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MANAGEMENT PROGRAM

FOR ALLIGATORWEED IN NORTH CAROLINA

by

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ABSTRACT

A survey to determine the extent of alligatorweed in North Carolina revealed 1023 ha of aquatic alligatorweed distributed among 32 counties and 1042 ha of terrestrial alligatorweed distributed among 9 counties. Major problems caused to North Carolina water resources by the weed are flooding and impedance to navigation. Neither alligatorweed flea beetles that originated from a collection in Southern Argentina, nor alligatorweed flea beetles collected from Florida, nor naturally occurring populations of alligatorweed stemborer exerted a useful level of alligatorweed suppression in North Carolina. Results of herbicide evaluations for controlling alligatorweed suggested that a successful alligatorweed management program can be implemented using glyphosate for management in lakes and rivers and imazapyr for non-irrigation ditchbanks. Tryclopyr was effective for controlling alligatorweed in preliminary evaluations and should be useful in the program pending expansion of EPA registration to aquatic sites and ditchbanks.

ACKNOWLEDGMENTS

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LIST OF COMMON AND CHEMICAL NAMES OF HERBICIDES USED IN THIS REPORT

Common Name or Designation	Chemical Name
ametryn	2-ethylamino-4-(isopropylamino)-6-(methylthio)-*s*-triazine
amitrole	3-amino-*s*-triazole
AMS	ammonium sulfamate
bromacil	5-bromo-3-*sec*-butyl-6-methyluracil
dalapon	2,2-dichloropropionic acid
dicamba	3,6-dichloro-*o*-anisic acid
dichlobenil	2,6-dichlorobenzonitrile
diuron	3,(3,4-dichlorophenyl)-1,1-dimethylurea
endothall	7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid
erbon	2-(2,4,5-trichlorophenoxy)ethyl 2.2-dichloropropionate
fenac	(2,3,6-trichlorophenyl)acetic acid
fenuron	1,1-dimethyl-2-phenylurea
fenuron TCA	1,1-dimethyl-3-phenylurea mono(trichloroacetate)
fluridone	1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(*H*)-pyridinone
glyphosate	*N*-(phosphonomethyl)glycine
hexazinone	3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1*H*,3*H*)dione
imazapyr	2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid
ipazin	2-chloro-4-(diethylamino)-6-(isopropylamino)--*s*-triazine
karbutilate	(m-(3,3-(dimethylureido)phenyl tert-butylcarbamate)
MCPA	(4-chloro-2-methylphonxy)acetic acid
maleic hydrazide	1,3-dihydro-3,6-pyridazinedione
metsulfuron methyl	methyl 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]-carbonyl]-amino]-sulfonyl]-benzoate
monuron	3,(*p*-chlorophenyl)-1,1 dimethylurea
neburon	1-a-butyl-3-(3,4-dichlorophenyl)-1-methylurea
paraquat	1,1'-dimethyl-4,4'-bipyridinium ion
picloram	4-amino-3,5,6-trichloro-1-pyrdinecarboxylic acid
silvex	2-(2,4,5-trichlorophenoxy)propionic acid
simazine	6-chloro-*N*,*N*'-diethyl-1,3,5-triazine-1,4-diamine

sulfometuron methyl	methyl 2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino] carbonyl]amino]sulfonyl]-benzoate
TCA	trichloroacetic acid
triclopyr	[(3,5,6-trichloro-1-pyrdinyl)oxyl acetic acid
2,4-D	(2,4-dichlorophenoxy)acetic acid
2,4,5-T	(2,4,5-trichlorophenoxy)acetic acid
2,3,6-TBA	2,3,6-trichlorobenzoic acid

CONCLUSIONS AND RECOMMENDATIONS

Termination of alligatorweed management in 1970 has allowed the weed to increase seven-fold over a 1963 survey in North Carolina. Locally abundant infestations in the Lumber, Chowan, and Pasquotank basins seriously impact water resources and agriculture in North Carolina by reducing recreational value, causing flooding, and by invading terrestrial habitats in cropland. Based on evaluations of herbicide and biological suppressants, the following management of alligatorweed is recommended:

1. The North Carolina Department of Natural Resources and Community Development, Division of Water Resources, which has recently taken the lead role for implementation of aquatic weed control in the state, should expand the Alligatorweed Management Program that was initiated in 1984 and described in this report. The program should be expanded to other areas in the state where alligatorweed restricts public use of water or is a potential cause of flooding. The program should also be expanded to include creek and canal tributaries that are nursery grounds for future alligatorweed infestations of the treated areas. Glyphosate, at recommended rates, should be used for alligatorweed management in lakes and rivers. Two applications will be necessary the first year. Imazapyr should be used at a rate of 0.06 to 0.12 kg ae/100L on a spray to wet basis for alligatorweed management on non-irrigation ditchbanks. With two consecutive applications, alligatorweed will be essentially eliminated from some ditches, and reinfestation can only occur by vegetative reintroduction. The initial implementation will require some effort and expense. However, after alligatorweed is initially reduced, only maintenance control operations will be necessary, that will

require, at most, one annual visit per site for spot treatments.

2. The North Carolina Agricultural Extension Service should strive to keep private landowners informed of current management practices for alligatorweed. It should stress to the landowners the importance of controlling the weed when identified on their land and avoiding dispersal on farm equipment such as cultivators, draglines, and backhoes.

3. Efforts should continue to develop the most cost-effective herbicides for alligatorweed management. Particular attention should be given to better determine the effectiveness of triclopyr for controlling alligatorweed and the potential for developing EPA registration for aquatic sites for triclopyr and imazapyr.

4. Efforts should be continued to develop biological suppressants that are adaptable to North Carolina's climate.

INTRODUCTION

Alligatorweed (Alternanthera philoxeroides) is a fast-growing, herbaceous, warm season, facultative aquatic, perennial plant. It is a South American species that was first identified in the United States in 1890. By the 1960's the plant occupied over 160,000 acres of water in the southeastern United States, from Florida to Virginia (Gangsted, 1977), and was recognized as a serious aquatic weed due to its ability to form thick floating mats of vegetation that can severely impede navigation, reduce water quality, cause flooding, and increase sedimentation rates in water bodies.

Extensive efforts by the United States Department of Agriculture (USDA) and United States Army Corps of Engineers (USACE) have led to suppression of alligatorweed in its southern range using several biological suppressants. These biological agents include alligatorweed thrips (Amynothrips andersoni), alligatorweed stemborer (Vogtia malloi) and alligatorweed flea beetle (Agasicles hygrophila). Attempts to establish alligatorweed flea beetles in North Carolina have been unsuccessful, apparently due to the insect's cold sensitivity (USAEC, WES 1981). The USDA and North Carolina Department of Agriculture are currently trying to develop a cold-tolerant alligatorweed flea beetle which may be effectively established in North Carolina, but as yet this has been unsuccessful (Langeland et al, 1984).

Management of alligatorweed with herbicides has been difficult. A large number of herbicides, formulations, and application methods have been evaluated, primarily the phenoxy herbicides. It is widely observed that phenoxy herbicides give rapid top kill of alligatorweed but fail to translocate to the viable apical buds from which regrowth occurs usually

before 5-8 weeks (Zurburg et al, 1961). This is an unusual problem considering the mobility of these materials in many other plants.

Silvex has been relatively effective for controlling alligatorweed in many areas; however, in North Carolina those results have not been duplicated. In a large extended alligatorweed management program carried out in North Carolina and South Carolina about 3000 herbicide treatments were evaluated over a 5-year period. These treatments included a variety of application methods, carriers, and herbicides. The herbicides used included 2,4,5-T, 2,4-D, MCPA, 2(2,4-DP) (dalapon), silvex esters and amides, fenac, amitrole and 2,3,6-TBA, TCA, AMS, endothall, simazine, neburon, fenuron, monuron, diuron, monuron TCA, fenuron TCA and erbon. In addition, treatments included oil/water carriers, weighted emulsions of silvex and 2,4-D granular applications, overlay treatments and repeated spraying of new growth with silvex and 2,4-D. Results were erratic over the evaluation period but indicated that effective control occurred only when flooding of the treated areas occurred shortly after herbicide treatment. Silvex, the most consistently effective material evaluated, provided less than 50% control when applied as a spray solution. Granular applications of silvex gave acceptable control only when the plant was emersed, flowering, and well rooted. Excellent control was observed when 2,4-D and fenac were applied in combination 8-10 weeks before first frost and flooded with 18-36" of water just after treatment (Steenis & McGilvrey, 1961).

In Florida, 78 herbicides were evaluated for alligatorweed control under greenhouse conditions. Of these herbicides, 2,4-D ester, silvex, silvex xylene emulsion, diquat, ipazin, endothall, paraquat, and an experimental dimethylurea compound were selected for further field tests

on the basis of efficacy. After extensive field tests, it was concluded that only silvex and silvex xylene emulsion suppressed alligatorweed for up to 8 weeks. The remaining treatments failed to suppress alligatorweed past 6 weeks. At 8 weeks regrowth was proceeding or beginning for all treatments although silvex treatments provided the best suppression (Blackburn, 1963).

Ametryne was evaluated for alligatorweed control in both the greenhouse and field. Greenhouse studies indicated acceptable control at 8 weeks. However, field tests indicated that 3 applications of ametryne + 2,4-D over a 4 month period reduced alligatorweed growth only 33% after 6 months and was judged ineffective (Weldon and Blackburn, 1967).

In South Carolina several herbicides have been recognized as inhibitors of alligatorweed growth when applications are followed by flooding. These herbicides, which include maleic hydrazide, amitrole, dalapon, erbon, silvex, MCPA and 2,4-D acetamide, have given 90-100% control under such flooding conditions, but are highly ineffective in areas not subject to flooding (Steenis and McGilvrey, 1961).

Dichlobenil has been evaluated for alligatorweed control in South Carolina, Georgia, Florida, and Louisiana. The treatments used involved several granular applications and foliar applications with and without nonphytotoxic oils. The granular applications were applied in both summer and winter time periods. The results of the evaluations indicate that foliar applications of dichlobenil are ineffective regardless of addition or deletion of nonphytotoxic oils. Granular dichlobenil applied in summer was ineffective; however, winter applications were effective when the treated area was drained 2 weeks before treatment and allowed to stand 10 weeks after treatment (Weldon et al, 1968).

Data collected from evaluations of 17 herbicide treatments show that only silvex + amitrol foliar applied late in the season provided better than 50% control 4 months after treatment. All other treatments were less than 30% at 4 months. Those treatments included granular formulations of silvex, 2,4-D, fenac, sodium arsenite, and endothall + 2,4,5-T and foliar applications of paraquat, diquat, silvex, picloram, amitrol, fenac, fenac + diquat, amitrol + diquat, amitrol + picloram, silvex PGBEE + amitrol and picloram + silvex PGEE + amitrol (Spencer, 1967).

Other data from South Carolina indicate 90% control of terrestrial alligatorweed one year after treatment with karbutilate granular herbicide and 90% control of rooted-emersed alligatorweed with spring applications of granular dichlobenil (Blackburn Durden, 1974).

Silvex has generally been considered the only consistently effective herbicide for alligatorweed control. The USACE Wilmington District began an alligatorweed control program in North Carolina in 1960 using silvex as the primary herbicide. In 1970 this program was stopped due to concern over environmental and health impacts of silvex and because alligatorweed was no longer occurring at problem levels[1]. In 1979, as a result of public concern over possible environmental and health risks, the EPA initiated actions to suspend the use of Silvex and in 1983 banned all uses of the material (Gangstad, 1984).

During the early 1980's the North Carolina Agricultural Extension Service began receiving many requests for information on how to control

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[1]Environmental assessment, Aquatic Plant Control Program (Rett Act of 1965). United States Army Corps of Engineers, Wilmington District. 1984.

alligatorweed and widespread reports of problems caused by the plant in drainage canals, lakes, ponds, and rivers. Glyphosate, which had recently been registered for aquatic use, was recommended, but many complaints were received indicating that unsatisfactory control resulted. In response to these complaints the North Carolina State University Crop Science Department began, in 1983, evaluating newly introduced herbicides for alligatorweed control in order to develop better recommendations. Since many of the alligatorweed problems originated in publicly owned waters, questions arose over renewal of federal assistance for alligatorweed management. It was therefore decided that a thorough survey should be conducted in order to document the extent and nature of problems that were being caused by alligatorweed. This report presents data from three years of testing herbicides for alligatorweed control in North Carolina and data from a survey of alligatorweed in North Carolina in 1984, and it recommends actions to be taken based on these data.

MATERIALS AND METHODS

Alligatorweed Survey

Questionnaires (Appendix) were mailed to county extension chairmen, district fisheries biologists, and soil conservationists representing all North Carolina counties to the east of the western boundaries of Scotland, Hoke, Harnett, Wake, Durham, and Granville Counties requesting information related to the occurrence, location or problems caused by alligatorweed. In general, county extension personnel, fisheries biologists, and soil conservationists cooperated so that extension personnel and soil conservationists reported on agriculturally related occurrences, and fisheries biologists reported on occurrences in creeks, rivers, lakes, and other public waters. This allowed cooperators to report within their own areas of expertise and minimized redundancies. Occurrences in three counties not included in the survey area were recorded from routine weed identifications and recommendations conducted by the project leader. When identification or area estimates were in question, sight inspections were made, if possible, by the principal investigator. Estimable areas of infestation were reported in acres and these values were converted to metric values and rounded to the nearest whole number.

Biological Suppressants

Alligatorweed flea beetles that were reared from genetic stock collected from colder extremes of the organism's natural range in Argentina (Buckingham and Boucias, 1982) were obtained from the USDA Quarantine lab in Gainesville, Florida. Three hundred adult insects were released

on August 19, 1983 at a 0.5 ha pond in Salemburg, North Carolina that was 33% covered by alligatorweed mats. September 1, 1983 a second release of six hundred adult insects was made at this site and a release was made at a 0.25 ha, 100% covered pond in Penderlea (Pender County), North Carolina. Nine thousand Florida-collected alligatorweed flea beetles were obtained from the United States Army Corps of Engineers, Jacksonville District, on June 7, 1984 and released in the Thirty-foot Canal (Washington County, North Carolina). All releases were conducted according to United States Army Engineers Waterways Experiment Station guidelines (USAEWES, 1981). All these sites were monitored routinely for presence of the beetles and damage caused to the alligatorweed during the year of release and the following spring.

Herbicide Evaluation

Floating Alligatorweed

Two and a half ha of alligatorweed in the Scuppernong River between the County Road 1155 bridge and the Washington/Tyrrell County line were treated with a tank mix containing 0.60 kg ae glyphosate per 100L, 0.5% non-ionic surfactant and 0.075% poly-acrylamide copolymer on August 6, 7, and 9, 1984. The foliage was sprayed to wet using a handgun with a D-8 nozzle. Reapplication was made October 18, 1984. This exercise was conducted to demonstrate, on a large scale, the effectiveness of this recommendation for controlling floating mats of alligatorweed, and the feasibility of maintenance control of alligatorweed; not for data collection.

Rooted Alligatorweed

Various herbicides, rates, and herbicide combinations were evaluated for effectiveness of controlling rooted-emersed alligatorweed in shallow drainage canals located in the Coastal Plain province of North Carolina. All applications were made to wet foliage (or uniformly cover the ditch bank and bottom) by handgun using a D-8 nozzle. Plot sizes were 400 m^2 or larger so that operational level herbicide application could be simulated. Treatments were replicated within a ditch, and among ditches located in different counties where possible. Although it was not always possible to replicate treatments, due to various constraints, large plot size should average the evaluation over most environmental variability. Obvious environmental differences among replications are noted in the text.

Herbicide efficacy was evaluated subjectively on a scale between 0 and 100 where 0 represents the condition where all visible vegetation remains living after herbicide application, and 100 represents the condition where all visible vegetation is apparently moribund.

Statistical analysis of the data is purposely omitted because some treatments are not replicated, and/or N is small for replicated treatments; and because statistical analysis is probably not appropriate for subjective ratings. Rather, all data are reported. Furthermore, because anything less than excellent (90-100) long-term alligatorweed control is unacceptable, since rapid regrowth and renewal of the problem will occur, detection of delicate differences between treatments is not necessary.

RESULTS AND DISCUSSION

Alligatorweed Survey

Alligatorweed is, essentially, confined to the Coastal Plain province in North Carolina but is widespread and locally abundant in this area. Twenty-nine of forty-five Coastal Plain counties reported alligatorweed occurrences (Figure 1). The only non-Coastal Plain occurrences reported were a small patch in one pond and one terrestrial occurrence (that has reportedly been eliminated) in Stanly County in the Piedmont Plateau province, and one occurrence in Woodlake in Moore County, an occurrence in a lake in Lee County, and in one pond in Vance County. The latter two occur in the Sandhills province. Actual area of infestation of alligatorweed (or other vegetation) is often difficult to determine when it occurs. For instance, portions of an infestation are often inaccessible or, in the case of terrestrial alligatorweed in New Hanover County, it is widespread throughout the county and individual inspections would not have been feasible. In such cases we have listed density in the county as widespread (W) or sparse (S) and un-estimable (UE). Total areas of infestation should, therefore, be construed relatively rather than absolutely. Our estimated totals are probably underestimates because where alligatorweed was considered un-estimable it was not included in the totals.

Terrestrial alligatorweed is very scattered in the Coastal Plain of North Carolina. It occurs in only seven counties (Table 1). However, it is locally abundant in those counties where it occurs and we have observed severe problems caused to soybeans and ornamental plant production caused by heavy infestation.

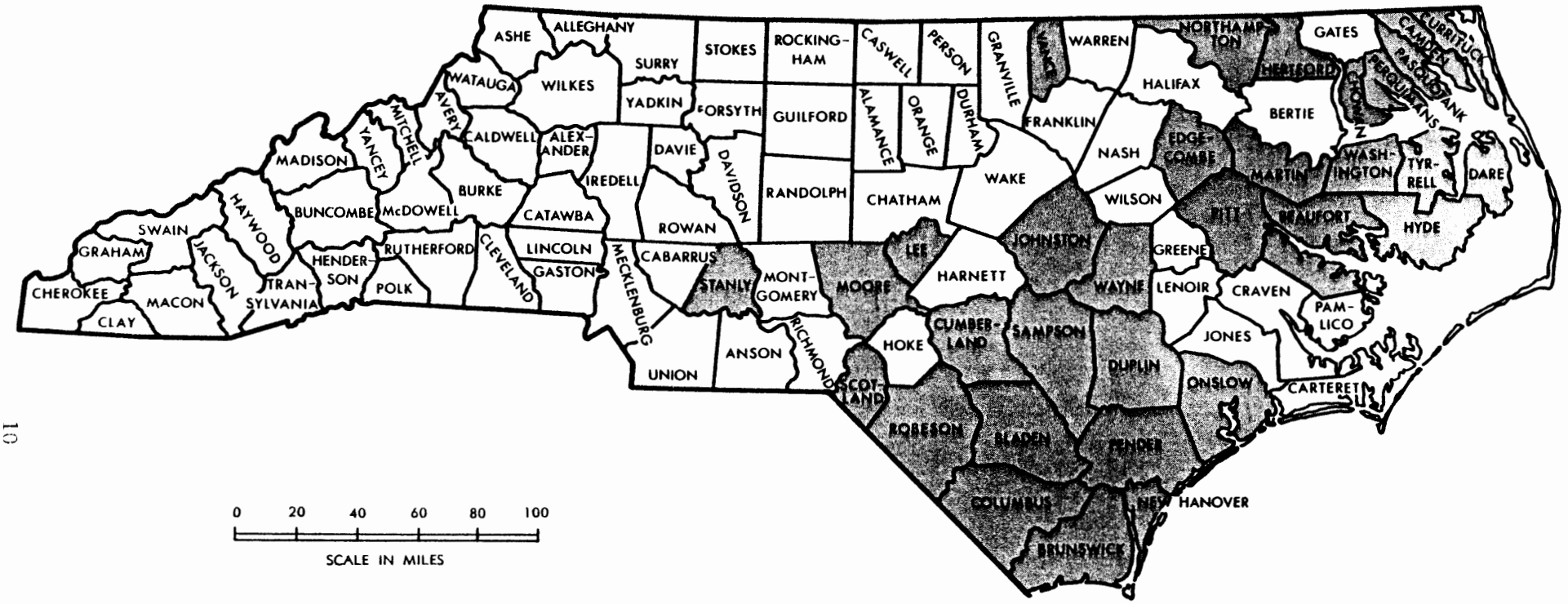

Figure 1. North Carolina counties (shaded) that reported alligatorweed (Alternanthera philoxeroides) during 1984.

Table 1. Summary of alligatorweed (Alternanthera philoxeroides) occurrence in North Carolina counties reported by county agricultural extension service offices, soil conservationists, and district fisheries biologists during 1984 survey.

County	Type of Occurrence			
	Terrestrial	Drainage Canals	Ponds or Lakes	Streams and Rivers
	hectares			
Beaufort	0	0	0	S-UE
Bladen	0	34	4	0
Brunswick	0	4	6	127
Camden	0	0	0	S-UE
Chowan	0	0	81	S-UE
Columbus	810	40	128	119
Cumberland	0	W-UE	10	0
Currituck	0	0	2	0
Dare	0	0	0	S-UE
Duplin	0	<1	14	0
Edgecombe	0	16	0	0
Hertford	0	0	3	S-UE
Hyde	4	9	2	0
Johnston	0	0	<1	0

Table 1. Continued

Martin	0	0	0	W-UE
New Hanover	W-UE	W-UE	W-U	U-E
Northampton	4	0	2	0
Onslow	0	0	4	0
Pasquotank	0	W-UE	0	W-UE
Pender	S-UE	0	1	0
Perquimans	5	6	0	W-UE
Pitt	W-UE	W-UE	0	0
Robeson	0	23	47	142
Sampson	0	0	1	0
Stanly	<1	0	>1	0
Scotland	0	0	1	0
Tyrrell	162	65	0	45
Vance	0	0	1	0
Washington	62	19	0	12
Wayne	0	0	56	S-UE
Total	1,042	216	362	445

A total of 362 ha of alligatorweed occurring in ponds and lakes was reported in 65% of the counties that contained the weed. Most of these occurrences were in private impoundments. The only reported occurrences of alligatorweed in public lakes were in Lake Waccamaw and Lake Tabor in Columbus County and Greenfield Lake in Wilmington. Small ponds, or coves of large lakes can become totally covered by floating alligatorweed mats.

Alligatorweed occurs in ten North Carolina coastal rivers, the Alligator, Cape Fear, Little (Pasquotank co., Perquimans Co.), Lumber, Pamlico, Pasquotank, Scuppernong, Tar, and Waccamaw; and along the shore of the Albemarle Sound. It is not reported to cause problems in open water or wide river reaches, except for occasionally obstructing boat slips or boat docks. Its major impact is exerted in the upper narrow river reaches, small creeks and bays, and drainage canals where it can completely stop navigation by forming extensive mats that extend from one side of the water body to the other. Restricted waterflow can cause severe flooding when mats break loose and pile up at water-course restrictions during heavy precipitation.

Although alligatorweed is widespread throughout the coastal plain province, two major locations of heavy infestations occur (Figure 2). One of these is in the Northeast that includes the Pasquotank, Chowan, Roanoke, and Tar-Pamlico drainages, from the Pasquotank River to Tranter's Creek. The other is in the southeast corner of the state and includes the Cape Fear and Lumber drainage basins from the South River southwest into South Carolina.

Severe problems have been reported in the northeast location in the Scuppernong River and tributaries where boat passage has become

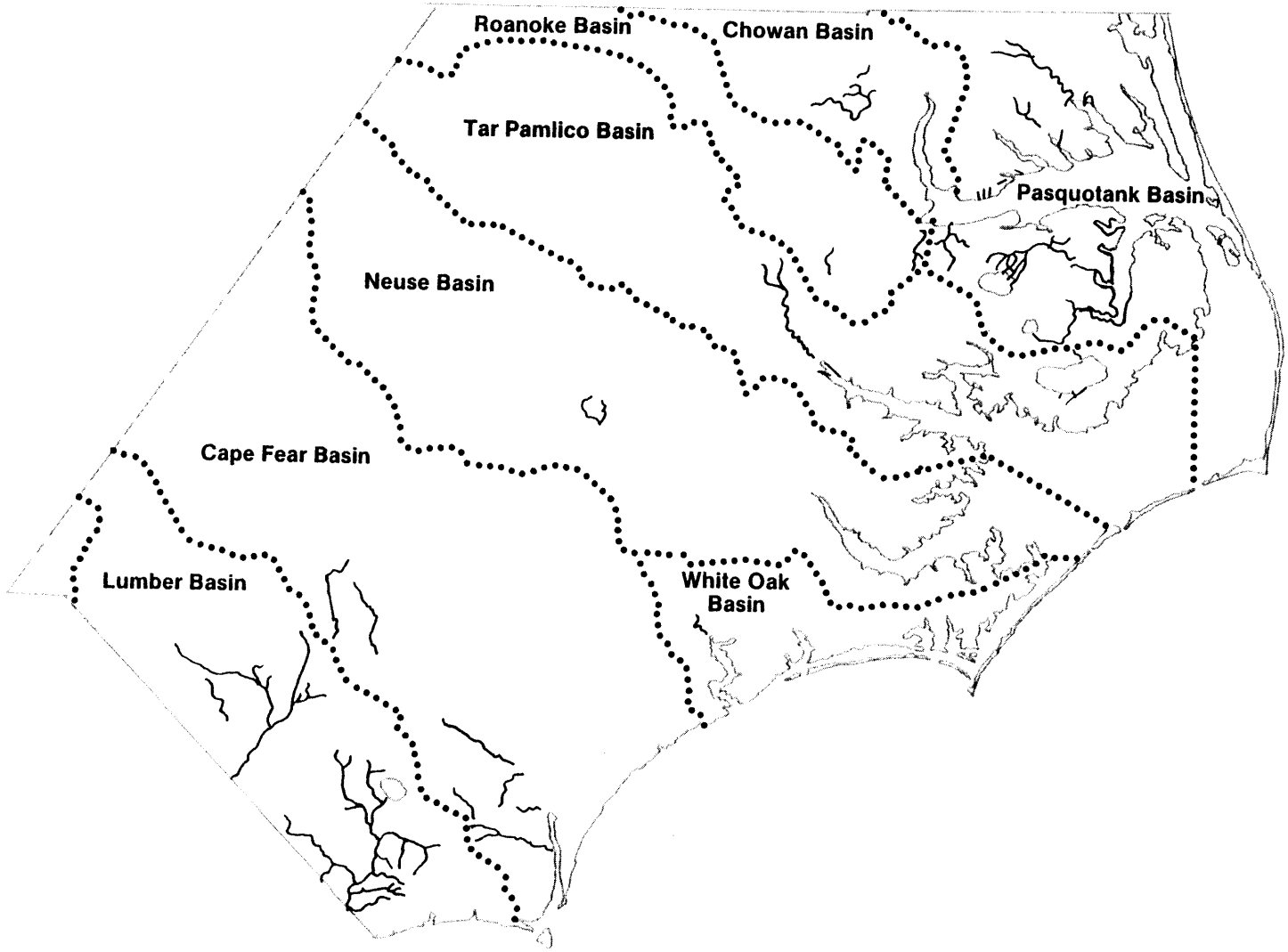

Figure 2. Locations of major infestations (heavy lines) in North Carolina in 1984.

impossible in reaches above Cross Landing. Draglines are often necessary to remove blockages from bridges crossing the river and tributaries. Alligatorweed in drainage canals below Phelps Lake that drain into the Scuppernong River and in drainage canals located in other areas of Washington and Tyrrell Counties totals 84 ha. This is a substantial area considering that this represents 339 km of canals (assuming an average canal width of 2.5m) that can indirectly affect large cropland and residential areas by causing flooding. Other major alligatorweed infestations associated with the northeast location occur in the Pasquotank River and tributaries, Little River, Symond Creek, Hall's Creek, Mackey's Creek, Canaby Creek, Ahoskie Creek, Tranter's Creek, and drainage canals in Hyde County.

Alligatorweed infestations in the southeast location are associated mainly with the Lumber and Waccamaw Rivers. One hundred and sixty five ha of alligatorweed were reported in the Lumber River and tributaries. These include Back Swamp, Little Jacobs Swamp, Jacobs Swamp, Big Swamp, and Old Field Swamp. One hundred and seventy five ha of alligatorweed were reported in the Waccamaw River and tributaries that include Grissett Swamp, Seven Creeks, CawCaw Swamp, White Marsh, Fryer Swamp, Scippio Creek, Wet Ash Swamp, and Bear Branch. On the periphery of this loci, 49 ha of alligatorweed were reported in Harrison Creek, Turnbull Creek, Livingston Creek, Town Creek, Hoods Creek, and Sturgeon Creek that drain into the Cape Fear River, and Lyons Swamp Canal that drains into the South River.

The 1043 ha of aquatic alligatorweed in North Caroline estimated in this survey is in contrast to 153 ha reported in 1963 (USACE, 1965). This apparent six-fold increase in a twelve-year time span is a good ex-

ample of the rate at which a noxious aquatic weed can become a major water resource problem if not managed at a maintenance control level.

Biological Suppressants

Alligatorweed Flea Beetle

Alligatorweed flea beetles did not result in measurable control of alligatorweed at the sites in Sampson and Pender counties where potentially cold-tolerant insects were released. Inspections during September and October 1983 revealed only minor feeding by the insects; and several inspections during 1984 revealed no evidence that the insects had overwintered.

Early June is the earliest that alligatorweed flea beetles can be expected to be available in sufficient quantity for mass release from collection areas in Florida. At the time of our release on June 7, 1984 the Thirty-foot Canal was 30% covered with alligatorweed. Ideally we would like to be able to introduce the insects when the mats are just initiating from the canal banks so as to prevent growth to this level. At the alligatorweed coverage that was present, our release rate was approximately 10 insects/m^{-2} of vegetation. Since the habitat was relatively restricted by canal banks and a culvert at the end of the release site we hoped to see some reduction of the alligatorweed mats as the population increased; and we planned to apply herbicides to part of the release site to determine if the insects could be used along with herbicides to prevent regrowth. However, nature intervened.

Five weeks after release of alligatorweed flea beetles, heavy precipitation occurred that caused alligatorweed mats in the Thirty-foot

canal to break loose. Vegetation piled up against the culvert at the end of the release site, and after severe flooding of adjacent fields occurred, the vegetation was removed by dragline. Several days after this occurrence alligatorweed flea beetles were observed feeding on the piled up alligatorweed and a residual population was observed feeding on the small amount of alligatorweed attached along the canal bank. This was an excellent opportunity to determine if an existing population of alligatorweed flea beetles could prevent regrowth of alligatorweed. Three weeks after the precipitation occurrence beetle-feeding was still evident but the alligatorweed was reforming a mat outwardly from the canal bank. Disappointingly, alligatorweed had regrown to 30-50% coverage of the canal water surface by mid-October (fifteen weeks).

Based on observations made during this project and on previous attempts to establish alligatorweed flea beetles in North Carolina (Langeland et al, 1983), we do not consider use of these insects as a potential alligatorweed suppressant in this area unless a cold-tolerant strain is selected that will overwinter in sufficient populations to cause suppression of alligatorweed as it emerges in spring. And, based on the apparent inability of alligatorweed flea beetles to suppress mat expansion in this study, it is still questionable whether a cold tolerant selection will be effective.

Alligatorweed Stemborer

Alligatorweed stemborer releases were not made during this project, however, during the extensive traveling through Coastal Plain areas to evaluate herbicide applications, damage from naturally occurring populations of these insects was noted. Damage from alligatorweed stemborer,

observed as wilting apical stem portions, totally necroticic stems, or completely necrotic mats was widespread from mid-August through October. Many mats that became totally necrotic began to regrow from sprouting or axillary buds after the insect population had apparently diminished or moved. Mats were sometimes observed to continue growth and expansion ahead of the damaged area. Unfortunately, damage occurs too late in the year and is not complete enough to offer alligatorweed control. Even the most damaged mats present as great a potential flooding problem and navigation impedance as the healthy mat.

It has been suggested (USAE, WES 1973) that mat destruction by insects late in the growing season could cause reduced vegetation density or elimination the following growing season. This phenomenon was not observed. Alligatorweed mats grew back rapidly the following year where complete necrosis of the upper mat had been observed the previous year.

It is unclear whether alligatorweed stemborers survive winter in North Carolina or whether observed populations migrate from more southerly locations. Considering the devastating temporary impact that stemborers have upon alligatorweed growth, early spring feeding may cause growth suppression. However, a better understanding of the insect's population ecology will be necessary to determine the feasibility of its use as a biological suppressant for alligatorweed in North Carolina.

Herbicide Evaluation

Floating Alligatorweed

Few herbicides are registered by the EPA for application to al-

ligatorweed growing in aquatic sites. A 1.25% solution of glyphosate with 0.5% non-ionic surfactant is recommended for alligatorweed management, although repeat treatment will probably be necessary[2]. To demonstrate the effectiveness of this application for controlling alligatorweed and, thus, the feasibility of implementing a maintenance alligatorweed management program, we cooperated with the North Carolina Department of Natural Resources and Community Development, Division of Water Resources, in reducing the alligatorweed infestation in the Scuppernong River, between the bridge on county road 1155 and the Washington County line, to a maintenance level. The initial application of glyphosate to the 2.5 ha of alligatorweed that had been rendering the river completely non-navigable was reduced by about 90%. By the time of the second application (9 weeks) regrowth was occurring from some of the treated vegetation, whereas some mats had totally disappeared. Some mats apparently break up sufficiently after glyphosate application to allow them to be carried away by the river current. Glyphosate was reapplied to sprouting alligatorweed in previously treated areas, and some areas that were inaccessible in October were treated.

By the spring of 1985, alligatorweed was well under control in the 1984 demonstration area. Only maintenance spot applications were needed for alligatorweed mats that had broken loose from oxbows that were inaccessible in 1984, and for alligatorweed rooted on the bank that was beginning to form floating mats.

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[2]Rodeo herbicide for Aquatic Vegetation Management, Technical Manual, Monsanto Ag. Prod. Co., St. Louis, Missouri 63167.

The feasibility of implementing a maintenance alligatorweed management program was clearly demonstrated. Using matching funds from the United States Army Corps of Engineers "Aquatic Plant Control Program (Rivers and Harbors Act 1965)" the cost of this project to the state and Washington County was only $1190. For this effort several miles of river channel were reopened to public boating access, a serious flood potential was removed, and the need for routine draglining at river bridges was eliminated. Benefit analysis for this project is reported in footnote 1.

Synergism Between Glyphosate and Fluridone for Controlling Alligatorweed. Glyphosate and fluridone were applied to rooted alligatorweed alone and tank-mixed to test for synergism between the two herbicides.

Excellent control (90-100%) was observed two and four weeks after application (WAA) of glyphosate at rates of 0.18 and 0.36 Kg ae/100 L (foliage sprayed to wet) when applied in late summer (Table 2). Herbicide damage was observed as total necrosis and death of the upper portions of the alligatorweed mat. However, sprouting of axillary buds from lower in the mat or from rhizomes was observed six WAA; and by nine WAA control was poor (70%) in those plots evaluated (Table 2). Forty eight WAA (spring of the following year) control was nil to fair in all plots. No control was observed sixty WAA when glyphosate was not reapplied the following year. When plots did receive reapplication of glyphosate at 0.36 Kg ae/100 L in midsummer, control was poor sixteen WAA and control was nil to poor 48 WAA.

The large number of axillary buds that produce glyphosate symptom-free growth and subsequent regrowth of the mat is surprising considering

Table 2. Efficacy of glyphosate and fluridone, when applied alone or together, for controlling alligatorweed (Alternanthera philoxeroides) in shallow drainage canals in Washington and Perquimans Counties, NC.

Herbicide & Rate[1] (kg ai/100 L)	Level of Control[2] at Weeks After First Applic.						Second Applic.		Date of Applic.	
	2	4	6	9	48	60	16	48	1st	2nd
Glyphosate (4L) 0.18	90	-	-	40	0	0	-	-	9/83	--
Glyphosate (4L) 0.36	-	99	80	-	0	-	50	50	8/83	7/84
	-	99	95	-	70	-	20	0	8/83	7/84
	-	98	90	-	60	-	20	0	8/83	7/84
	98	-	-	40	50	0	-	-	9/83	-
Fluridone (4AS) 0.24	-	0	50	-	0	-	-	-	8/83	-
	-	50	50	-	0	-	50	50	8/83	7/84
	-	0	50	-	0	-	-	-	8/83	-
	50	-	-	90	0	0	-	-	9/83	-
Glyphosate (4L) 0.18+ Fluridone (4AS) 0.12	40	-	-	100	80	0	-	-	9/83	-
Glyphosate (4L) 0.36+ Fluridone (4AS) 0.24	-	99	98	-	0	-	80	50	8/83	7/84
	-	100	99	-	0	-	98	50	8/83	7/84
	-	100	99	-	60	-	98	50	8/83	7/84

[1]All tank mixes contained 0.50% non-ionic surfactant, 0.075% polyacrylamide copolymer and were applied to wet foliage by handgun with a D-8 nozzle.

[2]0 = all vegetation living, 100 = all vegetation moribund.

the translocation of glyphosate in many other plants (Sprangle et al, 1975; Claus and Behrens, 1976). Glyphosate is apparently not translocated to the quiescent buds, and/or metabolized at/or before it reaches the axillary buds in alligatorweed. We observed that initial response of alligatorweed to glyphosate and other herbicides is leaf abscission and nodal abscission. Therefore, we speculate that much of the glyphosate is lost in this manner before it can be translocated to plant parts that are underwater, underground, or otherwise protected from the herbicide spray.

Alligatorweed responded inconsistently to fluridone applied in late summer at a rate of 0.24 kg ai/100 L (foliage sprayed to wet). Poor control was observed four WAA in plots where alligatorweed was growing in damp soil (Table 2, plots treated 8/83) (drainage had been diverted to another canal due to blockages caused by alligatorweed). Six WAA most leaves had abscised, stems were inconsistently chlorotic, and many initiating buds were chlorotic and aborting. However, vigorously growing buds without symptoms were also beginning to appear, and control was poor. Fluridone did not control alligatorweed in these plots forty-eight WAA. Reapplication of fluridone to one of these plots resulted again in only poor control the year of application (Table 2). Fifty percent suppression was observed throughout the following year in this plot with some fluridone symptoms still apparent. Application of fluridone (0.24 kg ai/100 L) to alligatorweed growing in a ditch containing some static water and super-saturated soil resulted in excellent control throughout the growing season (Table 2, plot treated 9/83), but no residual control was observed the following year.

The initial response of alligatorweed growing in damp soil (Table 2,

treated 8/83) to application of a tank mix of 0.36 kg ae glyphosate and 0.24 kg ai fluridone/100 L was similar to that of glyphosate alone. Excellent control was observed four WAA. Axillary buds that sprouted after this application exhibited fluridone symptoms and aborted shortly after initiation. This effect on sprouting axillary buds resulted in excellent control in all damp soil plots six WAA. This was somewhat better than the good to excellent control observed with glyphosate alone and considerably better than the poor control observed with fluridone alone. Nil to poor control of alligatorweed was observed forty-eight WAA in these plots, which is similar to the response observed with glyphosate or fluridone alone. Re-application of the tank mix to these plots the following year resulted in good to excellent control for most of the growing season compared to poor control after reapplication of the compounds by themselves; 50% suppression was evident consistently the following year.

Application of glyphosate and fluridone tank-mixed at rates of 0.18 kg ae + 0.12 kg ai/100 L, or 0.36 kg ae + 0.24 kg ai/100 L to alligatorweed growing in ditches containing some static water and supersaturated soil resulted in excellent control (Table 2, plots treated 9/83) for the nine weeks remaining in the growing season the year of application. This response is again considerably better than that observed with glyphosate alone but similar to the response of fluridone alone in a static water/supersaturated situation. The apparent increased activity of fluridone alone or tank-mixed with glyphosate in the wetter soil suggests that fluridone uptake is facilitated by this condition, and the efficacy of fluridone for controlling rooted alligatorweed is sensitive to soil moisture. Good control was evident

forty-eight WAA of both rates of tank-mixed glyphosate and fluridone in the super-saturated plots (Table 2, plots treated 9/83). However, control did not persist through the following growing season.

Effect of Glyphosate Concentration on Level of Alligatorweed Control. Although a great deal of variability was observed within the two rates of glyphosate that were replicated, a trend toward increased alligatorweed control was observed as the concentration of glyphosate was increased between 0.24 and 0.96 kg ae/100 L (Table 3) where applied in June. Poor control was observed in the unreplicated plot where the lowest rate was applied. Poor to excellent control was initially observed with 0.36 kg ae/100 L, but control was poor eight WAA and lost by eighteen WAA in all plots. Likewise, control was initially excellent in an unreplicated plot where 0.48 kg ae/100L was applied, but control was poor by eight WAA and nil 18 WAA. At 0.60 kg ae/100 L, the recommended rate for alligatorweed control, initial control was also poor to excellent, was still poor to excellent eight WAA and was nil to poor by eighteen WAA. At 0.96 kg ae/100 L, somewhat higher than the label rate, excellent control was observed through eight WAA in an unreplicated plot. However, even at this rate, control was poor eighteen WAA.

The somewhat reduced control observed with 0.36 kg ae/100 L, and with 0.60 kg ae/100 L applied in June, as compared to 0.36 kg ae/100 L applied in August and September (cf. Table 2 and Table 3), may be related to the physiological age of the alligatorweed, which allowed for even less translocation of the compound. The developmental stage of the plants may have caused this reduced control because large numbers of dormant buds had not initiated and were protected from the herbicide spray.

Table 3. Efficacy of various rates of glyphosate for controlling alligatorweed (Alternanthera philoxeroides) in shallow drainage canals located in Washington and Tyrrell Counties, NC, when applied in June, 1984 or reapplied in October, 1984.

Rate[1] (Kg ae/100 L)	Level of Control[2] at Weeks After First Application			Level of Control[2] at Weeks After Second Application		
	2	8	18	4	32	40
0.24	50	40	0	-	-	-
0.36	50	70	0	-	-	-
	95	50	0	-	-	-
	70	10	10	-	-	-
	50	10	0	100	50	0
0.48	96	50	0	-	-	-
0.60	50	80	0	-	-	-
	90	90	0	-	-	-
	70	50	30	-	-	-
	80	10	0	-	-	-
0.96	100	100	20	-	-	-

[1]All tank mixes contained 0.50% non-ionic surfactant, 0.075% polyacrylamide copolymer and were applied to wet foliage by handgun with a D-8 nozzle.

[2]0 = all vegetation alive, 100 = all vegetation moribund.

Efficacy of 2,4-D and Dicamba for Controlling Alligatorweed. Application of 2,4-D, dicamba, and a formulated combination of these herbicides at recommended rates for perennial broadleaf weed control resulted in good to excellent initial control with 2,4-D and excellent initial control with dicamba or the formulated combination (Table 4), when applied in spring, the time when these compounds should be most effective. After the initial damage from the herbicides (observed as total destruction of the upper portions of the mat), sprouting of axillary buds from lower portions of the mat and fragmented vegetation began and regrowth was rapid, resulting in poor control eight WAA and no control eighteen WAA. As suggested for glyphosate, rapid wilting and leaf and nodal abscission are probably responsible for the apparent lack of translocation and poor control at the rates of these compounds that were used and, which are effective for controlling many other broadleaf plants.

Efficacy of Imazapyr for Controlling Alligatorweed. Damage to alligatorweed appeared slowly after application of 0.03, 0.06, or 0.12 kg ae imazapyr/100 L. Symptoms were first observed as etiolation of the apical bud and apical growth followed by abortion of apical buds. These symptoms were subsequently (four weeks) observed on axillary growth. Symptoms appeared somewhat more rapidly with increasing concentration, but control was slow to occur in all cases. Two WAA, no control was observed at the lowest rate, nil to poor control at the middle rate, and

Table 4. Efficacy of 2,4-D and dicamba for controlling alligatorweed (Alternanthera philoxeroides) in a shallow drainage canal located in Tyrrell County, NC, when applied in June, 1984.

Herbicide	Rate[1] (Kg ae/100 L)	Level of Control[2] at Weeks After Application		
		2	8	18
2,4-D (dimethylamine)	0.46	80	50	0
2,4-D (dodecylamine (47.3%)	0.32	85	50	0
		80	50	0
		90	30	0
Dicamba (dimethylamine)	0.48	98	20	0
		100	60	0
		95	50	0
Dicamba (dimethylamine +	0.12+0.23	98	50	0
2,4-D (dimethylamine)		100	60	0
		99	50	0

[1]All tank mixes contained 0.50% non-ionic surfactrant, 0.075% polyacrylamide copolymer and were applied to wet foliage by handgun with a D-8 nozzle.

[2]0 = all vegetative alive, 100 = all vegetation moribund.

Table 5. Efficacy of imazapyr for controlling alligatorweed (Alternanthera philoxeroides) in shallow drainage canals located in Washington, Tyrrell, and Perquimans Counties, NC.

Rate[1] (Kg ae/100 L)	Level of Control[2] at Weeks After First Application					Level of Control[2] at Weeks After Second Application		Applic.Date	
	2	8	18	38	60	16	48	1st	2nd
0.03	0	100	--	30	0	--	--	8/83	--
0.06	0	100	--	90	--	100	100	8/83	8/84
	20	98	90	90	--	100	--	6/84	7/85
	50	100	99	--	--	--	--	6/84	
	0	95	99	--	--	--	--	6/84	
0.12	0	100	--	90	--	100	100	8/83	8/84
	50	95	99	95	--	100	--	6/84	7/85
	80	99	99	--	--	--	--	6/84	
	50	100	99	--	--	--	--	6/84	
	50	100	99	--	--	--	-	6/84	

[1]All tank mixes contained 0.50% non-ionic surfactant, 0.075% polyacrylamide copolymer, and were applied to wet foliage by handgun with a D-8 nozzle.

[2]0 = all vegetation living, 100 = all vegetation moribund.

only poor to good control at the highest rate (Table 5). The slow rate at which damage occurred to alligatorweed after application of imazapyr may have allowed for good translocation of the herbicide, to which alligatorweed is apparently highly sensitive. Eight WAA of imazapyr, excellent to total control of alligatorweed was observed in all plots, and eighteen WAA, excellent to almost total control was still observed in all plots evaluated. Living alligatorweed in the plots was apparently encroaching from areas of the ditchbank that had been missed by the herbicide spray, and not from regrowth of the affected alligatorweed. Imazapyr gave season-long control of alligatorweed after spring or summer application of all rates tested. In spring of the following year (48 WAA), excellent control was still observed in those plots evaluated (some plots were not evaluated further due to flushing and movement of alligatorweed mats in the ditches after high water conditions) where the two higher rates had been applied, but control was now poor at the lowest rate. As was observed the previous year, living alligatorweed in plots where the higher rates were applied was apparently a result of not receiving herbicide spray. However, at the lowest concentration, regrowth was occurring throughout the plot. Total regrowth occurred sixty WAA of this lowest rate. Re-application of either of the two higher rates to the small amount of vegetation remaining in the plots resulted in apparent complete elimination of alligatorweed from the plots.

A concern when using a highly phytoactive compound such as imazapyr for aquatic weed control is movement of the compound in water to non-target areas. It is therefore important that imazapyr symptoms were not observed outside the application area. A distinct demarcation of living

and moribund vegetation occurred at the edge of all plots. Imazapyr was apparently intercepted in sufficient quantity by the target vegetation and not released in active form, or rendered inactive after contact with water or soil in the ditch.

Preliminary Unreplicated Evaluations of Other Herbicides for Controlling Alligatorweed. Complete control of alligatorweed was observed with tryclopyr at a rate of 0.36 kg ae/100 L six and twelve WAA (Table 5). Translocation of the herbicide apparently occurred throughout the mat, because axillary bud sprouting was never observed and living rhizomes could not be found in the plot. Tryclopyr is not presently registered for aquatic weed control, but this labeling may be forthcoming. Tryclopyr may offer the most economical control for rooted alligatorweed and should be investigated further. Sulfmeturon methyl and metsulfuron methyl are closely related compounds that gave fair to good, and good to excellent control, respectively, when applied at various rates (Table 6). Therefore, these two compounds offer some potential for use in an alligatorweed control program, but further investigations should only be pursued if the manufacturer indicates the potential for obtaining an EPA registration for aquatic weed control. Hexazinone, diuron, fenatrol, and bromacil are compounds that are, at least, predominantly soil active. Therefore, even though good to excellent control was observed with these compounds (Table 6), they will have only limited application in an alligatorweed control program. Alligatorweed did not exhibit sensitivity to amitrole.

Table 6. Efficacy of several herbicides for control of alligatorweed (Alternanthera philoxeroides) in shalow drainage canals located in Washington County, NC.

Herbicide & Rate[1] (ai/100 L)		Application Date	Level of Control[2] at Weeks After Application			
			6	12	48	60
Diuron	3.84 kg	9/83	100	--	20	0
Fenatrol	3.90	10/84	--	--	100	--
Amitrole	1.44	10/84	--	--	0	--
Bromacil	0.96	6/85	70	90	--	--
Hexazinone	0.96	6/85	80	80	--	--
Triclopyr	0.36	6/85	100	100	--	--
Sulfmeturon methyl	33.75 g	8/85	75	--	--	--
	67.50		85	--	--	--
Metsulfuron methyl	1.13	8/85	80	--	--	--
	2.26		90	--	--	--
	4.52		95			

[1] All tank mixes contained 0.50% non-ionic surfactant 0.075% polyacrylamide copolymer, and were applied by handgun to uniformly cover the canal bottom and bank.

[2] 0 = all vegetation living, 100 = all vegetation moribund.

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Appendix

AGRICULTURAL
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North Carolina State University
School of Agriculture and Life Sciences

Crop Science Specialist - Weed Control
Box 7627
Raleigh, NC 27695-7627

August 17, 1984

MEMORANDUM

TO: County Extension Chairmen, District Fisheries Biologists, Soil Conservation Agents

FROM: K. A. Langeland

We are conducting a survey to determine the total acreage, and extent of problems caused by alligatorweed (Alternanthera philoxeroides) (sometimes called Hitlerweed in Eastern North Carolina). We hope that you can assist us in this effort.

Alligatorweed is an aquatic plant that was introduced into the United States from South America in the 1890's. It has caused severe flooding, loss of recreational value of water resources, and reduction in crop yields in several coastal North Carolina counties. We believe that a statewide alligatorweed management program, involving several agencies could correct current problems caused by alligatorweed and prevent potential problems. Prerequisite to organizing such a program is documentation of the extent of the problem.

Attached you will find a description and sketch of alligatorweed and a form that we must complete for each county. If you can complete the table without our assistance, please complete and return to:

K. A. Langeland
NCSU Weed Science Center
3123 Ligon Street
Raleigh, NC 27607
Phone: 919/737-2866

Maps locating infestations, documentation of flooding, historical notes, or any other information relating to alligatorweed in your county or area will be helpful. If you would like assistance in identifying alligatorweed or in conducting the survey, please contact me so that we can assist you. This request is being sent to County Extension Chairmen, District Fisheries Biologists, and Soil Conservation Service Agents, so please coordinate with these people to prevent duplication.

Please inform me as to how you intend to participate, or if you cannot assist, by September 1, 1984. Your cooperation will be greatly appreciated.

AGRICULTURAL
EXTENSION
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North Carolina State University
School of Agriculture and Life Sciences

K. A. Langeland
Crop Science Specialist - Weed Control
Box 7627
Raleigh, NC 27695-7627
Phone - 919/737-2866

Alligatorweed
(Alternanthera philoxeroides)
from E. O. Beal, 1977

ALLIGATORWEED is an herbaceous plant that forms dense floating mats on the water surface, can root into the substrate in shallow ditches and lake margins, and can invade moist soils.

Leaves are elliptic to oblanceolate (broadest above the middle), entire (smooth edges without teeth) and opposite. Stems are usually laying on the water surface or ground and only weakly erect toward the ends. Roots often develop at the nodes (where leaf and stem join). Stems can be up to one inch thick in floating mats, but tend to be narrower when rooted. The stems are always hollow which distinguishes alligatorweed from similar plants such as smartweed (Polyganum spp.). Flowers are white and occur in round clusters at the end of spikes that arise from the upper leaf axils.

Major identifying characteristics

1. Opposite entire leaves
2. Hollow stems
3. White flowers