beetle to eat and reproduce on other plants, including valued crops, failed.

Description—Adult alligatorweed flea beetles (Figure 8) are predominantly black in color with yellow stripes. They are air-breathers. Thus, all of their feeding activity occurs on abovewater portions of the plants. When the flea beetles have destroyed all food material in one area, the adults will migrate to other areas where alligatorweed is available. The alligatorweed flea beetle possesses well-developed wings and is capable of flight.

FIGURE 8

Life cycle—Female beetles lay their eggs in rows on the underside of the alligatorweed leaves (Figure 9). Each female can lay up to 1000 or more eggs during her lifetime. As these eggs hatch, in 5 to 6 days, the young larvae (Figure 9) immediately begin to feed on the underside of the leaves. Feeding

FIGURE 9

continues until the larvae mature, at which time they bore into the hollow stem of the plant where they develop into adult beetles. The adults then chew their way out of the stem and begin feeding on the leaves. The entire life cycle of the alligatorweed flea beetle, adult to egg to larvae to pupae to adult, requires approximately 30 days. The alligatorweed flea beetle is capable of producing six generations or more in a growing season.

Distribution—Successful releases of alligatorweed flea beetles have already taken place in Florida, Alabama, Mississippi, Louisiana, South Carolina, Georgia, and Texas.

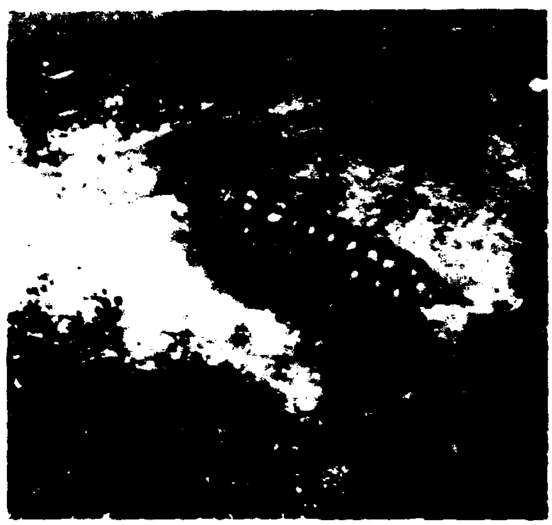
Alligatorweed thrips. The alligatorweed thrips, *Amynothrips andersonii* O'Neill (Thysanoptera:Phlaeothripidae), was brought into the United States for experimental purposes from Argentina in 1966.

Description—The alligatorweed thrips adult is a tiny, black insect that has small, brushlike wings (Figure 10). The nymphs are reddish-colored (Figure 11). They are most active on alligatorweed in the early spring and in the fall. Because of its limited ability to fly, migration of the thrips is very slow and is often attributable to passive means (e.g., floating to new areas on fragments of alligatorweed).

Life cycle.—The female alligatorweed thrips lays numerous eggs on the petiole of the alligatorweed leaf at its juncture with the stem. The emerging nymphs feed on the underside of the uppermost leaves. After a developmental period of approximately 25 days, the new adults are produced and the cycle is repeated. Thus, the thrips may produce up to seven or more generations in one growing season.

Distribution—Controlled releases of the alligatorweed thrips in the United

FIGURE 10



(Photos courtesy of USDA-SEA)
FIGURE 11

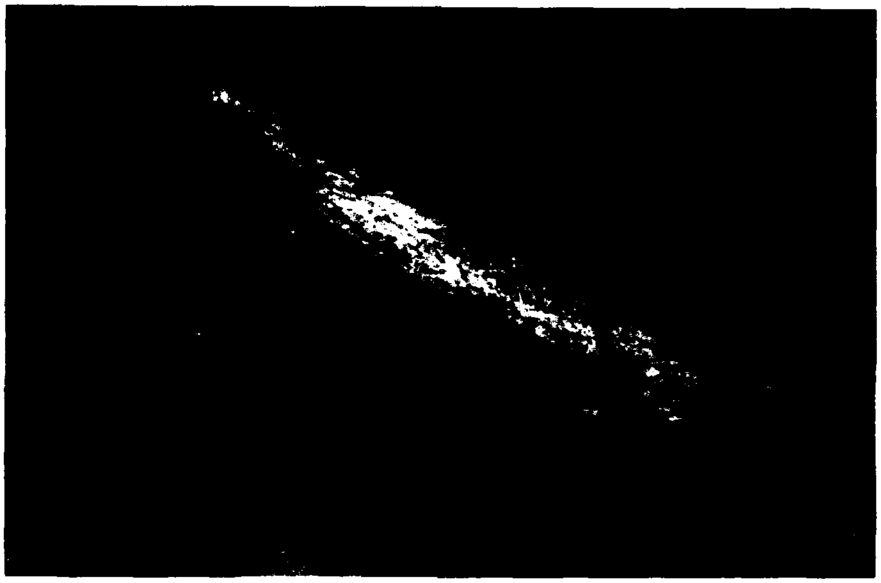


FIGURE 12

States have been made in selected areas of Florida, Georgia, South Carolina, Mississippi, and Texas.

Alligatorweed stem borer. The alligatorweed stem borer, Vogtia malloi Pastrana (Lepidoptera:Pyralidae), is a moth native to South America that was brought into the United States in 1968. It is the most recent biological agent of alligatorweed to be released in this country.

Description—The adult stem borer is a moth that ranges from 1/2 to 3/4 in. in length (Figure 12). Its dull brown forewings and grayish hind wings blend well with dead alligatorweed stems, which makes the resting moth hard to find. The adult has prominent labial palpi (projections) that extend forward from the head. The larvae are brown and are usually less than 1 in. in length (Figure 13). They are always found in the stem of the alligatorweed.

Life cycle—Female alligatorweed stem borers lay 200 to 300 eggs on the uppermost leaves. Several days later the eggs hatch and the tiny larvae begin boring into the young, tender plant stems.

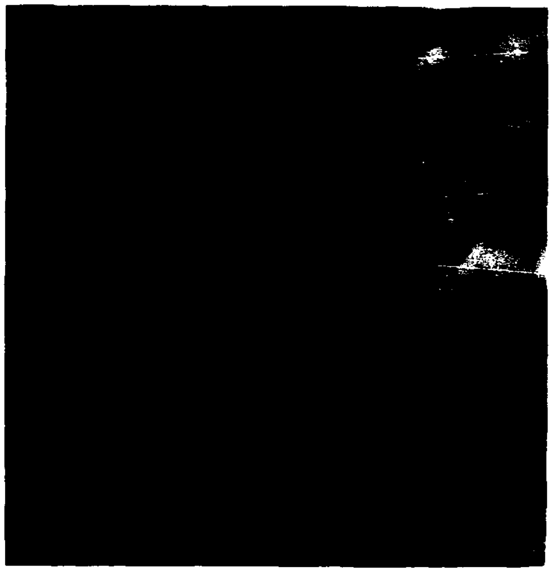


FIGURE 13

The larvae continue to feed, and each larva may bore into several stems during its development. When the larvae have completed their development, they seal up the internodal chamber and eat a hole partially through the stem wall, leaving a thin covering of plant tissue as a window. When the pupal period has been completed, the new adult moths emerge from the pupal case and exit the plant stems through the window. The life cycle of the alligatorweed stem borer is about 39 days. Thus, the stem borer may complete as many as four generations in 1 year.

Distribution—To date, releases have been made in selected areas of Florida, Georgia, North and South Carolina, and Alabama. Test results after the first release confirmed that the borers are an effective agent for the management of alligatorweed.

Damage Characteristics

Each of the insect agents produces distinctive damage characteristics, and it is possible to identify the agents feeding on alligatorweed by examining the type of damage being inflicted on the plants.

Alligatorweed flea beetle. Alligatorweed flea beetles feed on all plant parts above the waterline. The damage produced by the alligatorweed flea beetle larvae looks like small, circular pits on the underside of leaves (Figure 14). Older larvae create larger, more irregular scars. Larvae also chew holes in the plant's stem and adult flea beetles feed on the lush lower leaves (see illustration).

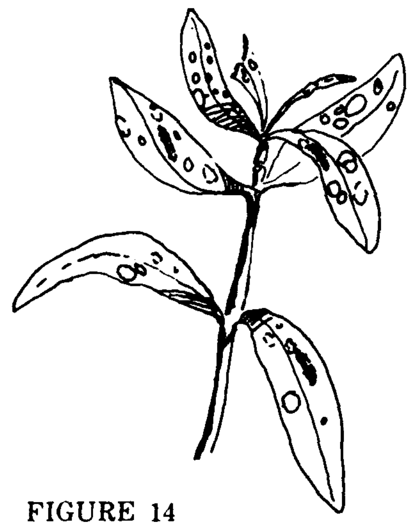


FIGURE 14

The constant assault of the larvae and adults of the alligatorweed flea beetle on alligatorweed eventually depletes the plant's stored food and its ability to produce new food. When the insect population develops to a sufficient level, the alligatorweed tissues become reduced to bare stems. At this point, the adult beetles will move to healthy alligatorweed colonies and the process is repeated. However, the devastated alligatorweed mats will begin to regrow from tissues below the water surface. When regrowth is sufficient to support the beetles, they will return. Over a long period of time, the combined effects of feeding by the beetles and adverse climatic conditions (e.g. freezing winter temperatures) may reduce or eliminate the alligatorweed infestation.

Alligatorweed thrips. Alligatorweed thrips damage can best be observed on the tender leaf buds, leaf tissues, and young flowers. They feed on the edges of leaves, which later dry and cause the leaf edge to become curled

FIGURE 15

(Figure 15). This damage also provides protection for other alligatorweed thrips to continue safely feeding within the curled leaf. A general stunted condition and leaf mutilation are characteristic of alligatorweed thrips damage. The thrips tend to prefer alligatorweed that grows on land, and only rarely feed on alligatorweed growing in water.

When the alligatorweed thrips population is in the developmental stages, damage can be observed in small patches scattered in the alligatorweed. As the population continues to develop, the damage will spread until the entire colony of alligatorweed is infested. At this point, the plants give the appearance of having been treated with the chemical herbicide 2,4-D. Because their effects are primarily on the newest portion of the plant, the alligatorweed thrips continue to prevent the production of healthy functional alligatorweed leaves. The result is that the alligatorweed plants have a reduced ability to produce food and are significantly weakened over a period of time.

Alligatorweed stem borer. Alligatorweed stem borer larvae feed inside the hollow stem, stopping the flow of nutrients to the upper portions of the plant. Stems and leaves die within a few days and appear wilted and drooped over (Figure 16). Soon they will fall over onto the floating mat, and the larvae will crawl out by creating exit holes in the stems.

Alligatorweed declines rapidly under a constant, heavy attack by the stem borer. When the population of the stem borer is high, the entire alligatorweed mat may be reduced to dead stems by late spring. In other cases, the maximum effects may not occur; however, decimation of the alligatorweed population in late summer or early fall may effectively prevent regrowth of the alligatorweed mat. Unlike the alligatorweed flea beetle, the stem borer may attack the terrestrial form of alligatorweed.

FIGURE 16

PART V: SELECTION AND USE OF INSECT AGENTS

Not only do the insect agents produce different effects on alligatorweed, the time of year when the greatest effects occur also varies. Thus, it is recommended that an effort be made to establish the full complement of agents on alligatorweed whenever possible. However, there are some circumstances in which there is a high probability that one or more of the agents would be unable to develop to the population levels required to achieve the desired level of management. Therefore, these factors (e.g. climate, flooding, pesticide use, etc.) must be considered when selecting the insect agents to be used.

Climatological Considerations

Both alligatorweed and the insect agents were introduced to North America. Therefore, the regional climate in this country may significantly affect the selection of insect agents. In some cases, the insect agents may not be necessary. Although alligatorweed has been found as far north as Virginia (Figure 17), it seldom becomes a problem in the northernmost areas of its range due to heavy frost damage during winter. In most of the gulf coast states, the climatic conditions are favorable for alligatorweed, and one or more of the insect agents should be introduced. However, specific climatic conditions may limit one or more of the insect agents. The response by each of the agents to these climatic conditions is considered in the following paragraphs.

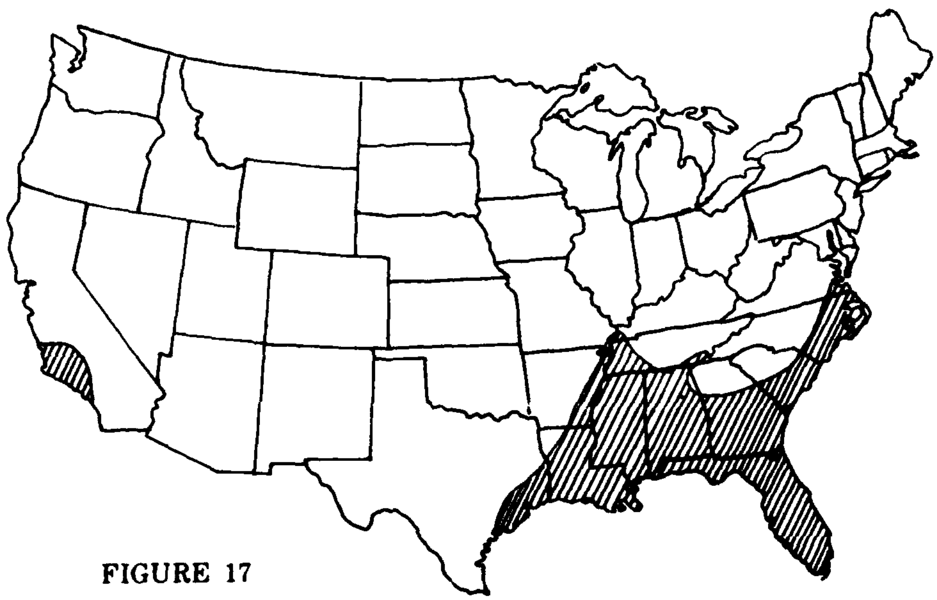


FIGURE 17

Alligatorweed flea beetle. The Florida climate and terrain come closest to matching the native environment of the alligatorweed flea beetle. Results of control tests in Florida have been quite satisfactory. With relatively few days of temperatures below freezing, alligatorweed flea beetles continue to survive in sufficient numbers to retain their status as effective biological agents. In areas north of the frostline, alligatorweed flea beetles must contend with the loss of both food and shelter during the winter months. The death rate of the alligatorweed flea beetle is quite high when frost damage occurs, and there is no assurance that there will be another generation of flea beetles in that area when spring returns. Heat also affects the alligatorweed flea beetle. Temperatures above 80° F reduce the insect's ability to reproduce. Therefore, alligatorweed flea beetles reproduce most effectively in the spring and fall.

Differences in plant nutrition from location to location cause physical changes in the alligatorweed. A low nutritional level in the plant causes alligatorweed stems to grow shorter and thinner. These smaller stems create problems of adequate space when the time comes for the insect to pupate. Deficiencies in the plant's food supply also cause smaller leaves and a reduced food supply for the beetle.

Alligatorweed thrips. Alligatorweed thrips are affected by climatic changes in much the same way as the flea beetle. However, not as much is known about the overwintering ability of the alligatorweed thrips.

The health and nutritional level of alligatorweed also affects population and distribution of the alligatorweed thrips. Alligatorweed thrips rely on chemical attractants within the alligatorweed to help them locate the plant. When this chemical makeup of the attractants is altered by the environment, the alligatorweed thrips population is not very effective. The inability of the thrips to travel for any significant distance also affects its overall effectiveness.

Alligatorweed stem borer. Alligatorweed stem borers are generally considered to be hardy, aggressive, reliable, and effective as a biological agent of alligatorweed. The alligatorweed stem borer can survive many days of below-freezing temperatures. Its impact on alligatorweed is quite rapid under normal conditions, and its excellent flying ability enables it to readily spread throughout the alligatorweed problem areas.

All stages of alligatorweed stem borers are affected by the nutritional condition and health of the alligatorweed, although not as drastically as the alligatorweed flea beetle and thrips. Insect predators have been observed to have a devastating effect on alligatorweed stem borer populations since all stages of the insect are of value to the insect food chain. Normal predators include spiders, flies, assassin bugs, lizards, and frogs. Spiders, using webs strung between alligatorweed stems, apparently inflict the heaviest toll on stem borer adult moths.

Other Considerations

During the development of operational plans to release the insect agents in a given area, other factors should be considered by conducting an initial site inspection, during which the following questions should be answered:

1. Are the insect agents already present? If all the agents are already present, then no further releases should be made. However, plans should be made to release any of the agents that are not already present.

2. Are there local site factors that may influence the establishment or success of the agents? The frequent use of insecticides in or near the release site or the obvious presence of potentially toxic chemicals should be recorded. The presence of stunted, discolored alligatorweed on the site should also be noted. Although the insects will attack such plants, the chances for establishment will be greatest on healthy, vigorously growing alligatorweed. The frequency of prolonged flooding or periods of extended dewatering of the site should be determined. The insect populations may be decimated by flooding, which would necessitate reintroduction of the agents. Extended periods of dewatering significantly limit reproduction of the alligatorweed flea beetle. Although one or more of these site factors may limit the effectiveness of the insect agents, it is recommended that they not be used as a basis for a decision not to release the agents on the site. The ultimate measure of suitability of the site for the management of alligatorweed by insect agents will be the performance of the agents after release. However, should the insects fail to become established after the initial releases, documentation of the above site conditions may help define the causes, and may also provide a basis for remedial or alternative actions.

In addition to the above considerations, appropriate State agencies should be contacted to obtain permission to release the insect agents on the site. Although State permits were obtained to release the insects at the time of their original distribution in states where alligatorweed is a problem, some states have additional or revised permit requirements. In most cases, the State Department of Agriculture has the responsibility for approving the releases. In a few cases, the State agency responsible for aquatic plant management operations is authorized to grant the permit. All necessary permits should be obtained prior to requesting or collecting the insects.

Determining the Number of Agents Needed

Once a decision has been made to release one or more biological agents for management of an alligatorweed problem, the number of individual insects required for initial release must be determined. Because the potential for population development in insect populations is great, relatively small numbers may be adequate for establishing a viable, reproducing insect population. In most cases, it would be impractical to release sufficient numbers of insects to provide immediate relief from an alligatorweed infestation. For most situations, the threshold number of individuals required to produce a viable, breeding population of any of the insect agents is 250 to 500, and it is recommended that this number of individuals of each agent be released on each alligatorweed infestation, regardless of the size of the infestation. When a breeding population has been established at the release site, the insects will disperse throughout the alligatorweed infestation, and the insect population can be expected to develop to levels capable of reducing the alligatorweed infestation within 2 to 3 years after release. After the population level of the insect agents has developed sufficiently to provide the desired level of management of the alligatorweed infestation, the site may be used as an area for collecting insects for release on alligatorweed in other areas of operational concern.

Sources of Insect Agents

Most states in which alligatorweed is a problem already have sites with established populations of one or more of the agents. Therefore, the simplest approach to obtaining the insects is to first contact the Corps of Engineers District Office that has jurisdiction over the site in which the release is desired. Aquatic plant management personnel will know the nearest site that already has a sufficient population of the agent for obtaining the number of individuals needed for release. Then, the insects can be obtained by using the collection methods described below. Sufficient numbers of insects should be available by June in most areas.

If a sufficient number of insects are not available locally, or if it is necessary to transport the insects across state boundaries, the Aquatic Plant Control Operational Support Center (OSC), U. S. Army Engineer District, Jacksonville, should be contacted for assistance. At present, interstate shipment of the insects requires a permit from the U. S. Department of Agriculture Plant and Health Inspection Service (APHIS). The OSC has an APHIS permit; however, shipment of insects by the OSC is limited to Corps of Engineers District Offices, State agencies that have cooperative agreements with District Offices, and other Federal agencies. Requests for the insect agents should be addressed to:

U. S. Army Engineer District,
Jacksonville
ATTN: Aquatic Plant Control
Operational Support Center
P. O. Box 4970
Jacksonville, FL 32232

The request should contain the following information:

- Type and life stage of insects requested.
- Total number of insects needed.
- Date needed.
- Name and address of person who will receive the insects.

Collecting Insects

The procedure to be used in collecting the insect agents will depend on the particular agent to be collected, the life stage to be released, and the method to be used in making the release.

Alligatorweed flea beetle. For collecting adults:

1. Locate an alligatorweed mat that has a large population of adults. Since the flea beetles usually prefer alligatorweed growing in standing water, a boat is needed in most cases.

2. Vigorously sweep an insect net through the upper portion of the alligatorweed mat (Figure 18). The adult flea beetles will accumulate in the bottom of the net.

3. After several sweeps, carefully empty the contents of the net into a 1-gal (3.8-ℓ) plastic collection container.

4. Perforate the lid of the container sufficiently to allow air exchange.

5. Repeat the process until the desired number of insects (250 to 500 individuals per release) has been collected.

6. Place several alligatorweed stems in the container to provide food material for the insects.

7. Keep the collection container out of the sun during the collecting process. This can be accomplished by placing the container in an ice chest that has just enough ice to keep the air cool.

To collect flea beetle larvae:

1. Locate an alligatorweed mat that has abundant larvae (Figure 9).

2. Examine the leaves of individual stems, remove the upper portion of stems containing larvae, and place them in a collection container. When the population of flea beetles is high, several larvae may be present on the same plant.

3. To avoid excessive handling, count the larvae as they are collected.

4. Place the closed collection container in an ice chest until packing for shipment or transfer.

For collecting eggs of the flea beetle:

1. Select a site that has a high population of adults.

FIGURE 18

2. Locate the egg masses (Figure 9) as double rows of eggs on the underside of leaves on the upper half of the alligatorweed stems.

3. Remove leaves containing the egg masses and place them egg side up on moist paper towels in a small, flat plastic container. Make sure that there is no standing water in the container.

4. Collect 20 to 30 viable egg masses for release on each site. Viable eggs will be yellowish and smooth across the surface (Figure 9), while eggs that have hatched will be silver-white with obviously broken walls on the individual eggs.

5. Place the container of egg masses in an ice chest until packing for shipment or transfer.

Alligatorweed thrips. All life stages of the thrips may be collected at the same time by using the following procedure:

1. Locate an alligatorweed mat that has a large population of thrips. Instead of searching for the individual insects, look for typical damage characteristics produced by the thrips (Figure 15).

2. Examine the stem tips of damaged plants to confirm that the nymphs and adults are present (Figures 10 and 11). Because the insects are very small, a hand lens should be used.

3. Collect the upper half of alligatorweed stems that show the typical damage characteristics and place them in a collection container. No fewer than 50 stems should be collected for each release site.

4. Place the closed container in an ice chest until packing for shipment or transfer. Do not perforate the lid of the container.

Alligatorweed stem borer. The only practical methods for collecting the stem borer involve collection of larvae. If the collection site is in the same general area as the release site and no shipping of the insects is required, use the following procedure:

1. Locate an area of an alligatorweed mat that has a large population of stem borers. The best indication of a large stem borer population will be the presence of numerous, recently wilted, but upright, stems (Figure 16).

2. When it has been determined that significant numbers of larvae are present, fill 3 to 5 large trash bags with alligatorweed from the site. It is not necessary to select individual stems; however, be sure that the collected plant material includes both recently wilted stems and older, larger stems located at or near the water surface.

3. Immediately protect the bags of collected alligatorweed from direct sunlight. To avoid excessive buildup of heat in the bags, leave the top of the bags open, and perforate the bags in several places.

If the insects are to be shipped, it will be necessary to collect smaller quantities of alligatorweed, as follows:

1. Locate an alligatorweed mat that has a large population of stem borers.

2. Collect stems that have recently wilted tips. Usually, each stem will contain one larva. Because the exact location of the larvae in the stems will not be known, break the stems at the water surface.

3. Place the stem segments containing the larvae in plastic bags. The total number of collected stems should be at least 250.

4. Place the plastic bags containing the stems in an ice chest on top of frozen KOOL-PAKS until packing for shipment.

Shipping or Transporting Insects

When the collected insects are to be transported directly to the release site, use the procedures described below.

Alligatorweed flea beetle. For adult flea beetles:

1. Remove the collection containers from the ice chest.
2. Examine the collected insects and remove any other types of insects present.
3. Place 250 adult insects and several alligatorweed stems in each shipping carton (quart-size ice cream cartons with tightly fitting lids are sufficient) and fasten the lids securely. To ensure that the lids of the cartons remain intact, tape the lids to the cartons. Perforate the lids to allow air exchange, but be sure that the perforations are not sufficiently large for the insects to escape.
4. Place the shipping cartons in an ice chest with enough frozen KOOL-PAKS added to keep the air in the ice chest cool during transit. Do not use loose ice because the resulting water may damage the insects. Dry ice should not be used because the gaseous carbon dioxide produced as the ice melts is lethal to the insects.
5. Transport the insects directly to the release site.

For transporting larvae or eggs, the same basic procedure should be used. However, use larger (gallon) containers to accommodate the larger quantity of plant material that must be transported. Do not perforate the lids of the shipping cartons.

Alligatorweed thrips. For all life stages:

1. Remove the collection containers from the ice chest.
2. Examine the collected stems and remove any other types of insects that are present.
3. Place the stems in a 1-gal (3.8-ℓ) shipping carton and fasten the lid securely. Do not perforate the lid.
4. Place the shipping carton in an ice chest containing frozen KOOL-PAKS.
5. Transport the insects directly to the release site.

Alligatorweed stem borer. When bags of alligatorweed containing larvae are to be transported directly to the release site, no additional preparations are necessary. However, the following precautions must be taken:

1. Leave the tops of the bags open during transit.
2. Protect the bags from exposure to direct sunlight.
3. Do not allow excessive heat buildup to occur in the transporting vehicle.
4. Transport the insects as rapidly as possible to the release site. Do not retain the plant material for more than 2 days.
5. Upon arrival at the release site, do not leave the bags of plant material in a closed vehicle or in direct sunlight while preparing for the release.

If the insects are to be shipped commercially, different packing procedures must be used. For the flea beetles and thrips, prepare the shipping cartons as outlined above. Prepare the shipping cartons for stem borers in the same manner as for the thrips. Once the shipping cartons have been prepared, use the following method:

1. Place the shipping cartons inside a larger box and fill the box with packing material containing frozen KOOL-PAKS. Seal the lid of the box with tape.

2. Place this box inside another box and tape the lid securely.

3. Wrap the outer box with heavy duty paper and ship immediately. Whenever possible, ship the insects on a commercial carrier that guarantees same-day or 1-day arrival.

4. Contact the person to whom the shipment is addressed, and inform him of how and when the shipment will arrive.

CAUTION: Remember that a Federal permit is required for the interstate shipment of any of these insect agents. Under no circumstances should such shipments be made without the proper permits.

Receiving Insects

When receiving insects, the following procedure should be followed:

1. Open the boxes immediately upon arrival and remove the shipping cartons.

2. Examine shipments of larvae or adults to confirm that the insects are still alive.

3. Release the insects on the day of arrival whenever possible.

4. If the immediate release of the insects is not possible, place the shipping cartons in a refrigerator at 42° to 44°F (5.6° to 6.7°C)

5. Remove the insects from the refrigerator for 2 hr each day to provide an opportunity for them to feed. If the insects are held in this manner for longer than 2 days, place several fresh alligatorweed stems in the shipping cartons.

6. Do not store shipments of adults or larvae for more than 5 days before releasing them. If eggs are to be released, make the release within 3 days after arrival.

Releasing Insects

Techniques to be used in releasing the insect agents vary according to the species and life stage to be released.

Alligatorweed flea beetle. Whenever possible, use adult flea beetles for releases, primarily because they are the easiest life stage to collect, ship, and release; they are hardy; and they produce the most rapid rate of population development. The following steps should be taken when releasing adult flea beetles:

1. Select one location in the mat that contains healthy, vigorously growing alligatorweed as the release point. Be sure that the release point is located in standing water.

2. Place two open shipping cartons containing a total of 500 individuals directly onto the alligatorweed mat at the release point. The adult flea beetles will quickly escape from the cartons and distribute themselves on the surrounding alligatorweed. The shipping cartons should not be removed until at least 1 week after the release.

3. Make sure that the shipping cartons remain above the water surface because they may contain eggs laid during shipment. These eggs will hatch, and the resulting larvae will begin to feed on the alligatorweed.

4. Release the insects as early in the spring as possible, but not before the danger of frost or freezing temperatures has passed.

Fewer numbers of adults may be released. However, such releases may result in failure of establishment or an increased period of time required for development of a sufficient population to provide the desired level of management. The release of fewer than 250 adults on a site is not recommended.

The following procedure should be used for the release of larvae of the alligatorweed flea beetle:

1. Remove the plant material containing the larvae from the shipping carton, and place the plant material directly on the mat among healthy alligatorweed plants.
2. Place all of the plant material at the same release point. Make sure that all plant material remains above the water surface.
3. Release a total of 400 to 700 larvae on the site.
4. Make the release as soon as possible in the spring after the danger of frost has passed.

Releases of the flea beetle may also be made with eggs, although this method should be employed only when sufficient numbers of adults or larvae are unavailable. Use the following procedure for releasing eggs:

1. Remove the leaves with egg masses from the shipping carton.
2. Examine the underside of each leaf in the plant material to determine if egg masses are still viable, and carefully remove all leaves that have viable egg masses (see Figure 9).
3. Attach each leaf containing an egg mass to a leaf on the upper one third of a healthy alligatorweed stem at the selected release point. To accomplish this, place the underside of the leaf with the egg mass against the underside of the leaf of the healthy alligatorweed plant, and use either a paper clip or pin to hold the leaves together. This should be accomplished in such a way that the healthy alligatorweed plant and the egg masses are not damaged.
4. Release a total of 600 to 900 eggs on the site. Since the average number of eggs per egg mass is approximately 30, it will be necessary to attach between 20 and 30 leaves containing egg masses to alligatorweed leaves on the site.
5. Make the release as early in the spring as possible, but after the danger of frost has passed.

Alligatorweed thrips. Because the adults and nymphs of the alligatorweed thrips are very small, it is impractical to make separate releases of these life stages. The following steps should be taken in releasing the thrips:

1. Remove the alligatorweed stem tips containing the thrips from the shipping cartons.
2. Select one release point and place the stem tips directly on the alligatorweed mat among healthy alligatorweed plants growing at or near the shoreline.
3. If the release point is in standing water, make sure that the plant material remains above the water surface.
4. Make the release with no fewer than 50 stem tips.
5. Release the insects as soon as possible in the spring.

Alligatorweed stem borer. If the

stem borer is available from local sources, collect the plant material infested with the insects according to the technique described earlier and make the release as follows:

1. Select a single location in the alligatorweed mat that has healthy, vigorously growing plants.

2. Scatter the contents of the bags of plants on the alligatorweed mat. Do not merely dump the contents of the bags onto the mat and leave them in piles. Such action could result in some of the material being forced beneath the water surface.

3. Place all of the material within a radius of 10 ft (3 m).

This method is particularly effective for late summer or early fall releases because the field population of stem borers will be greatest at this time of year. However, releases should not be made later than 1 month prior to the date of the first expected frost. Depending on the availability of sufficient field populations of insects, this method can also be used for spring releases.

If the release is to be made with shipped insects, use the following method:

1. Remove the alligatorweed from the shipping cartons.

2. Place the stem segments containing the larvae directly on the alligatorweed mat at the selected release site. Make sure that the stem segments remain above the water surface.

3. Release a minimum of 250 larvae within a area 1 m by 1 m (3.3 ft by 3.3 ft). Since there will usually be only one larva in each stem, a minimum of 250 stem segments should be placed on the site.

4. Release at any time during the growing season, except during the last month prior to the first expected frost.

Checking for Population Establishment

To determine if the biocontrol agents have become established, onsite inspections for insect damage will be necessary. By looking for characteristic damage (pages 19 and 20) and the extent of that damage, the observer can readily determine if the insects have established themselves in their new environment. Alligatorweed flea beetle damage can be detected after 1 month by noting larval damage (see Figure 14, page 19) on the underside of apical leaves. Alligatorweed thrips damage in the form of subtle curling of the leaf edges at the growing tip should not be expected until at least 40 days after release (see Figure 15, page 20). Alligatorweed stem borers are established if wilted upper leaf portions of alligatorweed are observed near the release site (see Figure 16, page 20) 30 days after release.

Monitoring of the release sites should be continued at monthly intervals to determine the progress of population development. In the event that the biocontrol agents did not become established, an effort should be made to determine the factor or factors responsible for the lack of establishment. If it is determined that failure of establishment was due to a temporary situation, then additional releases of the biocontrol agents should be made. If the factor(s) responsible for failure of establishment are long term, or if repeated attempts at establishing the biocontrol agents are unsuccessful, then consideration should be given to alternative methods of control.

Achieving and Maintaining the Desired Level of Management

Although the total eradication of alligatorweed on a given site may be desirable, it is seldom achieved, regardless of the management methods used. This is especially true when biological agents are used. However, an initial significant reduction in the alligatorweed population should be expected within 2 to 3 years after release, after which a recurring pattern of increased alligatorweed growth followed by an increase in insect populations should develop.

Under conditions favorable to development of the insect populations, the established insect agents will increase to a level that results in a significant decrease in the alligatorweed population. In many cases, the entire alligatorweed mat may be reduced to the water surface. When this occurs, there will be a much smaller amount of suitable plant material for reproduction and feeding by the insects. Therefore, the insect populations will decline. Because the reduced insect populations will result in less pressure on the alligatorweed population, it will begin to increase. When sufficient plant regrowth has occurred, the insect populations will begin to increase until the populations reach the levels required to produce another significant reduction in the alligatorweed population. Each time this pattern is repeated, the size of the alligatorweed mat should be reduced and, in many cases, the mat will be reduced to a narrow fringe at the shoreline. This pattern has been achieved on many sites in the southeastern United States, and there has been a great reduction in the total population of alligatorweed.

Although the above pattern should be expected to develop, the degree and rate at which it develops will be determined by a large group of site-specific environmental and cultural factors. Therefore, it is not possible to predict the level of management that can be expected on a specific site within a given time frame. However, the pattern described above should be well established within 2 to 3 years after the insects have been released. As long as environmental conditions favorable to the insect populations continue, the level of management achieved in this time frame should be maintained.

When significant environmental or cultural changes occur on the site, the pattern may be significantly altered. For example, an abnormally cold winter or prolonged flooding may result in the elimination of the insect populations. When these or other changes occur that significantly reduce or eliminate the insect populations, steps should be taken to reintroduce the insects as soon as possible.

Estimated Level of Required Effort

Because the costs associated with using the insect agents will vary according to the site, the specific agents to be used, and the methods employed in the collection and release of the insects, it is not possible to present specific cost analyses. However, it is possible to identify the major sources of costs that can be expected, which include the following:

Operational planning. Considering that methodologies for obtaining and releasing the insect agents have already been defined, the planning should establish procedures for the initial site inspection, define how and where the insects will be obtained, select the release method to be used, and outline the level and timetable for monitoring the site after the release. All necessary permits must be obtained. In most cases, these activities should require no more than 5 man-days to complete.

Initial site inspection. On the initial visit to the site, the operations personnel must determine whether or not the insect agents are already present, the vigor of the alligatorweed, and the presence of other factors that may affect the success of the release. Tentative release points should be selected at this time. This effort should require no more than 2 man-days to complete, including travel time.

Obtaining insects. When the insects are to be obtained locally, costs will include travel to the collection site, labor for collecting the insects, and travel to the release site. The total personnel and time requirements for this activity should be no more than two individuals for 3 days. Also, if the insects are to be obtained through the OSC, shipping costs will be paid by the requesting agency. However, these costs are minimal. When the request can be incorporated into the routine biological management activities of the Jacksonville District, there will be no charges for the collection of the insects. When the request requires special effort by Jacksonville personnel, the incurred labor and travel costs will be paid by the requesting agency.

Release of the insects. Costs associated with releasing the insects will include travel to the release site (this is already identified as a cost when insects are collected locally), and the necessary labor for making the release. Regardless of the release method to be used, the onsite time required for the release should not exceed 2 man-hours.

Monitoring. Costs associated with monitoring the release site will include travel to and from the release site, and labor for inspecting the site. A monitoring trip is necessary 40 days after the release to confirm that establishment has occurred. Additional monitoring for population development and level of achieved control should be conducted twice annually (May-June and October). Onsite inspection time should involve no more than 4 man-hours per release site.

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In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

The use of insects to manage alligatorweed / by Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station. -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1981.

33 p. : ill. ; 27 cm. -- (Instruction report / U.S. Army Engineer Waterways Experiment Station ; A-81-1)

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