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Changes in Nontarget Wetland Vegetation Following a Large-Scale Fluridone Application

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ABSTRACT

Surface areas of floating-leaved, emergent, and scrub-shrub wetland plant communities were measured using an aerial imaging methodology before and 1 yr after fluridone (1-methyl-3-phenyl-5-[-3 (trifluromethyl) phenyl]-4 (*1H*)-pyridinone) was applied in a 134-ha lake and two hydrologically connected 4-ha ponds in southwestern Washington to control Eurasian watermilfoil. No significant losses in surface area of emergent wetland or scrub-shrub wetland plant communities occurred, while loss of floating-leaved aquatic plant communities was 28% in the lake and 100% in the ponds. Large-scale fluridone application for Eurasian watermilfoil control can be accomplished in a manner sensitive to nontarget emergent and scrub-shrub wetland protection, although some losses of floating-leaved aquatic plants may be unavoidable. In addition, aerial survey utilizing video imaging technology can expedite wetland plant community measurements.

Key words: fluridone, SONAR™, wetlands, aerial imaging, hyperspectral, aerial photography.

INTRODUCTION

Fluridone is an aquatic herbicide that inhibits carotenoid synthesis in plants, thus exposing their chloroplasts to photodegradation (Bartels and Watson 1978). While the susceptibility of many aquatic plant species to fluridone has been studied (McCowen *et al.* 1979; Arnold 1979, Netherland *et al.* 1993), effects on heterogeneous wetland plant communities adjacent to lakes or ponds are not well documented.

Due to concerns over possible impacts of a proposed fluridone treatment on nontarget wetland species within and adjacent to a lake and wetland system, the Washington State Department of Ecology required a wetland monitoring and loss mitigation program to be in place before permitting the herbicide application. Under the monitoring program, surveys were to be completed immediately before and 1 yr after the herbicide treatment to assess impacts and need for mitigation. The aerial survey described herein was a part of that program.

Interpretation of aerial photographs and digital imagery gathered by satellite-borne sensors has often provided data for wetlands mapping and assessments (Carter 1976, Carter 1978, Tiner 1984). The use of airborne video remote sensing, however, is a relatively recent development (Meisner 1986), as is the development of hyperspectral imaging technology (Rinker 1990).

Our objective was to assess the impact of the fluridone application on nontarget wetlands by measuring the change in horizontal surface area of floating-leaved (predominantly waterlilies—*Nymphaea odorata* Ait.), emergent (predominantly cattails—*Typha latifolia* L.), and scrub-shrub (dominated by willows—*Salix* spp.) wetland plant communities within and adjacent to the treated lake and downstream wetland areas.

MATERIALS AND METHODS

The study was conducted on the Long Lake system in Thurston County, WA (47°01'N, 122°47'W). The system is comprised of Long Lake, 134 ha in area, Long's Pond, 4 ha and hydrologically connected to Long Lake by subsurface flow, and Lois Lake, 4 ha, which receives surface flow from Long Lake.

The applicator, Resource Management of Tumwater, WA, followed a "block treatment" plan developed in consultation with the U.S. Army Engineer Waterways Experiment Station (WES), Washington State Department of Ecology, and Thurston County staff. This program was based, in part, on previous fluridone concentration/exposure time evaluations (Netherland *et al.* 1993) and called for uniform dispersion of the herbicide while maintaining a fluridone concentration near 30 ppb for 6 to 8 weeks. Since the use of rhodamine WT dye to track water movement and fluridone dispersion, as specified in the

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program protocol, was not permitted by county officials, fluridone residues determined after each application were used by WES personnel to adjust the treatment plan as it proceeded (Getsinger 1992, personal communication).

Long Lake was treated with fluridone on July 2, July 17, July 31, and August 14, 1991, in 0.2- to 4.2-ha treatment block areas dispersed throughout the littoral zone. No two adjacent blocks were treated on the same date (Figure 1). One application was made in Long's Pond on July 17, while the hydrologically connected Lois Lake received no direct herbicide application at any time. In all areas, the herbicide was applied as an aqueous suspension just beneath the water's surface at a rate of 9.3 L/ha. On July 2 several floating-leaved, emergent, and scrub-shrub wetland plant communities in and adjacent to each waterbody were observed at close range to provide ground-based data for use in the aerial survey.

In the aerial survey methodology, color still photography was used first to locate and identify plant communities previously ground-truthed. On June 14, 1991, Kodak Echtachrome 100Hc 35-mm film was used to collect oblique color photographs of all nearshore and wetland areas within the project. Before takeoff, the camera and lens package was mounted in a Cessna 172 airplane for oblique imaging at a 45-deg angle to the lake surface. Each frame provided a view of the lakeshore and adjacent nearshore and wetland areas. West banks were photographed from 11:00 am to 12:00 pm DST and east banks from 2:00 pm to 3:00 pm DST to minimize shadow interference. Overlap between image frames permitted a continuous view to aid in referencing locations seen. On July 17, 1992, post-treatment oblique photography was collected in the same manner described above, except that images in both color and Echtachrome 2236 false-color infrared (CIR) 35-mm slide film were collected at all locations.

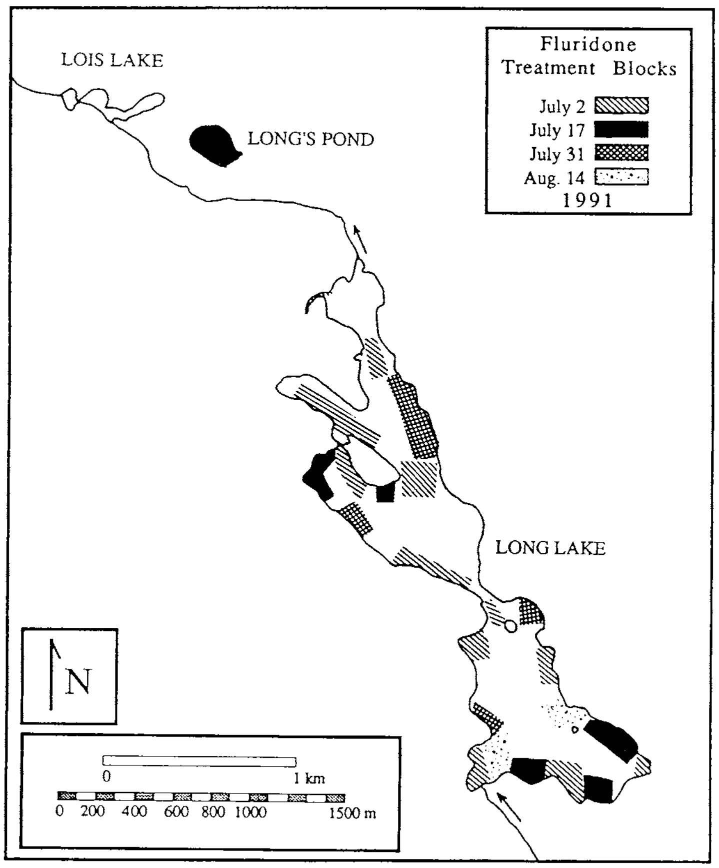

Figure 1. Locations and approximate sizes of treatment block areas receiving fluridone applications in 1991. The areas indicated as treated on July 2 cumulatively covered 33.4 ha, those treated on July 17 cumulatively covered 16.7 ha, those treated on July 31 cumulatively covered 8.3 ha, and areas treated on August 14 cumulatively covered 8.3 ha.

After film processing, the 1991 color images and 1992 color and CIR images were referenced to 7.5 Minute USGS Topographic maps. The set of visible and infrared images were then loaded into an image magnifier, and images were viewed at 20X and 80X magnification. Notes were made regarding vegetation conditions, and each color image was compared with the corresponding CIR image. Each floating-leaved, emergent, and scrub-shrub wetland community viewed on the 1991 imagery was roughly mapped for reference during the video analysis phase.

On June 14, 1991, and July 20, 1992, aerial hyperspectral video imagery was collected. During each flight session, imagery was collected from 12:00 pm to 2:00 pm DST to minimize shadows from the vertical perspective. An industrial grade RCA black and white VHS video camera specially equipped with a modified Ultracon tube was installed vertically in the floor of a Cessna-172 airplane and connected to a power supply, professional grade portable VHS recorder, and monitor. The camera was filtered to receive only those wavelengths of light useful for detecting variation in chlorophyll-*a* absorbance in green plants.[2] Transects were flown over all project areas at an altitude of 400 m MSL (approximately 350 m above Long Lake's surface). This provided a ground footpath of 250 m with footpaths of adjacent transects overlapping approximately 20%.[3]

To analyze the hyperspectral imagery for plant community detection and measurement, an IBM-based airborne video analysis system (Water Watch™) was used. Selected

[2]Spectral band selection for chlorophyll-*a* absorbance is discussed by Dr. Forest Dierberg in Remote Sensing for Water Quality Monitoring in the Tennessee Valley: Field Test of Two Systems. Tennessee Valley Authority, Water Resources Division. August 1992. TVA/WR-92/17. 123 pp.

[3]For a discussion of scale and image dimension considerations peculiar to video format, see the previously cited article by Meisner 1986.

video frames were digitized by the system's 512 x 512 8-bit image capture board yielding picture elements (pixels). The resulting image resolution equaled the resolution of the original VHS image. The image capture board distinguished 256 shades of gray and assigned each pixel a value (1 to 256) based on recorded light intensity. Reflectance characteristics of various plant community types were determined by sampling the gray-scale values of selected ground-truthed plant communities. A spectral classification and false-coloring scheme (Figure 2) was then developed to delineate and visually enhance all plant communities previously identified on color and CIR imagery (Figure 3).

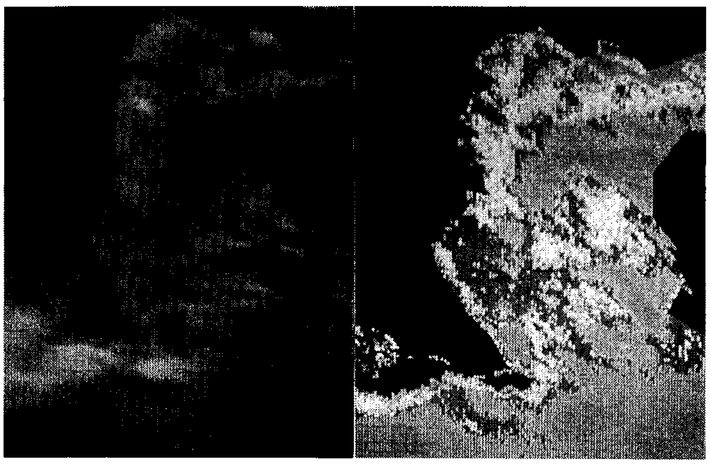

Figure 2. One wetland community area as seen on hyperspectral video imagery. On the left is the black and white hyperspectral image showing variation in chlorophyll-*a* absorbance, on the right is a black and white reproduction of the color-enhanced classified image produced to delineate plant community boundaries.

To quantify the impacts of fluridone on aquatic plants and wetlands, the digitized video imagery was scaled for measurements by the computer system. Scaling targets were measured on the ground and on the video monitor, and these measurements were used by the system's software to calculate the ground area represented by each pixel, approximately 0.24 m^2. All delineated plant communities were then measured in hectares on both the pre-treatment 1991 imagery, and the post-treatment 1992 imagery. Similar wetland plant communities seen within any video frame were measured together as one "wetland community area." Comparisons of pre and post-treatment areas of wetland communities were then made.

RESULTS AND DISCUSSION

Change in area of emergent wetlands (Table 1) was -3% in Long Lake -4% in Long's Pond, and +3% in Lois Lake. Change in area of scrub-shrub wetlands was +4% in Long Lake, and +7% in Long's Pond. The scrub-shrub component of the Lois Lake wetland community was included with the emergent community area for that area because scrub-shrub species were mixed with emergent wetland plants and were not easily discernible on imagery. The changes in areas of emergent and scrub-shrub wetlands do not appear significant in terms of indicating fluridone impacts because of interference in the area comparison caused by two factors. First, there was a chlorotic appearance in some of the surviving wetland vegetation after the fluridone treatment. Chlorosis in plants surviving in fluridone-treated waters has been observed by researchers including Bartels and Watson (1978) and Van and Steward (1985), and is an expected symptom of fluridone uptake. Chlorosis in portions of surviving plants seen in 1992 imagery made the delineation of these wetland communities by spectral classification more difficult, which may have resulted in a loss of accuracy in area measurements. Second, 1991-92 was an unusually dry winter and drier-than-normal wetland soil conditions in 1992 may have allowed expansion of emergent and scrub-shrub wetlands into lower areas,

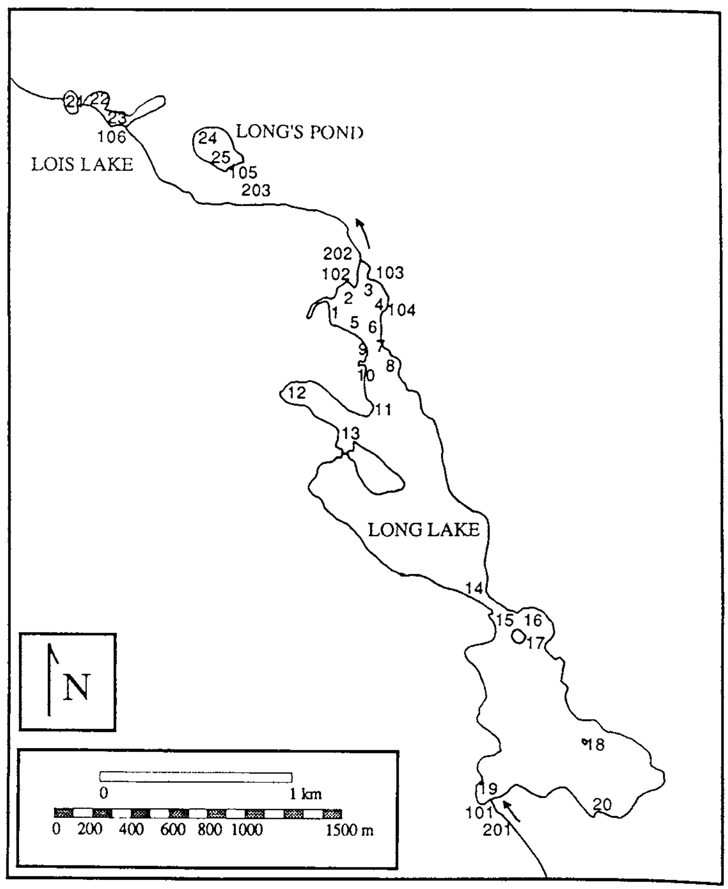

Figure 3. Locations of wetland community areas measured. Numbering refers to the Image Numbers listed in Table 1.

TABLE 1. MEASUREMENTS OF WETLAND COMMUNITY AREAS DELINEATED ON THE LONG LAKE SYSTEM IN THURSTON COUNTY, WA, USING THE WATER WATCH™ HYPERSPECTRAL VIDEO IMAGE PROCESSING SYSTEM.

Image No.	1991 (ha)	1992 (ha)	% change
	Emergent wetland[1]		
Long Lake			
101	0.32	0.31	-4
102	0.08	0.09	10
103	0.15	0.14	-8
104	0.12	0.11	-3
Total	0.67	0.65	-3
Long's Pond			
105	0.51	0.49	-4
Lois Lake			
106	0.61	0.63	3
	Scrub-shrub wetland[2]		
Long Lake			
201	0.21	0.22	4
202	0.08	0.08	5
Total	0.29	0.30	4
Long's Pond			
203	0.25	0.26	7
Lois Lake scrub/shrub community is included in emergent class.			
	Floating-leaved aquatic plants[3]		
Long Lake			
1	0.58	0.47	-19
2	0.47	0.19	-60
3	0.94	0.54	-43
4	0.93	0.62	-34
5	0.69	0.44	-36
6	0.32	0.27	-15
7	0.53	0.55	3
8	0.25	0.20	-20
9	0.20	0.18	-10
10	0.28	0.29	4
11	0.26	0.23	-12
12	0.29	0.28	-3
13	0.20	0.17	-12
14	0.68	0.40	-41
15	0.70	0.63	-11
16	0.47	0.33	-30
17	0.36	0.32	-12
18	0.27	0.24	-9
19	0.46	0.14	-70
20	0.64	0.33	-49
Total	9.52	6.81	-28
Long's Pond			
24	0.14	0.00	-100
25	0.50	0.00	-100
Total	0.64	0.00	-100
Lois Lake			
21	0.19	0.00	-100
22	0.11	0.00	-100
23	0.19	0.00	-100
Total	0.49	0.00	-100

[1]Dominated by *Typha latifolia.*
[2]Dominated by *Salix* spp.
[3]Dominated by *Nymphaea odorata.*

possibly obscuring losses. As the measured areas showed changes of only 3 to 7%, it is likely these factors could have resulted in part or all of the detected changes in vegetation.

Chlorosis in leaves did not hamper the delineation of floating-leaved aquatic plant communities by spectral classification as they were floristically simple and their boundaries distinct. Detected loss in surface area of all floating-leaved aquatic plant communities in Long Lake was 28%, and change in area varied from +4% to -70% for different community areas. Those communities suffering the greatest losses were near the inlet stream (Figure 3, #19), near the outlet stream (#2 and #3), just below the narrowest portion of the lake (#14), and one community in the southeast portion of the lake (#20), all of which lost over 40% of their surface areas. Meanwhile, Long's Pond and Lois Lake showed 100% loss of floating-leaved aquatic plant communities.

Causes of the considerable variation in losses to floating-leaved aquatic plant communities are not clear from our data. All of the plant communities in Long Lake which lost over 40% of their surface area were located within fluridone-treatment block areas, except for the two near Long Lake's outlet stream. However, the location of a community within a treatment block area would not appear to account for greater control since residue sampling performed by Thurston County personnel throughout the treatment period indicated that the treatment block areas of Long Lake contained similar fluridone residues (mean 33.6 ppb, range 10 to 60, standard deviation 13.2, n = 43) as other parts of the lake (mean 33.7 ppb, range 19 to 42, standard deviation 8.5, n = 4), while the mean of the concentrations recorded in Lois Lake was 24.7 ppb (range 19 to 30, standard deviation 1.53, n = 9) and concentration in Long's Pond on August 15 was 30 ppb. Also, residue uniformity increased throughout the lake over the treatment period as shown by the decrease in the standard deviation of residue measurements from 11.7 for those taken on July 11 to 3.6 for those taken on August 15 (Thurston County Public Works 1991).

Although post-treatment chlorosis and drought conditions may have reduced the accuracy of area measurements in the emergent and scrub-shrub communities, results of this aerial survey suggest that large-scale fluridone application targeting Eurasian watermilfoil can be accomplished without significant losses of nontarget emergent or scrub-shrub wetlands. Waterlily decline resulted from this treatment program; however, the program's July/August time frame may have exacerbated this decline. The original WES recommendation was for treatments during spring. Regrowth of the waterlilies will be monitored along with other communities in future phases of the project. The aerial survey methodology utilizing hyperspectral video imaging proved valuable in expediting the wetland plant community measurements and has provided imagery which will be useful as baseline data in future phases of the monitoring program.

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