Integrated Aquatic Plant Management Plan for Parrotfeather Management on the Chehalis River

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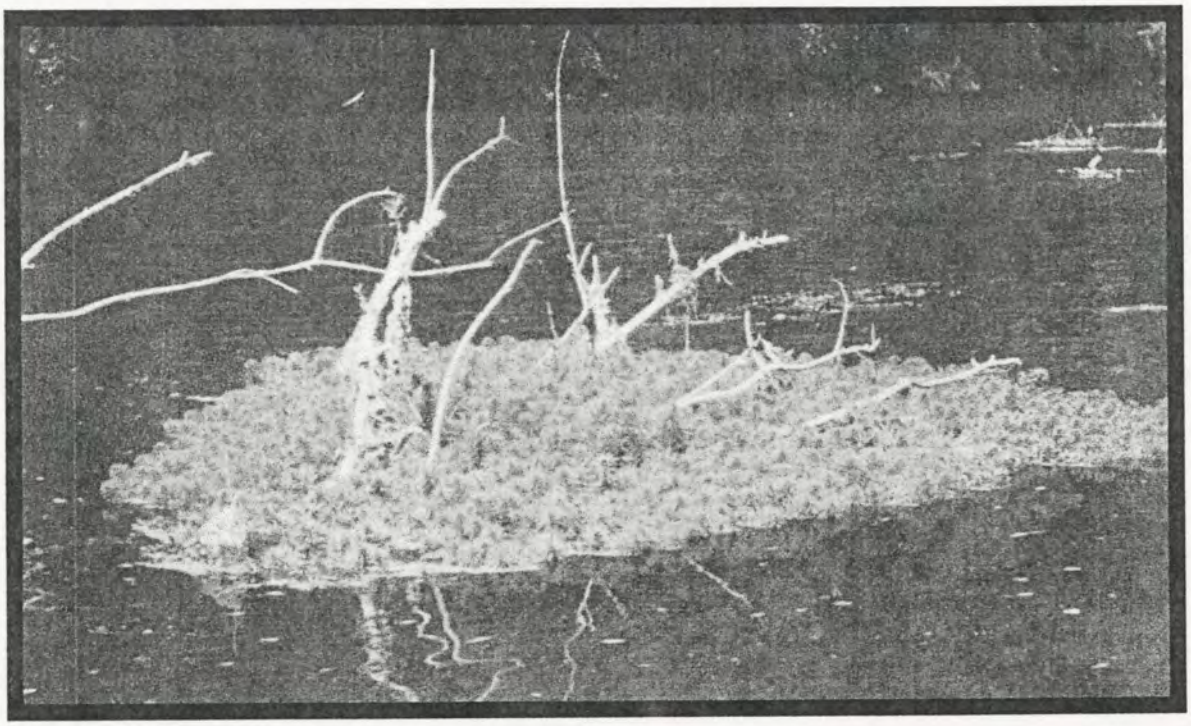

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Purpose

The purpose of the action plan is to provide a baseline to work from in the management of parrotfeather in the Chehalis River system. In order for the plan to work, various volunteer groups, agencies and landowners will have to participate for the program to succeed. The goal of the plan is not to just target parrotfeather as another weed problem or blemish on the landscape, but to direct our control efforts as a way of protecting the benefits and the ecological characters that the Chehalis River provides to the region.

Chehalis River Basin Description:

The Chehalis River Basin lies between the Deschutes River Basin on the east and the Cowlitz River Basin on the south, the Willapa Hills on the west, and the Olympic Range on the north. The basin includes parts of Lewis, Thurston, Cowlitz, Pacific, Grays Harbor, Mason, Jefferson, and Wahkiakum counties.

The Chehalis River Basin is the second largest river basin in the state of Washington outside the Columbia River Basin. The total drainage area of the Chehalis River Basin is 2,660 square miles of which approximately 85% is forest lands. Approximately 257 square miles (164,000 acres), or 9.7% of the basin is agricultural land.

The Chehalis River system is largely rain-fed with precipitation levels which range from 45 inches per year in the eastern Chehalis River valley to over 200 inches in the Olympic Mountains. Estimated average annual discharge of the entire basin is 11,208 cubic feet per second.

The major population centers, Chehalis, Centralia, Elma, Montesano, Aberdeen, and Hoquiam, depend on surface waters of the basin for the largest portion of their municipal and industrial supplies. The principal industrial use of water is in the manufacturing of wood, pulp and paper products. Aberdeen's industrial water system supplies most of this water from the Wynoochee River, with the remainder from Lake Aberdeen.

Land within the basin is mostly forest cover with interspersed agricultural and residential areas. Forest lands, which constitute approximately 77% of the Upper Chehalis Basin (upstream of Porter) and 91% of the lower basin (downstream of Porter), are generally located on the upland areas with scattered amounts on bottom lands. Most forested acres are corporation-owned with the remainder being privately or government-owned (Capitol State Forest, Mt. Baker-Snoqualmie National Forest and Olympic National Forest).

Intensive agriculture and irrigation occur mostly in the low-lying valleys along the Chehalis River and its tributaries. Commercial farms in the basin are following national trends of increased acreage and reduced numbers. Primary use of agricultural land is for crop production (133,000 acres). Pasture comprises 1.8%, or 31,000 acres, of the basin. The anadromous fish resources of the basin are of national significance to sport, tribal, and commercial fishing and are important to the economy of the Chehalis Basin.

Background: Parrotfeather

Parrotfeather, *Myriophyllum aquaticum,* has been introduced worldwide for use in indoor and outdoor aquaria, because of its attractiveness and ease of cultivation. It is also a popular aquatic garden plant. However, it has escaped cultivation and spread by plant fragments and intentional plantings. While parrotfeather may provide cover for some aquatic organisms, it can seriously change the physical and chemical characteristics of lakes and streams. Infestations can alter aquatic ecosystems by shading out the algae in the water column that serve as the basis of the aquatic food web. In addition, the plant provides choice mosquito larvae habitat. In California, the species is becoming an increasing problem in irrigation and drainage canals. A 1985 survey of irrigation, mosquito abatement, flood control, and reclamation agencies in California indicated that parrotfeather infested nearly 600 miles of waterways and over 500 surface acres. In Washington, the Longview Diking District estimates that it spends about $30,000-40,000 per year on parrotfeather control in drainage ditches. Dense infestations in southern Africa have caused flooding and drainage problems in shallow rivers and streams. The plant can also restrict recreational opportunities in these bodies of water.

Plant Description

Parrotfeather gets its name from its feather-like leaves which are arranged around the stem in whorls of four to six. Parrotfeather has both submersed and emergent leaves, with the submersed form being easily mistaken for Eurasian watermilfoil (*Myriophyllum spicatum*), a close relative. The submersed leaves are 1.5 to 3.5 centimeters long and have 20 to 30 divisions per leaf. The emergent leaves are 2 to 5 centimeters long and have 6 to 18 divisions per leaf. The bright green emergent leaves are very stiff and a darker green than the submersed leaves. The emergent stems and leaves are the most distinctive trait of parrotfeather, as they can grow up to a foot above the water surface and look almost like small fir trees. Submersed leaves are limp and often appear to be decaying, but the stems are very robust. Adventitious roots form at the nodes. When attached to a bank, parrotfeather stems can extend out several yards over the water surface. Flowers are inconspicuous and are borne in the axils of the emergent leaves. The white flowers are approximately 1/16 inch long.

Distribution

Parrotfeather is a native of the Amazon River in South America, but it has naturalized worldwide, especially in warmer climates. In the United States, the plant is found throughout the southern United States and northward along both coasts. It is found further north on the west coast, because of the milder climates associated with the more northern latitudes on the west coast.

Presently, Washington's parrotfeather infestations appear to be limited to coastal lakes and streams, and the southwest Washington portion of the Columbia River. Parrotfeather is found throughout the drainage system in the Longview/Kelso area, infests many of the drainage ditches in Wahkiakum County, and was discovered growing in the Chehalis River in 1994. As of 1996, no parrotfeather populations have been discovered in eastern Washington.

Parrotfeather is found in freshwater lakes, ponds, streams, and canals and appears to be adapted to high nutrient environments. It tends to colonize slowly moving or still

water rather than in areas with higher flow rates.

While it grows best when rooted in shallow water, it has been known to occur as a floating plant in the deep water of nutrient-enriched lakes.
The emergent stems can survive on wet banks of rivers and lake shores, so it is well adapted to moderate water level fluctuations.

Even in South America, virtually all parrotfeather plants are female. Male plants are unknown outside of South America, so no seeds are produced in North American populations. Since parrotfeather also lacks tubers or other specialized reproductive over-wintering structures like turions, it spreads exclusively by plant fragments outside of its native range. Unlike Eurasian watermilfoil, parrotfeather does not form autofragments. However, fragments can be formed mechanically and will readily root. With its tough rhizomes, parrotfeather can be transported long distances on boat trailers. Rhizomes stored under moist conditions in a refrigerator survived for one year.

Legal Direction, Cooperation and Stewardship

Parrotfeather, *Myriophyllum aquaticum* is a Class B noxious weed on the Washington State Noxious Weed List. It is designated for mandatory control in all counties except Clark, Cowlitz, and Wahkiakum counties. Parrotfeather was adopted to the State Weed List in 1994 by the Washington State Noxious Weed Control Board (WSNWCB). The Washington State Dept. of Agriculture with cooperation from the WSNWCB oversees and directs the regulations of the plant quarantines.

Cooperation with landowners and the public is integral to the management of noxious weeds. In the aquatic / riparian environment it is not always clear where landownership starts or ends. It is the desire of the Lewis County Noxious Weed Control Board that everyone look beyond jurisdictional boundaries and take an active role in management of parrotfeather and the stewardship of the Chehalis River.

Goal One
Integrated Weed Management

Determine the best methods for an integrated approach to weed management and implement on-the-ground operations.

Discussion:

It is recognized that an Integrated Weed Management approach, where all weed management practices are considered for use, is the best approach where noxious weeds have infested an area.

Where noxious weeds do not currently exist, the cheapest, most effective, and highest-priority IWM technique is prevention. IWM is a decision making process that uses site specific information to make decisions about treatment choices. IWM is based on the fact that combined strategies for weed management work more effectively than a single strategy. These strategies for the control of parrotfeather are discussed in greater detail in the appendices.

Prevention methods, bottom screening, manual and mechanical removal, and herbicide treatments are the control techniques that are available for the management of parrotfeather.

Is eradication of parrotfeather in the Chehalis River a realistic goal or even a desirable goal in terms of cost or environmental impacts? A great deal of information about parrotfeather management is not fully understood in this river system which makes this question difficult to answer at this time. Regardless of whether the plant can be eradicated, control measures needs to be approached with both long term and short term objectives. The short term objectives should focus on prevention and trying to achieve no new infested areas.

Other short term objectives would include: control of lightly infested areas and control of satellite areas.

Areas that are large and well established should be treated with the objective of controlling the perimeter spread. Containment of these areas for a period of time will hopefully allow other control techniques to be proven and then applied.

Strategies:

Conduct IWM using the best combination of the following control tactics:
Cultural
Physical
Biological
Herbicides
Prevention

Selection criteria of pest management methods:

Least hazardous to human health.
Least damaging to the general environment.
Most cost effective in the long and short term.
Easiest to carry out.
Least toxic to non-target organisms.

Goal Two
Inventory-Survey-Monitoring

Ensure that adequate inventory data are available on the distribution of parrotfeather.

Discussion:

Early detection, treatment and containment of invaders is an extremely effective method of weed management. Future periodic surveys followed by prompt treatment will ensure that new invaders do not become established and spread further.

Strategies:

Use of a standard inventory and mapping guideline will be used.

Maintain records with the following information:
Locations of infestations including river mile, date found, name of field person, area and density involved (% covered), identification of other surrounding aquatic plants.

Where possible include a data point with the aid of Geographical Position Systems (GPS) unit.

Annual surveys should occur sometime during the months of July, August and September.

Surveys should be carried out with a boat that is best suited for the various water conditions on the Chehalis River.

Survey efforts should include those river miles where parrotfeather was not previously recorded.

Maintain records on control treatments and the evaluation of their effectiveness.

Survey data will be updated on an annual basis.

In cooperation with others (public and agencies) develop and implement automated databases for the storage and retrieval of parrotfeather location information.

Ensure that the data is functional for use in geographical information Systems and made available to others.

Encourage the public to utilize the volunteer survey form to assist in recording noxious weed locations.

Monitor and note changes in plant (Parrotfeather) characteristics.

Emphasis is placed on learning the best, least problem causing method for managing parrotfeather at each site.

Goal Three
Prevention and Detection

Develop and maintain a prevention and early detection program.

Discussion:

Prevention, early detection, and eradication of early- detected parrotfeather sites are the most practical, economical, and effective means of weed management where weeds have not currently been introduced or established. Prevention is best accomplished by ensuring that new vegetative reproductive plant parts are not introduced into a new area.

Early detection is identifying and documenting newly introduced parrotfeather plants into formerly uninfested areas. This task can be greatly enhanced by encouraging adjacent landowners, managers, and river users to recognize and document parrotfeather populations, and coordinate their efforts with state and local parrotfeather management entities.

Common methods of introduction include:

Movement of unclean boats, trailers, and gear to clean sites.

Natural movement of broken plant fragments.

Sales of parrotfeather for landscaped ponds or aquariums.

Movement by wildlife including: Beaver, Otter & Nutria.

Strategies:

Maintain signs at boat launches in the region.

Ensure that quarantines are enforced.

Work with other agencies to consider and include information regarding noxious weeds.

Focus survey efforts to detect new or small sites.

Distribute and encourage the use of the parrotfeather inventory form.

Work with watershed groups to increase awareness of noxious weeds.

Generate volunteer groups to help spread the word about parrotfeather and to accomplish the goals of the IWM Plan.

Goal Four
Education and Awareness

Generate support of the program for parrotfeather management.

Discussion:

Awareness of what parrotfeather is and the problems it causes will help land managers and the public understand why long-term management is important. Education about the impacts of parrotfeather to the natural diversity of flora and fauna of an area is an important facet of any long-term weed management plan.

Federal, State, and local agency personnel, as well as private landowners involved in parrotfeather management programs, should have proper training in the management methods.

Educating the next generation of land managers and landowners is just as important as what current land managers and landowners know today.

Knowing how and where parrotfeather is spread is critical in preventing the expansion of parrotfeather into new territories. Recognizing that parrotfeather fragments can be spread on boats, trailers, gear, and even by some species of wildlife, is essential in knowing how to prevent the spread of parrotfeather. Relaying this information to the public, other agencies, and the academic community will greatly assist in the effort of parrotfeather control.

Strategies:

Develop and deploy various educational and public awareness materials, including video tapes, printed brochures, posters and county fair displays. Distribute the information to river groups, hunters, fisherman and at boat launches.

Recruit volunteers for the opportunities to train others and to assist with the awareness campaign.

Develop and implement outreach plans at both the County and State office levels to improve public understanding of the need to control the spread and to manage the populations of parrotfeather.

Target these audiences:
Schools
Youth organizations
Watershed and sub-watershed groups.
Water recreation clubs and other casual river users.
Fisherman and hunters.
Tribal members.
Native plant societies and garden clubs.

Goal Five
Coordination and Planning

Ensure that management for parrotfeather is carried out efficiently and consistently across jurisdictional and political boundaries.

Discussion:

It is imperative that the Lewis County Noxious Weed Control Board continue and expand the cooperation with other Weed Boards, agencies, organizations and private landowners in the fight against parrotfeather.

Sharing weed management plans, training sessions and other resources will improve efficiency and effectiveness.

Strategies:

Initiate and continue coordination with other groups and agencies.

Develop and support training courses in inventory, monitoring, and control methods with opportunities for field level participation.

Coordinate treatment of parrotfeather with other local groups or agencies responsible for noxious weed control.

Develop and standardize the procedure for data storage, management and exchange.

Identify and initiate the process for securing financial resources to carry-out weed management plans for parrotfeather.

Re-evaluate and refine treatment tactics and changes to the management system.

Focusing Efforts:

Establish management priorities for parrotfeather in the following areas:

Stop the spread to uninfested lands.

Concentrate on small patches and isolated infestations.

Contain heavily weed-infested areas.

APPENDIX ONE
Integrated Weed Management Guidelines

Cultural Control

Quarantines
Quarantines identify plants known to be invasive and a detriment to the state's natural resources. Current Washington regulations prohibit parrotfeather to be transported, bought, sold, offered for sale, or to distribute plants or plant parts or to intentionally transport plants or plant parts. These regulations will serve to prevent the continued introduction of parrotfeather into Washington.

Re-vegetation / Shading
Little information is known about the use and effectiveness of Re-vegetation or plant competition as a means of controlling parrotfeather. Areas have been observed where parrotfeather is a co-dominate with Reed Canarygrass, *Phalaris arundinacea*, an aggressive perennial grass.

Parrotfeather is not affected by the low light of shaded areas. Observations of parrotfeather indicate that it grows very well under dense shaded canopies of Willow, *Salix spp.* and in full sun light.

Wildlife Manipulation
While conducting the plant surveys on the Chehalis River, there were several parrotfeather sites where there was significant wildlife activity. Beaver, Otter, and Nutria were suspected of creating trails on the river banks and through the dense parrotfeather vegetation. The animal activity caused the plants to break or fragment resulting in further spread of parrotfeather. Before plant control actions are taken consider the following:
1. Determine whether wildlife or wildlife feeding programs can be managed to reduce parrotfeather infestations.
2. Determine the feasibility of manipulating wildlife movement that would reduce or contain the parrotfeather infestation.

Physical Control

Bottom Screening
Bottom screening provides an inexpensive and effective means of controlling aquatic plants. A bottom screen is a cloth-like material that covers the plant being controlled. The screens block light, preventing the growth of the plant.

Screening materials should be opaque and of a sturdy material that doesn't tear easily. Ideally these materials should be heavier than water and permeable to the gases that will be generated by rotting vegetation. Materials suitable for screening include burlap, woven synthetics, perforated black mylar, landscaping fabric, and geotextile used in road construction. Remember that some fabrics, such as burlap, will deteriorate more rapidly than others. Screening material is generally stretched across a pre-constructed frame.

Keep in mind that the materials used for framing need to be durable (metal or wood).

Bottom screening has some limited use in controlling parrotfeather. Work performed by the Lewis Co. Weed Board indicates that the changing water levels, associated woody debris, uneven terrain, livestock, wildlife and the aggressive rhizomatous expansion of the plant may limit this measure as an effective tool on well established plants. Barriers need to be placed early and maintained regularly through the fall season.

Where the parrotfeather is not suspended in water, the use of a clear or black plastic covering may be an effective measure to kill small, compact infestations. The covering will trap heat and increase temperature that will be highly destructive to the weed.
Timing: May, June.
Tools / Equipment: cardboard, geotextile fabrics, burlap, frame material, stakes, rope, plastic film.
Permit required.

Manual Removal

Hand pulling or raking out, water suspended plants is manageable and effective on small patches. Hand pulling parrotfeather that is rooted into the substrate or entangled in woody debris results in the stems breaking and stimulating new shoots to emerge. Follow-up treatments will be essential to ensure complete removal. In addition careful attention has to be given to removing any broken fragments during the removal process.

Removal of the plant material off site is the best method of disposal. The plant material can also be placed in plastic bags and allowed to decompose on site. The decomposition will occur quickly during the summer months when temperatures are high. It shouldn't be relied upon during the fall season. Removal of the plastic bags needs to occur prior to increased water levels. Paper sacks did not give the same results in the decomposition of the plants.
Timing: Months of June, July, August.
Tools /Equipment: Garden rake, plastic bag, boat (?), large, plastic containers. *Permit required.*

Controlled Burning \Steam

Controlled burning is an effective tool when used for annual weeds control and for some perennial weeds when incorporated with other practices . The high water content of parrotfeather and its affiliation with an aquatic environment would limit burning as an effective tool. It would take an enormous amount of energy to penetrate the layers of stems and leaves above the water level and would have no impact on the submersed vegetation.

The use of steam or hot water would require similar inputs compared to burning. Concern for the impacts on other aquatic organisms and an increases in water temperatures eliminates these treatments as an effective management tool.

Mechanical Removal

Parrotfeather populations can be successfully cut and harvested, but the dense and extensive rhizomes are very difficult to manage. The mechanical harvesting causes extensive fragmentation and broken plant pieces . These small portions of plant material are then very difficult to remove with machinery. Any plant cut but not removed will regrow rapidly.

Because parrotfeather can spread readily through fragmentation mechanical controls including rotovation (underwater rototilling) will only enhance the rate of spread in the

Chehalis River system.

Limited access points, difficulties in navigation through shallow water and extensive growth along the shorelines would restrict operations and increase the expense of operations. For these reasons mechanical removal is not recommended at this time in the Chehalis River system.

In closed water systems, (sloughs, ponds) mechanical control can be implemented similar to the Longview Diking District operation. They utilize a dragline and a truck-mounted crane with a special attachment to clean the ditches of parrotfeather. The drag line project operates from August to December each year with control generally lasting for one growing season. *Permits required.*

Biological Control

While biological control agents are not presently available, potential agents do exist. A complex of insects feed on parrotfeather in its native habitat. *Lysathia Flavipes* (Boheman), a flea beetle found on parrotfeather in Argentina, causes moderate damage to parrotfeather under field conditions. Also found in Argentina is a weevil, *Listronotus marginicollis* (Hustache), that apparently feeds only on parrotfeather in its native range. Additional insects have been found on parrotfeather in Florida. *Lysathia ludoviciana* (Fall.), a flea beetle native to the southern U.S. and Caribbean, will use parrotfeather as a host plant for larvae under laboratory conditions. However, the flea beetle is not found on parrotfeather in the field.

Two members of the tortricidae family, *Argyrotaenia ivana* (Fernald) and *Choristoneura parallela* (Robison) have also been found on parrotfeather in Florida, but their effect on the plant is unknown. In addition, larvae of the caterpillar, *Parapoynx allionealis* (Walker), mine parrotfeather leaves, but the impact these larvae could have on parrotfeather is also unknown.

Fungal control options exist as well. An isolate of *Pythium carolinianum* (Matt). collected in California has shown some promise as a potential bio-control agent. Parrotfeather stems that were experimentally inoculated with this fungus produced significantly less growth than control plants.

Grass carp are most appropriately used for impounded water bodies where low intensity control of submersed plants is desired. Grass carp have a distinct preference for the aquatic plants that they eat. Their use in a river system without a confinement system would not be effective in targeting the undesirable plant. The use of grass carp for parrotfeather control is not a viable or recommended control option.

Parrotfeather has a high tannin content, so most grazers, including grass carp and livestock, find it unpalatable. Observations of native waterfowl including ducks and geese indicate that parrotfeather is not a desired food source.

Herbicide Treatments

Although parrotfeather is considered by some to be susceptible to herbicides, it is difficult to achieve complete control. The emergent stems and leaves have a thick waxy cuticle, and it requires a wetting agent to penetrate this cuticle. Often the weight of the spray will cause the emergent vegetation to collapse into the water where the herbicide is washed off before it can be

translocated throughout the plant. Reports show excellent control of parrotfeather with 2,4-D, diquat, diquat and complexed copper, endothall dipotassium salt, and endothall and complexed copper. Fair control was obtained with acrolein and glyphosate. The Monsanto Company suggests that applying a 1 3/4 percent solution of Rodeo® (aquatic version of Roundup®) with surfactant to the plants in the summer or fall when water levels are low would give about 95 percent control of the plants. Control of parrotfeather may be achieved with low-volatility ester of 2,4-D at 4.4-8.9 kg ha, sprayed onto the emergent foliage. The granular formulation of 2,4-D is needed to control parrotfeather for periods greater than 12 months.

It is more effective when applied to young, actively growing plants. In actual practice, the Longview Diking District report little success with using herbicides to control parrotfeather. Glyphosate causes the emergent vegetation to turn black but within two weeks the plants have recovered. An experimental fall application of triclopyr to parrotfeather also proved to be ineffective. Of the above herbicides, endothall, glyphosate, and copper are permitted for aquatic use in Washington waters, but copper is generally permitted only as an algicide.

Fluridone is available as the EPA-registered herbicide Sonar® for use in the management of aquatic plants in freshwater ponds, lakes, reservoirs, and irrigation canals. Fluridone is effectively absorbed and translocated by both plant roots and shoots. Fluridone demonstrates good control of submersed and emergent aquatic plants, especially where there is little water movement.

Other herbicide treatments being explored include:
Repeated application of glyphosate to parrotfeather in seasonally dry areas where the herbicide would not be washed off.
Garlon 3A ®, triclopyr, is registered for use in seasonally dry ditches and other riparian settings. The effectiveness of this product will be evaluated as an effective measure.

Portland State University will be performing a research evaluation on the combination of Garlon 3A and Tryclopyr. The conclusion\ findings will be reported in January 1998.

APPENDIX TWO
Action Plan for Parrotfeather Management on the Chehalis River

Action Plan for Parrotfeather Management on the Chehalis River

Actvity		Timing	Responsibility(*)
Coordination and Planning			
1.	Coordinate with other agencies and tribes to increase the efficiency of survey datta storage, management and exchange.	Feb - April October - November	LCNWCB
2.	Develop and support training courses in inventory, monitoring and control methods with opportunities for field level participation.	Feb - April	WEED BOARDS
3.	Continue to identify and initiate the process for securing financial resources to carryout weed management plans for parrotfeather.	Year round	WEED BOARDS, CRC, DOE, CTC, DNR, WDFW
4.	Continue to coordinate the education, surveying, and control of parrotfeather with other local groups, agencies and tribes responsible for noxious weed control.	Year round	LCNWCB
5.	Evaluate the parrotfeather management program and recommend necessary changes to achieve goals.	Annually	WEED BOARDS, DOE, WSNWCB
Education and Awareness			
1.	Educate and encourage the public to: identify parrotfeather, utilize the volunteer survey form to record noxious weed locations, and pull small sites where applicable.	Year round	WEED BOARDS, CRC, DOE
2.	Distribute educational and public awareness material about aquatic noxious weeds to hunters, fishermen and various river users.	Year round	WEED BOARDS, CRC, DOE
3.	Install and maintain parrotfeather information signs at public boat launch sites.	Year round	WEED BOARDS
4.	Continue to work with organized watershed and river groups, hunters, fishermen and boating clubs to increase awareness of the impact of aquatic noxious weeds.	Year round	WEED BOARDS

Action Plan for Parrotfeather Management on the Chehalis River

Activity		Timing	Responsibility
Parrotfeather Control			
1.	Carryout research on herbicides and other treatments to control parrotfeather.	January '97 & '98	LCNWCB, PSU
2.	Continue wtih field survey to observe and record changes in the biological characteristics and environmental impacts on parrotfeather.	Year round	TECHNICAL STAFF
3.	Apply and evaluate barrier and hand pulling sites to determine the impact on parrotfeather.	June - September	TECHNICAL STAFF
4.	Continue to generate a volunteer base to conduct surveys and carryout hand control actions.	April - September	WEED BOARDS, CRC
5.	Apply for permits to use herbicides and barriers to control parrotfeather.	February, March, April	WEED BOARDS, AQUATIC APPLICATORS
6.	Survey and identify heavily infested areas and achieve control through targeted applications of aquatic herbicides.	June - September	WEED BOARDS

Process:

The Action Plan activities (Control\Survey, Coordination\ Planning and Education \ Awareness) will be carried out in the months described from 1997 through 2002. At the beginning of each growing season, an evaluation of the previous years actions will be reviewed by a technical review committee.

The committee will evaluate the results of control treatments, surveys of plant communities and awareness efforts.

Process (continued)

The number of parrotfeather sites recorded, plant coverage and densities and the actual number of people involved in the education and volunteer efforts will be included as measurable findings in evaluation of the Plan for Parrotfeather Management on the Chehalis River.

With the conclusions from the evaluation process, and the addition of any new information, the management objectives will be included in the upcoming years work plan.

In January of 2002 a full assessment of the Management Plan For Parrotfeather Management o the Chehalis River will be made by the review committee and future actions will be directed by the group.

The Technical Review Committee will be made up of Weed Board Coordinators, and representatives from the Dept. of Ecology , Washington State Noxious Weed Control Board, The Chehalis Tribal Council, Dept. of Natural Resources and the Dept. of Fish and Wildlife.

* LCNWCB ..... Lewis County Noxious Weed Control Board
WEED BOARDS ..... Grays Harbor County , Lewis County, Thurston County
CRC ..... Chehalis River Council
DOE ..... Department of Ecology
DNR ..... Department of Natural Resources
WDFW ..... Washington Department of Fish and Wildlife
CTC ..... Chehalis Tribal Council
WSNWCB ..... Washington State Noxious Weed Control Board
PSU ..... Portland State University
AQUATIC APPLICATORS ..... Washington State Certified Applicators
TECHNICAL STAFF ..... Trained Staff of Agencies and Organization

APPENDIX THREE
Quarantines and Regulations

A Summary of Current Quarantines and Regulations in Washington State

WAC 16-752-400 through 420, WAC 16-752-500 through 525, and WAC 16-752-600 through 660 prohibit the transport, buy, sell, offer for sale, or to distribute plants or plant parts or to intentionally transplant wild plants or plant parts.

These quarantines identify plants known to be invasive and a detriment to the state's natural resources. These regulations will serve to prevent the continued introduction of these problem plants into Washington.

APPENDIX FOUR
Washington State Noxious Weed Control Board
Written Findings: Parrotfeather

WRITTEN FINDINGS OF THE
WASHINGTON STATE NOXIOUS WEED CONTROL BOARD
(October 1994)

Scientific Name: *Myriophyllum aquaticum* (Vell.) Verdc.; Synonyn: *Myriophyllun brasiliense* Camb.

Common Name: Parrot feather

Family: Haloragaceae

Legal Status: Class B: (a) regions 1, 2, 3, 4, 5, 6, 7, 9, 10
(b) Region 8 except Clark, Cowlitz, and Wahkiakum counties.

Description and Variation: Parrot feather gets its name from its feather-like leaves which are arranged around the stem in whorls of four to six. Parrot feather has both submersed and emergent leaves, with the submersed form being easily mistaken for Eurasian watermilfoil (*Myriophyllun spicatum*), a close relative. The submersed leaves are 1.5 to 3.5 centimeters long and have 20 to 30 divisions per leaf. The emergent leaves are 2 to 5 centimeters long and have 6 to 18 divisions per leaf. The bright green emergent leaves are very stiff and a darker green than the submersed leaves. The emergent stems and leaves are the most distinctive trait of parrot feather, as they can grow up to a foot above the water surface and look almost like small fir trees. Submersed leaves are limp and often appear to be decaying but the stems are very robust. Adventitious roots form at the nodes. When attached to a bank, parrot feather stems can extend out several yards over the water surface. Flowers are inconspicuous and are borne in the axils of the emergent leaves. The white flowers are approximately 1/16 inch long.

Economic Importance: Because of its attractiveness and ease of cultivation, parrot feather has been introduced worldwide for use in indoor and outdoor aquaria! It is also a popular aquatic garden plant. However, it has escaped cultivation and spread via plant fragments and intentional plantings. While parrot feather may provide cover for some aquatic organisms, it can seriously change the physical and chemical characteristics of lakes and streams. Infestations can alter aquatic ecosystems by shading out the algae in the water column that serve as the basis of the aquatic food web. In addition, the plant provides choice mosquito larvae habitat. In California, the species is becoming an increasing problem in irrigation and drainage canals. A 1985 survey of irrigation, mosquito abatement, flood control, and reclamation agencies in California indicated that parrotfeather infested nearly 600 miles of waterways and over 500 surface acres. In Washington, the Longview Diking District estimates that it spends about $30,000-40,000 per year on parrot feather control in drainage ditches. Dense infestations in southern Africa have caused flooding and drainage problems in shallow rivers and streams. The plant can also restrict recreational opportunities in these bodies of water.

Geographic Distribution: Parrot feather is a native of the Amazon River in South America, but it has naturalized worldwide, especially in warmer climates. In the United States, the plant is found throughout the southern United States and northward along both coasts. It is found

further north on the west coast because of the milder climates associated with the more northern latitudes on the west coast. Presently, Washington's parrot feather infestations appear to be limited to coastal lakes and streams, and the southwest Washington portion of the Columbia River. Parrot feather is found throughout the drainage system in the Longview/Kelso area, infests many of the drainage ditches in Wahkiakum County, and was discovered growing in the Chehalis River in 1994. As of 1994, no parrot feather populations have been discovered in eastern Washington.

Habitat: Parrot feather is found in freshwater lakes, ponds, streams, and canals and appears to be adapted to high nutrient environments. It tends to colonize slowly moving or still water rather than in areas with higher flow rates. While it grows best when rooted in shallow water, it has been known to occur as a floating plant in the deep water of nutrient-enriched lakes. The emergent stems can survive on wet banks of rivers and lake shores, so it is well adapted to moderate water level fluctuations.

History: Indigenous to South America, parrot feather was probably introduced to North America in the late 1800s; the exact date is unknown. The first collection made of this species was in the Washington D.C. area in 1890. It was reported from South Africa in 1918 or 1919, Japan in 1920, New Zealand in 1929, Australia in the 1960's, and England in the 1970's. Couch and Nelson report a single population of parrot feather in western Washington in 1944. An herbarium specimen was collected from Skamokowa, Wahkiakum County in 1983.

Growth and Development: This rhizomenous perennial exhibits an annual pattern of growth. In the spring, shoots begin to grow rapidly from overwintering rhizomes as water temperatures increase. Rhizomes function as a support structure for adventitious roots and provide buoyancy for emergent growth during the summer. Emergent stems and leaves extend from a few inches to over 1 foot above the waters surface. Underwater leaves tend to senese as the season advances. Plants usually flower in the spring but some plants may also flower in the fall. The inconspicuous flowers form where the emergent leaves attach to the stem. In fall parrot feather typically dies back to the rhizomes. In some areas, like western Washington, parrot feather may maintain considerable winter biomass. Because parrot feather lacks tubers, turions, and winterbuds, rhizomes serve all those functions. Parrot feather does not store phosphorus or carbon in its rhizomes and this characteristic may explain the failure of parrot feather to invade areas with severe winters.

Reproduction: Even in South America, virtually all parrot feather plants are female. Male plants are unknown outside of South America, so no seeds are produced in North American populations. Since parrot feather also lacks tubers or other specialized reproductive overwintering structures like turions, it spreads exclusively by plant fragments outside of its native range. Unlike Eurasian watermilfoil, parrot feather does not form autofragments. However, fragments can be formed mechanically and will readily root. With its tough rhizomes, parrot feather can be transported long distances on boat trailers. Rhizomes stored under moist conditions in a refrigerator survived for one year.

Response to Herbicides: Although parrot feather is considered by some to be susceptible to herbicides, it is difficult to achieve complete control. The emergent stems and leaves have a thick waxy cuticle and it requires a wetting agent to penetrate this cuticle. Often the weight of the spray will cause the emergent vegetation to collapse into the water where the herbicide is washed off before it can be translocated throughout the plant. Westerdahl and Getsinger report excellent control of parrot feather with 2,4-D, diquat, diquat and complexed copper, endothall dipotassium salt, and endothall and complexed copper. Fair control was obtained with acrolein and glyphosate. The Monsanto Company suggested that applying a 1 3/4 percent solution of Rodeo® (aquatic version of Roundup®) with surfactant to the plants in the summer or fall when water levels are low would give about 95 percent control of the plants. Control of parrot feather may be achieved with low-volatility ester of 2,4-D at 4.4-8.9 kg ha. sprayed onto the emergent foliage. The granular formulation of 2,4-D was needed to control parrot feather for periods greater than 12 months. It is more effective when applied to young, actively growing plants. In actual practice, the Longview diking district report little success with using herbicides to control parrot feather. Glyphosate causes the emergent vegetation to turn black but within two weeks the plants have recovered. An experimental fall application of triclopyr to parrot feather also proved to be ineffective. Of the above herbicides, endothall, glyphosate, and copper are permitted for aquatic use in Washington waters, but copper is generally permitted only as an algicide.

Response to Cultural Methods: Parrot feather's exceedingly robust rhizomes can survive overwinter water levels draw downs in California irrigation canals as rhizomes buried in the sediment.

Response to Mechanical Methods: Because this plant can spread readily through fragmentation of rhizomes, mechanical controls such as cutting, harvesting, and rotovation (underwater rototilling) should be used only when the extent of the infestation is such that all available niches have been filled. Using mechanical controls while the plant is still invading, will tend to enhance its rate of spread. Parrot feather populations can be successfully harvested, but the dense tough rhizomes are very heavy and the plant regrows rapidly. In Longview, the Diking District relies on a dragline to remove infesting parrot feather plants. A truck-mounted crane with a special attachment plucks weeds out of the ditch. They conduct the drag line operation from August to December in each year with control generally lasting for one growing season.

Biocontrol Potentials: Parrot feather has a high tannin content, so most grazers, including grass carp, find it unpalatable. Grass carp also prefer soft plants, like *Elodea canadensis* and the tough, woody parrot feather stems are not preferred. While biological control agents are not presently available, potential agents do exist. A complex of insects feed on parrot feather in its native habitat. *Lysathia flavipes* (Boheman), a flea beetle found on parrot feather in Argentina, causes moderate damage to parrot feather under field conditions. Also found in Argentina is a weevil, *Listronotus marginicollis* (Hustache), that apparently feeds only on parrot feather in its native range.

Additional insects have been found on parrot feather in Florida. *Lysathia ludoviciana* (Fall.), a flea beetle native to the southern U.S. and Caribbean, will use parrot feather as a host plant for larvae under laboratory conditions. However, the flea beetle is not often found on parrot

feather in the field. Two members of the tortricidae family, *Argyrotaenia ivana* (Fernald) and *Choristoneura parallela* (Robison) have also been found on parrot feather in Florida, but their effect on the plant is unknown. In addition, larvae of the caterpillar, *Parapoynx allionealis* (Walker), mine parrot feather leaves, but the impact these larvae could have on parrot feather is also unknown.

Fungal control options exist, as well. An isolate of *Pythium carolinianum* Matt. collected in California has shown some promise as a potential biocontrol agent. Parrot feather stems that were experimentally inoculated with this fungus produced significantly less growth than control plants.

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**References available from the Washington State Noxious Weed Control Board office in Kent.*

To find out more about Parrotfeather and Parrotfeather control in Washington, contact:

Lewis County Noxious Weed Control Board
360 N. W. North Street MS: AES02
Chehalis, WA 98532-1900
Phone: (360) 740-1215

To find out more about weeds and weed control in Washington, contact:

Washington State Noxious Weed Control Board
1851 South Central Place, Suite 211
Kent, WA 98031-7507
(206) 872-2318
(206) 872-2972

APPENDIX FIVE
Chehalis River Parrotfeather Management
1996 Noxious Weed Survey

APPENDIX SIX
Volunteer Survey Form for Identifying Locations of Parrotfeather

PARROTFEATHER PROJECT

GENERAL INVENTORY FORM

(USE - other agency or general public)

PLEASE FILL OUT A SEPARATE FORM FOR EACH LOCATION WHERE YOU HAVE OBSERVED PARROTFEATHER (PF).

1. DATE (MMDDYY) _____

2. YOUR NAME _____

3. YOUR PHONE NUMBER (DAYTIME) _____

RECORD THE FOLLOWING INFORMATION ABOUT YOUR PARROTFEATHER OBSERVATIONS.

4. ADDRESS OR COMMON PLACE NAME WHERE SEEN _____

5. LEGAL DESCRIPTION,IF KNOWN (TOWNSHIP,RANGE,SECTION) _____

6. ESTIMATED SIZE OF PATCH IN ACRES OF SQUARE FEET _____

7. ESTIMATED (PF) DENSITY - % OF AREA COVERED
   1=<1% 2=1-10% 3=10-50% 4=50+% _____

8. TYPE OF WATERWAY; I.E.: BACKWATER SLOUGH, RIVER _____

9. NEAREST ESTIMATED RIVER MILE (MAP ON BACK) _____

10. BRIEF DRIVING DIRECTIONS _____

11. PLEASE SKETCH THE AREA WHERE THE (PF) WAS OBSERVED; SHOWING THE NEAREST ROAD INTERSECTION AND FEATURES.

SKETCH MAP HERE

Figure 1.

CHEHALIS RIVER BASIN
RIVER MILE INDEX

Acknowledgements

Chehalis River Council
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Washington State Dept. of Ecology
Washington Water Weeks Staff, EPA / DOE
Washington State University / Lewis Co. Cooperative Extension
Washington State Dept. of Fish and Wildlife
Washington State Noxious Weed Control Board

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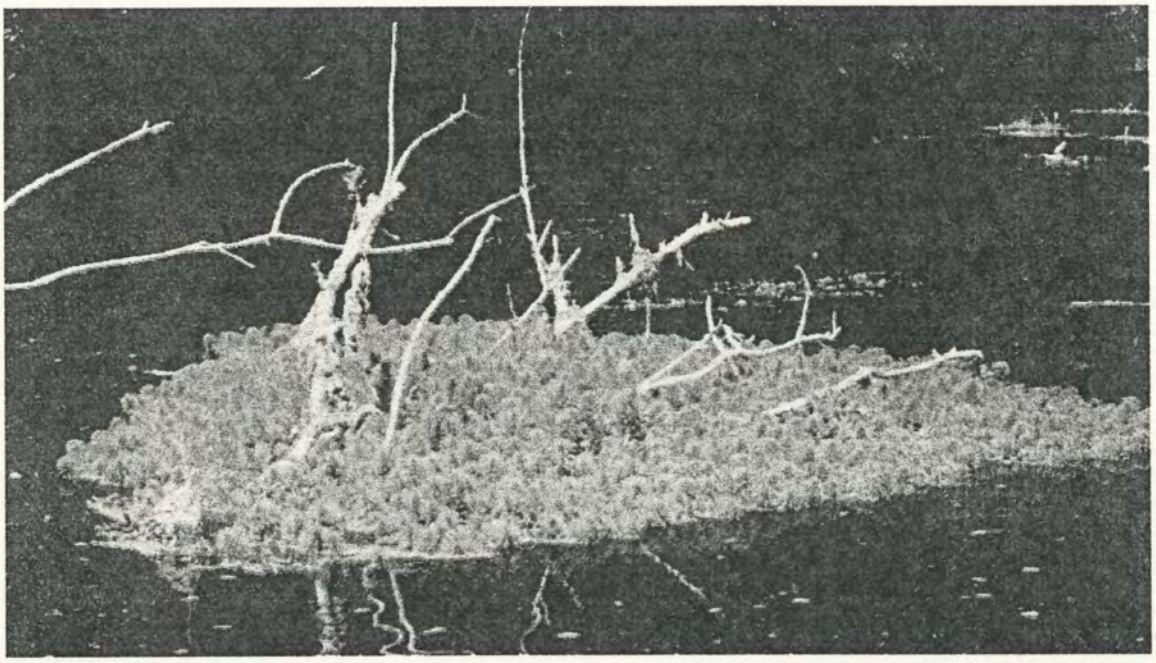
Chehalis River Parrotfeather Management 1996 Noxious Weed Survey



Presented by:

Lewis County Noxious Weed Control Board

Bill Wamsley, Coordinator

Kevin L. Hupp, Project Lead

Chehalis River
Parrotfeather Management
1996 Noxious Weed Survey

Presented by:

Lewis County Noxious Weed Control Board

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Purpose

Weed boards in the past have done an outstanding job of recognizing new invasive terrestrial weeds as they have emerged on the landscape. Since Purple loosestrife, *Lythrum salicaria*, was adopted to the Washington State Noxious Weed List, more attention has been given by weed boards to the aquatic flora.

In August of 1994, during a survey for Purple loosestrife, an unusual looking aquatic plant was found in the Chehalis River near Centralia. It was identified as Parrotfeather, *Myriophyllum aquaticum*. Parrotfeather was added to the State Noxious Weed List in the spring of 1994.

The finding of parrotfeather led to the Lewis County Noxious Weed Board submitting a grant proposal to the Department of Ecology with the purpose of gathering more information about the aquatic plant in the Chehalis River. The following survey report is a product of the work performed in 1996. In addition, an Integrated Aquatic Plant Management Plan for Parrotfeather in the Chehalis River was prepared to direct future actions.

INTRODUCTION

Parrotfeather (*Myriophyllum aquaticum*), an aquatic plant native to the Amazon River in South America, was introduced to Washington for use in aquaria. Parrotfeather is a class B noxious weed, designated for control in regions 1,2,3,4,5,6,7,9,10 and region 8 except Clark, Cowlitz, and Wahkiakum counties. Because of its attractiveness and ease of cultivation, parrotfeather has been introduced worldwide for use in indoor and outdoor aquaria. It is also a popular aquatic garden plant.

However, it has escaped cultivation and spread via plant fragments and intentional plantings. While parrotfeather may provide cover for some aquatic organisms, it can seriously change the physical and chemical characteristics of lakes and streams.

Infestations can alter aquatic ecosystems by shading out the algae in the water column that serve as the basis of the aquatic food web. In addition, the plant provides choice mosquito larvae habitat.

Parrotfeather gets its name from its feather-like leaves which are arranged around the stem in whorls of four to six. Parrotfeather has both submersed and emergent leaves, with the submersed form being easily mistaken for Eurasian watermilfoil (*Myriophyllum spicatum*), a close relative.

The submersed leaves are 1.5 to 3.5 centimeters long and have 20 to 30 divisions per leaf. The emergent leaves are 2 to 5 centimeters long and have 6 to 18 divisions per leaf. The bright green emergent leaves are very stiff and a darker green than the submersed leaves. The emergent stems and leaves are the most distinctive trait of parrotfeather, as they can grow up to a foot above the water surface and look almost like small fir trees. Submersed leaves are limp and often appear to be decaying, but the stems are very robust. Adventitious roots

form at the nodes. When attached to a bank, parrotfeather stems can extend out several yards over the water surface. The white flowers are inconspicuous (approximately 1/16 inch long) and are borne in the axils of the emergent leaves. Plants usually flower in the spring but some plants may also flower in the fall. The inconspicuous flowers form where the emergent leaves attach to the stem. Parrotfeather plants outside of their native range are female and therefore infertile--no seed production.

This rhizomatous perennial exhibits an annual pattern of growth. In the spring, shoots begin to grow rapidly from over-wintering rhizomes as water temperatures increase. Rhizomes function as a support structure for adventitious roots and provide buoyancy for emergent growth during the summer. Emergent stems and leaves extend from a few inches to over 1 foot above the water's surface. Underwater leaves tend to age as the season advances.

In the fall, parrotfeather typically dies back to the rhizomes. In some areas, like western Washington, parrotfeather may maintain considerable winter biomass. Because parrotfeather lacks tubers, turions, and winter buds, rhizomes serve all those functions. Parrotfeather does not store phosphorous or carbon in its rhizomes and this characteristic may explain the failure of parrotfeather to invade areas with severe winters.

In California, the species is becoming an increasing problem in irrigation and drainage canals. A 1985 survey of irrigation, mosquito abatement, flood control, and reclamation agencies in California indicated that parrotfeather infested nearly 600 miles of waterways and over 500 surface acres. In Washington, the Longview Diking District reports parrotfeather as their worst weed pest and estimates that they spend about $30,000 - $40,000 per year to control 25 miles of parrotfeather in their 43 mile drainage ditch system. Dense infestations in southern Africa have caused flooding and drainage problems in shallow rivers and streams. The plant can also restrict recreational opportunities in these bodies of water.

In 1994, parrotfeather was found in the Chehalis River in southwestern Washington (Appendices A, E). The second largest river basin in the state, the Chehalis provides habitat for a variety of fish, including coho, chinook, and chum salmon, and steelhead and anadromous cutthroat trout. Sloughs and other slow water habitats support populations of the Olympic mudminnow, a species of special concern in that it's restricted to coastal streams in Washington. Parrotfeather threatens the habitat of these species by lowering productivity and pH., as well as causing severe dissolved oxygen problems. Parrotfeather can have a particular impact on salmonids, since it occupies fry rearing habitat.

The parrotfeather infestation in the Chehalis River appeared to be new, but the full extent of the infestation was not yet known. Scattered infestations had been reported between river miles 67 and 39 (Appendix D). Herbarium records show that a parrotfeather plant was collected on Sept. 13, 1944. It was found in a wetland 2 miles east of Aberdeen in Grays Harbor County.

Because parrotfeather can reproduce by fragmentation, it could colonize the entire river system if action is not taken. Control work was hampered by a lack of survey information and effective control strategies. Therefore, the project proposed to carry out a comprehensive survey for parrotfeather. Survey objectives included:

1) Survey the Chehalis River system from the South Fork of the Chehalis River to Grays Harbor and record the extent of the parrotfeather infestation and other aquatic noxious weeds including: Purple loosestrife, Eurasian watermilfoil (*Myriophyllum spicatum*), Reed canarygrass (*Phalaris arundinacea*), and Brazilian elodea (*Egeria densa*) .

2) In addition to surveying, remove any small infestations of parrotfeather.

METHODS

The survey was conducted by Weed Board personnel, contractors and with trained volunteers. The survey was broken down into four geographic sections:

Lewis County
Starting upstream of the South Fork of the Chehalis River (River Mile (RM) 91*) to the Thurston County line. (* Note this was increased upstream for ease of access to the river). The Lewis County section was divided into several sections based on length and accessible put-in and take-out sites. The Newaukum River and several other small water bodies near the Chehalis River were included in the survey. Information was recorded by Lewis County staff.

Thurston County
Starting from the Thurston County line (RM 60) to the Grays Harbor County line (RM 51). Information was recorded by Thurston County Weed Board staff and Lewis County staff in order for personnel to observe any difference from the previous season.

Grays Harbor County (Upstream)
Starting from the Thurston County line (RM 51) extending downstream to the Sickman-Ford Bridge (RM 44) near Oakville. The survey information was recorded by Lewis County staff.

Grays Harbor County
Starting from the Sickman-Ford Bridge (RM 44) to Grays Harbor including the mouths of the tributaries (Satsop, Wynoochee, Wishkah and Hoquiam). The survey was conducted by Resource Management Inc. (RMI). (Appendix C).

An aerial survey of the Lewis County portion of the river was performed on May 24, 1996. This provided a visual overview of the river and allowed for the larger sites to be photographed and recorded so that the ground survey would be more efficient.

The parrotfeather density rating used for this survey was a visual evaluation of the size of plant coverage in this section of the river. *Less than or equal to 100 sq. ft.* was used for small infestations bigger than a single fragment and equal to 100 sq. ft. *Greater than 100 sq. ft. and less than an acre* was used for medium infestations bigger than 100 sq. ft. and less than an acre. *Greater or equal to an acre* was estimated for large infestations an acre in size or larger.

Equipment

The survey was performed using a 16 foot Coleman canoe or a 10 foot aluminum boat with a 5 horsepower motor. A Magellan Global Positioning System (GPS), receiver model Nav DLX-10 was used to record site and boundary data. The hand held device records longitude and latitude coordinates using global satellites as reference points.

The surveys were performed June through September 1996. River miles 51 through 75 were covered twice during this period to increase the detection of aquatic plants.

Infested sites were recorded with the GPS unit and in a field note book where the approximate river mile and additional detailed information could be recorded. This information recorded by GPS was used to produce a map with a Geographical Information System (GIS).

Sites with small amounts of plant material were recorded, removed with a hand rake, and disposed of, on each survey run.

RESULTS

The extent of the parrotfeather infestation on the Chehalis River was found to be much more extensive than previously thought. Compared to 1994 and 1995, 26 new sites have been recorded in 1996, within the 42 mile stretch(RM 75-33), as a result of the survey. The five large sites, each an acre or larger in size, occur near Porter, Oakville, Galvin and Chehalis (Appendices A, B, C).

Other noxious aquatic plants found include: Purple loosestrife (*Lythrum salicaria*), Reed canarygrass (*Phalaris arundinacea*)and Brazilian elodea (*Elodea densa*).

Lewis County

Near Galvin (RM 64-65), a number of small infestations are scattered along both shorelines for about one mile (Appendices A, B). Most of these sites are well within the main channel of the river. The seven sites that were found in 1995 had grown considerably and had pioneering sites nearby.

Six additional sites were recorded and removed in the area between the Newaukum and Skookumchuck Rivers. This section of river known as the "Centralia Reach", was identified by the Department of Ecology for having impaired water conditions due to the deep channel and low summer flows. Preventing the establishment of parrotfeather in this section of the river will reduce any further degradation of water quality.

The follow up surveys, late in the season, found an increased amount of emergent growth compared to the earlier surveys. Higher water levels due to the late season flooding may have caused the parrotfeather to emerge later when water levels dropped.

The Newaukum River was surveyed from Stan Hedwall Park (RM 2) to the Chehalis River (RM 75). No noxious weeds were found in this stretch.

The Skookumchuck River was not surveyed for parrotfeather in 1996. The river was surveyed by the Lewis and Thurston County Weed Boards in 1995 (Appendix D). No noxious weeds were recorded on this river within Lewis or Thurston counties.

In Lewis County several ponds, lakes, and sloughs disconnected from the main stem of the Chehalis were surveyed for parrotfeather. Plummer Lake, Borst Lake and Hayes Lake were all surveyed because of their close proximity to the Chehalis River.

Parrotfeather was not found in any of these water bodies. Brazilian elodea was found in Plummer Lake and was quite extensive along the shoreline. Heavy plant growth extends out 20 feet from shore on the west and north shorelines. Conversations with local residents indicate that the plant has been present for the past few years and increasing in density. Plummer lake is connected to the Chehalis River by a culvert that extends west of the lake and under Interstate 5. Brazilian elodea is a Class B Designate weed in Lewis, Thurston and Grays Harbor counties.

Other non-named sites surveyed where parrotfeather was found include:
Slough near Interstate Avenue and I-5, sloughs at Riverside Golf Course, slough near Highway 603 and Riverside Road and a slough off of Scheuber Road (Appendix B).

Reed canarygrass was found to be extensive along the shoreline of the Chehalis River throughout the system. Densities varied but Reed canarygrass was often the dominant or co-dominant emergent plant. Reed canarygrass is a Class C noxious weed.

No new Purple loosestrife plants were recorded except for what is mentioned in the RMI survey. Purple loosestrife was recorded and hand pulled in the Chehalis River at RM 71 in 1995 and in the Newaukum River at RM 16 in 1994.

Thurston County Survey:
The Thurston County section of the river was surveyed early in the season by Lewis County staff. One new site was observed at RM 59 where plants were found in a small slough. The parrotfeather infestation at this site was less than 200 square feet (Appendices A, B, D).

Thurston County staff hand pulled and applied a barrier to the site. A follow up survey occurred in September with no additional plants found.

The Upper Grays Harbor Survey:
One location of parrotfeather was documented in this stretch of the river (Appendices A, B). A small slough (RM 44) downstream of Garrard Creek was found to have a dense population. The parrotfeather was isolated in the slough and no plants were found in the main channel. Two other sites surveyed in this river section resulted in finding no parrotfeather but are of concern because of the large backwater habitat that they provide. They include a two acre slough at river mile 45 and the mouth of the Black River (RM 47).

Grays Harbor County
See Chehalis River Parrotfeather Survey Summer 1996 - Resource Management Inc. (Appendix C)

Other aquatic plants observed in the project area:
Alisma plantago-aquatica, American water plantain
Brassenia schreberi, Watershield (located at Hayes Lake, Centralia)
Ceratophyllum demersum, Coontail
Elodea canadensis, Elodea
Iris pseudacorus, Yellow Iris
Juncus spp., Rush
Lemna minor, Duckweed
Nuphar luteum, Yellow water-lily
Nymphaea odorata, Fragrant waterlily (located at Hayes Lake, Centralia)
Polygonum amphibium, Water smartweed
Polygonum cuspidatum, Japanese knotweed
Polygonum hydropiperoides, Smartweed
Potamogeton spp., Pondweeds
Potamogeton illionesis, Illinois pondweed
Ranunculus spp., Water buttercup
Scripus acutus, Hardstem bulrush
Scripus spp., Bulrush
Sparganium spp., Burreed
Typha spp., Cattail

RECOMMENDATIONS FOR FUTURE SURVEYS

1) Build upon and consolidate noxious weed survey information known in the Chehalis River system. Encourage the cooperation of the Thurston and Grays Harbor County Noxious Weed Control Boards, The Chehalis Tribe, other agencies and the public in gathering and distributing the information.

2) Record new parrotfeather sites with the aid of GPS and update county and regional maps.

3) Continue to identify and survey other small sloughs and ponds within the Chehalis River Basin for parrotfeather and other aquatic noxious weeds.

4) Continue to monitor and control new infestations of parrotfeather in the "Centralia Reach" area.

5) Continue to monitor and control new infestations of parrotfeather downstream of the Galvin area.

6) Develop a management plan for Brazilian elodea at Plummer Lake.

Failure to control parrotfeather could be environmentally devastating. Therefore, it is imperative to discover and control infestations when they are small.

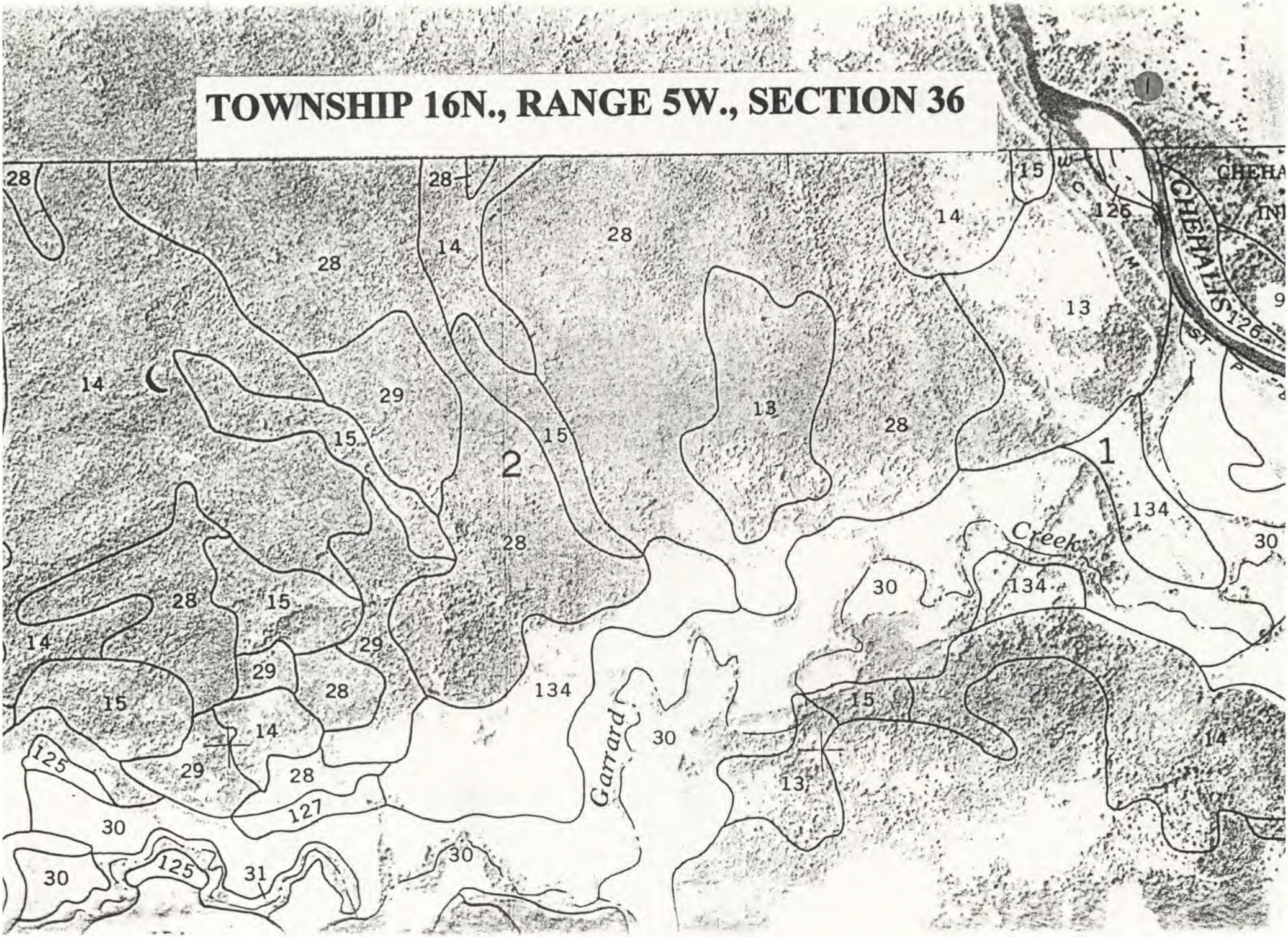
APPENDIX A
Chehalis Basin Map
River Mile Index

CHEHALIS RIVER BASIN
RIVER MILE INDEX

APPENDIX B
Parrotfeather Survey Maps

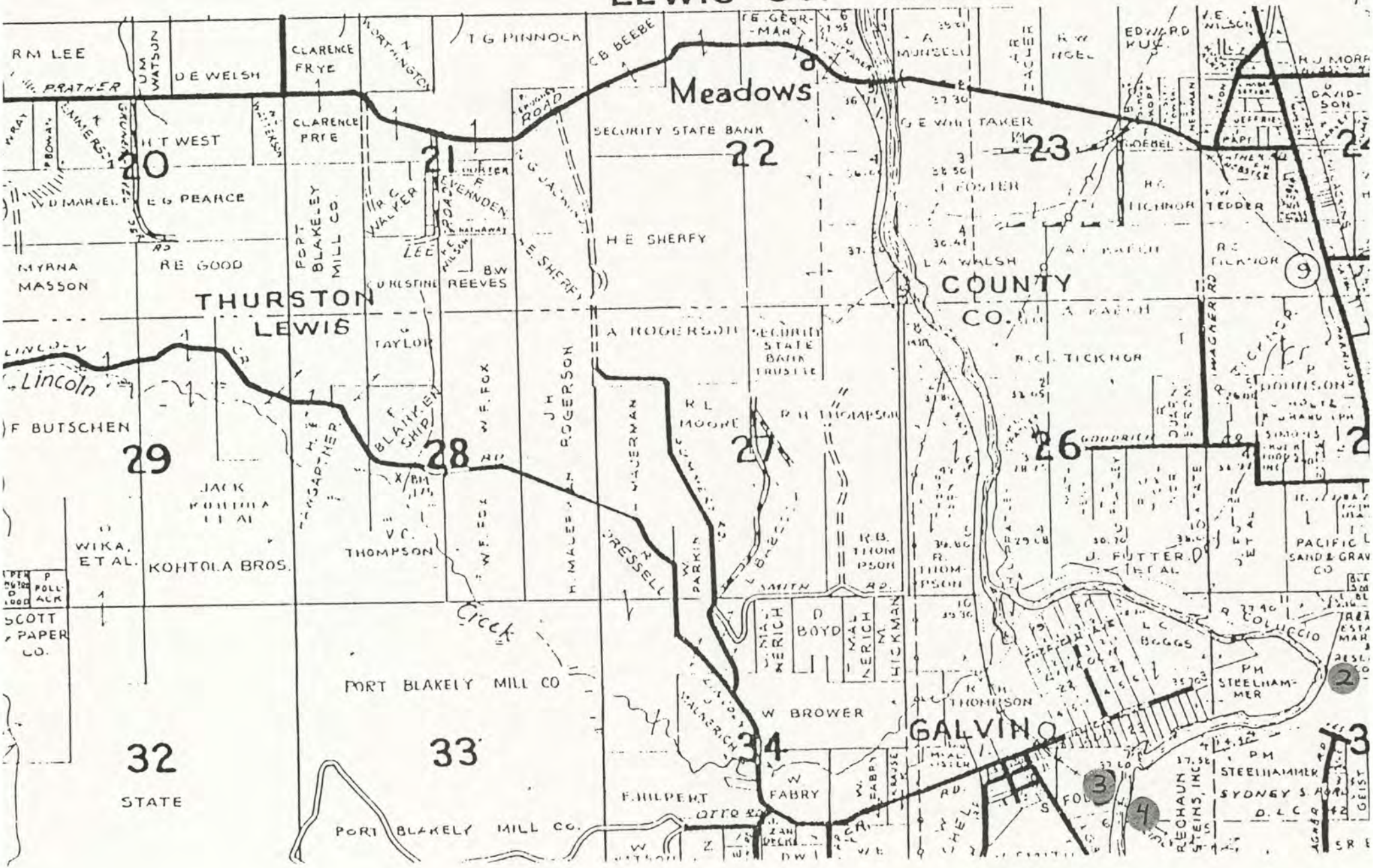
(Positions of weed sites on base maps are only approximate.)

TOWNSHIP 16N., RANGE 5W., SECTION 36



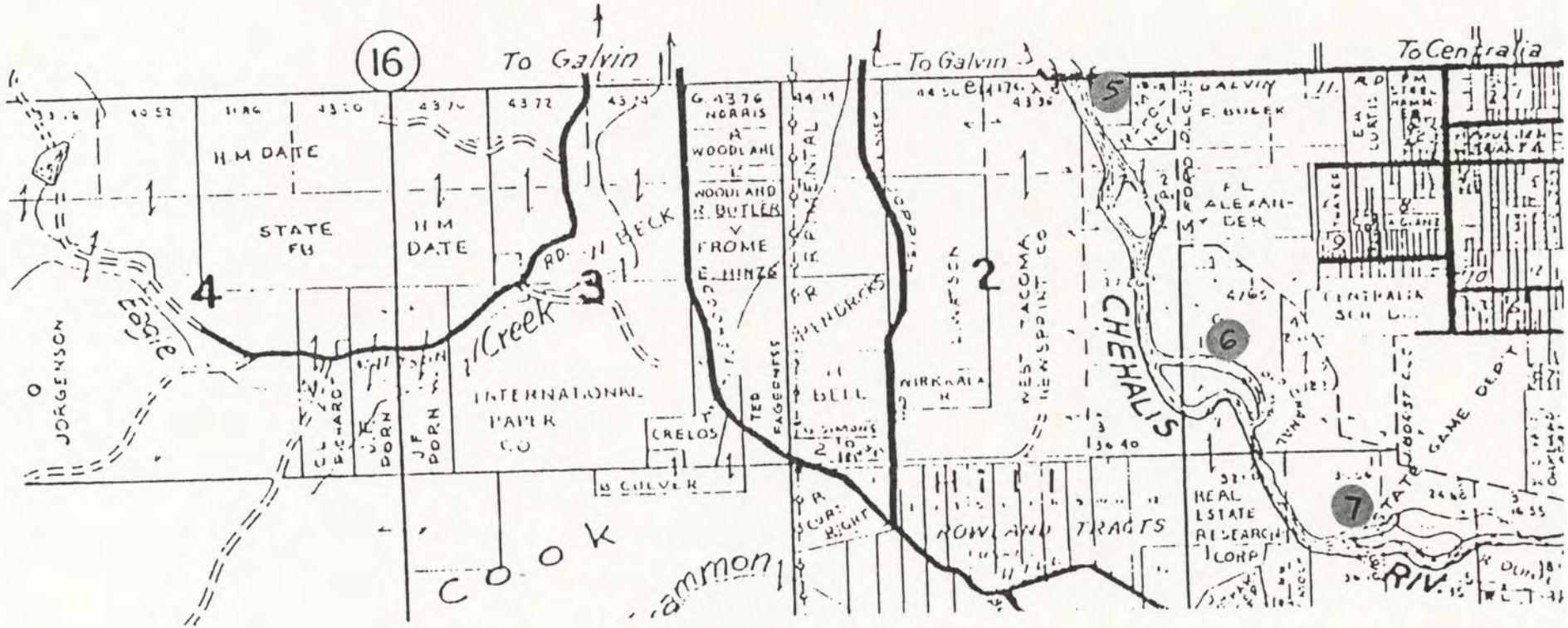
TOWNSHIP 15 N., RANGE 3 W.W. M.

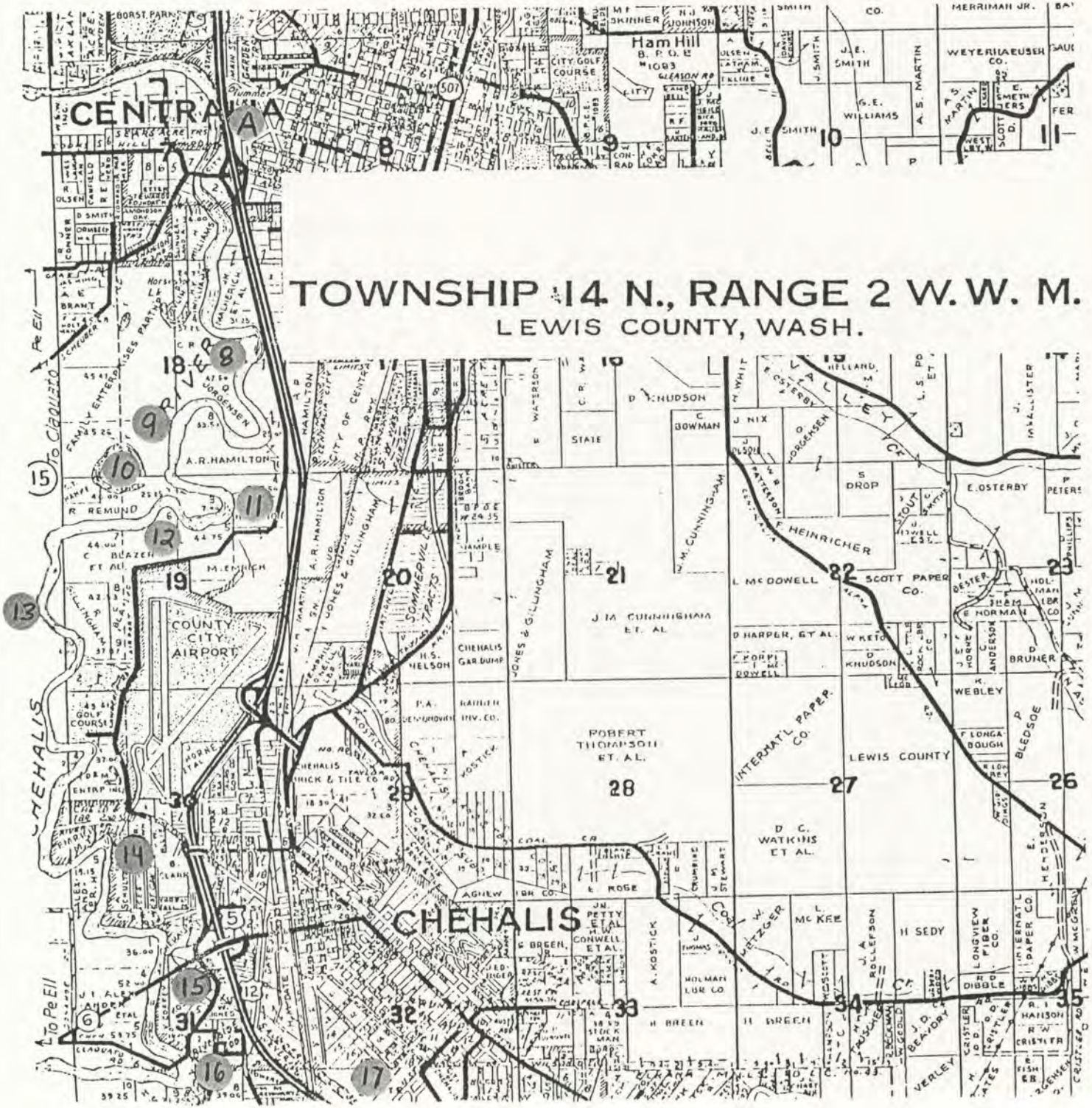
LEWIS CO. WASH.



TOWNSHIP 14 N.. RANGE 3 W.W. M.

LEWIS COUNTY. WASH.




TOWNSHIP 14 N., RANGE 2 W.W.M.
LEWIS COUNTY, WASH.
CENTRALIA
CHEHALIS
Ham Hill
B. P. O. E.
#1093
CITY GOLF COURSE
COUNTY CITY AIRPORT
SCOTT PAPER CO.
INTERNATL. PAPER CO.
LEWIS COUNTY
ROBERT THOMPSON ET. AL.
28
J. M. CUNNINGHAM ET. AL.
21
A. R. HAMILTON
M. CUNNINGHAM
E. OSTERBY
F. HEINRICHER
L. McDOWELL
D. HARPER, ET AL.
D. C. WATKINS ET AL.
J. N. PETTY ET AL.
W. CONWELL ET AL.
H. BREEN
H. SEDY
McKEE
E. ROSE
A. KOSTICK
E. BREEN
J. A. ROLLEFSON
LONGVIEW FIBER CO.
D. BRUHER
E. NORMAN
WEBLEY
F. LONGABOUGH
P. BLEDSOE
E. HENDERSON
R. I. HANSON
R. W. CRISTLER
J. D. BEAVORT
VERLEY
W. VETZGER
S. DROP
C. BOWMAN
J. NIX
STATE
P. KNUDSON
W. KETO
CHEHALIS GAR DUMP
CHEHALIS BRICK & TILE CO.
HOLMAN LBR. CO.
AGNEW LBR. CO.
GOLF COURSE
To Olympia
To Pe Ell
To Pe Ell
SOMMERVILLE TRACTS
JONES & GILLINGHAM
A. R. HAMILTON
R. REMUND
C. BLAZEN ET AL.
M. EMRICH
FAMILY ENTERPRISES PARTNERSHIP
C. R. JORGENSEN
A. B. HAMILTON
CITY OF CENTRALIA
WEYERHAEUSER CO.
MERRIMAN JR.
J. E. SMITH
G. E. WILLIAMS
A. S. MARTIN
E. SMETHERS
SCOTT
WEST LBR. CO.
J. MACALLISTER
HEILAND
L. S. PD ET AL
CHEHALIS R.
COAL CR.
SKOOKUM CR.
CRR
NO. PAC. RY.
SOU. PAC. RY.
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1996 Site Information for Noxious Weeds

Parrotfeather

Site Number 1
Address or common place name where seen: Chehalis River, below Garrard Creek
Legal description: T16N, R5W, Sec. 36, SW SE
Estimated size of infestation: Acre or greater
Type of waterway: Backwater slough
Nearest estimated river mile: River Mile #44
GPS coordinates: 123.15.355 46. 49. 428 Way point (WP)#60
Date found: 7/14/96

Site Number 2
Address or common place name where seen: Chehalis River; Prather / Maple Lane
Legal description: T15N., R3W., Sec. 36, SE NW
Estimated size of infestation: greater than 100 sq. ft. and less than 1 acre.
Type of waterway: Backwater slough
Nearest estimated river mile: River Mile #59
GPS coordinates: 123.01.971 46.47.111 WP #90
Date found: 7/24/96

Site Number 3

Address or common place name where seen: Chehalis River, Galvin Bend
Legal description: T 15N., R 3W., Sec. 35, NW SE
Estimated size of infestation: At least 16 individual sites. (acre or greater)
Type of waterway: Main channel of the Chehalis River
Nearest estimated river mile: River Mile #64
GPS coordinates: 123.01.233 46.44.586 WP #190
Date found: 9/20/96

Site Number 4
Address or common place name where seen: Chehalis River, Galvin
Legal description: T 15N., R 3W., Sec. 35, SE SE
Estimated size of infestation: less than 100 sq. ft.
Type of waterway: Main channel of the Chehalis River
Nearest estimated river mile: River Mile #64
GPS coordinates: 123.01.185 46.44.450 WP #192
Date found: 9/20/96

Site Number 5
Address or common place name where seen: Chehalis River, Galvin Bridge
Legal description: T 14N., R 3W., Sec. 2, NE NE
Estimated size of infestation: less than 100 sq. ft.
Type of waterway: Main channel of the Chehalis River
Nearest estimated river mile: River Mile #64
GPS coordinates: 123.01.88 46.44.146 WP #199
Date found: 10/20/96

Site Number 6
Address or common place name where seen: Chehalis River, Port of Centralia slough
Legal description: T 14N., R 3W., Sec. 1, NW SW
Estimated size of infestation: less than 100 sq. ft.
Type of waterway: Backwater slough
Nearest estimated river mile: River Mile #65
GPS coordinates: 123.01.126 46.43.937 WP #73
Date found: 7/18/96

Site Number 7
Address or common place name where seen: Atkinson Pond
Legal description: T 14N., R 3W., Sec.12, NE NW
Estimated size of infestation: less than 100 sq. ft.
Type of waterway: Pond, not connected to the Chehalis River
Nearest estimated river mile: River Mile #65
GPS coordinates: 123.00.829 46.43.680 WP #39
Date found: 7/12/96

Site Number 8
Address or common place name where seen: Chehalis River, downstream of Salzer Creek
Legal description: T 14N., R 2W., Sec. 18, SE NE
Estimated size of infestation: less than 100 sq. ft
Type of water way: Main channel of the Chehalis River
Nearest estimated river mile: River Mile #69
GPS coordinates: 122.58.830 46.41.390 WP #149
Date found: 8/30/96

Site Number 9
Address or common place name where seen: Chehalis River, upstream of Salzer Creek
Legal description: T 14N., R 2W., Sec. 18, SE SW
Estimated size of infestation: less than 100 sq. ft.
Type of waterway: Main channel of the Chehalis River
Nearest estimated river mile: River Mile #69
GPS coordinates: 122.58.642 46.41.735 WP #148
Date found: 8/30/96

Site Number 10
Address or common place name where seen: #1617 Scheuber Rd.
Legal description: T 14N., R 2W., Sec. 18, SW SW
Estimated size of infestation: acre or greater
Type of waterway: private slough not connected to the Chehalis River
Nearest estimated river mile: River Mile #70
GPS coordinates: 122.59.223 46.41.647 WP #208
Date found: 9/20/96

Site number 11
Address or common place name where seen: Chehalis River, upstream of Salzer Creek II
Legal description: T 14N., R 2W., Sec. 19, NE NW
Estimated size of infestation: less than 100 sq. ft.
Type of waterway: Main channel of the Chehalis River.
Nearest river mile: River Mile #70
GPS coordinates: 122.59.597 46.40.954 WP #85
Date found: 7/19/96

Site Number 12
Address or common place name where seen: Slough, Riverside Golf Course
Legal description: T 14N., R 2W., Sec. 19, SE NW
Estimated size of infestation: greater than 100 sq. ft. and less than 1 acre.
Type of waterway: Slough, not connected to the Chehalis River
Nearest river mile: River Mile #70
GPS coordinates: 122.59.238 46.40.641 WP #42
Date found: 7/12/96

Site Number 13
Address or common place name where seen: Chehalis River, upstream of Scheuber Drainage Ditch
Legal description: T 14N., R 3W., Sec.25, NE SW
Estimated size of infestation: less than 100 sq. ft.
Type of waterway: Main channel of the Chehalis River.
Nearest river mile: River Mile #72
GPS coordinates: 122.59.344 46.39.924 WP #150
Date found: 8/30/96

Site Number 14
Address or common place name where seen: Chehalis River, Water Treatment Out fall
Legal description: T 14N., R 2W., Sec. 30, SE NW
Estimated size of infestation: less than 100 sq. ft.
Type of waterway: Main channel of the Chehalis River.
Nearest river mile: River Mile #74
GPS coordinates: 122.59.712 46.41.138 WP #86
Date found: 7/19/96

Site Number 15
Address or common place name where seen: Chehalis River Slough; Hwy. 6 / Newaukum Ave. Rd.
Legal description: T 14N., R 2W., Sec. 31, NW SE
Estimated size of infestation: acre or greater
Type of waterway: Backwater Slough
Nearest river mile: River Mile #75
GPS coordinates: 122.58.817 46.39.378 WP #183
Date found: 9/16/96

Site Number 16
Address or common place name where seen: Chehalis River, below Alexander Park
Legal description: T 14N., R 2W., Sec. 31, NW SE
Estimated size of infestation: less than or equal to 100 sq. ft.
Type of waterway: Main channel of the Chehalis River
Nearest river mile: River Mile #75
GPS coordinates: 123.01.004 46.43.623 WP #71
Date found: 7/18/96

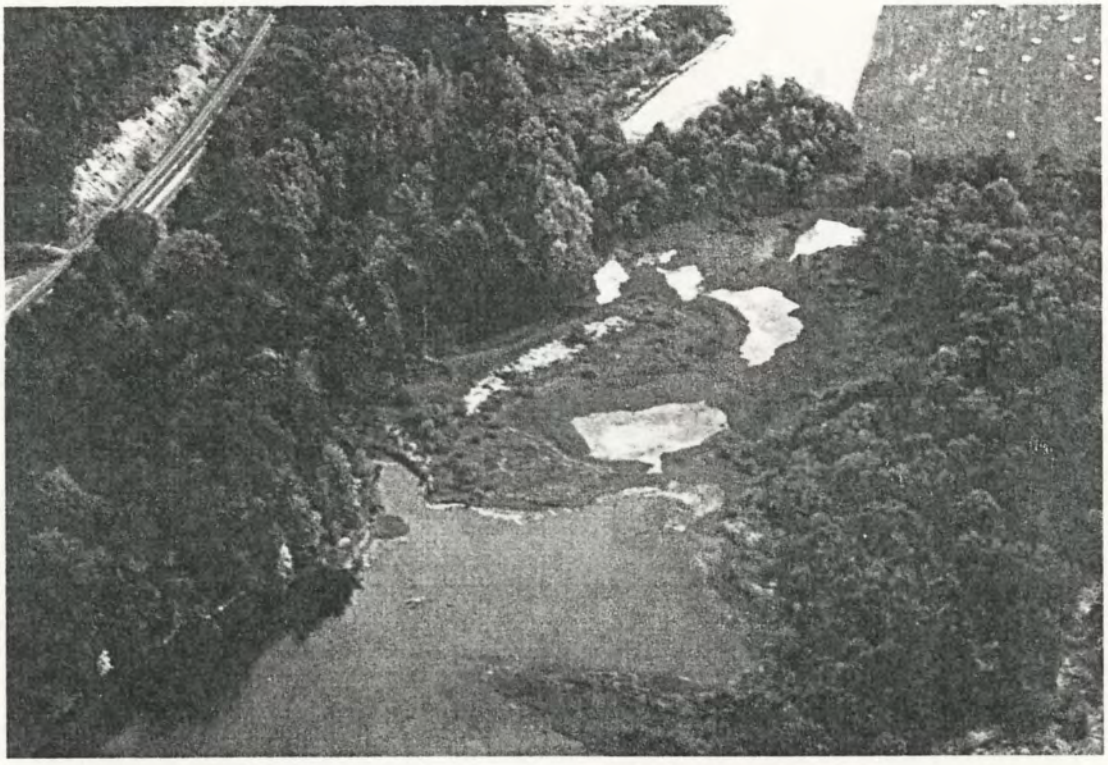
Site Number 17
Address or common place name where seen: Slough, Pony Soldier Motor Inn; Interstate 5
Legal description: T 14N., R 2W., Sec. 32, NE SW
Estimated size of infestation: less than 100 sq. ft.
Type of waterway: Slough not connected to the Chehalis River
Nearest river mile: River Mile #76
GPS coordinates: 122.57.197 46.38.676 WP #186
Date found: 9/16/96

Brazilian elodea

Site Number A
Address or common place where seen: Plummer Lake; NE of I-5 and Mellen St.
Legal description: T14N., R2W., Sec. 18, SE NE
Estimated size of infestation: acre or greater
Type of waterway: Private lake
Nearest river mile: River Mile #66
GPS coordinates: 122.58.27 46.43.03 WP #137
Date found: 8/2/96

APPENDIX C
Chehalis River Parrotfeather Survey
Summer 1996
Resource Management, Inc.

Chehalis River Parrotfeather Survey Summer 1996



Prepared for:

Lewis County Noxious Weed Board

Presented by:

Resource Management, Inc.

2900 B 29th Ave. SW
Tumwater, WA 98512
www.halcyon.com/rmi

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Methods and Materials	5
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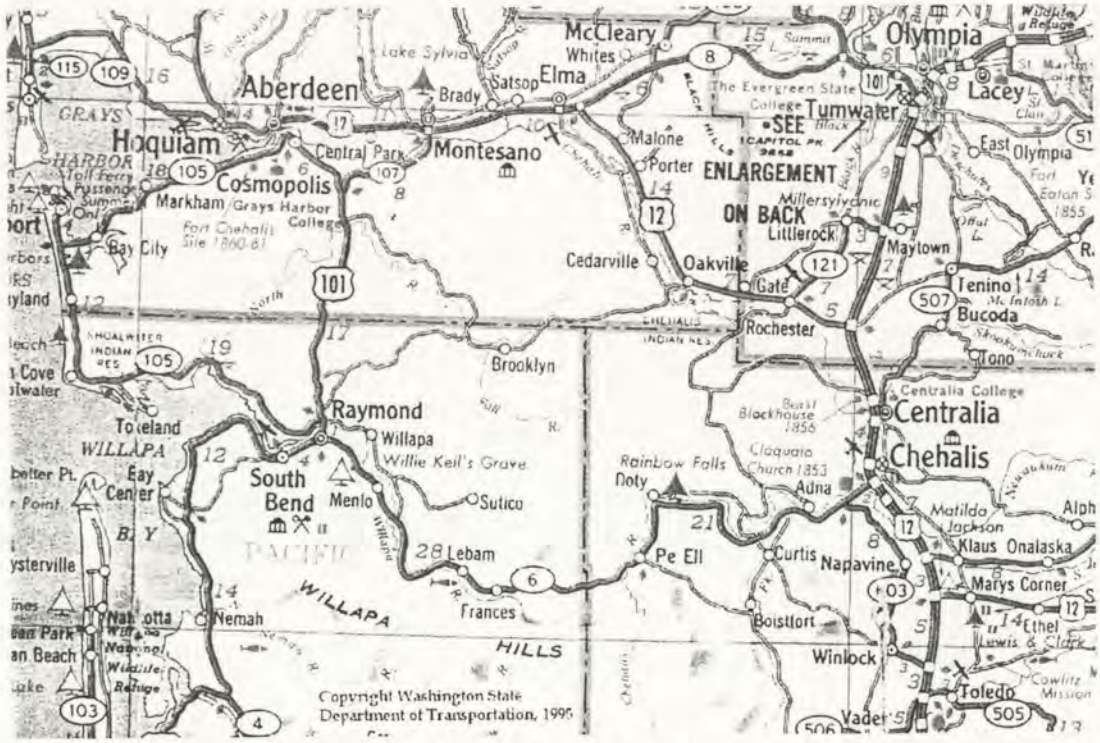
Appendix II - Parrotfeather Coordinates	17
Appendix III - Purple Loosestrife Coordinates	18

Introduction and Background

The Chehalis River Basin is the second largest drainage in Washington and its watershed covers much of the southwest portion of the state. The Chehalis River headwaters are located near Pe Ell, near the Lewis County/Pacific County border. The River flows in an easterly direction through the Cities of Chehalis and Centralia where it is joined by the Newaukum and Skookumchuck Rivers; these two systems drain the areas northeast and southeast of Chehalis. The Chehalis River then flows north to Grand Mound, turns to the northwest, and is joined by the Black River. The Black River drainage runs well to the north into Thurston County and has a number of tributary creeks. At Oakville, the Chehalis turns to the northwest in a narrow valley and is joined by over 16 significant creek systems before turning west at Elma and running to Grays Harbor. In this reach, the Satsop and the Wynoochee River add to the flow. Much of this section of the river is also influenced by the tide from the Pacific Ocean.

The Chehalis and its tributary rivers and creeks are mostly not impeded by dams or other barriers to fish passage. There are dams on the upper portions of the Wynoochee and Skookumchuck Rivers, but these are at the very upstream portions of these drainages and contribute minimal interference with fish movement up the many lower tributary creeks that are critical to fish spawning. In addition to being the second largest drainage in the state, the Chehalis River is also one of the few systems with few barriers to salmonids. There is limited urban growth in this extensive watershed and fish habitat remains above what may



This map shows the general Chehalis River Watershed, the RMI study area centered on the River Channel from Oakville to Aberdeen

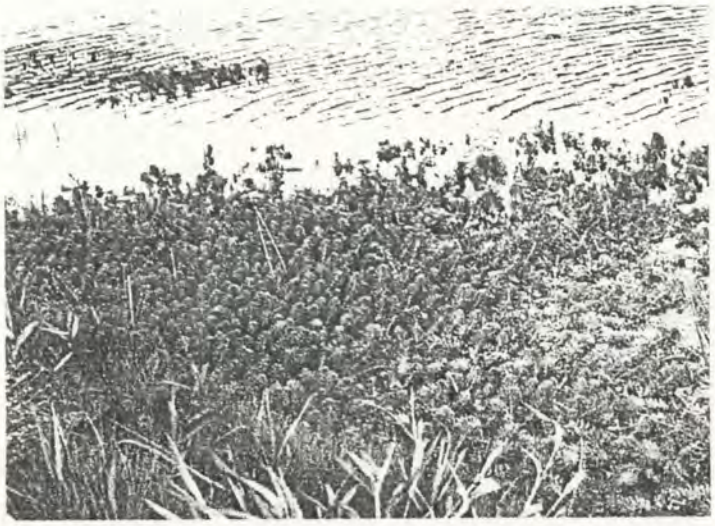
be found in many of the Puget Sound Rivers systems where both hydroelectric structures and development have impacted salmon habitat. The Chehalis continues to offer a vast amount of fish habitat through littoral zone vegetation and water impoundments.

The Chehalis river system supports salmon runs that are critical to both tribal and sport fishing groups. There are hundreds if not thousands of miles of tributaries that may support salmon. The Chehalis River itself has a number of critical side channel and oxbow areas that are critical habitat for downstream migrating juvenile fish. It is in these areas that a recent discovery of a noxious exotic aquatic weed has begun to cause concern to regional resource managers.

One of the major threats to water resources in the Pacific Northwest are introduced exotic weeds. There are a number of noxious aquatic weeds that have overrun critical lake, river, and wetland habitats in Washington State. Weeds like Eurasian Milfoil have been widely distributed around the region and have degraded water quality parameters that are critical to fish survival. Purple Loosestrife has replaced beneficial native wetland vegetation in a number of large waterfowl breeding areas in the state. Spartina has begun to expand into critical tidal mud flat and eel grass habitat in coastal estuaries such as Willapa Bay and is making inroads in Puget Sound. Other noxious aquatic weeds like Hydrilla have recently been discovered and are currently subject to eradication efforts in one King County Lake. Parrotfeather is a weed that has been present in drainage systems in the Longview, WA region for some time and has caused both habitat damage and impacted the functionality of these drainage conveyance systems. In recent years, many of these noxious aquatic weeds have been discovered in the Chehalis River basin.

Approximately two years ago, the Lewis County Noxious Weed Board discovered a colony of the aquatic weed *Myriophyllum aquaticum* or Parrotfeather, growing in backwaters of the Chehalis near Centralia. This weed had been adopted to the Washington State Noxious Weed List in 1994 because of problems it has caused in a number of drainage systems in the Longview, Washington area. Looking at points in the river, the Weed Board found that there were other backwater areas impacted by this plant in the Centralia area.

Parrotfeather is a submersed/emersed perennial aquatic plant. It is native of South America and was probably introduced to the United States through the aquarium trade. This weed is in the same family as Eurasian Milfoil, another problematic weed. Further south of Washington in Oregon and California, this weed causes substantial problems in lake, pond, drainage, and some irrigation systems. Parrotfeather has a unique emersed foliage form that can protrude from the water up to 20 cm. It forms a very thick surface mat and develops a considerable amount of plant biomass in the surface area of infested waters. This plant can have a dramatic impact on water quality of infested waters. Heavy surface mats of aquatic vegetation capture sunlight and convert it to heat energy. This warms the waters under the plant surface fairly dramatically. Heavy canopies of aquatic weeds can also affect oxygen levels under the mats. These mats limit the exchange of oxygen from the atmosphere to the water column. In addition, there can be daily fluctuation of oxygen levels in heavily infest-



This image shows a close up of a Parrotfeather mat forming in shallow water. This weed will form dense surface canopies which act to degrade water quality parameters including dissolved oxygen, temperature and pH under these mats.

ed waters, plants produce oxygen during photosynthesis during the day, but at night respiration uses up oxygen from the water column. Parrotfeather creates one other critical water quality problem when it exists at problematic levels. As the plant produces food through the process of photosynthesis, it will emit ions to the water column, a process that will lower the pH of the surrounding waters. In areas with substantial Parrotfeather infestations, pH levels in the infested waters can be depressed to levels well below those safe for aquatic organisms.

Temperature, oxygen and pH are critical water quality parameters to fish and especially salmon. Both trout and salmon are fish that require high levels of dissolved oxygen, cool water temperatures, and stable levels of pH. The presence of Parrotfeather at levels that impact these water quality parameters obviously will have an impact on salmon that utilize those waters. To this point, Parrotfeather has been discovered in many of the critical sheltered cove and oxbows off the main channel of the river. These areas are critical to salmon fingerling migrating out to sea. As Parrotfeather clogs these sections of the river and degrades water quality as described above, these areas will be lost as key habitat for this stage of the salmon life cycle. Given the importance of the salmon runs and the potential impact of this noxious weed on this resource, the Lewis County Noxious Weed Board took the initiative to survey the river and determine the extent of the problem.

The Weed Board applied for and was awarded a grant from the Washington Department of Ecology Freshwater Aquatic Plant Fund to conduct an extensive aquatic plant survey. The Chehalis River system has it's headwaters in Lewis County, but also has tributaries and main stream channels in Thurston and Grays Harbor Counties. The Lewis County Weed Board conducted the survey of all waters within the County boundaries. Thurston County Noxious Weed Board Personnel reviewed the Black River and portions of the river within that County. RMI was selected through a RFP process to conduct the survey work in Grays Harbor County.

This report outlines the efforts of RMI in this process.

Methods and Materials

The objectives of this project were to survey all of the Chehalis River in Grays Harbor County along with the first quarter mile of its major tributaries. The Lewis County Noxious Weed Board surveyed portions of the Chehalis in that county while the Thurston County Noxious Weed Board review the Black River system upstream from the Chehalis River. Populations of Parrotfeather have been found by both of these agencies.

RMI first secured accurate maps to provide a base for the river survey effort. USGS 7.5 Minute Topographic Quad Sheets were chosen as the base maps. Maps were secured from the Washington State Department of Natural Resources in Olympia. The survey area was delineated on these maps for use in the field. The end result of this project was the development of a Geographic Information System mapping effort for which 1992 TIGERfile™ maps were selected as the digital base map. The Grays Harbor County TIGERfile™ map was imported into TnTMIPS™ image processing software from the Washington State CD-ROM and converted to a MapInfo file. It files and maps were then reviewed in MapInfo and set up for data entry. Each site where a noxious aquatic plant occurred was entered as a point file matched with latitude and longitude coordinates and density ratings. This information was developed in a data base linked to the map files.

RMI biologists then performed a low level aerial survey of the area of responsibility. A Cessna 172 aircraft was used for this effort. The appropriate field Topographic maps were mounted on a clip board for use in the aircraft. Our team used a technique developed by our biologists for aerial pollution detection called Aerial Shoreline Analysis (ASA). This technique relies on low level oblique observation of shorelines of interest. The aircraft was positioned at approximately 1,000 feet above ground level with a 1000 foot offset from the channel. This provides an approximately 45 degree oblique observation angle to the shoreline. ASA methodologies also call for reviewing shorelines during daily periods of maximum sun exposure. This provides for better water penetration and illumination of conditions of interest. It also allows for better observation of the shoreline by limiting the impact of shadows. To accomplish this, shorelines were divided into morning, mid-day and afternoon shorelines depending on the geographic orientation of the river channel. The morning shorelines were those with a western exposure, mid day shorelines were those with a north and south orientation, and afternoon shorelines were those with an eastern exposure.

During the flight missions, areas where aquatic plant growth occurred were visible. Parrotfeather has a very distinctive light green growth form that extends above the water surface. A number of areas in the upstream portion of our survey where highlighted project field maps as potential sites for review on the ground. The aquatic plant growth patterns were also sketch mapped on the field maps during this flight.

The aerial survey of the river system provided an excellent picture of the conditions in the study area. Obtaining this visual aerial picture of the river, the survey team was able to direct ground-truthing efforts on the water. From this data RMI biologists developed a clear

understanding of where potential problems existed, the location of access points and boat ramps, and the occurrence of obstructions to navigation like low bridges and pipeline crossings. This information was used to design the field survey.

A second flight was performed in the late summer to provide the Lewis County Weed Board Management an overview of the sites discovered, collect additional photography, and document Purple Loosestrife infestations that were discovered in the downstream portion of the project area. Throughout this portion of the river valley, there are a number of old oxbow lakes and ponds that have been created by the river over the years, but are not hydraulically connected to the channel. The aerial observers did look at each of these during the two flight missions for evidence of Parrotfeather growth.

The actual equipment selected for the water survey was a combination of airboat and propeller driven vessels. A Panther Airboat was the primary survey vessel. Airboats can access many parts of the river system that other water craft would not reach. Most of the river system upstream from the Satsop River is vary shallow and fast moving. Conventional motor boats could not effectively operate in this portion of the river. Conventional prop boats were utilized downstream from Montesano. This section of the river had sufficient depth to make this feasible.

The upstream portion of the RMI survey area exhibited the highest potential for Parrotfeather location based on aerial analysis. The boat survey was to begin at the Oakville Bridge and move downstream, but that boat ramp had been damaged by the recent floods and the airboat could not access the river at that point. Access was gained downstream at Elma. The river was surveyed up stream to a point above the Oakville Bridge. The downstream portion of the river was surveyed utilizing the Montesano ramp.

The first boat survey of the river was completed during the period from June 27th through July 12th. Approximately 4 complete days were expended in this effort. A second survey of the system looked for both additional Parrotfeather infestations and Purple Loosestrife infestations. This work was completed between August 21st and September 6th. Again about 4 days were spent on the water looking at these areas. This time period was selected as the peak of the bloom season for Purple Loosestrife, making it easier to observe and map. Plants were observed to be well into their bloom during this work period.

Aquatic biologist storing GPS plant location data.

During the survey mission, quad maps, air photos, data recording forms, and GPS equipment were set up on the mapping vessel. Notes were recorded on the location of aquatic plant growth in the river system. When Parrotfeather or other noxious aquatic weeds were detected, they were sketched onto the Quad Sheets and their location was determined using Global Positioning System (GPS) technology.

Magellan Promark 10 Carrier Phase GPS equipment was utilized in this project. This GPS system is highly accurate and provided a latitudinal and longitudinal location of the plants discovered. At each location, the GPS was allowed to acquire a position fix over the plant beds and the location was stored in the system and recorded in field notes on the map.

Photography was collected of the infested sites during both the initial aerial survey, during the boat survey, and during a follow up aerial survey that was conducted with the Lewis County Weed Board late in the summer. These images will be made available to the County and are included in this report.

The survey data, GPS point files, notes, and maps were returned to RMI's Geographic Information System laboratory and assembled into a project map for inclusion in this report. In addition, this information was developed into a project file in a GIS software system to facilitate future mapping and control efforts. GIS is a technology that has substantial applications in the field of aquatic weed management. GIS software combines relational data base management systems with geography allowing development of maps that allows users to visually understand the location and extent of problems and access the data geographically.

For this project, the base maps selected for reporting were 1992 TIGERfile™ maps. These digital maps were developed by the US Census Bureau and are highly accurate with a 1:24,000 scale. This is same scale as the 7.5 minute USGS Quad sheets used in the field survey. TIGERfile™ maps are normally the base maps for County GIS facilities as well.

The TIGERfile™ maps were purchased by RMI and delivered on CD-ROM for the entire state. These maps have to be converted for inclusion and display in the GIS software selected for the project. We utilized MapInfo™ Professional 4.0 GIS software and conversions were made in TnTMIPS image processing software.

The GPS data for noxious aquatic weed sites was downloaded into a MapInfo™ table and software routines were used to geocode or create points on the map. Symbology and colors were selected that were representative of the two species of noxious aquatic weeds discovered during this survey. A green triangle represents the locations where Parrotfeather was documented, while an inverted purple triangle was selected for Purple Loosestrife locations. Each of these points is linked to a data base that includes the position number, the latitude and longitude information, and a density rating from 1 to 4.

The Parrotfeather density rating used for this project was a subjective evaluation of the extent of plant coverage compared to other sites observed in this section of river. A low rating of 1 was assigned to sites with very few scattered plants, probably just recently established at the site. A rating of 2 was assigned to areas where the plant had established and been present for some time. Rating 2 areas still had substantial habitat that could be colonized by Parrotfeather and expansion in coming years absent control would be probable. A rating of 3 was assigned to locations where Parrotfeather growth was starting to fill in open water habitat. A rating of 4 was considered to be the highest level of infestation observed

and a priority for control work. In these areas the plant has cut off open water habitat and created backwater ponds enclosed by the weed.

A similar density rating was applied to Purple Loosestrife infestations discovered, using a rating of 1 to 4 with 1 being single plant stands and 4 being extensive well established colonies of the weed. Plant densities were applied to each site to rate the extent of the infestation and help prioritize management efforts. This information is also useful to help track the expansion of the populations at each site, or the contraction of those populations if control measures are applied.

The maps and data table information created for this section of the project process are discussed in the results and discussion section below ad presented in the appendices. In addition, the table information is also presented. GIS files and scaled maps of the project area may be available to the various County departments if additional mapping is of interest to the Weed Board. In addition, we have the capability to add Lewis and Thurston County TIGERfile™ maps to this GIS project file and display all known noxious weed locations provided the Weed Board has additional GPS or latitude/longitude information.

Lastly, at the request of the Weed Board, RMI staff attended a workshop on September 10th in Chehalis to present the findings of this project to date. This meeting was well attended by interested state and local agencies.

Results and Discussion

Before discussing the extent and location of noxious aquatic weeds discovered during this survey, some comments about the river should be made. The winter of 1996 saw some of the worst flooding on the Chehalis River in recent memory. The damage from this flood was very evident during this survey. Much of the river channel in the RMI area of responsibility showed dramatic scouring and loss of land. There are also a few points where the river channel has been modified and oxbow lakes were created where the channel used to run. This flood in all probability had some impact on the extent and location of noxious aquatic weed infestations.

As is discussed below, there are areas in the downstream portion of our survey that were infested with Purple Loosestrife on the shoreline and in adjacent wetlands. Much of this area experienced considerable erosion as evidenced by miles of ten to twenty foot cliffs of exposed sediment. It is unclear, yet probable, Purple Loosestrife previously infested the shoreline soils lost to the flood at some level. It is also unclear what impact flooding may have had on the Parrotfeather levels in the river. This mapping project provides an opportunity for early detection of any plants that may re-colonize these disturbed areas.

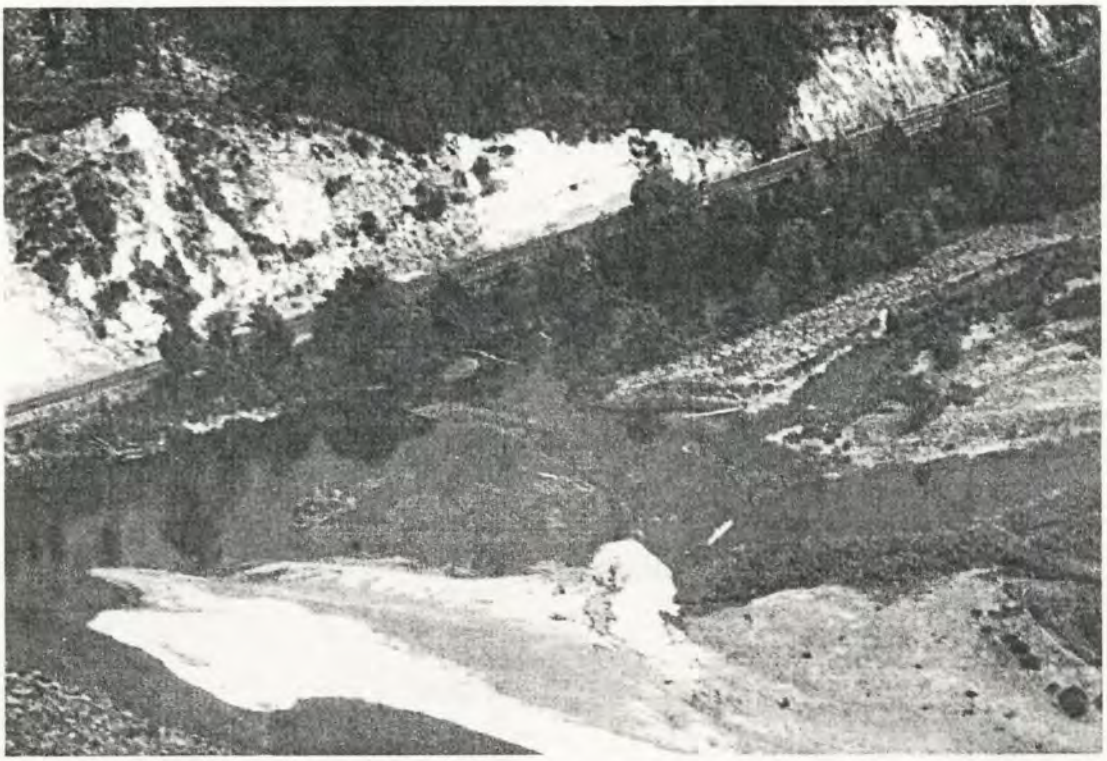
Parrotfeather detection was the primary goal of this project, culminating in the mapping of nine sites where this noxious weed occurred. The Parrotfeather table in the appendix pro-

This is an aerial image of the Site 5 Parrotfeather Infestation. This is a backwater cove off the main channel of the river and one of the important areas where young salmon can find shelter during the early periods of their life cycle. Parrotfeater has cut off the back of this previously open water area forming two small ponds. Water quality has been degraded in these areas and they are no longer available as habitat. The sand bar in the lower part of the image also has Parrotfeater and that growth will further restrict access to this area over time.

vides the location numbers, the GPS coordinate points, and a density rating for each of the sites. The map in the appendix also shows the locations of these finds. The Parrotfeather discovered and mapped during this mission was found from River Mile 34 upstream to Approximately River Mile 43.

The locations where Parrotfeather was detected were with one exception all in sheltered backwater areas off the main river channel. At the upstream end of the survey near the Oakville Boat ramp a few plants were detected and mapped growing along the shoreline in the main channel. The remaining sites were in either small or large coves and side channel areas out of the flow pattern of the river. With the exception of the site discussed below, these infestations were less than 1 acre of plant coverage. If left unchecked Parrotfeather will dominate these side channel and cove areas in the near future.

Site number 5 had the largest infestation of Parrotfeather found and is representative of the potential this plant has for impact on fish and wildlife habitat. There is from 1 to 2 acres of Parrotfeather located at this site. The site was an oxbow or former river channel area that extended approximately 1,000 feet back from the main river channel. These sheltered waters would provide excellent rearing or resting habitat for fish. The back one third of this area is completely cut off from the river by the Parrotfeather growth. In addition, small pond enclosures formed by the Parrotfeather are close to overrun with this noxious weed with small



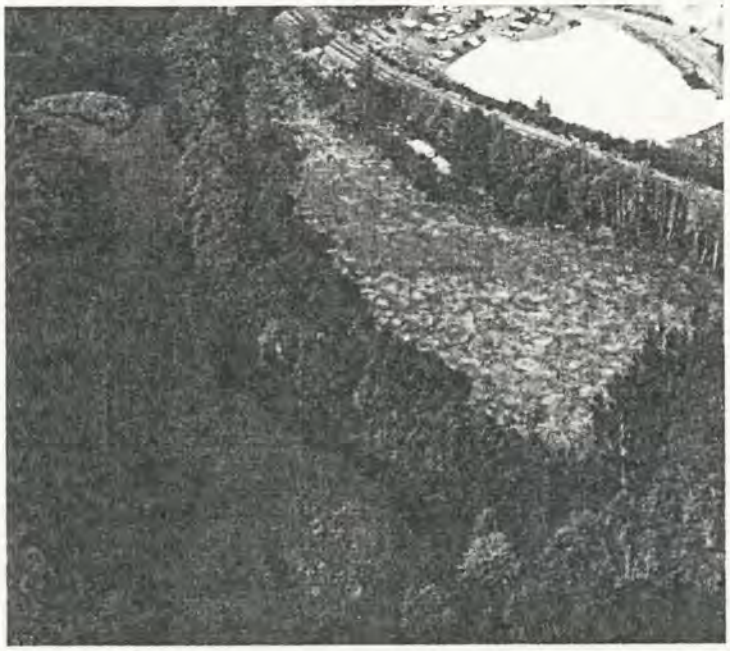
This image shows the River Channel and the opening to an extensive oxbow lake, key backwater habitat. Note the Parrotfeather infestation on the Sandbar about to cut this large area off from the main channel. There are a number of pioneering colonies of this plant further back in the Oxbow Lake. Highway 12 appears in the top of the image.

areas of open water remaining. Further out toward the river channel, the Parrotfeather has established in very thick beds along the shoreline and had also colonized a small sand bar at the mouth of the cove. If allowed to continue, it is probable that this growth will cut off the cove completely from the river system and remove this area as salmon habitat. While the other sites on this section of river which are mapped had similar growth conditions, Parrotfeather typically had not yet colonized the entire backwater area as in site 5. It is probable that these will be closed off in the near future without control efforts.

No Parrotfeather was discovered growing in the main channel of the river. This was an interesting observation in that many other native aquatic plants occurred in the main channel at various points in the system. It is possible that Parrotfeather may not colonize high flow areas. Recent flooding may have also washed out any occurrences of this plant that may have previously colonized the main river banks. The river should be reviewed in future years to confirm this observation or document the spread of the plant into the river channel.

It is also interesting to note that no Parrotfeather was discovered below the mouth of the Satsop River. There are tidal fluctuations of the lower stream water levels and it is both possible that water flow and soil salinity have had an impact on freshwater macrophyte growth in this transitional estuarine area. Many species of Myriophyllum, for example Eurasian Milfoil are tolerant of high salinity. The first discovery of Eurasian Milfoil occurred in the Chesapeake Bay where at peak it infested in excess of 25,000 acres.

A spot check of the salinity in the area below the Satsop showed increase salt levels as we moved toward Grays Harbor. Research conducted by Dr. Dave Sutton of the University of Florida IFAS Fort Lauderdale Aquatic Plant Research Laboratory in 1980 did show that Parrotfeather was found to be one of the most tolerance to salt water. He determined that based on that type of data, this plant would do well in many coastal areas where saltwater intrusion occurs. As we did not observe any Parrotfeather in these downstream areas, the conclusion at this point would be that it has either not yet reached these bays, or it can not tolerate the water movement created by the tides.



This picture is of the mouth of the Satsop River. The shoreline in this area and the island at the center of the lower image are heavily infested with the noxious wetland weed, Purple Loosestrife. It appears from our survey, that this is the source of seed production for a number of the pioneering colonies of this weed we mapped in the lower portion of the survey area. There are very few Loosestrife plants upstream from this and we feel that tidal influence may have played a role in the upstream spread. Downstream from this point there are well distributed, but still small colonies of this weed. It is critical that management efforts begin to target this plant as it currently has not expanded to convert wetlands to monoculture stands.

In the Central Park area, there are extensive backwater channels such as Blue Slough and Mox Chuck Slough that could be impacted by this weed as it spreads. As is recommended below, there should be additional survey work performed in the future to watch for downstream movement of this plant and provide control before it establishes.

While the river survey did not directly look at many of the ponds and lakes present in the Chehalis River Valley, the aerial work did focus on them as part of our protocols. It is clear from the air that there are aquatic plants present in many of these systems. Parrotfeather has a distinctive green color that was easily observable from the air, and we did not see any evidence of it's presence in these pond and small lake systems. That does not mean that it is not present in these systems; there could be small groups of plants that would not be visible from altitude. As these ponds are not connected to the river and access is very limited to the public, it is probable that there are not infestations of noxious aquatic weeds in these systems originating from river or boat trailer traffic. It is also probable that if there were noxious aquatic weeds present, their impact on the river would be minimal because there is no direct connection for plant fragments or seeds to move to the channel. There should be some public education/identification offered to such land owners to help determine the presence of noxious aquatic weeds in these systems and help provide control recommendations.

Another major problem aquatic and wetland weed is Purple Loosestrife. We did not observe any Purple Loosestrife in the upper sections of our river survey. Upon launching our efforts in the lower portion of the survey area we discovered extensive stands of this noxious weed at the mouth of the Wynoochee River. All of the margins of the Wynoochee within approximately 0.25 miles of the Chehalis are heavily impacted with extensive growth of well established older Loosestrife plants. We also mapped 51 additional locations where this plant occurs on the Chehalis River system. There are a few small colonies of Loosestrife upstream from the Wynoochee, but these are relatively new. There is also a tidal influence here, and it is very possible that seeds were distributed upstream from the Wynoochee through this mechanism. Downstream from the Wynoochee, there are also a number of mostly recent or pioneering infestations of Loosestrife. The locations, GPS coordinates, and density ratings are presented in the table in the appendix of this report and represented on the map. The major infestation was located at River Mile 13 at the mouth of the Wynoochee River. We discovered a few locations upstream from this site, but no Loosestrife plants above River Mile 14. The downstream boundary of Loosestrife plants found and mapped was River Mile 7.

The Purple Loosestrife observed occurred mostly above the high tide line. Plants thinned out and disappeared as the river transitions into Grays Harbor. A field test of the salinity showed that there was a marked increase in salinity near where the last plants were observed. In addition, the side channels off the river near Aberdeen exhibited no Purple Loosestrife growth, while fresh water wetlands near Highway 12 and the Aberdeen Landfill have had extensive populations of this weed for some time. It may be that salt water or the daily tidal currents play a role in limiting the spread of this noxious weed in this section of the river. There have been documented cases on the East Coast where managers utilized salt water intrusion into wetlands infested with established stands of Purple Loosestrife with little or no resulting impact, so perhaps the more critical role is tidal water movement. In any event, the spread of the plant should be monitored and further review of the downstream sites will show if expansion into these areas is possible.

No other noxious submerged aquatic plants were discovered during this mission. There were a number of native aquatic plants present in the upper portions of the River system above the areas influenced by the tides. The most predominant plant in the main channel of the river was Illinois Pondweed. This plant was well distributed from Oakville to the Wynoochee River mouth. There are also areas between the Satsop River mouth and Oakville with extensive beds of filamentous algae present on the river bottom, possibly indicating excessive nutrient levels in those areas. Most of the coves in this upper section of river had a number of native species including pondweeds, elodea, and coontail in the areas not impacted with Parrotfeather.

It should be noted that the noxious weed Eurasian Milfoil has been discovered in Scott Lake in southern Thurston County. This lake is connected to the Black River through a creek and the Black River drains into the Chehalis River. Eurasian Milfoil thus has the potential to infest much of the Chehalis River system. Milfoil grows very well in flowing water and is a major problem in irrigation delivery systems with flows in excess of that in this section of

river. Eurasian Milfoil can also thrive in brackish and salt water as sighted in Chesapeake Bay earlier in this report. As such, there may be large areas of grays Harbor that could also support this noxious weed. Future surveys should monitor for this weed as well as it could have a greater impact on habitat than Parrotfeather if it establishes in the river. Brazilian Elodea has also been discovered by the residents of Plummer Lake in Centralia and confirmed by the Lewis County Noxious Weed Board. This lake is connected to the river by a culvert. While this connection may be more direct that the Scott Lake connection, Eurasian Milfoil may pose the greater threat to the lower Chehalis system because of the ability of that plant to colonize both backwaters, flowing waters, and brackish waters.

Reed Canary Grass is a plant also listed on the state noxious weed list and this plant was observed in all sections of this study area at various densities. In many cases, this weed is so widely distributed that control is not economically feasible. It's distribution through the system was too extensive to map using point file systems.

Spartina is another noxious weed of concern in estuary habitat in this area. As we neared the river delta, there are a number of areas that appear to be excellent habitat for Spartina infestation. There were also extensive areas below Central Park and Higgins Island that had exposed mud flats during low tide that could support this plant. At one site located on the north shore of the channel at River Mile 4.25, near the mouth of a small unnamed creek, a stand or clone of a plant resembling Spartina was observed. This area should be checked again during upcoming survey work with a key for this plant to confirm identify.

Recommendations

The first critical step that should be taken is an integration of all mapping and survey efforts that have been undertaken in the river basin. While our firm conducted the survey work along the river in Grays Harbor County, both the Lewis County Noxious Weed Board and the Thurston County Noxious Weed Board have also looked at the river and its major tributaries in their areas of jurisdiction. All of this data should be assembled into a map for the entire basin so an integrated plant management efforts may be developed. Future efforts should focus on controlling and removing the noxious aquatic plants from the river system and include monitoring for the introduction of additional problem species such as Eurasian Milfoil. Incorporation of mapping data into a Geographic Information System could benefit all of the jurisdictions by accounting for increases of the current plant populations or decreases associated with control efforts. The GPS points we have developed for this project can be imported to most GIS software.

An Integrated Aquatic Plant Management Plan should be developed immediately for the Chehalis river system following Department of Ecology guidelines. Much of the work under this RMI project and other mapping efforts have provided essential information for this planning process. The potential impact of Parrotfeather on salmon habitat should make this effort a high priority and implementation of control strategies should begin as soon as possible.

Control of Parrotfeather would ideally begin in early 1997. At this point there are relatively few acres of this noxious weed present in the RMI surveyed portion of the river system. Combined with the other areas where this weed has been detected by Lewis and Thurston County staff, there still are not extensive acreages that need to be attacked. There are however large areas of prime salmon side channel habitat that are threatened by this weed. It should be fairly cost effective to begin control efforts in the near future.

Most of the areas RMI mapped are not accessible to mechanical control technologies like aquatic plant harvesters and rotovators. Portions of the river are too shallow for this equipment to navigate to the work site. In areas where is it possible to access with equipment, there is also a concern about creating fragments. This plant is fairly fragile and it is probable that it will fragment during this type of operation. When attacking a pioneering colony of many Milfoil species in a lake or river system, it is seldom recommended that mechanical control technologies be applied because of the potential to further distribute the plant by creating fragments. In some cases where pioneering infestations of Eurasian Milfoil were discovered and targeted with harvesting operations, it in effect advanced the spread and colonization of the entire lake system. With the exception of the site mapped just down stream from the Oakville Boat Launch, all of the infestations mapped in RMI efforts were beyond the scope of a hand pulling operation.

Selective herbicide applications could be the most effective approach to controlling Parrotfeather. There is work being conducted by Dr. Mark Sytsma of Portland State University to review herbicides and other control methodologies. His work should be included in the development of the integrated aquatic vegetation management plan. RMI has produced a number of these plans and would be willing to assist the Noxious Weed Board towards development of this document.

It should be noted that all of the Parrotfeather infestations mapped by RMI are accessible by airboats and other aquatic application equipment. The mode of action of the aquatic herbicides that are effective on this weed are fairly rapid, and the areas mapped would not have problems with water exchange. There exist few actual acres of Parrotfeather infestation and any applications would be treating a small areas of shoreline and cove. If left unchecked, much larger applications may be necessary as the plants spread. Permits required by the Washington Department of Ecology for any application of herbicides to waters of the state would be required here.

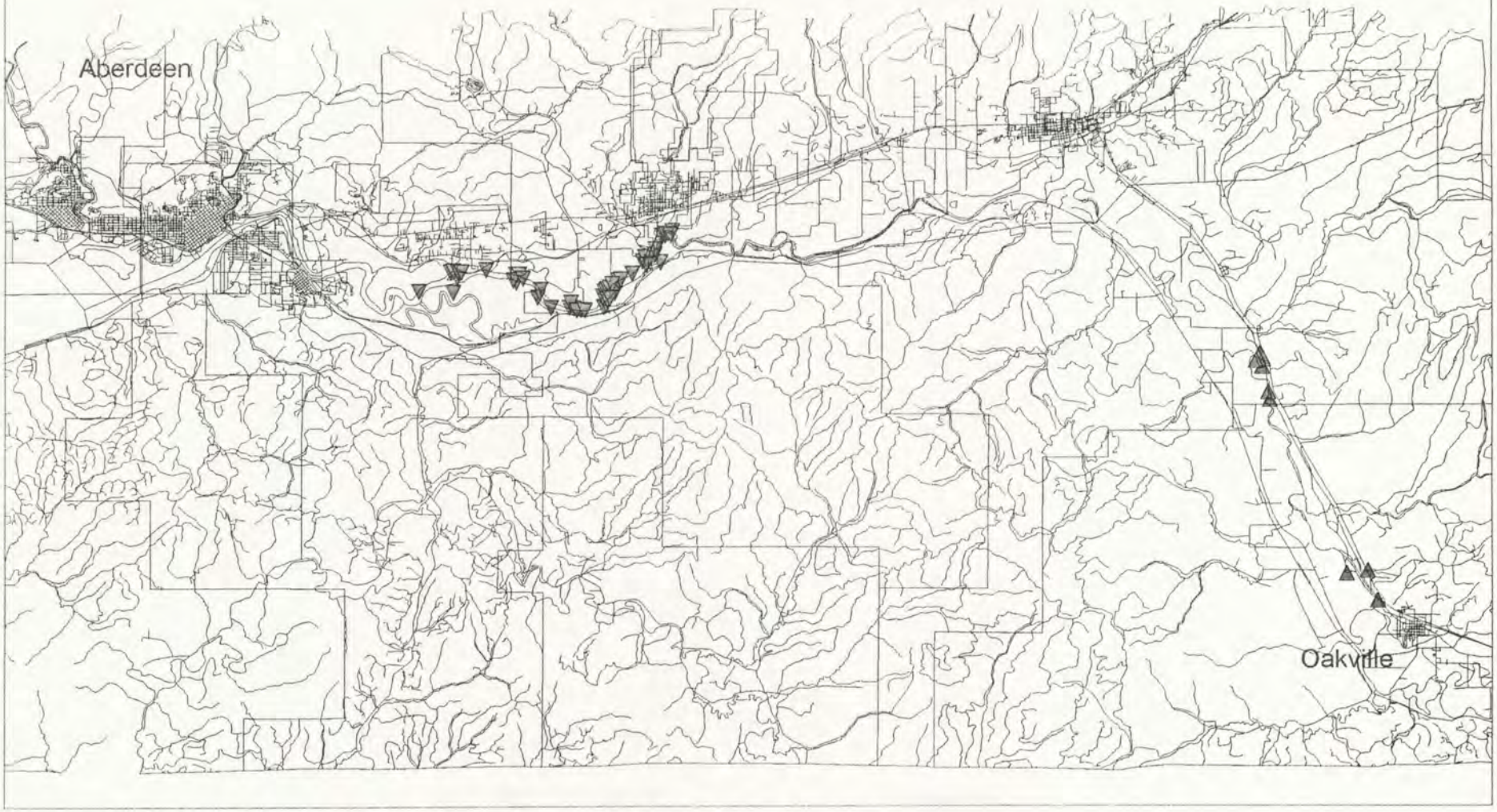
The downstream areas of the river where Purple Loosestrife have been mapped should also see some attention. With few exceptions, the plant colonies mapped are in the pioneering stages and a management plan targeting these plants now will save substantial areas from infestation in later years. There are large wetland areas in the river with one or two Loosestrife plants present that will deteriorate if Loosestrife is allowed to expand unchecked. RMI boat and aerial observations have provided estimates that less than 1 percent of the wetlands adjacent to the river that would support Loosestrife are currently impacted by it. This weed will expand rapidly, however, and without control measures major infestations of this weed can be expected in the next several years.

Both control measures and additional monitoring should be implemented to protect the Chehalis' critical wetland habitats. It is probable that recent floods removed much of the Purple Loosestrife present in the Grays Harbor County section of river as large sections of shoreline have been eroded. This provides a cost effective opportunity to attack this remaining problem vigorously in 1997. It also provides an opportunity for Loosestrife to expand if left unchecked; this weed does very well in disturbed landscapes and the exposed banks of the river caused by the flood could offer that type of site. The areas RMI observed are in Grays Harbor County and there should be some interface with public agencies in this region a to encourage control efforts.

There is at present a significant opportunity to stem the expansion and loss of habitat by both Parrotfeather and Purple Loosestrife. The RMI mapping effort and the other survey work that has been accomplished this year is an excellent start to the management planning of these plants. As this information is developed into a GIS package, any future mapping efforts can easily be added for comparison and analysis. Control work needs to be focused on as soon as possible to limit noxious weed impact. There is a significant opportunity to get ahead of these two noxious weed problems. The resource agencies of this state should seize this opportunity and protect these sections of this important river system.

Appendix I

Weed Survey Map



Chehalis River Noxious Aquatic Weed Survey
Grays Harbor County, Summer 1996

NORTH

▲ Parrotsfeather
▼ Purple Loosestrife

Resource Management, Inc. for Lewis County Noxious Weed Board
2900-B 29th Ave SW, Tumwater, WA 98512 360-754-3460

Appendix II

Parrotfeather Location Coordinates and Densities

Number	x	y	Density
1.0000	-123.2508	46.8491	1.0000
2.0000	-123.2556	46.8591	2.0000
3.0000	-123.2659	46.8581	2.0000
4.0000	-123.3029	46.9161	2.0000
5.0000	-123.3038	46.9186	4.0000
6.0000	-123.3080	46.9313	2.0000
7.0000	-123.3063	46.9297	2.0000
8.0000	-123.3068	46.9270	2.0000
9.0000	-123.3096	46.9292	1.0000

Appendix III

Purple Loosestrife Location Coordinates and Densities

Site	x	y	Density
1	-123.7156	46.9523	1
2	-123.7125	-46.9520	2
3	-123.6990	46.9520	3
4	-123.6971	46.9569	3
5	-123.7002	46.9587	3
6	-123.6990	46.9590	3
7	-123.6965	46.9587	2
8	-123.6951	46.9587	2
9	-123.6831	46.9594	2
10	-123.6685	46.9579	2
11	-123.6668	46.9579	2
12	-123.6682	46.9554	2
13	-123.6699	46.9560	1
14	-123.6651	46.9566	1
15	-123.6567	46.9527	1
16	-123.6579	46.9502	1
17	-123.6514	46.9468	1
18	-123.6425	46.9468	3
19	-123.6405	46.9466	3
20	-123.6388	46.9462	3
21	-123.6369	46.9462	2
22	-123.6416	46.9485	4
23	-123.6388	46.9460	3
24	-123.6349	46.9460	3
25	-123.6256	46.9470	2
26	-123.6245	46.9481	3
27	-123.6262	46.9506	1
28	-123.6254	46.9521	2
29	-123.6242	46.9529	1
30	-123.6247	46.9524	1
31	-123.6237	46.9530	2
32	-123.6229	46.9535	3
33	-123.6216	46.9546	3
34	-123.6240	46.9495	2
35	-123.6228	46.9501	1
36	-123.6205	46.9517	3
37	-123.6188	46.9558	1
38	-123.6175	46.9561	1
39	-123.6120	46.9580	1
40	-123.6071	46.9621	1
41	-123.6058	46.9635	4
42	-123.6053	46.9609	4
43	-123.5984	46.9618	1
44	-123.6010	46.9644	1
45	-123.6008	46.9660	1
46	-123.5979	46.9706	1
47	-123.5925	46.9721	1
48	-123.5960	46.9706	2
49	-123.5955	46.9711	3
50	-123.5945	46.9714	2
51	-123.5932	46.9709	2

APPENDIX D
1995 Aquatic Noxious Weed Survey: Thurston County

MID-TERM GRANT REPORT
G9500167

SURVEY OF SELECTED RIVERS OF THURSTON COUNTY FOR THE PURPLE LOOSESTRIFE, *LYTHRUM SALICARIA*

October 9, 1995

PURPOSE:

During July and August, 1995, Thurston County Noxious Weed Control surveyed the following rivers in Thurston County: the Black River, the Chehalis River, McAllister Creek, the Nisqually River, the Skookumchuck Reservoir, and the Skookumchuck River. The purpose was to survey for the presence of the noxious weed purple loosestrife (*Lythrum salicaria*) and to inventory the aquatic plant communities of the river systems. As other noxious aquatic and terrestrial plants were found they were identified and their locations were noted.

EQUIPMENT:

The equipment used to complete the project included: a Momentum 14-foot self-bailing white water raft, an Easy Rider 15-foot canoe, a 14-foot aluminum jet boat, a Magellan NAV 5000 DLX GPS unit, and a scientific aquatic plant sampling tool (garden rake).

HELICOPTER SURVEY:

A three-hour helicopter survey of the Black River, Chehalis River, Skookumchuck River, Skookumchuck Reservoir, and the Nisqually River was carried out by Perry Beale on July 25, 1995.

BLACK RIVER SURVEY RESULTS: There was very good visibility from the air on this river system. Many areas are inaccessible from land as the river turns into marsh for quarter-mile sections. The dominant species visibly present from the air on the river was *Douglas spirea*. One plant of purple loosestrife was seen approximately 200 yards south of the 110th street bridge (coordinates: 46 55.641N / 123 00.494W).

CHEHALIS RIVER SURVEY RESULTS: There was good visibility from the air on the north shoreline, but the south shoreline was lined with more trees having more shaded areas making it difficult to see. A few new, previously unknown, tansy ragwort sites were visible. No purple loosestrife was visible.

SKOOKUMCHUCK RIVER SURVEY RESULTS: This river was lined with tall trees. It was very difficult to see other vegetation from the air. No purple loosestrife was visible.

SKOOKUMCHUCK RESERVOIR SURVEY RESULTS: This reservoir was very clean, very little vegetation around the rocky, steep shoreline. This reservoir is located in the heart of managed forest land. There was a lot of fireweed visible. No purple loosestrife was visible.

NISQUALLY RIVER SURVEY RESULTS: This river has a lot of sandbars with young, fast growing trees (alder and cottonwood). The dominant plant visible along the shoreline was reed canary grass. Meadow knapweed was visible on a couple of the sand bars. Some butterfly bush was evident, resembling purple loosestrife. No purple loosestrife was visible.

METHODS:

A combination of methods were used to sample the river systems. These were visual and rake sampling. Each shoreline was inspected by observers in a boat. Special attention was given to areas of slow moving water and back waters. Most of the time visual sampling was sufficient due to low water conditions and good water visibility. Blind rake sampling was done when the substrate was not visible. It was then used to ascertain if plants were actually growing out of view from the surface.

The scientific aquatic plant sampling tool (the rake) was invaluable in retrieving plants located in both deep and fast moving water. The rake has a five-foot wooden handle and 14 two-inch cast steel tines. Six feet of 3/8-inch poly rope was attached to the handle giving it an approximate length of 11 feet. In this configuration the tool is slightly negatively buoyant. The addition of one to three pounds of weight would expedite matters if a lot of deep water sampling needed to be done.

Data collected at the sampling sites consisted of physical specimens and notation of location in latitude and longitude, measured by a hand held global positioning system (GPS) unit. Voucher specimens of the plants were pressed and dried, and will be mounted.

VOLUNTEERS:

Most important of all were the volunteers. Without the help of volunteers this project would have been long, very long. We would still be dragging the raft over log jams or across gravel bars someplace a long way from the take out point. Contacts were made

with groups such as Adopt-A-Beach, the Nisqually River Council, the Chehalis River Council, and the Deschutes River Improvement Association. A training workshop was held on April 15. At the workshop, a group of potential volunteers was given a detailed outline of the project. The group learned the importance of controlling non-native, noxious plants; it was given instruction on boat handling and water safety; and was trained in species identification. The volunteers were all strongly impressed with the fact that the continuing health of these waterways will depend, at least in part, on their long-term vigilance in watching the vegetation appearing in the rivers. Volunteers who were not at the workshop were given one-on-one training by weed control staff prior to their time on the rivers.

Volunteering their time for this project were: Bill Wamsley, Laurie Penders, Lisa Lantz, Jennifer Parsons, Beth Dubble, John Johnson, Kit Paulsen, Ann Marie Currie, Jeff Grimm, Rob Healy, Julie Hover, Chris Soderstrom, Robert Moody, and Robert Smith. Special thanks are due Mr. Smith for letting us use his property to exit the Nisqually River.

NOXIOUS WEED CONTROL STAFF:

Prior to the first of the surveys, the Noxious Weed Control staff was trained intensively, by The Outdoor Adventure Center of Olympia and Tacoma, in white water boat handling and safety, and completed training and certification in first aid and CPR. Staff participating in the training and the surveys were: Mike McKay, Perry Beale, Dan Miller, and Kelly McAllister

AMENDMENT TO ORIGINAL GRANT:

During the survey of the Chehalis River, an extensive infestation of the noxious weed parrot feather (*Myriophyllum aquaticum*) was discovered. Parrot feather is listed on the Washington State Noxious Weed List [WAC 16-750-011(32)] as a class B noxious weed designated for control in District 5, which includes Thurston County. This led to Grant G9500167 being amended to include the collection of these plants as they are found in the river. The Chehalis River Council was helpful in getting volunteers together and in removing most of the plant material. The collected plants were removed from the river to high ground and spread as a thin layer on top of low brush or reed canary grass. The plants were allowed to air dry rendering them non-viable. The Chehalis River Council covered the river from Borst Park to the Thurston/Grays Harbor county line at Independence. Hundreds of pounds of fresh plant material was removed from the river. Thurston County Noxious Weed Control did a follow up survey to check for any plants missed by the River Council volunteers.

On August 28, Bill Wamsley and Mike McKay surveyed the river from Prather Road to Independence on the east side. Plants were found in four locations. These were removed from the river and spread to dry as above.

On August 29, Bill Wamsley and Mike McKay surveyed the river from Borst Park to the Prather Road. This section had been covered by volunteers; Bill had been present on that occasion. Both sides of the river were checked, to the Galvin bridge, on the east side only. The amount of plant material removed is difficult to estimate, but the boat had to be unloaded five or six times, and accounted for only half way to Prather Road.

On August 30, Bill Wamsley, Chris Soderstrom and Mike McKay, with two boats, started from the Galvin Bridge and continued the control work on both sides of the river to Prather Road. Again, the amount of plant material was difficult to estimate. The boats were unloaded four to five times. The plant material was handled as above.

On August 31, the final section of the river was completed, that is, the east side from Prather Road to Independence. Dan Miller and Mike McKay did this section of the river, finding plants in six places The plants were removed and treated as above. The river banks were then clear of parrot feather. There are, however, a couple of places where dry sloughs are infested with the plant. These plants will probably wash out into the river during the coming winter, with the first high water. Another location has been reported on the Black River in Grays Harbor County, down stream from the Highway 12 Bridge. Another has been confirmed in the slough past Oakville at the ramp.

SPECIES LIST BY WATER BODY:

CODE	*SCIENTIFIC*	COMMON
CHEHALIS RIVER		
ELOD	*Elodea canadensis*	Canada waterweed
RICH	*Potamogeton richardsonii*	Richardson's pondweed
DUCK	*Lemna minor*	Duck weed
BUR1	*Sparganium eurycarpum*	Bur-reed (emergent)
BUR2	*Sparganium angustifolium*	Bur-reed (submersed)
FOIL*	*Myriophyllum aquaticum (Brasiliense)*	Parrot feather
REED	*Phalaris arundinacea*	Reed canarygrass
FILA	*Filamentous algae*	Filamentous algae
PULY*	*Lythrum salicaia*	Purple loosestrife (Lewis Co)
COON	*Ceratophyllum demersum*	Coontail
RLPW	*Potamogeton epihydrus*	Ribbon-leaf pondweed
IRIS	*Iris pseudacorus*	Yellow flag iris
BUTR	*Ranunculus aquatilis*	White water buttercup
BLACK RIVER		
PULY*	*Lythrum salicaria*	Purple loosestrife (previously known sites)
ZOST	*Potamogeton Zosterformis*	Eel grass pondweed
CINQ	*Potentila Paulistris*	Purple cinquefoil
IRIS	*Iris pseudacorus*	Yellow flag iris
ROBB	*Potamogeton robbinsii*	Robbin's pondweed

CODE	*SCIENTIFIC*	COMMON
ELOD	*Elodea canadensis*	Canada waterweed
NITE	*Nitella spp.*	Nitella
BUR2	*Sparginium angustifolium*	Bur reed (submersed)
BUR1	*Sparginium eurycarpum*	Bur reed (emergent)
VALS	*Vallisneria americana*	American wild celery
COON	*Ceratophyllum demarsum*	Coontail
MIMU	*Mimulus guttaus*	Monkey flower
DUCK	*Lemna minor*	Duckweed
IMPA	*Impatience noli-tangere*	Touch-me-not
HIPP	*Hippuris vulgaris*	Mares tail
NMIL	*Myriophyllum hippuroides*	Northern watermilfoil
NAJA	*Najas guadalupensis*	Water-nymph
PEPR	*Polygonum hydropiper*	Water pepper
FILA	*Spirogyra spp.*	Filamentous algae
YWLI	*Nuphar polysepalum*	Yellow water lily

SKOOKUMCHUCK RIVER

RLPW	*Potamogeton epihydrus*	Ribbonleaf pondweed
ZOST	*Potamogeton zosterformis*	Eelgrass pondweed
LSPW	*Potamogeton praelongus*	Long-stalked pondweed
ELOD	*Elodea canadensis*	Canada waterweed
DUCK	*Lemna minor*	Duckweed
BUR1	*Sparginium eurycarpum*	Bur reed (emergent)
BUR2	*Sparginium angustifolium*	Bur reed (submersed)
FILA	*Spirogyra spp*	Filamentous algae
BUTR	*Ranunculus aqualilis*	White water buttercup

NISQUALLY RIVER

CLPW	*Potamogeton crispus*	Curley leaf pondweed
ELOD	*Eleodea canadensis*	Canada waterweed
NAJA	*Najas guadelupensis*	Water nymph
BUR1	*Sparginium eurycarpum*	Bur-reed (emergent)
BUR2	*Sparginium angustifolium*	Bur-reed (submersed)

NOXIOUS SPECIES FOUND ON GRAVEL BARS

MEKN*	*Centaurea pratensis (C.jacea x nigra)*	Meadow Knapweed

McALLISTER CREEK

ELOD	*Elodea Canadensis*	Canada waterweed
RLPW	*Potamogeton epihydrus*	Ribbon leaf pondweed
BUR1	*Sparginium eurycarpum*	Bur reed (emergent)
BUR2	*Sparginium angustifolium*	Bur-reed (submersed)
CLPW	*Potamogeton crispus*	Curley leaf pondweed
PLAN	*Alisma plantago-aquatica var. Americanum*	Water plantain
DUCK	*Lemna minor*	Duckweed

CODE	*SCIENTIFIC*	COMMON
HIPP	*Hippuris vulgaris*	Mares tail
PEPR	*Polugonum hydropiper*	Water pepper
DSRU	*Eleocharis parvula (?)*	Dwarf spikerush (non-blooming best guess)
PLPW	*Potamogeton pectinatus*	Fennel leaved pondweed
MIMU	*Mimulus guttatus*	Yellow monkey flower

NOXIOUS SPECIES FOUND ON CREEK BANK

PEST	*Sonchus arvensis var. arvensis*	Perennial sowthistle

SKOOKUMCHUCK RESERVOIR

No aquatic plants found

PLANTS FOUND GROWING IN THE DRAWDOWN ZONE (seedling stage)

	Panicum capillare	Witch grass
	Salix spp	Willow
	Carex spp	Sedge
REED	*Phalaris arundinacea*	Reed canarygrass
	Bidens frondosa	Beggars tick
DSRU	*Eleocharis spp.*	Spike rush
	Equisetum fluviatile	Horse tail
	Polygonum persicaria	Lady's thumb
TARA	*Senecio jacobeae*	Tansy ragwort
BULL	*Cirsium vulgare*	Bull thistle
	Epilobium angustifolium	Fireweed
	Chenopodium album	Lambs quarter
	Alnus rubra	Red alder
POAK	*Rhus radicans*	Poison oak

RIVER DATA POINTS:

CHEHALIS RIVER

46 43.526N 123 00.930W (GQ-5) FOIL*

. . . Location of the "mother lode " of Parrot Feather. This is a slough on the east side of the river approximately 1/2 mile upstream from the Galvin bridge. Approximately 1.5 acres. This site is located in Lewis County and is the farthest up the river parrot feather was found.

46 47.255n 123 02.018w FOIL*

. . . Location of 1 meter square of parrot feather, additional plants are immediately downstream 50 feet

---

* This symbol indicates the species is a B-Designate noxious weed in Thurston County.

46 42.444n 123 02.613w FOIL*
. . . Parrot feather unrooted fragment at the water's edge. This site is on the west side of the river, in view of the Grand Mound Elementary School. This plant was removed from the river and hung in the brush to dry above the cut bank.

46 48.071n 123 06.115w FOIL*
. . . Parrot feather floating in the river; hung up on a log.

46 40.827n 122 59.455w PULY*
. . . Purple Loosestrife north of the golf course in Chehalis behind the twin silos of a dairy. This site is located in Lewis County and the plant was dug and removed from the river and later pressed.

46 47.143n 123 01.977w FOIL*
. . . Parrot feather floating in the river; hung up in the over-hanging dogwood trees.

46 47.211n 123 01.980w FOIL*
. . . Parrot feather location

46 47.825n 123 07.184w FOIL*
. . . Last parrot feather found in Thurston County. The location is the Independence Road bridge on the west side, in a log jam, on the bridge piling

Note: The entire Mid-Term Grant Report is 14 pages in length.

APPENDIX E
Comprehensive list of Parrotfeather Sites 1994--1995--1996

Parrotfeather Sites in 1994

Small Parrotfeather infestations = Coverage is less than or equal to 100 sq. ft.
Chehalis River, Near Mellen Street (Joint Survey: LCNWCB & TCNWCB)

Parrotfeather Sites in 1995

Small Parrotfeather infestations = Coverage is less than or equal to 100 sq. ft.
Chehalis River, Galvin Bridge
Chehalis River, Below Galvin Bridge
Chehalis River, Prather Bridge
Chehalis River, Grand Mound Elementary School
Chehalis River, Independence Bridge

Large Parrotfeather infestations = Coverage is greater or equal to one acre.
Chehalis River, Oakville Boat Launch
Chehalis River, Atkinson Slough

Parrotfeather Sites in 1996

Small Parrotfeather infestations = Coverage is less than or equal to 100 sq. ft.
Chehalis River, Galvin (WP #192)
Chehalis River, Galvin Bridge (WP #199)
Chehalis River, Port of Centralia Slough (WP #73)
Atkinson Pond (WP #39)
Chehalis River, Downstream of Salzer Creek (WP #149)
Chehalis River, Upstream of Salzer Creek (WP #148)
Chehalis River, Upstream of Salzer Creek II (WP #85)
Chehalis River, Upstream of Scheuber Drainage Ditch (WP #150)
Chehalis River, Water Treatment Out-fall (WP #86)
Chehalis River, Below Alexander Park (WP #71)
Slough Pony Soldier Motor Inn, Interstate 5 (WP #186)

Medium Parrotfeather infestations = Coverage is greater than 100 sq. ft. and less than one acre.
Chehalis River, Prather / Maple Lane (WP #90)
Slough Riverside Golf Course (WP #42)

Large Parrotfeather infestations = Coverage is greater or equal to one acre.
Chehalis River, Below Garrard Creek (WP #60)
Chehalis River, Galvin Bend (WP #190)
Scheuber Road, #1617. Private pond (WP #208)
Chehalis River Slough; Hwy. 6 & Newaukum Ave. Rd. (WP #183)

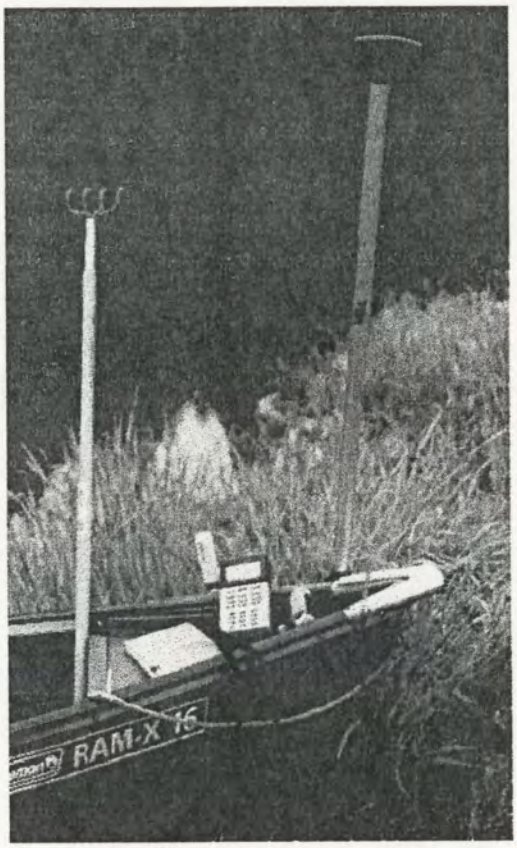
Other Findings by Resource Management Inc.

Small Parrotfeather infestations = Few Scattered Plants
This includes two sites. One near Porter and near the Oakville Boat Launch.

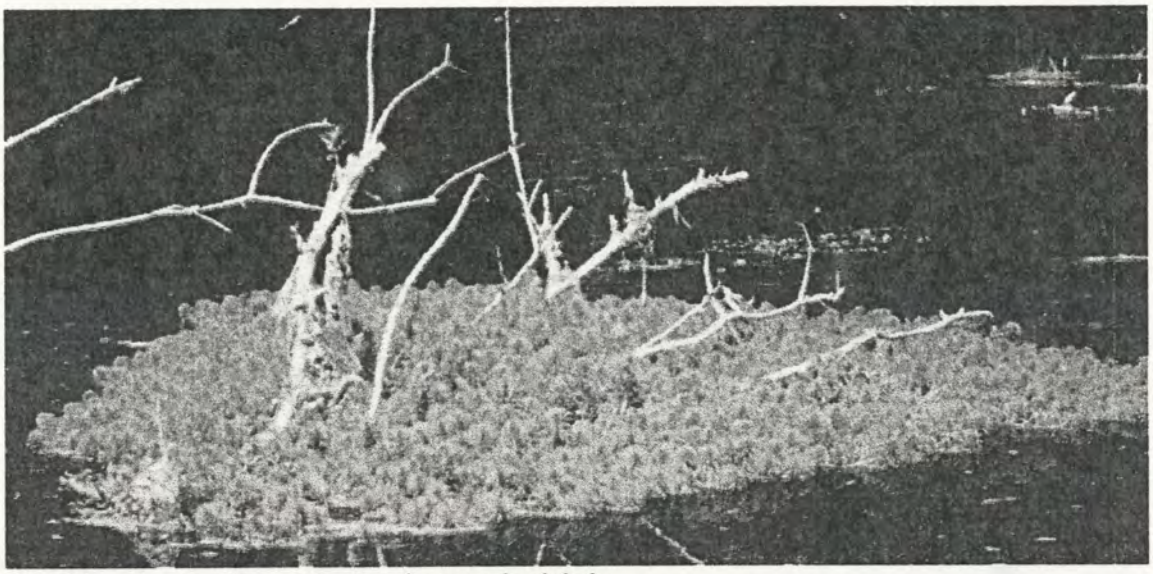
Medium Parrotfeather infestations = Plant had established and has been present for some time.
This includes six different sites between the Oakville Boat Launch and the Porter Bridge.

Large Parrotfeather infestations = Plant has cut off open water habitat and created "ponds".
A large backwater slough upstream of Porter.

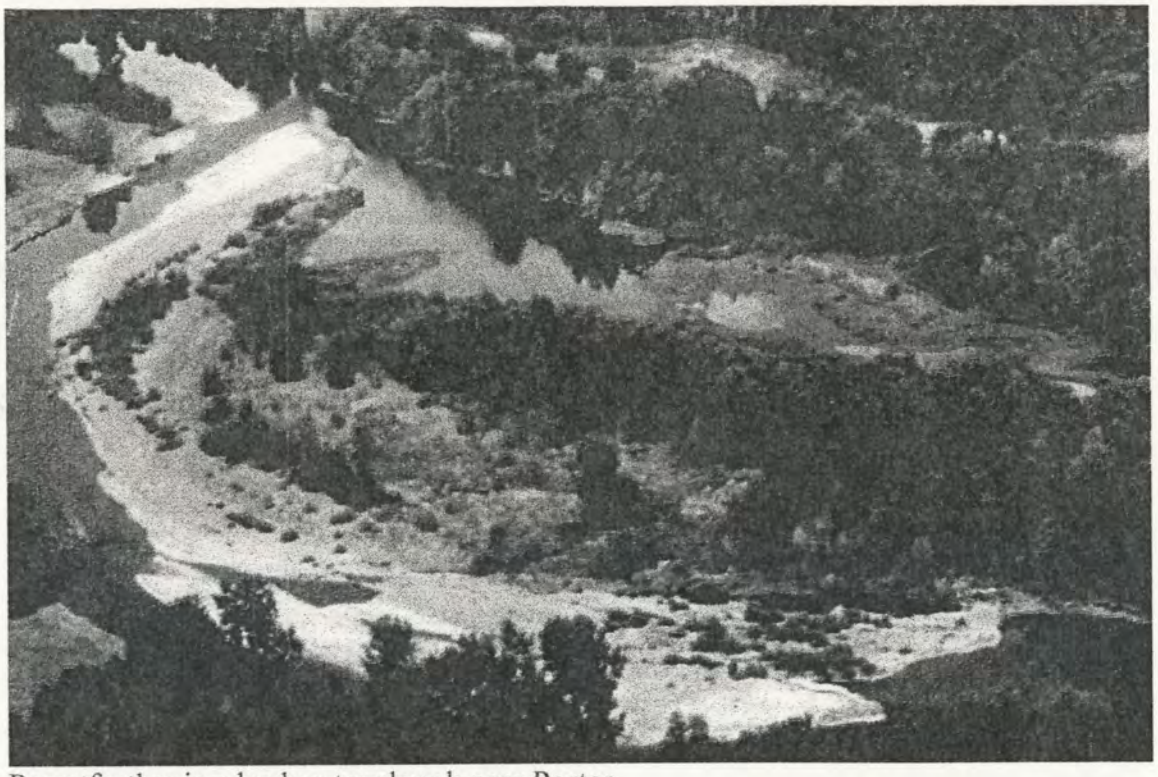
Parrotfeather and Smartweed



Survey Equipment

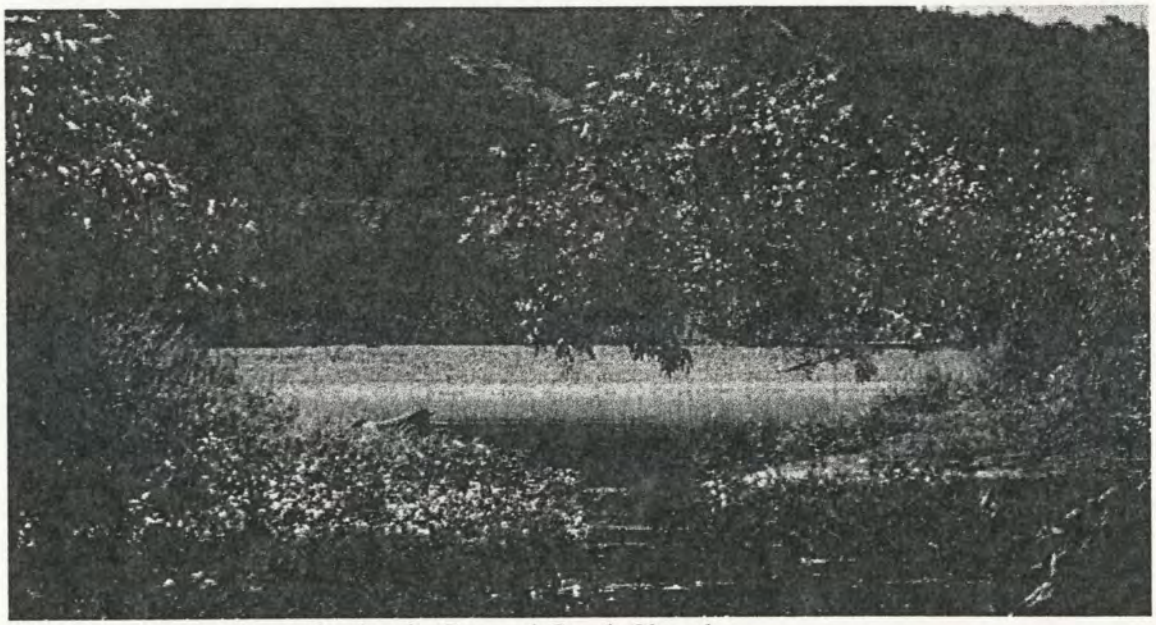


Site Number 5 - Parrotfeather in woody debris.



Parrotfeather in a backwater slough near Porter.

Site Number 5 - Parrotfeather in Galvin Slough.



Site Number 1 - Parrotfeather in Garrard Creek Slough.

Acknowledgements

Chehalis River Council
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Washington State University / Lewis Co. Cooperative Extension
Washington State Noxious Weed Control Board

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Freshwater Aquatic Weeds
Management Program
and Lewis County

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Parrotfeather

Myriophyllum aquaticum Vellozo Verdcourt

Background

Parrotfeather, a native of South America, has been distributed widely in North America because of its popularity as an ornamental aquatic plant. When introduced into natural systems parrotfeather forms dense stands that can dominate the flora of shallow lakes and streams.

Earliest records of parrotfeather on the west coast of North America are from southern California in 1912. There are reports that the plant was introduced into natural systems in the San Fransisco Bay area to maintain a population for horticulturalists. The earliest record of parrotfeather in Washington is 1944.

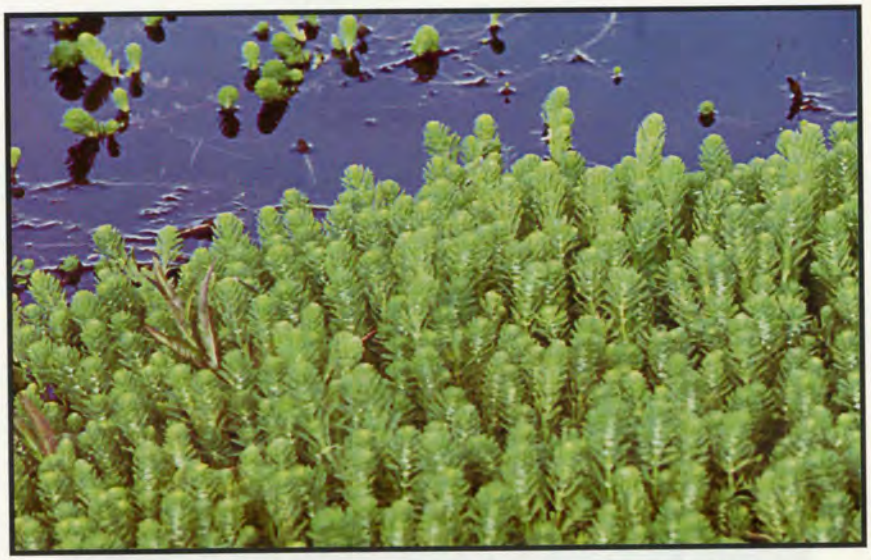
Parrotfeather is currently widespread in coastal areas from San Fransisco to Washington, in California's Central Valley, and the Willamette Valley in Oregon. In Washington, major infestations are in southwestern counties, including the Chehalis River. Scattered populations can also be found in Puget Sound lowland lakes. Parrotfeather has not been reported east of the Cascades in Washington.

Identification

Parrotfeather is easily identified by its bright green emergent foliage that grows above the water surface. Emergent stems are typically unbranched, with whorls of finely dissected leaves. In crowded stands the emergent stems can be up to 25 cm (10 inches) long.

Flowers are inconspicuous. The small, white flowers are located in the axils of emergent leaves. Parrotfeather is dioecious, male and female flowers occur on separate plants. Only female plants are present in North America.

Parrotfeather also has a submersed growth form. Submersed leaves are typically a reddish color, and are more finely dissected than the emergent leaves. Submersed leaves have a feathery shape, much like other *Myriophyllum* species, however, submersed leaves of parrotfeather are typically larger and more finely dissected than other milfoils. Submersed leaves are most commonly present in winter months, when freezing kills emergent stems. After emergent growth is established, submersed leaves are quickly shed.



Parrotfeather has distinctive emergent stems that are bright green.

Biology and Ecology

Parrotfeather has a "creeping emergent" growth form. As the emergent stem elongates, lower leaves are shed and new shoots and roots form at the nodes. Because the emergent stems have access to atmospheric carbon dioxide, parrotfeather is probably the most productive milfoil species.

Parrotfeather stands can develop dense mats of floating, leafless stems (rhizomes) in the upper part of the water column. The rhizome mat and the emergent stems shade the lower water column and reduce phytoplankton production in infested waterbodies.

Parrotfeather infestation can dramatically alter an aquatic ecosytem. Metabolic activities of the plant can lower dissolved oxygen concentrations and pH. These changes in water chemistry, as well as the physical effect of the dense plant beds, degrade the habitat value for fish and other organisms.

Since only female plants are present in North American populations, parrotfeather does not set seed. Parrotfeather is dispersed only by stem/rhizome fragments. Rhizomes can survive periods of drawdown provided dessication is not too severe.

Parrotfeather can entirely cover a small pond or shallow lake.

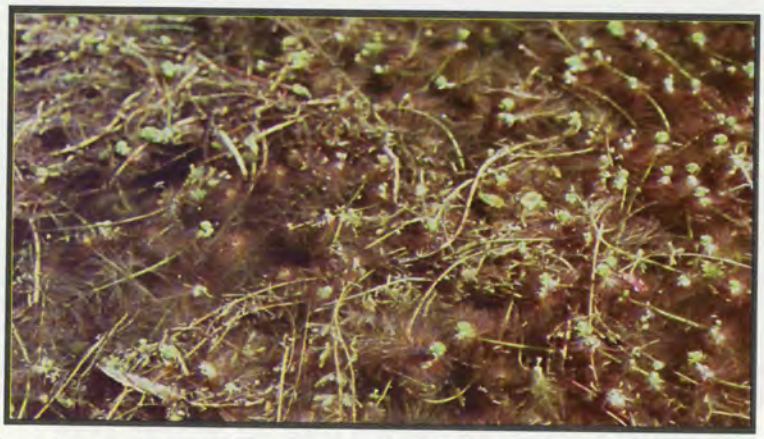
Control

Parrotfeather can be managed with physical and chemical techniques. The plant is hypersensitve to phenoxy herbicides (e.g., 2,4-D), however, emergent leaves have a waxy cuticle that limits uptake of foliar-applied herbicides. Translocation of systemic foliar, and water-applied herbicides is limited and repeat applications are required for control.

In deeper water, parrotfeather can be physically removed by hand or with a mechanical harvester. In shallow (< about 30 cm or 12 inches) water the adventious roots may reach the sediment making physical removal difficult. Stem fragments produced in physical removal may spread the infestation.

Covering parrotfeather with plastic or other material after drawdown may be effective if large areas can be covered. Covers may have to be maintained for extended periods because of the persistance of the rhizomes.

As with all invasive plants, control is most easily achieved when it is performed before the plants establish large stands.



The submersed growth form of parrotfeather is present when freezing temperatures kill emergent stems.

Additional Information

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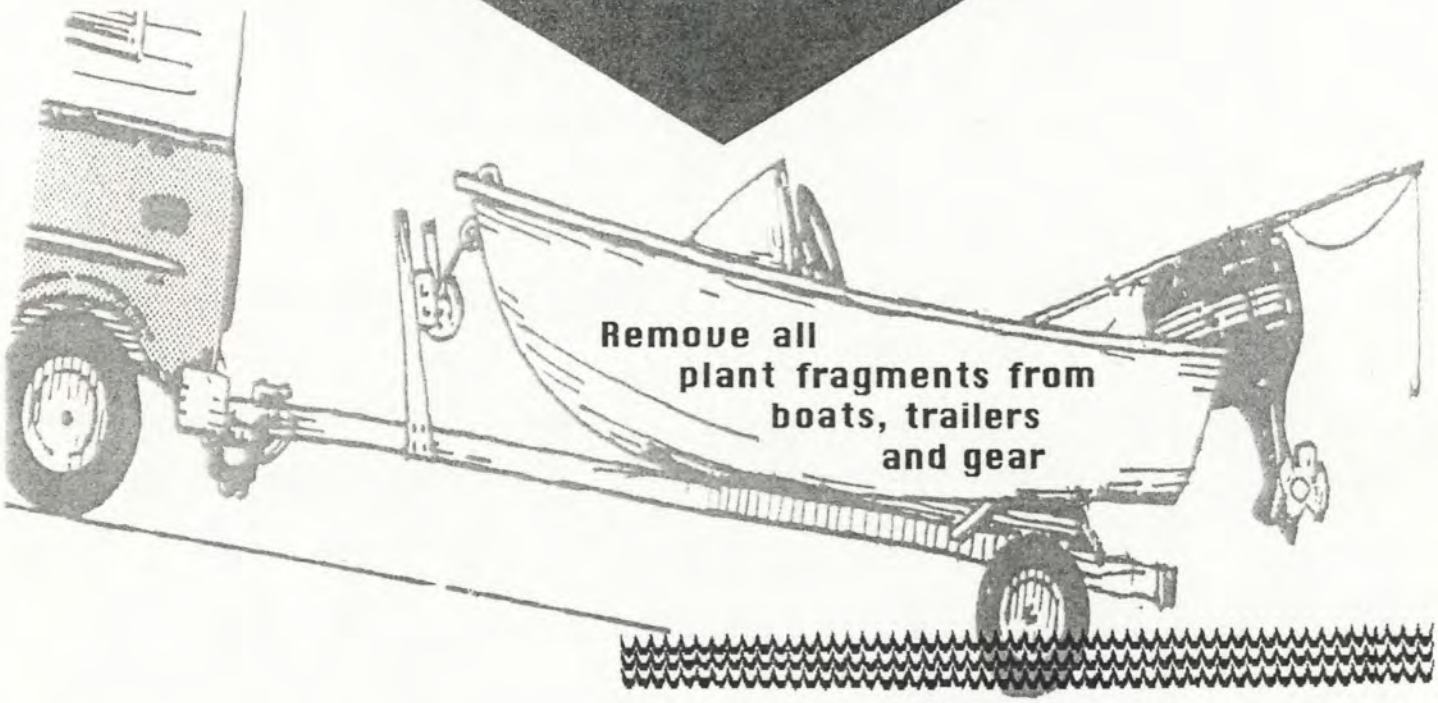
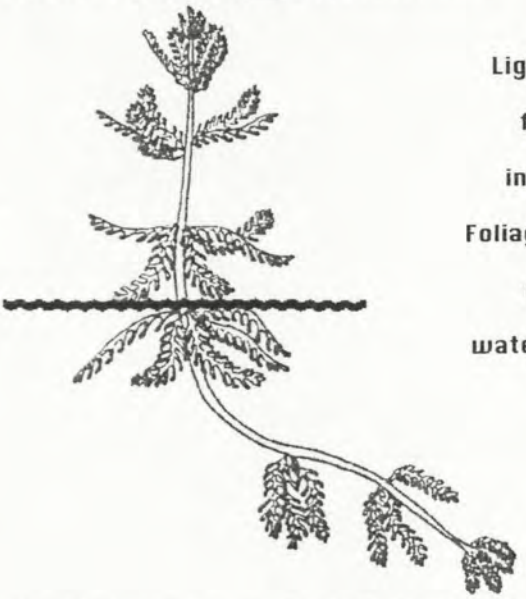
Produced by Mark Sytsma, Portland State University, for the Lewis County Noxious Weed Control Board and the Washington Department of Ecology.

Parrotfeather Management Area



- Parrotfeather is a troublesome aquatic plant that can disrupt the beneficial water quality needed for fish and wildlife.
- Parrotfeather can reduce water flow and increase flooding.
- Do your part to help manage invasive aquatic plants.



Light green foliage in whorls

Foliage 3" - 12" above water surface.

A cooperative program of the Lewis & Thurston County Weed Boards, Grays Harbor County, Washington State Noxious Weed Control Board, Dept. of Ecology and the Chehalis River Council.
For more information call (360) 273-6137

Combination Treatment of Parrotfeather with Triclopyr and Fluridone: Interim Report

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February 1998

Combination Treatment of Parrotfeather with Triclopyr and Fluridone: Interim Report

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Portland State University

This report summarizes data collected to-date on a study of interactions between fluridone and triclopyr in the management of parrotfeather (*Myriophyllum aquaticum*). The report includes data from one experiment and proposes an additional experiment to better elucidate the potential for interaction and synergy between the two compounds. An earlier experiment, not reported here, was conducted using the design described in the original proposal that resulted in rapid death of parrotfeather at both triclopyr concentrations. Both fluridone concentrations in the earlier experiment resulted in significant bleaching and suppression of growth.

Methods

Myriophyllum aquaticum stems were collected from Smith Lake on the Oregon Coast, approximately five miles southwest of Astoria. A greenhouse population was established and maintained in 2'x3'x7" containers containing carbon-filtered tap water supplemented with a 30:10:10 fertilizer (GrowMore Orchid). The plants used in experiments were started as ten-centimeter apical stem sections from the greenhouse population that were planted in 0.5 L plastic containers containing a 2:1 mixture of sand and clay collected from Sauvie Island. The soil used in the experiments was supplemented with 26 g per container of a 1:1 mix of 18:6:12 and 14:14:14 time-release fertilizer (Osmocote).

Each experimental plant was submerged in separate 11 L containers containing 5.75 L of carbon-filtered tap water and grown under ambient light supplemented with fluorescent lights (Sylvania Gro-Lux WS) on a 14-hr photoperiod. Plants were grown in the container for three weeks before initiation of herbicide treatment, and were moved every week throughout the experiment to reduce variability from location within the greenhouse.

The herbicide treatments were conducted as a static renewal experiment, with complete water exchange conducted weekly. A pH meter was used to monitor pH levels in the water between exchanges. High and low air and water temperatures were monitored using a mercury maximum/minimum thermometer.

Plants were allowed to establish in pots and grow for three weeks prior to herbicide treatment. Seventeen treatments with six replicates for each treatment were randomly applied (see Table 1). Triclopyr treatments were spray-to-wet applications (approximately 6 mL per treatment)

with deionized water applied as a control. Fluridone treatments were applied by exchanging the 5.75 L of water in each container with the appropriate treatment concentration.

Each treatment was maintained until the seventh week, when three plants were randomly selected for harvest. The harvested plants were divided into stems, leaves, adventitious (water column) roots, roots (in the sediment), and the planted stem section. Plant parts were placed in paper bags and dried at ~65 C to a constant weight. Fluridone treatment of the remaining plants was stopped after the seventh week and the containers refilled with carbon filtered water. Regrowth was allowed for three additional weeks before the remaining three plants were harvested, separated, dried, and weighed as above.

Table 1. Experimental treatments and timeline for combination treatment fluridone/triclopyr experiment.

Fluridone	Triclopyr				Replicates Harvested	
(Day 1 through Day 49)	*Foliar spray to wet Rate*	*Day of Application*				
		Day 1	*Day 7*	*Day 21*	*Day 49*	*Day 70*
Control					3	3
	0.01%	x			3	3
	0.1%	x			3	3
1 ppb		x			3	3
1 ppb	0.01%	x			3	3
1 ppb	0.01%		x		3	3
1 ppb	0.01%			x	3	3
1 ppb	0.1%	x			3	3
1 ppb	0.1%		x		3	3
1 ppb	0.1%			x	3	3
10 ppb		x			3	3
10 ppb	0.01%	x			3	3
10 ppb	0.01%		x		3	3
10 ppb	0.01%			x	3	3
10 ppb	0.1%	x			3	3
10 ppb	0.1%		x		3	3
10 ppb	0.1%			x	3	3

Results

Preiminary analysis (statistical analysis of the data has not been completed) indicates that fluridone and triplopyr at the treatment concentrations effected parrotfeather growth (Figures 1 and 2). Plants treated with fluridone at 1 ppm did not exhibit marked differences from control plants until the second harvest (10 weeks after treatment and three weeks after fluridone treatment was discontinued). The 1 ppm fluridone-treated plants did exhibit some photo-bleaching at the nodes of the stem, but other obvious treatment effects were not present. The higher fluridone

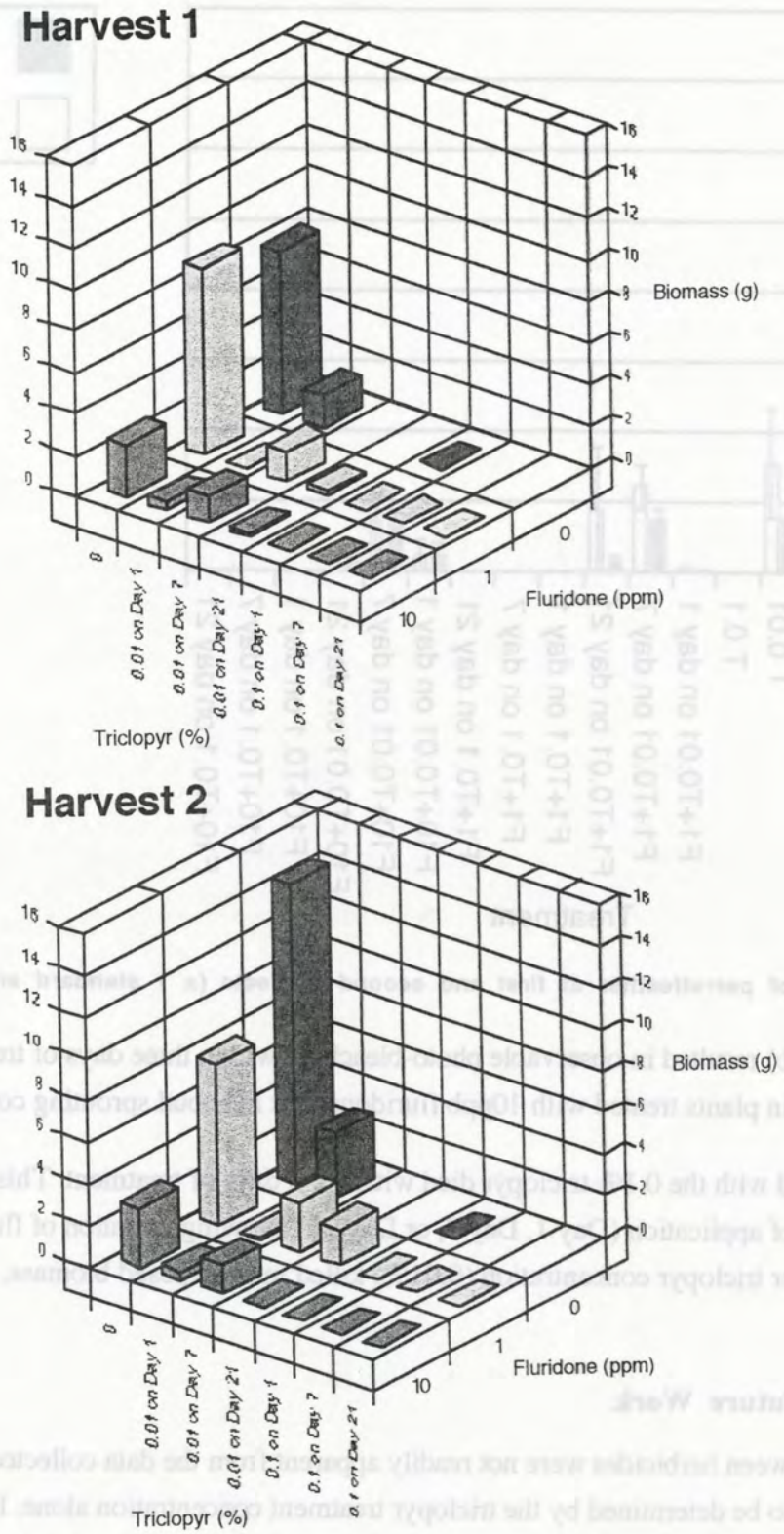

Figure 1. Biomass of parrotfeather at first and second harvests.

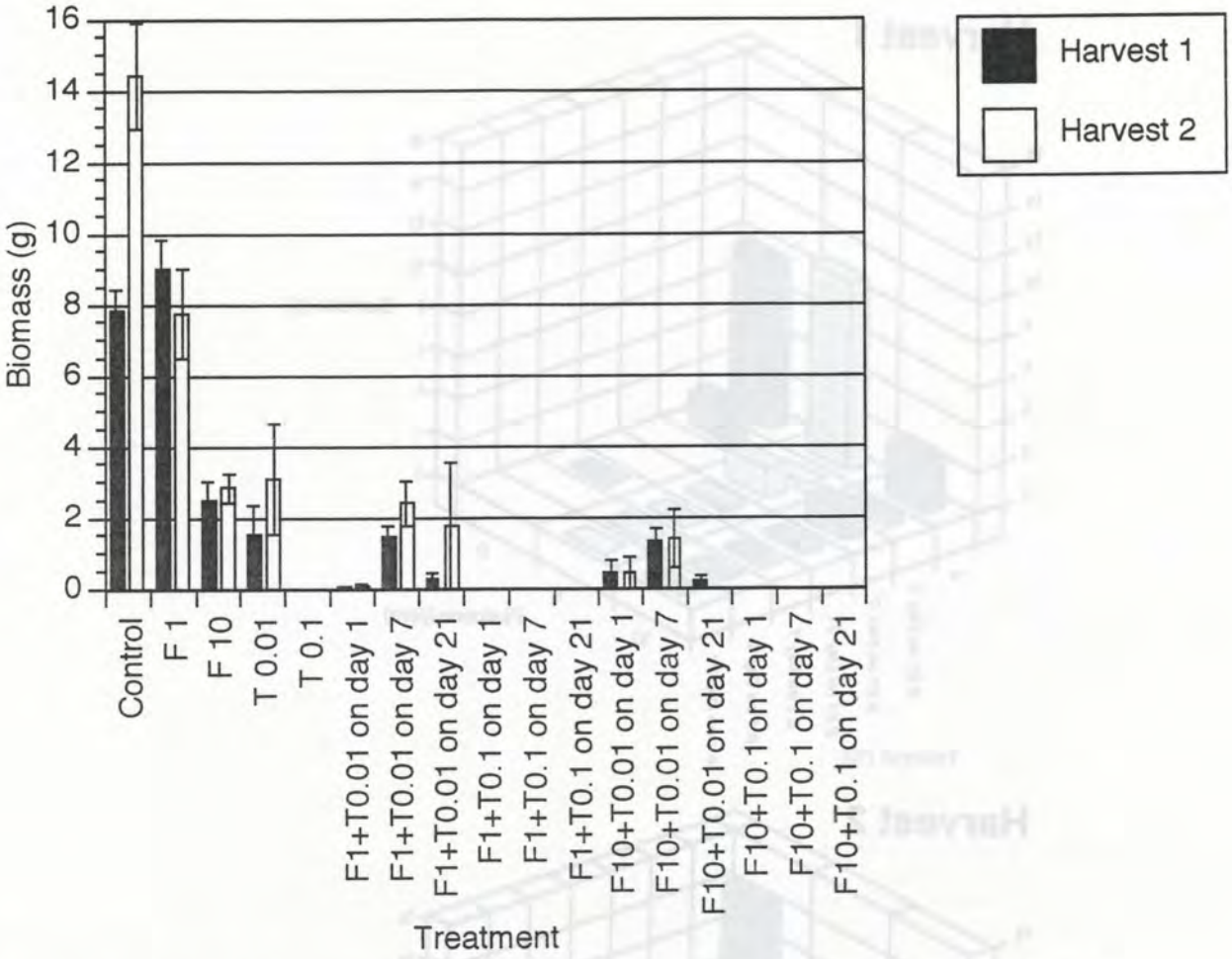

Figure 2. Biomass of parrotfeather at first and second harvests (± 1 standard error).

concentration (10ppb) resulted in observable photo-bleaching within three days of treatment. Stem growth was limited in plants treated with 10ppb fluridone, but new bud sprouting continued.

Plants treated with the 0.1% triclopyr died within 2-3 days of treatment. This was not affected by the day of application (Day 1, Day 7, or Day 21 following initiation of fluridone exposure). The lower triclopyr concentration (0.01%) killed most exposed biomass, but regrowth followed.

Discussion and Future Work

Interactions between herbicides were not readily apparent from the data collected. Effects on the plants appeared to be determined by the triclopyr treatment concentration alone. It is possible that the severity of impact from the triclopyr may be due to the size of the treated plants. Unlike field conditions, no significant rhizome mat was present before treatment. This could allow greater translocation of the foliar-applied triclopyr to the submerged stem and roots, killing the entire plant.

High nutrient availability in the soil and low availability in the water column may have supported faciliated translocation of herbicide. Thus, synergism may occur but greenhouse and container constraints on plant size prior to treatment may have resulted in masking of fluridone effects by the more significant effects of triclopyr.

In summary, triclopyr concentrations appeared to be too high to determine if a synergistic effect exists between the two herbicides. The effects exhibited by triclopyr appear to be similar to a contact herbicide on the treatment population, either killing the entire plant or just the emergent portions depending on the concentration.

Results from this experiment suggest the need for a follow-up study with lower triclopyr concentrations to determine if any interaction between the two herbicides exists. The proposed additional experiment will be designed to elucidate any interaction between the two herbicides, but results will not be readily transferred to the field. In the next experiment, fluridone will be applied at 1 ppb. This concentration exhibited minimal effects and did not restrict growth compared to the control replicates. Triclopyr will then be applied in three concentrations: 0.001%, 0.0001%, and 0.00001%. Application of triclopyr will take place on the first day of Fluridone treatment and 7 days after treatment. Response to treatments will be measured by chlorophyll concentration as well as biomass. These observations will show any interaction through increased photo-bleaching and/or decreased biomass compared to controls and plants treated with only one of the herbicides. The effect of plant size at treatment will be examined by treating plants grown for three weeks and six weeks prior to treatment. The experiment will run for four weeks.

The proposed additional experiment will extend the project past the contract date. We anticipate completion of the experiment, data analysis and final reporting will be completed by June 30, 1998.

Appendix 1: Parrotfeather data summary

Treatment	Control		F1		F10		T 0.01		T 0.1	
Harvest	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
above	7.28	13.85	10.44	5.84	1.49	3.61	0.58	4.50	0.00	0.00
sediment	8.40	17.23	8.79	7.36	3.03	2.38	3.07	0.00	0.00	0.00
biomass (g)		12.13	7.65	10.10	2.94	2.52	1.02	4.80	0.00	0.00
Mean	7.84	14.40	8.96	7.77	2.49	2.84	1.56	3.10	0.00	0.00
Std Error	0.56	1.50	0.81	1.25	0.50	0.39	0.77	1.55	0.00	0.00

Treatment	F1:T0.01 (day1)		F1:T0.01 (day 7)		F1:T0.01 (day 21)		F1:T0.1 (day1)		F1:T0.1 (day 7)	
Harvest	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
above	0.02	0.00	1.39	3.35	0.05	0.00	0.00	0.00	0.00	0.00
sediment		0.14	1.96	2.66	0.43	5.32	0.00	0.00	0.00	0.00
biomass (g)	0.03	0.00	1.00	1.14		0.00	0.00	0.00	0.00	0.00
Mean	0.02	0.05	1.45	2.38	0.24	1.77	0.00	0.00	0.00	0.00
Std Error	0.01	0.05	0.28	0.65	0.19	1.77	0.00	0.00	0.00	0.00

Treatment	F1:T0.1 (day 21)		F10:T0.01 (day 1)		F10:T0.01 (day 7)		F10:T0.01 (day 21)		F10:T0.1 (day 1)	
Harvest	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
above	0.00	0.00		0.00	1.96	0.86		0.00	0.00	0.00
sediment	0.00	0.00	0.03	1.32	1.33	2.91	0.00	0.00	0.00	0.00
biomass (g)		0.00	0.79	0.00	0.64	0.38	0.35	0.00	0.00	0.00
Mean	0.00	0.00	0.41	0.44	1.31	1.38	0.18	0.00	0.00	0.00
Std Error	0.00	0.00	0.38	0.44	0.38	0.78	0.18	0.00	0.00	0.00

Treatment	F10:T0.1 (day 7)		F10:T0.1 (day 21)	
Harvest	H1	H2	H1	H2
above	0.00	0.00	0.00	0.00
sediment	0.00	0.00	0.00	0.00
biomass (g)	0.00	0.00	0.00	0.00
Mean	0.00	0.00	0.00	0.00
Std Error	0.00	0.00	0.00	0.00

Appendix 2: Parrotfeather biomass data

Harvest	Plant#	Treatment	Part	Wgt(g)	gt(Audite
2	35	Control	AR	0.901	0.901
2	35	Control	L	3.1862	3.1862
2	35	Control	PS	0.022	0.022
2	35	Control	R	0.096	0.096
2	35	Control	S	9.7644	9.7644
2	35	Control	TOTAL	13.97	13.97
2	35	Control	ABVSOIL	13.852	13.852
2	60	Control	AR	1.0017	1.0017
2	60	Control	L	4.5991	4.5991
2	60	Control	PS	0.0546	0.0546
2	60	Control	R	0.1833	0.1833
2	60	Control	S	11.6344	11.6344
2	60	Control	TOTAL	17.473	17.473
2	60	Control	ABVSOIL	17.235	17.235
2	70	Control	AR	0.3943	NA
2	70	Control	L	2.8369	NA
2	70	Control	PS	0.0083	0.0083
2	70	Control	R	0.0406	0.0406
2	70	Control	S	8.9	NA
2	70	Control	TOTAL	12.18	12.18
2	70	Control	ABVSOIL	12.131	12.131
1	86	Control	AR	0.2944	0.2944
1	86	Control	L	2.3827	2.3827
1	86	Control	PS	0.0063	0.0063
1	86	Control	R	0.0584	0.0584
1	86	Control	S	4.6062	4.6062
1	86	Control	TOTAL	7.348	7.348
1	86	Control	ABVSOIL	7.2833	7.2833
1	93	Control	AR	0.3778	0.3778
1	93	Control	L	3.0001	3.0001
1	93	Control	PS	0.0341	0.0341
1	93	Control	R	0.1213	0.1213
1	93	Control	S	5.0263	5.0263
1	93	Control	TOTAL	8.5596	8.5596
1	93	Control	ABVSOIL	8.4042	8.4042
2	2	F10	AR	0.2754	0.2754
2	2	F10	L	1.461	1.461
2	2	F10	PS	0.0174	0.0174
2	2	F10	R	0.0622	0.0622
2	2	F10	S	1.8706	1.8706
2	2	F10	TOTAL	3.6866	3.6866
2	2	F10	ABVSOIL	3.607	3.607
2	19	F10	AR	0.2197	0.2197
2	19	F10	L	0.7148	0.7148
2	19	F10	PS	0.0152	0.0152
2	19	F10	R	0.1193	0.1193
2	19	F10	S	1.4421	1.4421
2	19	F10	TOTAL	2.5111	2.5111
2	19	F10	ABVSOIL	2.3766	2.3766
1	39	F10	AR	0.0994	0.0994
1	39	F10	L	0.3506	0.3506
1	39	F10	PS	NA	NA
1	39	F10	R	0.0249	0.0249
1	39	F10	S	1.04362	1.04362
1	39	F10	TOTAL	1.51852	NA
1	39	F10	ABVSOIL	1.49362	1.49362
1	61	F10	AR	0.197	0.197

Appendix 2: Parrotfeather biomass data

1	61	F10	L	0.9609	0.9609
1	61	F10	PS	0.013	0.013
1	61	F10	R	0.0825	0.0825
1	61	F10	S	1.8771	1.8771
1	61	F10	TOTAL	3.1305	3.1305
1	61	F10	ABVSOIL	3.035	3.035
1	84	F10	AR	0.1518	0.1518
1	84	F10	L	0.9416	0.9416
1	84	F10	PS	0.0142	0.0142
1	84	F10	R	0.0806	0.0806
1	84	F10	S	1.8494	1.8494
1	84	F10	TOTAL	3.0376	3.0376
1	84	F10	ABVSOIL	2.9428	2.9428
2	91	F10	AR	0.1684	0.1684
2	91	F10	L	1.1703	1.1703
2	91	F10	PS	0.004	0.004
2	91	F10	R	0.0128	0.0128
2	91	F10	S	1.18	1.18
2	91	F10	TOTAL	2.5355	2.5355
2	91	F10	ABVSOIL	2.5187	2.5187
1	23	F10T0.1(D21)	PS	0.0103	0.0103
1	23	F10T0.1(D21)	R	0.0293	0.0293
1	23	F10T0.1(D21)	TOTAL	0.0396	0.0396
1	23	F10T0.1(D21)	ABVSOIL	0	0
1	31	F10T0.1(D21)	PS(D)	0.0122	0.0122
1	31	F10T0.1(D21)	R(D)	0.0267	0.0267
1	31	F10T0.1(D21)	TOTAL	0.0389	0.0389
1	31	F10T0.1(D21)	ABVSOIL	0	0
1	43	F10T0.1(D21)	PS	NA	NA
1	43	F10T0.1(D21)	R	0.062	0.062
1	43	F10T0.1(D21)	TOTAL	0.062	NA
1	43	F10T0.1(D21)	ABVSOIL	0	0
2	59	F10T0.1(D21)	PS	0.0127	0.0127
2	59	F10T0.1(D21)	R	0.0482	0.0482
2	59	F10T0.1(D21)	TOTAL	0.0609	0.0609
2	59	F10T0.1(D21)	ABVSOIL	0	0
2	79	F10T0.1(D21)	PS	0.0023	0.0023
2	79	F10T0.1(D21)	R	0.0473	0.0473
2	79	F10T0.1(D21)	TOTAL	0.0496	0.0496
2	79	F10T0.1(D21)	ABVSOIL	0	0
2	104	F10T0.1(D21)	PS	0.0058	0.0058
2	104	F10T0.1(D21)	R	0.0244	0.0244
2	104	F10T0.1(D21)	TOTAL	0.0302	0.0302
2	104	F10T0.1(D21)	ABVSOIL	0	0
1	7	F10T0.01(D1)	AR	0.0003	0.0003
1	7	F10T0.01(D1)	L	NA	NA
1	7	F10T0.01(D1)	PS	0.0062	0.0062
1	7	F10T0.01(D1)	R	0.0063	0.0063
1	7	F10T0.01(D1)	S	0.0286	0.0286
1	7	F10T0.01(D1)	TOTAL	0.0414	NA
1	7	F10T0.01(D1)	ABVSOIL	0.0289	NA
2	40	F10T0.01(D1)	PS	0.0194	0.0194
2	40	F10T0.01(D1)	R	0.0296	0.0296
2	40	F10T0.01(D1)	TOTAL	0.049	0.049
2	40	F10T0.01(D1)	ABVSOIL	0	0
2	55	F10T0.01(D1)	AR	0.0579	0.0579
2	55	F10T0.01(D1)	L	0.6017	0.6017
2	55	F10T0.01(D1)	PS	0.0194	0.0194

Appendix 2: Parrotfeather biomass data

2	55	F10T0.01(D1)	R	0.1138	0.1138
2	55	F10T0.01(D1)	S	0.6634	0.6634
2	55	F10T0.01(D1)	TOTAL	1.4562	1.4562
2	55	F10T0.01(D1)	ABVSOIL	1.323	1.323
1	62	F10T0.01(D1)	AR	0.002	0.002
1	62	F10T0.01(D1)	L	0	0
1	62	F10T0.01(D1)	PS	NA	NA
1	62	F10T0.01(D1)	R	NA	NA
1	62	F10T0.01(D1)	S	0.0294	0.0294
1	62	F10T0.01(D1)	TOTAL	0.0314	NA
1	62	F10T0.01(D1)	ABVSOIL	0.0314	0.0314
1	73	F10T0.01(D1)	AR	0.0446	0.0446
1	73	F10T0.01(D1)	L	0.3787	0.3787
1	73	F10T0.01(D1)	PS	0.0102	0.0102
1	73	F10T0.01(D1)	R	0.0371	0.0371
1	73	F10T0.01(D1)	S	0.3711	0.3711
1	73	F10T0.01(D1)	TOTAL	0.8417	0.8417
1	73	F10T0.01(D1)	ABVSOIL	0.7944	0.7944
2	82	F10T0.01(D1)	PS	0.0316	0.0316
2	82	F10T0.01(D1)	R	0.0086	0.0086
2	82	F10T0.01(D1)	TOTAL	0.0402	0.0402
2	82	F10T0.01(D1)	ABVSOIL	0	0
2	46	F10T0.01(D21)	PS	0.0086	0.0086
2	46	F10T0.01(D21)	R	0.0421	0.0421
2	46	F10T0.01(D21)	TOTAL	0.0507	0.0507
2	46	F10T0.01(D21)	ABVSOIL	0	0
1	65	F10T0.01(D21)	AR	NA	NA
1	65	F10T0.01(D21)	L	NA	NA
1	65	F10T0.01(D21)	PS	0.009	0.009
1	65	F10T0.01(D21)	R	0.0303	0.0303
1	65	F10T0.01(D21)	S	0.009	0.009
1	65	F10T0.01(D21)	TOTAL	0.0483	NA
1	65	F10T0.01(D21)	ABVSOIL	0.009	NA
2	69	F10T0.01(D21)	PS	0.005	0.005
2	69	F10T0.01(D21)	R	0.0314	0.0314
2	69	F10T0.01(D21)	TOTAL	0.0364	0.0364
2	69	F10T0.01(D21)	ABVSOIL	0	0
1	74	F10T0.01(D21)	PS	NA	NA
1	74	F10T0.01(D21)	R	0.036	0.036
1	74	F10T0.01(D21)	TOTAL	0.036	NA
1	74	F10T0.01(D21)	ABVSOIL	0	0
1	80	F10T0.01(D21)	AR	0.0457	0.0457
1	80	F10T0.01(D21)	L	0.0217	0.0217
1	80	F10T0.01(D21)	PS	NA	NA
1	80	F10T0.01(D21)	R	0.0329	0.0329
1	80	F10T0.01(D21)	S	0.285	0.285
1	80	F10T0.01(D21)	TOTAL	0.3853	NA
1	80	F10T0.01(D21)	ABVSOIL	0.3524	0.3524
2	95	F10T0.01(D21)	PS	0.0114	0.0114
2	95	F10T0.01(D21)	R	0.0446	0.0446
2	95	F10T0.01(D21)	TOTAL	0.056	0.056
2	95	F10T0.01(D21)	ABVSOIL	0	0
2	4	F10T0.01(D7)	AR	0.08	0.08
2	4	F10T0.01(D7)	L	0.3653	0.3653
2	4	F10T0.01(D7)	PS	0.0175	0.0175
2	4	F10T0.01(D7)	R	0.0689	0.0689
2	4	F10T0.01(D7)	S	0.4109	0.4109
2	4	F10T0.01(D7)	TOTAL	0.9426	0.9426

Appendix 2: Parrotfeather biomass data

2	4	F10T0.01(D7)	ABVSOIL	0.8562	0.8562
1	22	F10T0.01(D7)	AR	0.1351	0.1351
1	22	F10T0.01(D7)	L	0.7707	0.7707
1	22	F10T0.01(D7)	PS	0.0172	0.0172
1	22	F10T0.01(D7)	R	0.077	0.077
1	22	F10T0.01(D7)	S	1.0541	1.0541
1	22	F10T0.01(D7)	TOTAL	2.0541	2.0541
1	22	F10T0.01(D7)	ABVSOIL	1.9599	1.9599
1	29	F10T0.01(D7)	AR	0.098	0.098
1	29	F10T0.01(D7)	L	0.5538	0.5538
1	29	F10T0.01(D7)	PS	0.0116	0.0116
1	29	F10T0.01(D7)	R	0.046	0.046
1	29	F10T0.01(D7)	S	0.6744	0.6744
1	29	F10T0.01(D7)	TOTAL	1.3838	1.3838
1	29	F10T0.01(D7)	ABVSOIL	1.3262	1.3262
2	33	F10T0.01(D7)	AR	0.1546	0.1546
2	33	F10T0.01(D7)	L	1.0533	1.0533
2	33	F10T0.01(D7)	PS	0	0
2	33	F10T0.01(D7)	R	0.0768	0.0768
2	33	F10T0.01(D7)	S	1.7016	1.7016
2	33	F10T0.01(D7)	TOTAL	2.9863	2.9863
2	33	F10T0.01(D7)	ABVSOIL	2.9095	2.9095
2	51	F10T0.01(D7)	AR	0.0433	0.0433
2	51	F10T0.01(D7)	L	0.1671	0.1671
2	51	F10T0.01(D7)	PS	0	0
2	51	F10T0.01(D7)	R	0.0072	0.0072
2	51	F10T0.01(D7)	S	0.1682	0.1682
2	51	F10T0.01(D7)	TOTAL	0.3858	0.3858
2	51	F10T0.01(D7)	ABVSOIL	0.3786	0.3786
1	71	F10T0.01(D7)	AR	0.0555	0.0555
1	71	F10T0.01(D7)	L	0.2465	0.2465
1	71	F10T0.01(D7)	PS	0.005	0.005
1	71	F10T0.01(D7)	R	0.0136	0.0136
1	71	F10T0.01(D7)	S	0.339	0.339
1	71	F10T0.01(D7)	TOTAL	0.6596	0.6596
1	71	F10T0.01(D7)	ABVSOIL	0.641	0.641
2	10	F10T0.1(D1)	PS	0	0
2	10	F10T0.1(D1)	R	0	0
2	10	F10T0.1(D1)	TOTAL	0	0
2	10	F10T0.1(D1)	ABVSOIL	0	0
2	45	F10T0.1(D1)	PS	0	0
2	45	F10T0.1(D1)	R	0.0148	0.0148
2	45	F10T0.1(D1)	TOTAL	0.0148	0.0148
2	45	F10T0.1(D1)	ABVSOIL	0	0
1	50	F10T0.1(D1)	PS	0.0149	0.0149
1	50	F10T0.1(D1)	R	0.0088	0.0088
1	50	F10T0.1(D1)	TOTAL	0.0237	0.0237
1	50	F10T0.1(D1)	ABVSOIL	0	0
2	76	F10T0.1(D1)	PS	0.0091	0.0091
2	76	F10T0.1(D1)	R	0.0202	0.0202
2	76	F10T0.1(D1)	TOTAL	0.0293	0.0293
2	76	F10T0.1(D1)	ABVSOIL	0	0
1	85	F10T0.1(D1)	PS	0.0113	0.0113
1	85	F10T0.1(D1)	R	0.0122	0.0122
1	85	F10T0.1(D1)	TOTAL	0.0235	0.0235
1	85	F10T0.1(D1)	ABVSOIL	0	0
1	97	F10T0.1(D1)	PS	NA	NA
1	97	F10T0.1(D1)	R	NA	NA

Appendix 2: Parrotfeather biomass data

1	97	F10T0.1(D1)	TOTAL	NA	NA
1	97	F10T0.1(D1)	ABVSOIL	0	0
2	6	F10T0.1(D7)	PS	0.0121	0.0121
2	6	F10T0.1(D7)	R	0.0079	0.0079
2	6	F10T0.1(D7)	TOTAL	0.02	0.02
2	6	F10T0.1(D7)	ABVSOIL	0	0
1	13	F10T0.1(D7)	PS	0	0
1	13	F10T0.1(D7)	R	0	0
1	13	F10T0.1(D7)	TOTAL	0	0
1	13	F10T0.1(D7)	ABVSOIL	0	0
2	34	F10T0.1(D7)	PS	0.0121	0.0121
2	34	F10T0.1(D7)	R	0.0127	0.0127
2	34	F10T0.1(D7)	TOTAL	0.0248	0.0248
2	34	F10T0.1(D7)	ABVSOIL	0	0
1	52	F10T0.1(D7)	PS	0.0085	0.0085
1	52	F10T0.1(D7)	R	0.0165	0.0165
1	52	F10T0.1(D7)	TOTAL	0.025	0.025
1	52	F10T0.1(D7)	ABVSOIL	0	0
1	56	F10T0.1(D7)	PS	0.002	0.002
1	56	F10T0.1(D7)	D	0.0171	0.0171
1	56	F10T0.1(D7)	TOTAL	0.0191	0.0191
1	56	F10T0.1(D7)	ABVSOIL	0	0
2	101	F10T0.1(D7)	PS	0.008	0.008
2	101	F10T0.1(D7)	R	0.0057	0.0057
2	101	F10T0.1(D7)	TOTAL	0.0137	0.0137
2	101	F10T0.1(D7)	ABVSOIL	0	0
2	11	F1	AR	0.2108	0.2108
2	11	F1	L	1.4345	1.4345
2	11	F1	PS	0.0099	0.0099
2	11	F1	R	0.0807	0.0807
2	11	F1	S	4.1922	4.1922
2	11	F1	TOTAL	5.9281	5.9281
2	11	F1	ABVSOIL	5.8375	5.8375
2	15	F1	AR	0.366	0.366
2	15	F1	L	1.8374	1.8374
2	15	F1	PS	0.0089	0.0089
2	15	F1	R	0.0936	0.0936
2	15	F1	S	5.1565	5.1565
2	15	F1	TOTAL	7.4624	7.4624
2	15	F1	ABVSOIL	7.3599	7.3599
1	38	F1	AR	0.7233	0.7233
1	38	F1	L	2.9186	2.9186
1	38	F1	PS	0.0165	0.0165
1	38	F1	R	0.1809	0.1809
1	38	F1	S	6.7945	6.7945
1	38	F1	TOTAL	10.6338	10.6338
1	38	F1	ABVSOIL	10.4364	10.4364
1	72	F1	AR	0.4721	0.4721
1	72	F1	L	2.4614	2.4614
1	72	F1	PS	0.0314	0.0314
1	72	F1	R	0.067	0.067
1	72	F1	S	5.8539	5.8539
1	72	F1	TOTAL	8.8858	8.8858
1	72	F1	ABVSOIL	8.7874	8.7874
1	83	F1	AR	0.2016	0.2016
1	83	F1	L	2.5538	2.5538
1	83	F1	PS	0.0416	0.0416
1	83	F1	R	0.0834	0.0834

Appendix 2: Parrotfeather biomass data

1	83	F1	S	4.8919	4.8919
1	83	F1	TOTAL	7.7723	7.7723
1	83	F1	ABVSOIL	7.6473	7.6473
2	98	F1	AR	0.4295	0.4295
2	98	F1	L	3.0557	3.0557
2	98	F1	PS	0.0245	0.0245
2	98	F1	R	0.0645	0.0645
2	98	F1	S	6.6155	6.6155
2	98	F1	TOTAL	10.19	10.19
2	98	F1	ABVSOIL	10.101	10.101
2	3	F1T0.01(D1)	PS	0.0051	0.0051
2	3	F1T0.01(D1)	R	0.0033	0.0033
2	3	F1T0.01(D1)	TOTAL	0.0084	0.0084
2	3	F1T0.01(D1)	ABVSOIL	0	0
2	9	F1T0.01(D1)	AR	0.0257	0.0257
2	9	F1T0.01(D1)	L	0.0727	0.0727
2	9	F1T0.01(D1)	PS	0.0189	0.0189
2	9	F1T0.01(D1)	R	0.0166	0.0166
2	9	F1T0.01(D1)	S	0.0422	0.0422
2	9	F1T0.01(D1)	TOTAL	0.1761	0.1761
2	9	F1T0.01(D1)	ABVSOIL	0.1406	0.1406
1	49	F1T0.01(D1)	AR	0.0035	0.0035
1	49	F1T0.01(D1)	L	0.0063	0.0063
1	49	F1T0.01(D1)	PS	0.0127	0.0127
1	49	F1T0.01(D1)	R	0.0113	0.0113
1	49	F1T0.01(D1)	S	0.0063	0.0063
1	49	F1T0.01(D1)	TOTAL	0.0401	0.0401
1	49	F1T0.01(D1)	ABVSOIL	0.0161	0.0161
1	64	F1T0.01(D1)	AR	0.0023	0.0023
1	64	F1T0.01(D1)	L	NA	NA
1	64	F1T0.01(D1)	PS	NA	NA
1	64	F1T0.01(D1)	R	NA	NA
1	64	F1T0.01(D1)	S	0.036	0.036
1	64	F1T0.01(D1)	TOTAL	0.0383	NA
1	64	F1T0.01(D1)	ABVSOIL	0.0383	NA
2	88	F1T0.01(D1)	PS	0.017	0.017
2	88	F1T0.01(D1)	R	0.0185	0.0185
2	88	F1T0.01(D1)	TOTAL	0.0355	0.0355
2	88	F1T0.01(D1)	ABVSOIL	0	0
1	103	F1T0.01(D1)	AR	0.0024	0.0024
1	103	F1T0.01(D1)	L	0.0035	0.0035
1	103	F1T0.01(D1)	PS	0.0081	0.0081
1	103	F1T0.01(D1)	R	NA	NA
1	103	F1T0.01(D1)	S	0.0213	0.0213
1	103	F1T0.01(D1)	TOTAL	0.0353	NA
1	103	F1T0.01(D1)	ABVSOIL	0.0272	0.0272
2	26	F1T0.01(D21)	PS	0.0078	0.0078
2	26	F1T0.01(D21)	R	0.0311	0.0311
2	26	F1T0.01(D21)	TOTAL	0.0389	0.0389
2	26	F1T0.01(D21)	ABVSOIL	0	0
2	30	F1T0.01(D21)	AR	0.4107	0.4107
2	30	F1T0.01(D21)	L	1.6357	1.6357
2	30	F1T0.01(D21)	PS	0.024	0.024
2	30	F1T0.01(D21)	R	0.0864	0.0864
2	30	F1T0.01(D21)	S	3.2762	3.2762
2	30	F1T0.01(D21)	TOTAL	5.433	5.433
2	30	F1T0.01(D21)	ABVSOIL	5.3226	5.3226
2	41	F1T0.01(D21)	PS	0	0

Appendix 2: Parrotfeather biomass data

2	41	F1T0.01(D21)	R	0.0243	0.0243
2	41	F1T0.01(D21)	TOTAL	0.0243	0.0243
2	41	F1T0.01(D21)	ABVSOIL	0	0
1	53	F1T0.01(D21)	AR	0.008	0.008
1	53	F1T0.01(D21)	L	0.0143	0.0143
1	53	F1T0.01(D21)	PS	0.0049	0.0049
1	53	F1T0.01(D21)	R	0.0023	0.0023
1	53	F1T0.01(D21)	S	0.0277	0.0277
1	53	F1T0.01(D21)	TOTAL	0.0572	0.0572
1	53	F1T0.01(D21)	ABVSOIL	0.05	0.05
1	75	F1T0.01(D21)	AR	0.0798	0.0798
1	75	F1T0.01(D21)	L	0.0449	0.0449
1	75	F1T0.01(D21)	PS	0.0052	0.0052
1	75	F1T0.01(D21)	R	0.0315	0.0315
1	75	F1T0.01(D21)	S	0.3073	0.3073
1	75	F1T0.01(D21)	TOTAL	0.4687	0.4687
1	75	F1T0.01(D21)	ABVSOIL	0.432	0.432
1	87	F1T0.01(D21)	AR	NA	NA
1	87	F1T0.01(D21)	L	NA	NA
1	87	F1T0.01(D21)	PS	0.0056	0.0056
1	87	F1T0.01(D21)	R	NA	NA
1	87	F1T0.01(D21)	S	0.0614	0.0614
1	87	F1T0.01(D21)	TOTAL	0.067	NA
1	87	F1T0.01(D21)	ABVSOIL	0.0614	NA
1	37	F1T0.01(D7)	AR	0.1503	0.1503
1	37	F1T0.01(D7)	L	0.5267	0.5267
1	37	F1T0.01(D7)	PS	0.0201	0.0201
1	37	F1T0.01(D7)	R	0.0811	0.0811
1	37	F1T0.01(D7)	S	0.7136	0.7136
1	37	F1T0.01(D7)	TOTAL	1.4918	1.4918
1	37	F1T0.01(D7)	ABVSOIL	1.3906	1.3906
1	48	F1T0.01(D7)	AR	0.134	0.134
1	48	F1T0.01(D7)	L	0.7845	0.7845
1	48	F1T0.01(D7)	PS	0.0081	0.0081
1	48	F1T0.01(D7)	R	0.0165	0.0165
1	48	F1T0.01(D7)	S	1.0426	1.0426
1	48	F1T0.01(D7)	TOTAL	1.9857	1.9857
1	48	F1T0.01(D7)	ABVSOIL	1.9611	1.9611
2	54	F1T0.01(D7)	AR	0.1578	0.1578
2	54	F1T0.01(D7)	L	1.1204	1.1204
2	54	F1T0.01(D7)	PS	0.0148	0.0148
2	54	F1T0.01(D7)	R	0.0221	0.0221
2	54	F1T0.01(D7)	S	2.0741	2.0741
2	54	F1T0.01(D7)	TOTAL	3.3892	3.3892
2	54	F1T0.01(D7)	ABVSOIL	3.3523	3.3523
1	68	F1T0.01(D7)	AR	0.0878	0.0878
1	68	F1T0.01(D7)	L	0.3824	0.3824
1	68	F1T0.01(D7)	PS	0.0143	0.0143
1	68	F1T0.01(D7)	R	0.0214	0.0214
1	68	F1T0.01(D7)	S	0.5322	0.5322
1	68	F1T0.01(D7)	TOTAL	1.0381	1.0381
1	68	F1T0.01(D7)	ABVSOIL	1.0024	1.0024
2	94	F1T0.01(D7)	AR	0.1761	0.1761
2	94	F1T0.01(D7)	L	1.1715	1.1715
2	94	F1T0.01(D7)	PS	0.0144	0.0144
2	94	F1T0.01(D7)	R	0.0645	0.0645
2	94	F1T0.01(D7)	S	1.3176	1.3176
2	94	F1T0.01(D7)	TOTAL	2.7441	2.7441

Appendix 2: Parrotfeather biomass data

2	94	F1T0.01(D7)	ABVSOIL	2.6652	2.6652
2	102	F1T0.01(D7)	AR	0.1395	0.1395
2	102	F1T0.01(D7)	L	0.5436	0.5436
2	102	F1T0.01(D7)	PS	0.0186	0.0186
2	102	F1T0.01(D7)	R	0.022	0.022
2	102	F1T0.01(D7)	S	0.457	0.457
2	102	F1T0.01(D7)	TOTAL	1.1807	1.1807
2	102	F1T0.01(D7)	ABVSOIL	1.1401	1.1401
1	25	F1T0.1(D1)	PS	0.01	0.01
1	25	F1T0.1(D1)	R	0.0075	0.0075
1	25	F1T0.1(D1)	TOTAL	0.0175	0.0175
1	25	F1T0.1(D1)	ABVSOIL	0	0
1	66	F1T0.1(D1)	PS	0.0052	0.0052
1	66	F1T0.1(D1)	R	0.0081	0.0081
1	66	F1T0.1(D1)	TOTAL	0.0133	0.0133
1	66	F1T0.1(D1)	ABVSOIL	0	0
1	78	F1T0.1(D1)	PS	0	0
1	78	F1T0.1(D1)	R	0	0
1	78	F1T0.1(D1)	TOTAL	0	0
1	78	F1T0.1(D1)	ABVSOIL	0	0
2	89	F1T0.1(D1)	PS	0	0
2	89	F1T0.1(D1)	R	0.0297	0.0297
2	89	F1T0.1(D1)	TOTAL	0.0297	0.0297
2	89	F1T0.1(D1)	ABVSOIL	0	0
2	99	F1T0.1(D1)	PS	0.0116	0.0116
2	99	F1T0.1(D1)	R	0.0147	0.0147
2	99	F1T0.1(D1)	TOTAL	0.0263	0.0263
2	99	F1T0.1(D1)	ABVSOIL	0	0
1	105	F1T0.1(D1)	AR	0.3254	0.3254
1	105	F1T0.1(D1)	L	2.9819	2.9819
1	105	F1T0.1(D1)	PS	0.0395	0.0395
1	105	F1T0.1(D1)	R	0.1601	0.1601
1	105	F1T0.1(D1)	S	4.5376	4.5376
1	105	F1T0.1(D1)	TOTAL	8.0445	8.0445
1	105	F1T0.1(D1)	ABVSOIL	7.8449	7.8449
2	106	F1T0.1(D1)	PS	0	0
2	106	F1T0.1(D1)	R	0	0
2	106	F1T0.1(D1)	TOTAL	0	0
2	106	F1T0.1(D1)	ABVSOIL	0	0
1	5	F1T0.1(D21)	PS	0	0
1	5	F1T0.1(D21)	R	0	0
1	5	F1T0.1(D21)	TOTAL	0	0
1	5	F1T0.1(D21)	ABVSOIL	0	0
2	14	F1T0.1(D21)	PS	0.0076	0.0076
2	14	F1T0.1(D21)	R	0.0397	0.0397
2	14	F1T0.1(D21)	TOTAL	0.0473	0.0473
2	14	F1T0.1(D21)	ABVSOIL	0	0
1	18	F1T0.1(D21)	PS	NA	NA
1	18	F1T0.1(D21)	R	0.0265	0.0265
1	18	F1T0.1(D21)	TOTAL	0.0265	NA
1	18	F1T0.1(D21)	ABVSOIL	0	0
1	24	F1T0.1(D21)	AR	NA	NA
1	24	F1T0.1(D21)	L	NA	NA
1	24	F1T0.1(D21)	PS	0.0185	0.0185
1	24	F1T0.1(D21)	R	NA	NA
1	24	F1T0.1(D21)	S	0.0076	0.0076
1	24	F1T0.1(D21)	TOTAL	0.0261	NA
1	24	F1T0.1(D21)	ABVSOIL	0.0076	NA

Appendix 2: Parrotfeather biomass data

2	36	F1T0.1(D21)	PS	0.005	0.005
2	36	F1T0.1(D21)	R	0.0253	0.0253
2	36	F1T0.1(D21)	TOTAL	0.0303	0.0303
2	36	F1T0.1(D21)	ABVSOIL	0	0
2	42	F1T0.1(D21)	PS	0.0231	0.0231
2	42	F1T0.1(D21)	R	0.0195	0.0195
2	42	F1T0.1(D21)	TOTAL	0.0426	0.0426
2	42	F1T0.1(D21)	ABVSOIL	0	0
1	17	F1T0.1(D7)	PS	0.0142	0.0142
1	17	F1T0.1(D7)	R(D)	0.0136	0.0136
1	17	F1T0.1(D7)	TOTAL	0.0278	0.0278
1	17	F1T0.1(D7)	ABVSOIL	0	0
2	20	F1T0.1(D7)	PS	0.0113	0.0113
2	20	F1T0.1(D7)	R	0.0337	0.0337
2	20	F1T0.1(D7)	TOTAL	0.045	0.045
2	20	F1T0.1(D7)	ABVSOIL	0	0
2	27	F1T0.1(D7)	PS	0.0117	0.0117
2	27	F1T0.1(D7)	R	0.0655	0.0655
2	27	F1T0.1(D7)	TOTAL	0.0772	0.0772
2	27	F1T0.1(D7)	ABVSOIL	0	0
2	77	F1T0.1(D7)	PS	0.01	0.01
2	77	F1T0.1(D7)	R	0.0216	0.0216
2	77	F1T0.1(D7)	TOTAL	0.0316	0.0316
2	77	F1T0.1(D7)	ABVSOIL	0	0
1	81	F1T0.1(D7)	PS	0.0092	0.0092
1	81	F1T0.1(D7)	R	0.0364	0.0364
1	81	F1T0.1(D7)	TOTAL	0.0456	0.0456
1	81	F1T0.1(D7)	ABVSOIL	0	0
1	92	F1T0.1(D7)	PS	0.01	0.01
1	92	F1T0.1(D7)	R	0.0088	0.0088
1	92	F1T0.1(D7)	TOTAL	0.0188	0.0188
1	92	F1T0.1(D7)	ABVSOIL	0	0
2	12	T0.01(D1)	AR	0.3236	0.3236
2	12	T0.01(D1)	L	1.7269	1.7269
2	12	T0.01(D1)	PS	0.0051	0.0051
2	12	T0.01(D1)	R	0.0545	0.0545
2	12	T0.01(D1)	S	2.4492	2.4492
2	12	T0.01(D1)	TOTAL	4.5593	4.5593
2	12	T0.01(D1)	ABVSOIL	4.4997	4.4997
1	32	T0.01(D1)	AR	0.0571	0.0571
1	32	T0.01(D1)	L	0.2509	0.2509
1	32	T0.01(D1)	PS	0.0071	0.0071
1	32	T0.01(D1)	R	0.026	0.026
1	32	T0.01(D1)	S	0.2698	0.2698
1	32	T0.01(D1)	TOTAL	0.6109	0.6109
1	32	T0.01(D1)	ABVSOIL	0.5778	0.5778
1	47	T0.01(D1)	AR	0.155	0.155
1	47	T0.01(D1)	L	1.2064	1.2064
1	47	T0.01(D1)	PS	0.0105	0.0105
1	47	T0.01(D1)	R	0.0434	0.0434
1	47	T0.01(D1)	S	1.7098	1.7098
1	47	T0.01(D1)	TOTAL	3.1251	3.1251
1	47	T0.01(D1)	ABVSOIL	3.0712	3.0712
2	63	T0.01(D1)	PS	0.0062	0.0062
2	63	T0.01(D1)	R	0.0147	0.0147
2	63	T0.01(D1)	TOTAL	0.0209	0.0209
2	63	T0.01(D1)	ABVSOIL	0	0
1	67	T0.01(D1)	AR	0.2056	0.2056

Appendix 2: Parrotfeather biomass data

1	67	T0.01(D1)	L	0.4135	0.4135
1	67	T0.01(D1)	PS	0.0096	0.0096
1	67	T0.01(D1)	R	0.0288	0.0288
1	67	T0.01(D1)	S	0.3997	0.3997
1	67	T0.01(D1)	TOTAL	1.0572	1.0572
1	67	T0.01(D1)	ABVSOIL	1.0188	1.0188
2	90	T0.01(D1)	AR	0.2308	0.2308
2	90	T0.01(D1)	L	1.7252	1.7252
2	90	T0.01(D1)	PS	0.0192	0.0192
2	90	T0.01(D1)	R	0.0694	0.0694
2	90	T0.01(D1)	S	2.833	2.833
2	90	T0.01(D1)	TOTAL	4.8776	4.8776
2	90	T0.01(D1)	ABVSOIL	4.789	4.789
2	16	T0.1(D1)	PS	0.0235	0.0235
2	16	T0.1(D1)	R	0.0122	0.0122
2	16	T0.1(D1)	TOTAL	0.0357	0.0357
2	16	T0.1(D1)	ABVSOIL	0	0
2	21	T0.1(D1)	PS	0.0169	0.0169
2	21	T0.1(D1)	R	0.0162	0.0162
2	21	T0.1(D1)	TOTAL	0.0331	0.0331
2	21	T0.1(D1)	ABVSOIL	0	0
1	44	T0.1(D1)	PS	0	0
1	44	T0.1(D1)	R	0.0128	0.0128
1	44	T0.1(D1)	TOTAL	0.0128	0.0128
1	44	T0.1(D1)	ABVSOIL	0	0
1	57	T0.1(D1)	PS	0.0083	0.0083
1	57	T0.1(D1)	R	0.006	0.006
1	57	T0.1(D1)	TOTAL	0.0143	0.0143
1	57	T0.1(D1)	ABVSOIL	0	0
1	96	T0.1(D1)	PS	0.0108	0.0108
1	96	T0.1(D1)	R	0.015	0.015
1	96	T0.1(D1)	TOTAL	0.0258	0.0258
1	96	T0.1(D1)	ABVSOIL	0	0
2	100	T0.1(D1)	PS	0	0
2	100	T0.1(D1)	R	0	0
2	100	T0.1(D1)	TOTAL	0	0
2	100	T0.1(D1)	ABVSOIL	0	0

Combination Treatment of Parrotfeather with Triclopyr and Fluridone

Prepared for:

Lewis County Noxious Weed Control Board

and the

Washington State Commission on Pesticide Registration

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Combination Treatment of Parrotfeather with Triclopyr and Fluridone

Introduction

Aquatic systems in the Northwest are managed for a variety of beneficial uses. They provide drinking water, agricultural irrigation, rural and urban drainage, recreation, transportation, flood control, and fish and wildlife habitat. When invasive, non-native aquatic weeds enter aquatic systems these uses are degraded. Aquatic weeds block flow in irrigation and drainage canals, alter water temperature and chemistry, degrade fish and wildlife habitat, and interfere with recreation.

Parrotfeather (*Myriophyllum aquaticum*) is a particularly aggressive and damaging invasive aquatic plant. Introduced from South America, Parrotfeather is currently common between the Cascade and Sierra Nevada and coastal mountain ranges in Oregon and Northern California, and is widespread and abundant in coastal areas from northern California to the Columbia River (Sytsma 1992). Parrotfeather was first collected in Washington in 1944 near Aberdeen and is currently established throughout the Chehalis River from Centralia to Grays Harbor, in sloughs along the lower Columbia River, and in two private lakes in northwest Washington (Parsons 1996). Quarantined by the Washington Department of Agriculture in 1992, Parrotfeather sale and distribution is currently prohibited in Washington.

The plant can establish in systems with relatively low water column nutrient concentrations, but grows most prolifically in shallow, nutrient rich systems such as drainage ditches and shallow, eutrophic lakes and slack water areas in rivers (Sytsma 1992). Parrotfeather is heterophyllous, submersed and emergent leaves are formed. The submersed growth form is prevalent in winter and spring, however, most production occurs in summer when emergent stems and leaves are produced.

Parrotfeather infestation severely alters the structure and function of aquatic systems. Emergent stems branch as they elongate, and form a dense stand of emergent stems that may extend to 25 cm above the water surface. Emergent stem densities as high as 1500 stems/m^2 shade the water column and reduce primary production by phytoplankton in infested waterbodies (Sytsma 1992). Reduced phytoplankton production limits zooplankton production and the ability of the infested system to support a productive fishery. Thick mats of rhizomes (sensu Sytsma 1992) develop in the water column and reduce water movement; flooding is a common consequence of Parrotfeather infestation of drainage ditches (Sutton 1985). Respiration of the rhizome mat also consumes oxygen in the water and reduces dissolved oxygen concentration. Dissolved oxygen concentration less than 3 mg/L have been recorded below Parrotfeather mats (Sytsma 1992). In addition, Parrotfeather maintains charge balance by excreting a proton (H^+) when ammonium ion (NH_4^+) is a nitrogen source, which leads to acidification of infested waterbodies (Sytsma 1992).

The biology of Parrotfeather limits efficacy of herbicides available for management. Emergent leaves have a thick, waxy cuticle that limits chemical uptake. Surfactants do not increase herbicide efficacy (Anderson and Sytsma 1992). The rhizome mat that supports the emergent biomass does not have a high metabolic rate and there is little translocation of foliar-applied herbicides. Foliar application can reduce emergent biomass, but sprouting of buds on the rhizomes quickly re-establishes the emergent biomass (Anderson et al 1993a). Water applications of herbicides have demonstrated mixed results (Anderson et al 1993b, Perry 1996). The biological characteristics of Parrotfeather suggest that a combination treatment of foliage and water may provide better control than water or foliar application alone.

Aquatic weed management options are limited. The multiple-use character and flow characteristics of aquatic systems often prohibit use of the herbicides that can effectively control aquatic weeds. Biological control methods are not available for the most common aquatic weed species in the Northwest, and physical methods are often limited by site access and water level.

Given the restrictions on control methods that are imposed by the nature of aquatic systems, innovative approaches to management that enhance the efficacy of existing chemical management techniques are required.

Effective methods for control of Parrotfeather and other invasive aquatic plants are needed to protect the function and value of natural fish and wildlife habitats and manmade water systems throughout the Northwest. This report summarizes data collected in a study of interactions between fluridone and triclopyr in the management of parrotfeather (*Myriophyllum aquaticum*). The objective of the study was to elucidate the potential for interaction and synergy between the two compounds in control of Parrotfeather. An earlier experiment, not reported here, was conducted using the design described in the original proposal that resulted in rapid death of parrotfeather at triclopyr concentrations outlined in the proposal. Both fluridone concentrations in the earlier experiment resulted in significant bleaching and plant death.

Methods and Results

Experiment 1

Myriophyllum aquaticum stems were collected from Smith Lake on the Oregon Coast, approximately five miles south of Astoria. A greenhouse population was established and maintained in 2'x3'x7" containers containing carbon-filtered tap water (Table 1) supplemented with a 30:10:10 fertilizer (GrowMore Orchid). The plants used in experiments were started as ten-centimeter apical stem sections from the greenhouse population that were planted in 0.5 L plastic containers containing a 2:1 mixture of sand and clay collected from Sauvie Island, which is located northwest of Portland in the Columbia River. The soil used in the experiments was supplemented with 26 g per container of a 1:1 mix of 18:6:12 and 14:14:14 time-release fertilizer (Osmocote).

Each experimental plant was submerged in separate 11-L containers containing 5.75 L of carbon-filtered tap water and grown in a greenhouse at Portland State University under ambient light supplemented with fluorescent lights (Sylvania Gro-Lux WS) on a 14-hr photoperiod.

Plants were grown in the container for three weeks before initiation of herbicide treatment, and were moved every week throughout the experiment to reduce variability from location within the greenhouse.

The herbicide treatments were conducted as a static renewal experiment, with complete water exchange conducted weekly. High and low air and water temperatures were monitored every three to four days using a mercury maximum/minimum thermometer.

Plants were allowed to establish in pots and grow for three weeks prior to herbicide treatment. Seventeen treatments with six replicates for each treatment were randomly applied (see Table 2). Triclopyr treatments were spray-to-wet applications (approximately 6 mL per treatment) with deionized water applied as a control. Fluridone treatments were applied by exchanging the 5.75 L of water in each container with the appropriate treatment concentration.

Table 1. Nutrient concentrations (mg/L) in tap water and carbon-filtered water used in Parrotfeather experiments. Analyses conducted by US Forest Service Cooperative Chemical Analytical Laboratory at Oregon State University.

	Total P	SRP	NO3-N	NH3-N	Na	K	Ca	Mg	Fe
Tap Water	0.013	0.0050	0.002	0.273	3.02	0.31	3.20	1.077	0.00
Carbon-filtered Water	0.004	0.0010	0.138	0.090	2.56	0.18	1.58	0.583	0.47

Each treatment was maintained until the seventh week, when three plants were randomly selected for harvest. The harvested plants were divided into stems, leaves, adventitious (water column) roots, roots (in the sediment), and the planted stem section. Plant parts were placed in paper bags and dried at ~65 C to a constant weight. Fluridone treatment of the remaining plants was stopped after the seventh week and the containers refilled with carbon-filtered water. Regrowth was allowed for three additional weeks before the remaining three plants were harvested, separated, dried, and weighed as above.

Table 2. Experimental treatments and timeline for combination treatment fluridone/triclopyr experiment.

Fluridone	Triclopyr.					
(Day 1 through Day 49)	*Foliar spray to wet Rate*	*Day of Application*			*Replicates Harvested*	
		Day 1	*Day 7*	*Day 21*	*Day 49*	*Day 70*
Control					3	3
	0.01%	x			3	3
	0.1%	x			3	3
1 ppb		x			3	3
1 ppb	0.01%	x			3	3
1 ppb	0.01%		x		3	3
1 ppb	0.01%			x	3	3
1 ppb	0.1%	x			3	3
1 ppb	0.1%		x		3	3
1 ppb	0.1%			x	3	3
10 ppb		x			3	3
10 ppb	0.01%	x			3	3
10 ppb	0.01%		x		3	3
10 ppb	0.01%			x	3	3
10 ppb	0.1%	x			3	3
10 ppb	0.1%		x		3	3
10 ppb	0.1%			x	3	3

Fluridone and triplopyr at the treatment concentrations effected parrotfeather growth (Figures 1 and 2). Plants treated with fluridone at 1 ppm did not exhibit marked differences from control plants until the second harvest (10 weeks after treatment and three weeks after fluridone treatment was discontinued). The 1 ppm fluridone-treated plants did exhibit some photo-bleaching at the nodes of the stem, but other obvious treatment effects were not present. The higher fluridone concentration (10ppb) resulted in observable photo-bleaching within three days of treatment. Stem growth was limited in plants treated with 10ppb fluridone, but new bud sprouting continued.

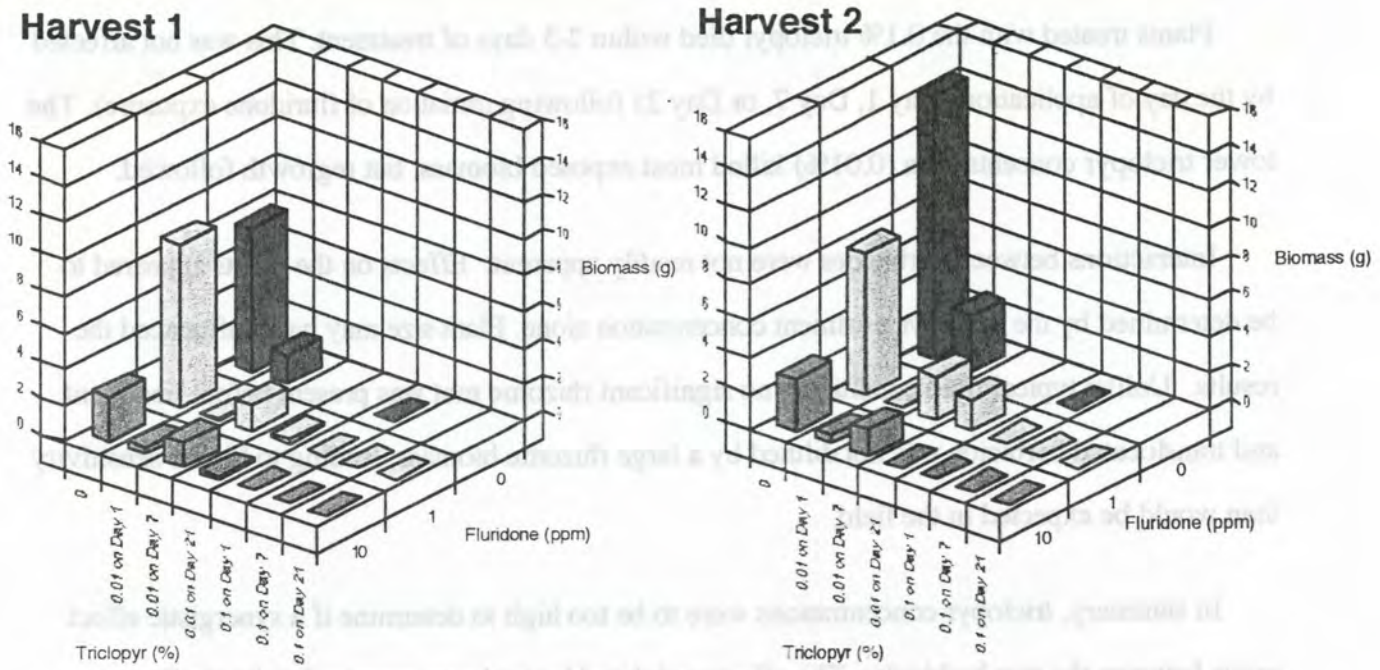


Figure 1. Biomass of parrotfeather in experiment 1 at first and second harvests.

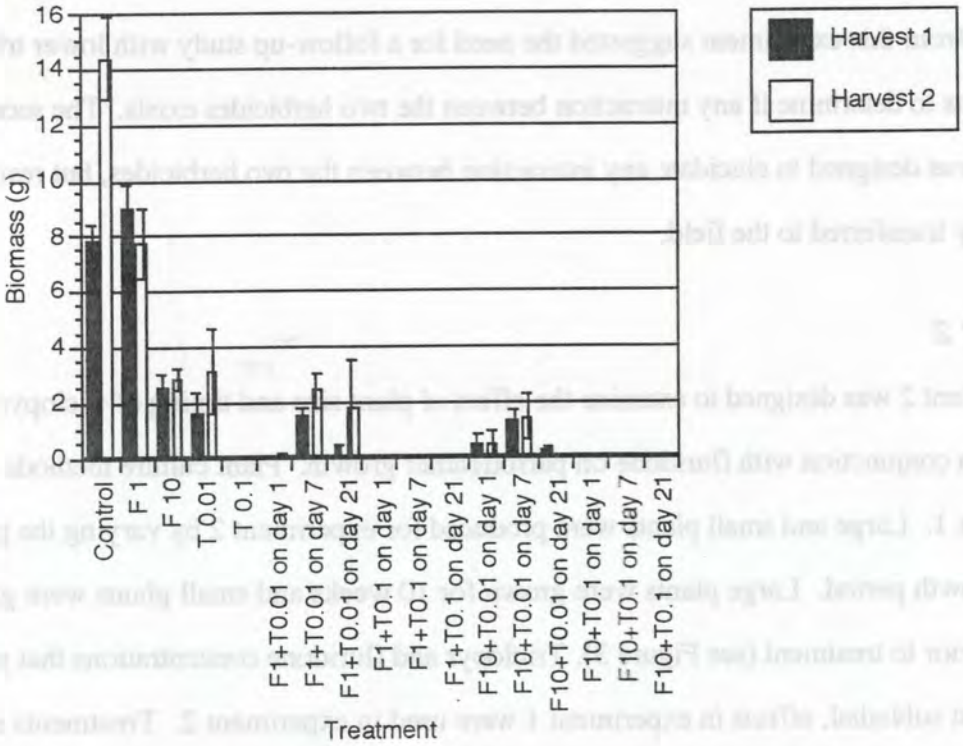


Figure 2. Biomass of parrotfeather at first and second harvests (± 1 standard error).

Plants treated with the 0.1% triclopyr died within 2-3 days of treatment. This was not affected by the day of application (Day 1, Day 7, or Day 21 following initiation of fluridone exposure). The lower triclopyr concentration (0.01%) killed most exposed biomass, but regrowth followed.

Interactions between herbicides were not readily apparent. Effects on the plants appeared to be determined by the triclopyr treatment concentration alone. Plant size may have influenced the results. Unlike typical field conditions, no significant rhizome mat was present before treatment, and translocated herbicide was not diluted by a large rhizome biomass, leading to higher sensitivity than would be expected in the field.

In summary, triclopyr concentrations were to be too high to determine if a synergistic effect exists between the two herbicides. The effects exhibited by triclopyr appeared to be similar to a contact herbicide on the treatment population, either killing the entire plant or just the emergent portions depending on the concentration.

Results from this experiment suggested the need for a follow-up study with lower triclopyr concentrations to determine if any interaction between the two herbicides exists. The second experiment was designed to elucidate any interaction between the two herbicides, but results will not be readily transferred to the field.

Experiment 2

Experiment 2 was designed to examine the effect of plant size and timing of triclopyr application in conjunction with fluridone on parrotfeather growth. Plant culture methods were as in experiment 1. Large and small plants were produced for experiment 2 by varying the pre-treatment growth period. Large plants were grown for 10 weeks and small plants were grown for four weeks prior to treatment (see Figure 3). Triclopyr and fluridone concentrations that produced detectable, but sublethal, effects in experiment 1 were used in experiment 2. Treatments included 0 and 1 ppb fluridone applied to the water and 0, 0.00001, 0.0001, and 0.001 percent triclopyr applied to the foliage of large and small plants. The effect of pretreatment with fluridone on

triclopyr efficacy was tested by applying triclopyr on the same day as fluridone treatment and seven days after fluridone treatment on large and small plants. All treatments were replicated four times.

Two response variables were measured in experiment 2: growth rate and leaf chlorophyll concentration. Four plants were randomly selected for harvest on the day of treatment to determine initial biomass. Harvested plants were broken down into stems, leaves, adventitious, roots suspended in the watercolum, and sediment roots. Four weeks after initiation of treatments the remaining plants were harvested. By the end of the experiment, the plants were quite large and harvesting was time consuming. Harvest of treated plants at the end of the experiment began four weeks after treatment and required two weeks to complete. Growth rate (GR) was calculated as:

$$GR = (B_h - B_i)/D_h$$

Where: B_h = biomass at final harvest;

B_i = mean biomass when treatments were initiated; and

D_h = days post-treatment

Leaf chlorophyll concentration was used as a second response variable. Emergent leaves were collected for chlorophyll measurement prior to, and weekly after, treatment. Approximately 100 mg fresh weight of emergent leaves were collected from each plant for chlorophyll measurement. Leaves were collected from the emergent stem two to five cm from the stem apex. Leaves were placed into sealed containers (scintillation vials) and placed on ice immediately after collection. Leaves were weighed and pigments were extracted with DMSO within five hours of collection. Chlorophyll *a, b*, and total carotenoids determined spectrophotometrically using methods and equations of Wellburn (1994).

Analysis of variance (ANOVA) was used to test for significant effects on growth rate and chlorophyll concentration. Herbicide and plant size effects were tested in a three-way ANOVA with plant size (large and small), triclopyr concentration (none, low, medium, and high), and

fluridone concentration (none and 1ppb) as factors. Day of application (Day 1 and Day 7 of fluridone application) effect was examined in a separate ANOVA, with size (large and small), and triclopyr concentration (low, medium, and high) included in the ANOVA. A log transformation was used to satisfy the assumptions of ANOVA for chlorophyll data. An arcsine-square root-transformation was used for plant growth rate data.

Water and air temperature in experiment 2 was measured every 15 minutes using Stowaway™ temperature loggers. Water temperature averaged 21.4 C and ranged from 10 to 28 C during experiment 2 (Figure 3). Air temperature averaged 24.3 C and ranged from 10 to 38 C (Figure 4).

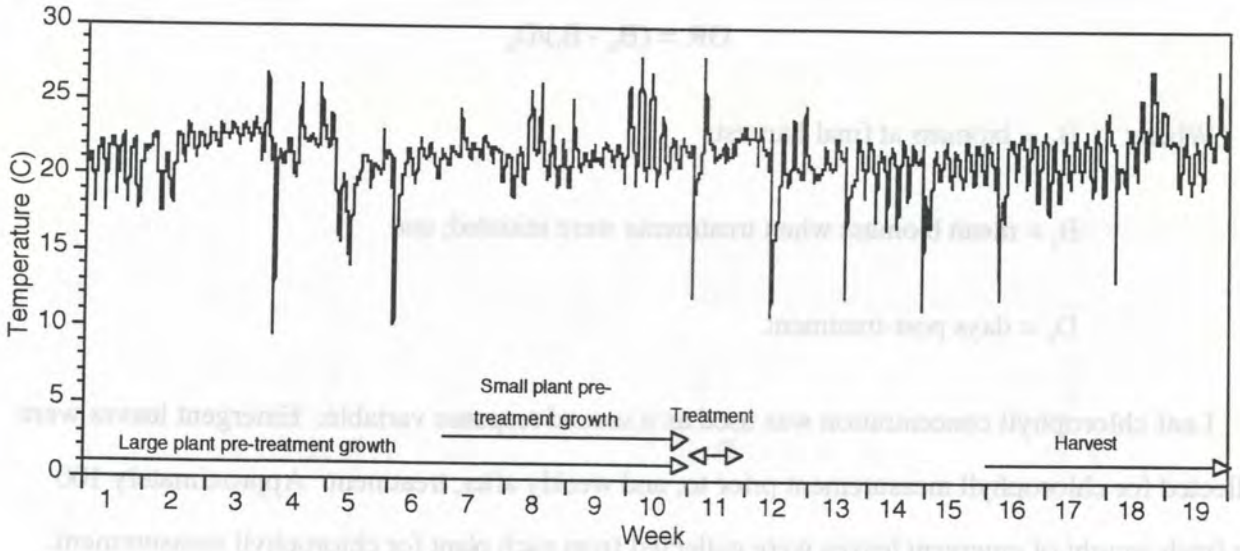


Figure 3. Water temperature during experiment 2.

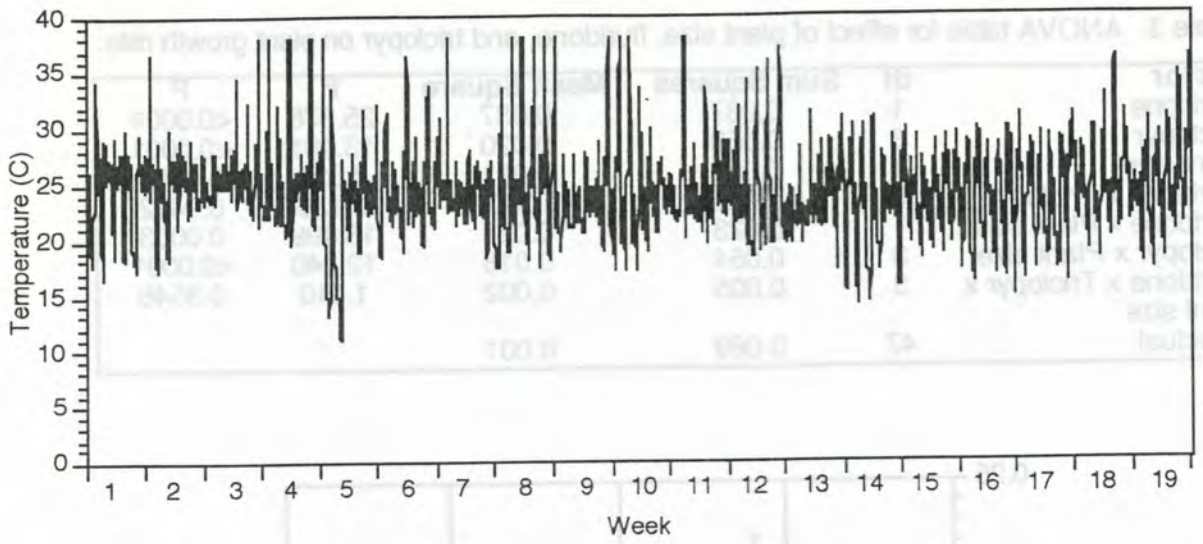


Figure 4. Air temperature during experiment 2.

Plant growth rate response

Plant size interacted with fluridone and triclopyr when plant growth rate was the response variable (Table 3). The fluridone x triclopyr interaction was not significant. Triclopyr reduced plant growth more in small plants than in large plants at the low and medium triclopyr rates when fluridone was present, however, at the highest concentration the growth rate of large plants was lower than that of small plants (Figure 5). Relative to control growth, the highest triclopyr concentration reduced growth of large plants but not small plants (Figure 6). At the intermediate concentration, small plant growth was reduced relative to the control, but not large plant growth. Fluridone reduced small plant growth but had no effect on large plant growth (Figure 7).

Table 3. ANOVA table for effect of plant size, fluridone, and triclopyr on plant growth rate.

Factor	df	Sum Squares	Mean Square	F	P
Fluridone	1	0.037	0.037	25.376	<0.0001
Triclopyr	3	0.059	0.020	13.491	<0.0001
Plant size	1	0.011	0.011	7.328	0.0094
Fluridone x Triclopyr	3	0.001	0.0002	0.129	0.9422
Fluridone x Plant size	1	0.023	0.023	15.499	0.0003
Triclopyr x Plant size	3	0.054	0.018	12.340	<0.0001
Fluridone x Triclopyr x Plant size	3	0.005	0.002	1.110	0.3546
Residual	47	0.069	0.001		

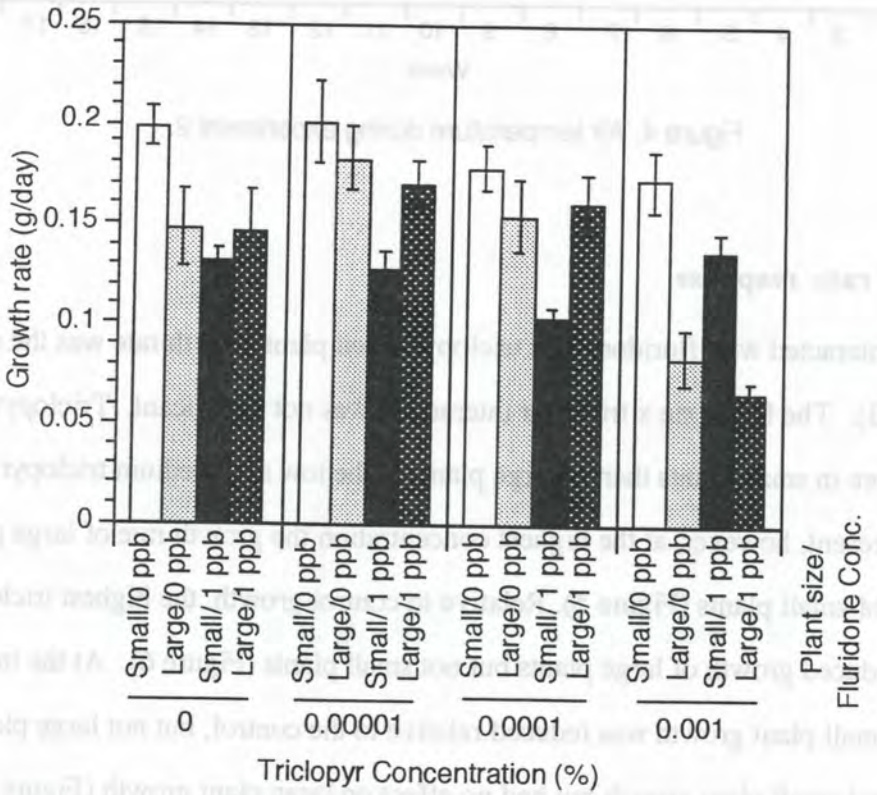


Figure 5. Growth rate of large and small parrotfeather plants treated with fluridone and triclopyr. (Bars indicate 1 standard error)

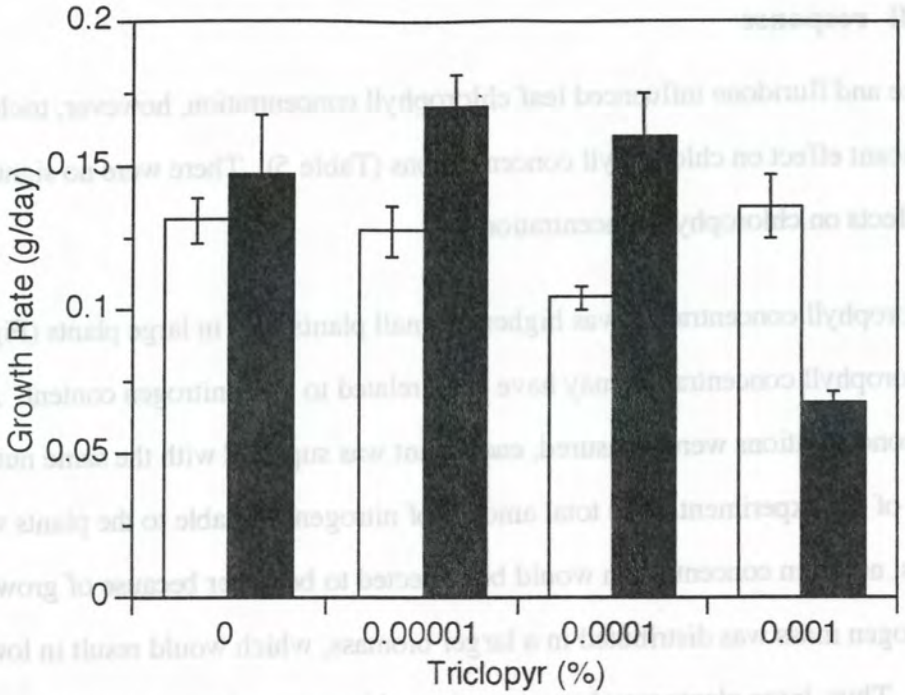


Figure 6. Interaction of plant size (open columns = small plants, filled column = large plants) on triclopyr effect on parrotfeather growth rate. (Bars indicate 1 standard error)

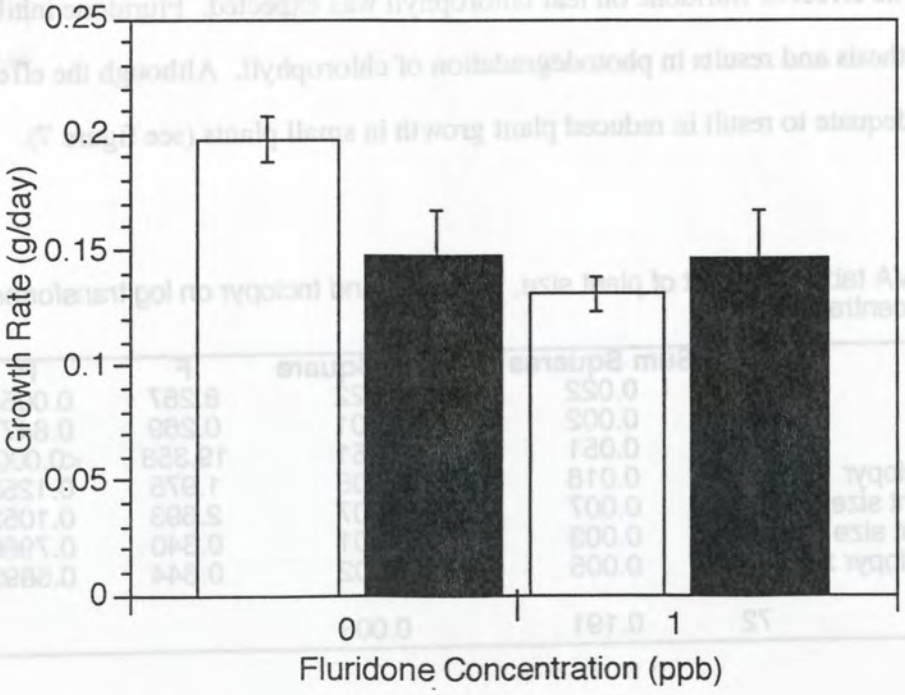


Figure 7. Interaction of plant size (open columns = small plants, filled column = large plants) on fluridone effect on parrotfeather growth rate. (Bars indicate 1 standard error)

Chlorophyll response

Plant size and fluridone influenced leaf chlorophyll concentration, however, triclopyr did not have a significant effect on chlorophyll concentrations (Table 5). There were no significant interaction effects on chlorophyll concentration.

Leaf chlorophyll concentration was higher in small plants than in large plants (Figure 9). Size effects on chlorophyll concentration may have been related to plant nitrogen content. Although no leaf nutrient concentrations were measured, each plant was supplied with the same nutrient dose at the beginning of the experiment. The total amount of nitrogen available to the plants was the same. In large plants, nitrogen concentration would be expected to be lower because of growth dilution. The same nitrogen mass was distributed in a larger biomass, which would result in lower nitrogen concentration. Thus, large plants may have experienced incipient nitrogen limitation.

Leaf chlorophyll concentration was lower in plants exposed to fluridone than in control plants (Figure 10). The effect of fluridone on leaf chlorophyll was expected. Fluridone inhibits carotenoid synthesis and results in photodegradation of chlorophyll. Although the effect was small, it was adequate to result in reduced plant growth in small plants (see figure 7).

Table 5. ANOVA table for effect of plant size, fluridone, and triclopyr on log transformed leaf chlorophyll concentration.

Factor	df	Sum Squares	Mean Square	F	P
Fluridone	1	0.022	0.022	8.267	0.0053
Triclopyr	3	0.002	0.001	0.269	0.8477
Plant size	1	0.051	0.051	19.358	<0.0001
Fluridone x Triclopyr	3	0.016	0.005	1.975	0.1253
Fluridone x Plant size	1	0.007	0.007	2.693	0.1052
Triclopyr x Plant size	3	0.003	0.001	0.340	0.7966
Fluridone x Triclopyr x Plant size	3	0.005	0.002	0.644	0.5893
Residual	72	0.191	0.003		

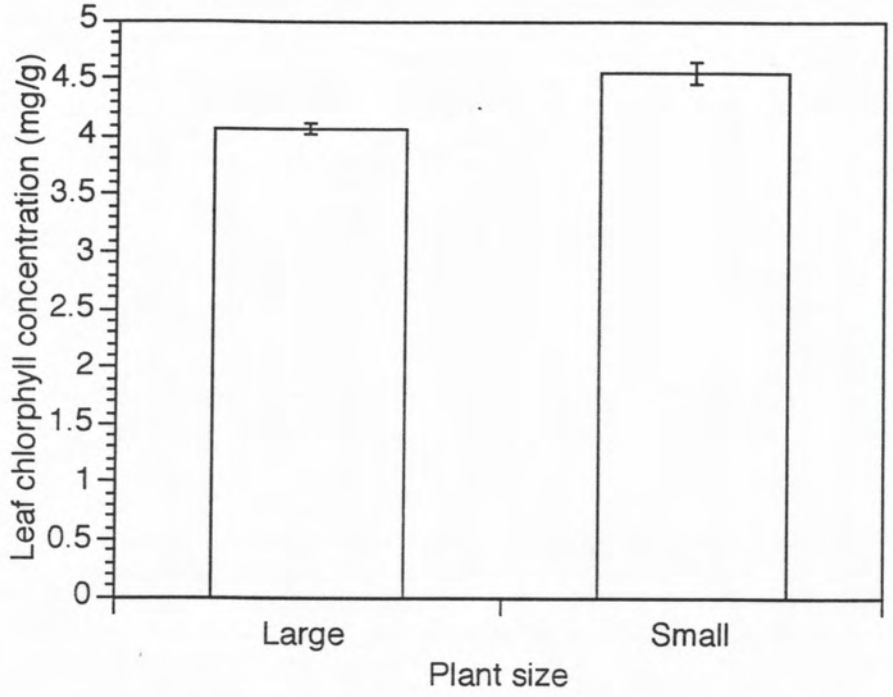


Figure 9. Effect of plant size on leaf chlorophyll concentration.

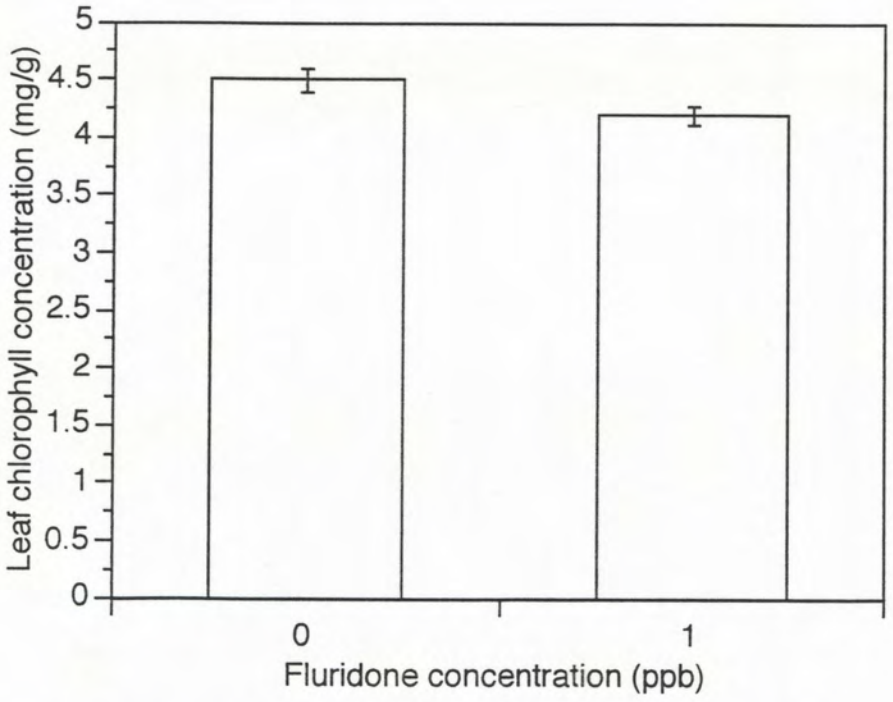


Figure 10. Effect of fluridone on leaf chlorophyll concentration.

Task Two: Water Quality Monitoring

The objective of this task was to monitor water quality conditions at locations where parrotfeather is established in backwaters and in those backwater areas that are void of aquatic noxious weeds. Four locations were monitored during the summer months. The monitoring sites were located near, Galvin (RM 65) and Garrard Creek (RM 44). The Chehalis Tribe Water Resource Team conducted water testing for: water temperature, pH, % saturation, dissolved oxygen and conductivity. In addition, water samples were collected and analyzed for the types and quantity of zooplankton and phytoplankton organisms.

Data collection for this task was completed. Results and summaries of the water quality, phytoplankton and zooplankton analysis are attached (appendix A). Monitoring and collection of the last data set for water quality was not collected due to service and repairs needed for the water lab. Delays in service and subsequent high-water levels prevented any additional collection of data. Future monitoring and collection of data will build on the knowledge of impacts from aquatic noxious weeds.

Water Quality Monitoring

Background

The interaction between macrophyte growth and the physical and chemical environment determines aquatic community structure and influences ecosystem level process (Carpenter 1981, Kemp et al. 1984, Frodge et al. 1990, Barko et al. 1991, Sand-Jenson et al. 1989, James and Barko1990, Barko et al. 1991, Sand-Jenson and Borum 1991).
Invasive aquatic macrophytes can alter habitat and nutrient cycling in aquatic systems (Carpenter and Lodge 1986, Madsen et al.1991), thereby influencing bottom-up as well as top-down control of system productivity. The objective of this task is to monitor field water quality conditions and biological perimeters in dense stands of Parrotfeather to demonstrate if this non-native plant alters habitat and displaces juvenile salmonids.

Methods

Four field locations were selected for monitoring during the summer months of 1998. The monitoring sites were located near Galvin (River mile 65) and Garrard Creek (Rm 44). These two sites were known to have extensive populations of parrotfeather. The control sites selected were back water areas that had native aquatic plant species and no parrotfeather. All back water areas were approximately one acre in size and directly connected to the Chehalis River. The Chehalis Tribe Water Resource Team was responsible for conducting the water testing. The team monitored for: water temperature, pH, percent saturation, dissolved oxygen and conductivity. Water samples were also collected and analyzed for the types and quantity of zooplankton and phytoplankton organisms.

Data collection for this task started on July 16, 1997 and was completed on September 11, 1997. Collection of data at the control stations was done at a fixed location with the aid of a GPS unit and field flagging. Collection of water samples at the Parrotfeather stations altered slightly as water levels decreased and vegetative cover increased. For the water quality monitoring a Hydro Lab, was calibrated in the Chehalis Tribe Water Quality laboratory and used in the field for data collection.

The Zooplankton and Phytoplankton samples were collected after the Hydro Lab analysis. The water samples were collected and preserved as suggested by WATER Environmental Service Inc. For the zooplankton samples, 12 liters of water was collected at set depths. The samples were then filtered and concentrated down to a 250 ml sample that was preserved, and kept cool until shipment to Water's lab. The phytoplankton samples were a composite of sub-samples totaling 12 liters of water that was collected at various depths. A one liter composite sample was preserved, and kept cool until shipment to Water's lab.

WATER Environmental Services, completed the phytoplankton and zooplankton assessment which included taxon Identification and enumeration, in January, 1998.

Results

Temperatures

Water temperatures were slightly higher at the Galvin stations (mean 20.9°C) compared to the Garrard Creek (19.17°C) stations. A location effect. Temperatures increased slightly over the sampling period at all stations. A variation that would be expected as ambient air temperatures increased. No statistical or significant change in the temperature was observed from the control stations (20.04°C) vs. the parrotfeather stations (20.08°C).

pH

The pH became more neutral or increased slightly over the sampling period for the control stations. There was a statistical difference in the pH at the control stations vs. the parrotfeather stations. The parrotfeather stations were more acidic (mean 6.66) compared to the control stations (6.96). These differences were recorded at both Galvin and Garrard Creek.

% Saturation

There was no location difference in the percent saturation of oxygen. Over the course of the sampling dates there was a variation from a high mean of 70.97% (7/31/97) to a low of 50.7% (7/16/97). There was a statistical difference in the treatments. The parrotfeather stations had a lower percent saturation (mean 31.63%) compared to a mean of 83.6% at the control locations.

Conductivity

There was a difference in the conductivity between river locations. The Galvin location had a higher conductivity reading compared to Garrard Creek. A statistical difference in the conductivity was measured between the treatments. The parrotfeather stations had a higher conductivity level (mean 164.28) compared to the control stations (133.98).

O2

A statistical difference in the level of oxygen was recorded between the treatments. The parrotfeather stations had a lower oxygen level (mean 2.74) compared to the control stations (7.55).

Discussion

Four water quality perimeters (pH, % saturation, conductivity and O2) were found to be significantly different at the parrotfeather stations compared to the control stations. Low values in pH, % oxygen saturation, and oxygen levels are indicators of poor water quality and unsuitable habitat for juvenile salmonids. The results indicate that the populations of Parrotfeather could be a contributing factor to these degraded water conditions. Temperature at all of the stations were on the high level and would contribute to the stress of juvenile Salmonids. Underwater observations by Mike Kelly, USFWS during a field visit to the Garrard Creek stations confirmed the dense vegetative mass of parrotfeather and the lack of use by fish species at the treatment site. Mike Kelly reported, no Salmonids were observed. He noted that, poor visibility due to algal blooms made it difficult to determine what other fish species may have been present. He indicated that one would not expect to see Salmonids in water this warm.

Biological activity, Zooplankton & Phytoplankton Assessment Results

Phytoplankton, number of taxon.
The number of phytoplankton taxon recorded at the control stations had a mean value of 5.0. At the parrotfeather stations the mean was 3.87. These values are for both the Galvin and Garrard Creek locations.

At the Galvin control station the mean number of taxon was 5.5 and for the parrotfeather treatment the mean was 4.0. The number of taxon at the Garrard Creek control station had a mean value of 4.5 and the parrotfeather treatment had a mean value of 3.75.

Phytoplankton, density (number / m3)
The density of organisms for the control stations had a mean value of 1,150(#/m3). At the parrotfeather stations the mean was 681. These values are for both the Galvin and the Garrard Creek locations.

At the Galvin control station the mean density was 2,099. The Galvin parrotfeather treatment had a mean value of 681. The Garrard Creek, control station had a density of 200 and the Garrard Creek parrotfeather treatment had a mean value of 681.

Zooplankton, number of taxon.
The number of zooplankton taxon recorded at the control stations had a mean value of 5.5. At the parrotfeather stations the mean value was 7.5. These values are for both the Galvin and the Garrard Creek locations.

At the Galvin control station the mean value of taxon recorded was 7.75 and for the Galvin parrotfeather treatment the mean was 6.75. The Garrard Creek control station recorded a mean of 3.3 taxon. The number of taxon recorded at the Garrard Creek parrotfeather treatment was 8.2.

Zooplankton, density # / m3
The density of zooplankton at the control stations had a mean value of 296,649. At the parrotfeather stations the mean value was 468,014. These values are for both the Galvin and the Garrard Creek locations.

The density of taxon at the Galvin control station had a mean value of 642,583. The density at the Galvin parrotfeather treatment had a mean value of 121,534.

The density of taxon at the Garrard Creek control station had a mean value of 49,285. The density at the Garrard Creek parrotfeather treatment had a mean value of 814,493.

Discussion

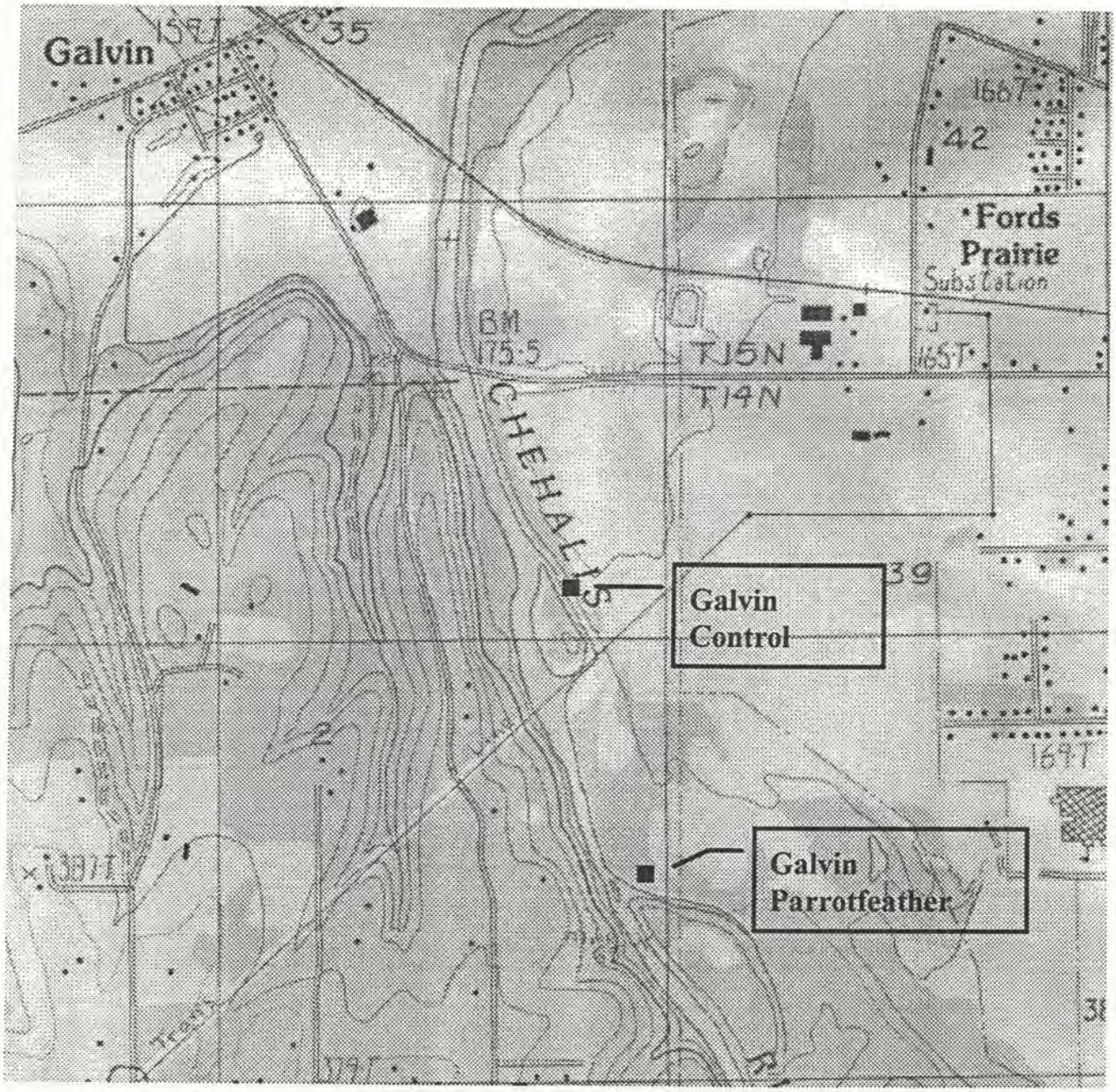
The phytoplankton and zooplankton data collected at the Galvin stations indicated that the number of species represented and the quantity of organisms was fewer at the parrotfeather sites compared to the control sites. These findings may indicate that the parrotfeather does block light energy and interferes with the productivity of the phytoplankton organisms.

At the Garrard Creek stations the opposite was found with one exception. The number of phytoplankton taxon represented at the Garrard Creek control station was higher compared to the parrotfeather station. All other data at this location indicated a greater number of taxon and density of organism existed at the parrotfeather station compared to the control.

Further examination of the taxon recorded at the Garrard Creek stations may reveal that the increased numbers of Zooplankton seen may represent species that are suited for the water quality conditions (Low pH, low O2) that were recorded.

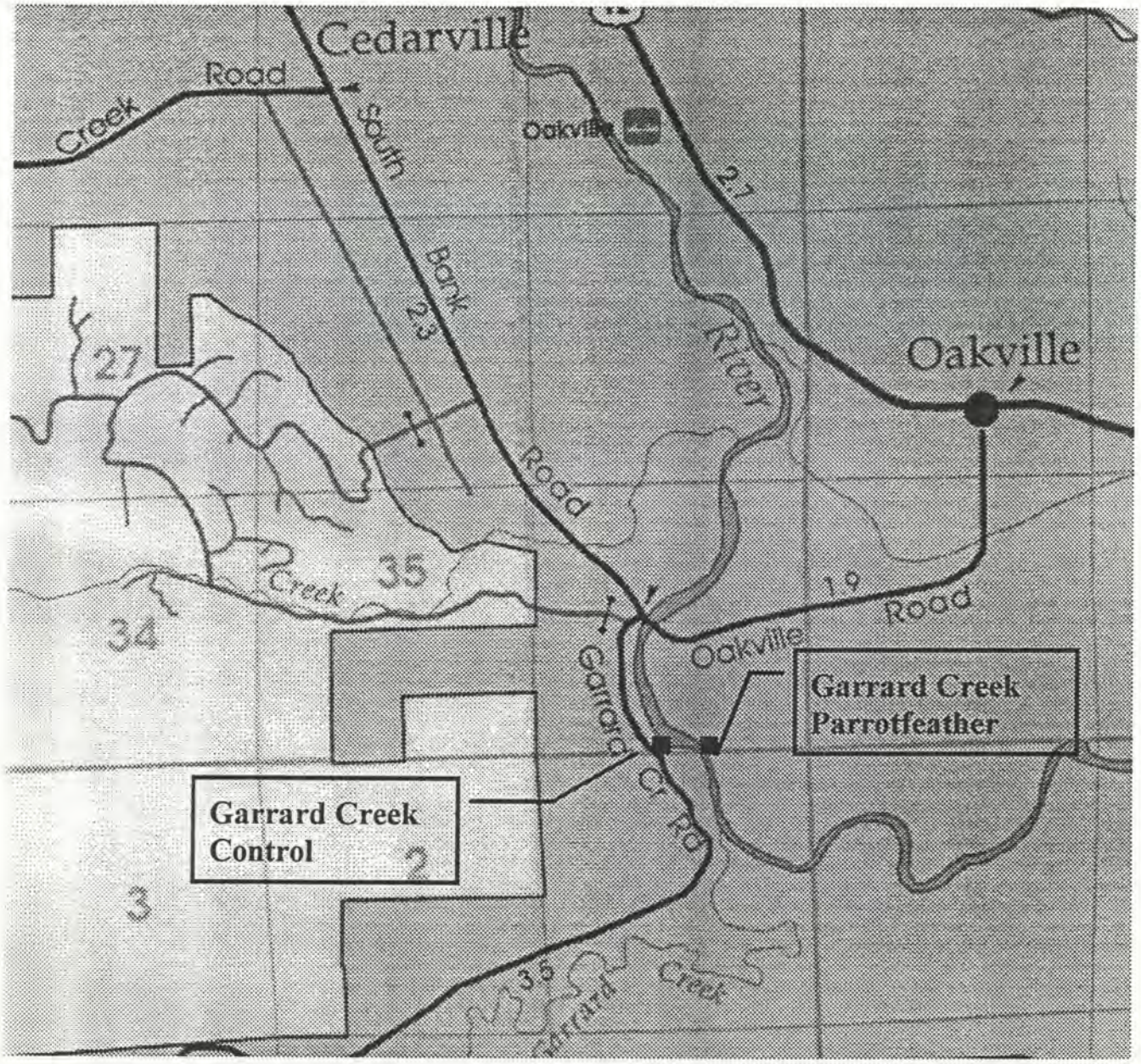
The sampling protocol for the zooplankton and phytoplankton analysis could be improved to obtain a large volume sample with minimal disturbance through the water column. Team members found that as the vegetative cover and density of stems increased over the summer months it became more difficult to collect at the previous location without a great deal of disturbance to the water column. Samples were collected on the fringe of plant mats or in small areas of open water for ease of operation and to minimize disturbance. Plankton numbers may have been greater along these plant edges.

A possible solution to the collection methods in the future would be to utilize a water pump and a weighted collection hose that can be suspended over and down into the vegetative mat of parrotfeather.



Galvin Control: T 14N, R 3W, Sec. 2, NW SW. River mile 65.

Galvin Parrotfeather: T 14N, R 3W, Sec. 2, NE NW. River mile 65.12.



Garrard Creek Control: T16N, R5W, Sec. 36, SW SE. River mile 44.

Garrard Creek Parrotfeather: T16N, R5W, Sec. 36, SW SE. River mile 44.