Economic Considerations of Integrated Hydrilla Management A Case History of Johns Lake, Florida

by
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Introduction

Aquatic plant managers in the field make recommendations based largely on biology; however, actual management decisions are many times based largely or entirely on economics and politics. Human population growth in Florida has put tremendous pressure on water resources with dire biological, economic, and political consequences (Stocker 1993). Since 1980, the State of Florida has spent $70,000,000 on hydrilla (*Hydrilla verticillata*) control in public water bodies alone, an average of $4.67 million/year.[2] In Florida, there has recently been a growing gap between funding needs and funding available for hydrilla management, and the current funding gap (fiscal year 1994-95) stands in excess of $6,000,000.[2] Some lakes have been denied hydrilla treatment in the last few years because of funding shortfalls, and canals have basically not been funded the last 2 years because of the same funding shortfalls. Phillippy et al. (1989) found hydrilla established in 59 of the 100 largest lakes in Florida and calculated that a 10-percent (total surface area) fluridone herbicide treatment to control hydrilla in those 59 lakes would cost approximately $48,000,000. By 1992, hydrilla was known to be established in 69 of these same 100 largest lakes (Trent et al. 1992). If the remaining 31 largest lakes became infested with hydrilla, the economic consequences would be unmanageable at current funding levels. Funding levels have been decreasing, not increasing, in recent years.[2] The specter of the inability to afford hydrilla control when necessary translates to loss of biodiversity because of the ability of hydrilla to outcompete native macrophytes (Haller and Sutton 1975; Small, Richard, and Osborne 1985; Langeland 1990; Howard-Williams 1993), increased sedimentation rates (Joyce et al. 1992), stunted and slow-growing game fish populations (Hinkle 1986; Langeland 1990; Killgore, Hoover, and Morgan 1991), impairment of multiple uses (Small, Richard, and Osborne 1985; Langeland 1990), and loss of economic revenue (Colle et al. 1985, 1987; Langeland 1990). Maximum benefits to fish and wildlife attributed to macrophyte populations generally occur at intermediate macrophyte cover and density (Hinkle 1986; Wiley et al. 1984; Wiley, Tazik, and Sobaski 1987; Langeland 1990; Killgore, Hoover, and Morgan 1991; Petr 1987, 1993).

The use of grass carp alone or integrated with other hydrilla management methods has proven to be an efficient and cost-effective management tool (Stott et al. 1971; Stott and Buckley 1978; Osborne 1982; Shireman, Colle, and Canfield 1986; Sutton, Vandiver, and Neitzke 1986; Sutton and Vandiver 1986; Leslie et al. 1987; Wiley, Tazik, and Sobaski 1987; Pershe, Setaram, and Baird 1987; Cooke 1988) and may need to be increasingly relied on in the future if economic downturns continue. However, one fear of using integration is that this technique can result in nontarget effects because of its sometimes unpredictable power or unpredicted climatic events. This report accounts for a case history of a hydrilla control program in Johns Lake, Florida,

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[2] Personal Communication, 1994, Jeff D. Schardt, Florida Department of Natural Resources, Tallahassee, FL.

integrating triploid grass carp (*Ctenopharyngodon idella*) and contact herbicides. A brief economic analysis comparing this technique with a program using fluridone herbicide for hydrilla control is included along with largemouth bass (*Micropterus salmoides*) response to the habitat alteration.

Materials and Methods

Johns Lake is a 979-ha lake located in central Florida at latitude 28°32′ and longitude 81°38′ and is the 64th largest named lake in Florida (Shafer et al. 1986). Substrate is generally sandy with limited accumulations of silt. Some limited organic accumulation occurs in deeper water zones. Johns Lake is a prairie-type lake, and water levels have fluctuated over a range of approximately 4 m since 1960. During 1981, a drought year, large expanses of maidencane (*Panicum hemitomon*) became established in offshore areas, creating morphologically diverse habitat. The number of macrophyte species has also been diverse in recent years, with approximately 14 submersed and over 20 emergent and floating-leaf macrophyte species represented. Johns Lake has historically been utilized primarily for fishing, with very little other multiple-use activity occurring. Hydrilla was first noted in 1985 and was well established (0.8 ha); contact herbicide treatments targeting hydrilla were initiated in January 1986 (Table 1). Triploid grass carp were integrated beginning February 1988 and stocked over a period of 3 years (Table 2) to keep a population of small fish (25.4 to 43.5 cm) present in the lake, as unpublished data and project observations indicated that smaller fish targeted hydrilla

Table 1
Contact Herbicide Formulations, Rates, and Area Treated by Year in Johns Lake Integrated Hydrilla Control Program

Date	Formulation	Rate	Hectares Treated
1986	Diquat and Copper	22 and 42 L/ha, respectively	1.6
1987	Aquathol K	56 to 84 L/ha	35.6
1988	Aquathol Granular	359 to 448 kg/ha	31.8
1989	Aquathol Granular	359 to 448 kg/ha	25.5
Total			94.5

Table 2
Number of Triploid Grass Carp Stocked by Season and Resulting Total Stocking Rate per Hectare and Total Stocking Rate per Vegetated Hectare in Johns Lake Integrated Hydrilla Management Program

Date	Number of Triploid Grass Carp Stocked	Total Rate/Hecare	Total Rate/ Vegetated Hectare
Spring 1988	5,000	5.1	7.1
Fall 1988	510	5.6	7.9
Spring 1989	2,000	7.7	9.4
Fall 1989	1,631	9.5	11.4
Spring 1990	1,253	10.6	11.4
Total	10,394		

more effectively. Also, serial stocking is indicated to be more efficient and cost-effective over the long run (Wiley, Tazik, and Sobaski 1987). Integrated control with contact herbicides was selected because of the possibility of funds not being available for large-scale fluridone herbicide treatments. An economic analysis was made by comparing the cost of materials (triploid grass carp and contact herbicides) actually used in this management program with what the cost of materials would have been (contact herbicides and fluridone) in a strictly herbicidal management program. The projected costs of a fluridone hydrilla management program were based on conservative assumptions of a full-lake treatment first being required in 1988 and repeat treatments being required once every 3 years. Cost calculations were based on $1,000/3.8 L of fluridone product and an 8.3-percent (81.2-ha) treatment at a rate of 4.7-L fluridone/hectare treated. The objective of this hydrilla management program in Johns Lake was to reduce or eliminate hydrilla while maintaining as much native vegetation as possible. The west side of Johns Lake was surveyed biannually using a recording fathometer (Raytheon model DE-719C) to determine percent frequency of occurrence and percent volume infestation of macrophytes in the water column as described by Maceina and Shireman (1980). The east side of Johns Lake was surveyed and macrophytes qualitatively described every other year by a

Department of Natural Resources biologist. Largemouth bass were sampled by biannual electrofishing surveys and total abundance, catch per unit effort (CPUE), proportional stock density (PSD), relative stock density (RSD), and relative weight values (W_r) calculated. A Mini-Bass Small Boat Tournament Trail angler survey from a November 1993 event was also summarized.

Results and Discussion

Macrophytes

Initial hydrilla growth was exponential, even with the concurrent herbicide treatments. However, after stocking of the final group of triploid grass carp in 1990 and expanded herbicide treatments in 1988 and 1989, hydrilla standing crop was eliminated by fall 1991 (Figure 1), with only a trace of hydrilla noted fall 1993. Limited sampling for tubers in the substrate revealed none; therefore, hydrilla tuber reserves in Johns Lake may have been depleted in a span of approximately 3 years. However, tubers are not evenly distributed, and the limited substrate core sampling could have easily missed some concentrations of tubers.[1] However, data from four other central Florida lakes with sandy substrates also indicated probable tuber depletion approximately 3 years after hydrilla standing crop was eliminated (Trent et al. 1992). Data from Rodman Reservoir, Florida, indicated that sandy substrates contained higher numbers of hydrilla tubers than organic substrates. However, the sandy substrate tubers appeared to germinate at a faster rate with multiple dewaterings (Haller and Shireman 1983). Van and Steward (1990) found monoecious hydrilla tubers to survive over 4 years in undisturbed sediments in the

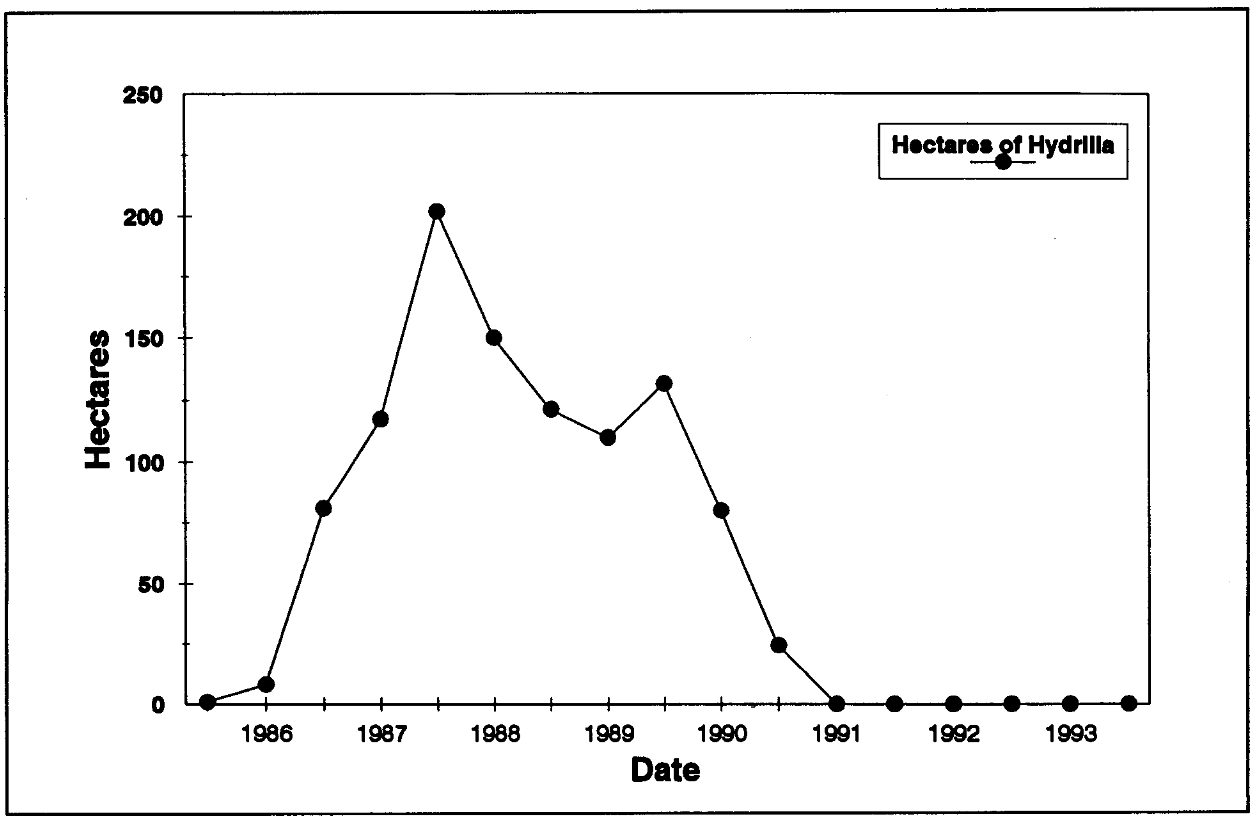

Figure 1. Aerial coverage of hydrilla (hectares) in west Johns Lake by year

1 Personal Communication, 1994, William T. Haller, Center for Aquatic Plants, University of Florida, Gainesville, FL.

laboratory. Depletion of hydrilla tuber and turion propagules in the substrate has not normally been possible using herbicides only. However, new technology utilizing fluridone or bensulfuron methyl to inhibit hydrilla tuber and turion production may soon be available (MacDonald et al. 1993; Langeland 1993; Haller, Fox, and Hanlon 1992; Van and Vandiver 1992).

Concurrent with hydrilla reductions, total native macrophyte coverage in west Johns Lake initially increased and then declined (Figure 2). This data also demonstrates the movement of triploid grass carp through a boatable canal into a nontarget area (northwest pool), as total submersed macrophyte coverage decreased there as well. Percent volume infestation of macrophytes in the water column in west Johns Lake obtained a maxima of 5 to 7 percent in 1988-1989 and then decreased to current values of less than 1-percent volume. Some individual macrophyte species showed increasing trends in coverage (Table 3) such as fragrant water lily (*Nymphaea odorata*), bladderworts (*Utricularia* spp.), and stoneworts (*Nitella* spp.). However, preliminary 1994 data indicate a current decrease in fragrant water lily coverage because of the previous expansion into habitats that will not support this plant over the long-term.[1] Also, major decreases were seen in the emergent offshore community consisting of maidencane and, to a lesser extent, lake rush (*Fuirena scirpoidea*). The current coverage of both these species is less than 1 ha. Offshore maidencane communities did not historically exist during a high water cycle (1960-1973), and rising water levels during 1991 and 1992 probably were responsible for decreased maidencane coverage in some of the deeper water areas. However, most of the maidencane

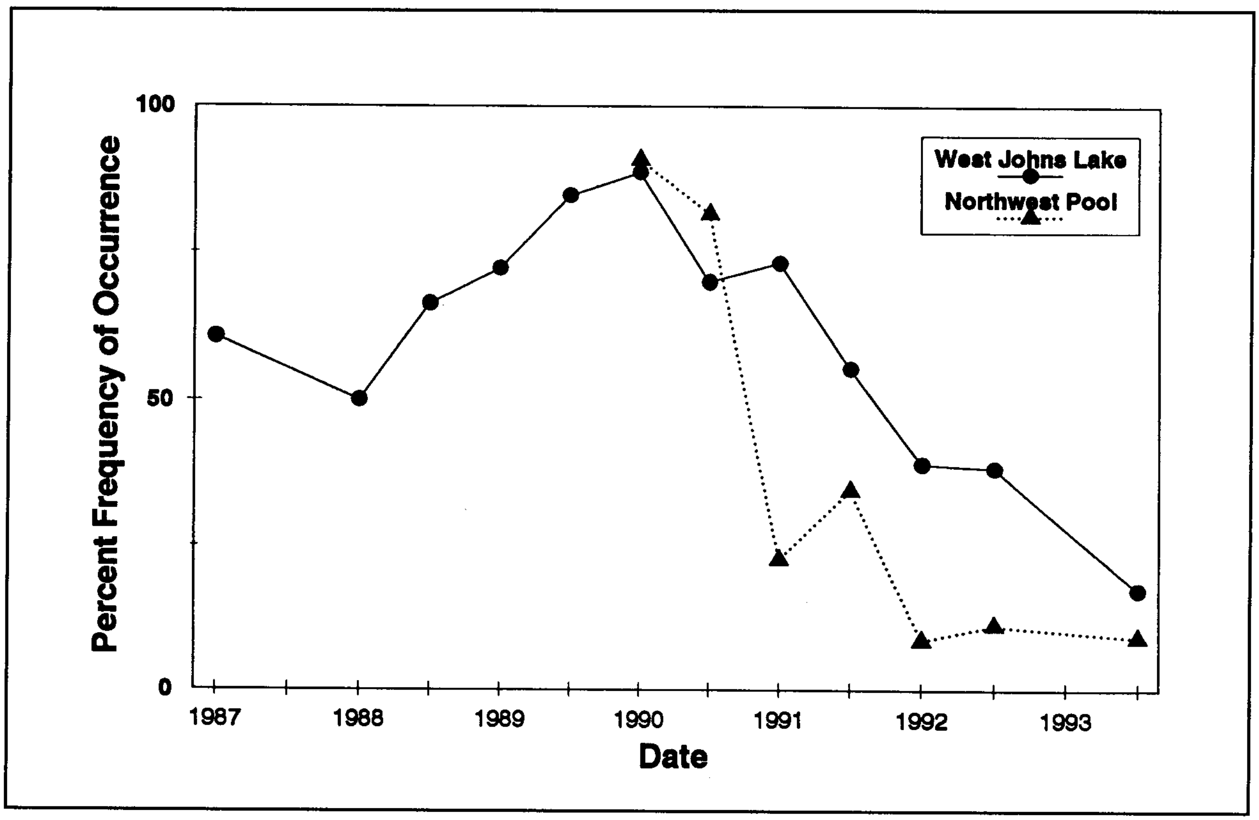

Figure 2. Percent frequency of occurrence of submersed macrophytes in west Johns Lake by year as determined by permanent recording fathometer transects

[1] Personal Communication, 1994, Dean G. Barber.

Table 3
Approximate Aerial Coverage in Hectares of Major Macrophyte Species in Johns Lake by Year[1]

Macrophyte Species	1986	1987	1988	1989	1990	1991	1992	1993
Hydrilla verticillata	7	166	122	132	24	0	0	trace
Nitella spp.	1	N/A	6	N/A	304	N/A	81	N/A
Eleocharis spp.	1	N/A	49	N/A	28	N/A	16	N/A
Utricularia spp.	24	N/A	49	N/A	101	N/A	223	N/A
Najas guadalupensis	2	N/A	24	N/A	57	N/A	32	N/A
Micranthemum glomeratum	20	N/A	6	N/A	7	N/A	7	N/A
Chara spp.	trace	N/A	trace	N/A	3	N/A	1	N/A
Ludwigia arcuata	49	N/A	32	N/A	36	N/A	36	N/A
Ceratophyllum demersum	2	N/A	30	N/A	65	N/A	32	N/A
Filamentous algae	7	N/A	4	N/A	trace	N/A	1	N/A
Panicum hemitomon	34	N/A	51	N/A	43	N/A	1	N/A
Panicum repens	24	N/A	34	N/A	44	N/A	60	N/A
Nymphaea odorata	7	N/A	26	N/A	40	N/A	49	N/A
Nuphar luteum	6	N/A	18	N/A	12	N/A	7	N/A
Fuirena scirpoidea	28	N/A	28	N/A	12	N/A	1	N/A
Typha spp.	97	N/A	122	N/A	105	N/A	81	N/A
Pistia stratiotes	0	0	10	13	4	4	1	3
Eichhornia crassipes	36	9	14	11	1	8	9	3
Total Macrophyte Coverage	450	600	700	800	910	800	748	650

[1] Data from Department of Natural Resources annual surveys.

reduction can be attributed to feeding by triploid grass carp after the hydrilla decline and appears consistent with observations by Trent et al. (1992) of similar feeding on palatable emergent species during late summer/early fall after individual triploid grass carp have achieved weights greater than 9 kg. This phenomenon may be related to a periodic need for cellulose in the diet (Das and Tripathi 1991) of larger triploid grass carp. Bonar et al. (1990) found a negative correlation between cellulose and macrophyte preference of triploid grass carp and probably is the more general characteristic of their food selection behavior.

Although native macrophytes currently exist at much lower levels than desired, the percent frequency of occurrence is expected to show increasing trends again in 2 to 5 years, with percent volume infestation of the water column increasing at a somewhat slower rate. These predictions are based on adequate water clarity (Figures 3 and 4) for macrophytes to reestablish in over 70 percent of the lake, longevity of triploid grass carp being only 10 years or less (Sutton and Vandiver 1986; Trent et al. 1992), and suspected decreased feeding rates of very large triploid grass carp (Osborne and Sassic 1981). Removal of a portion of the remaining triploid grass carp population in Johns Lake would accelerate regrowth of native plants, but without hydrilla as a habitat component if the hydrilla tuber reserves have indeed been depleted. A residual population of triploid grass carp in Johns Lake would still be effective for targeting any hydrilla regrowth that might occur, as has been observed over a longer term in Lake Fairview, Florida (Trent et al. 1992). Clapp et al. (1993) found that triploid grass carp in Lake Yale, Florida, preferred hydrilla over native macrophytes, feeding on hydrilla disproportionately to its abundance in the lake.

Comparison of management techniques

Actual dollar expenditures for materials used in this integrated hydrilla management program compared with the projected expenditures for materials in a strictly herbicidal hydrilla management program using fluridone (Table 4) results in a cost savings of over $200,000 in the time span of 9 years (1986-1994) by using the integrated approach. This disparity in management program materials costs will continue to grow, as little or no

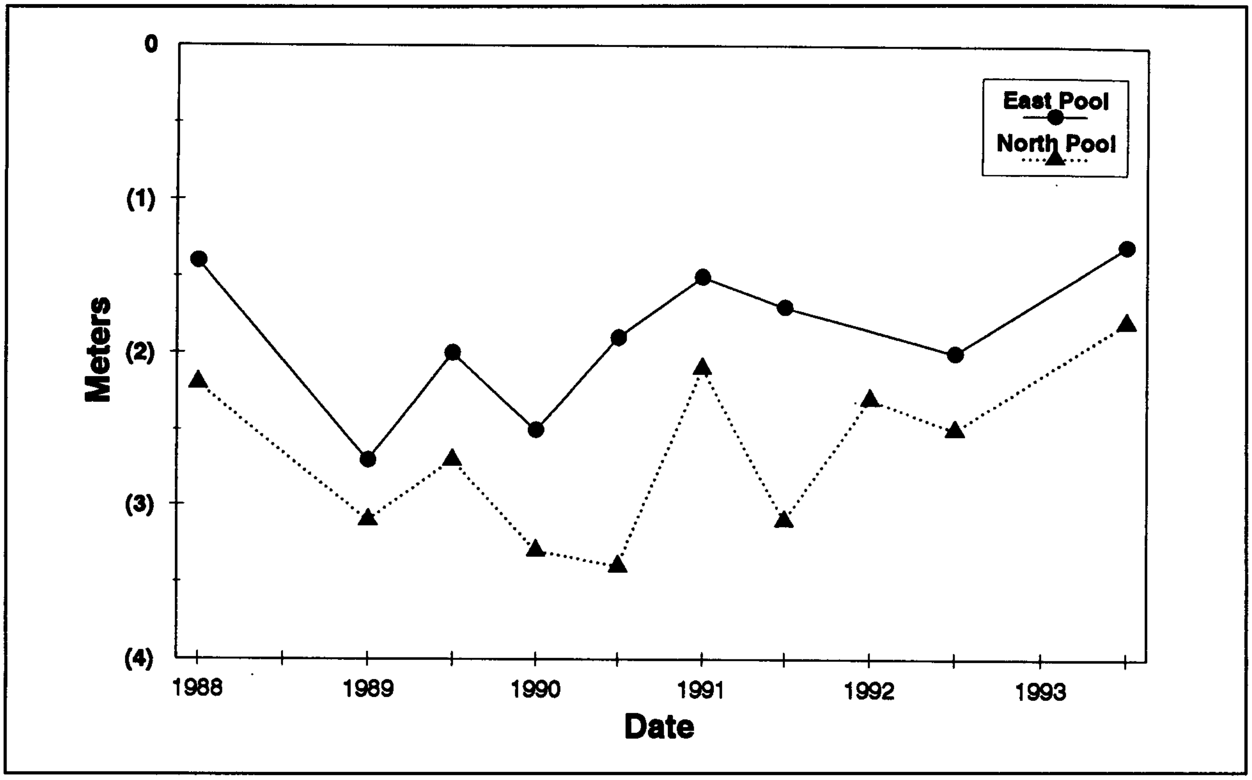

Figure 3. Secchi visibility readings in west Johns Lake by year

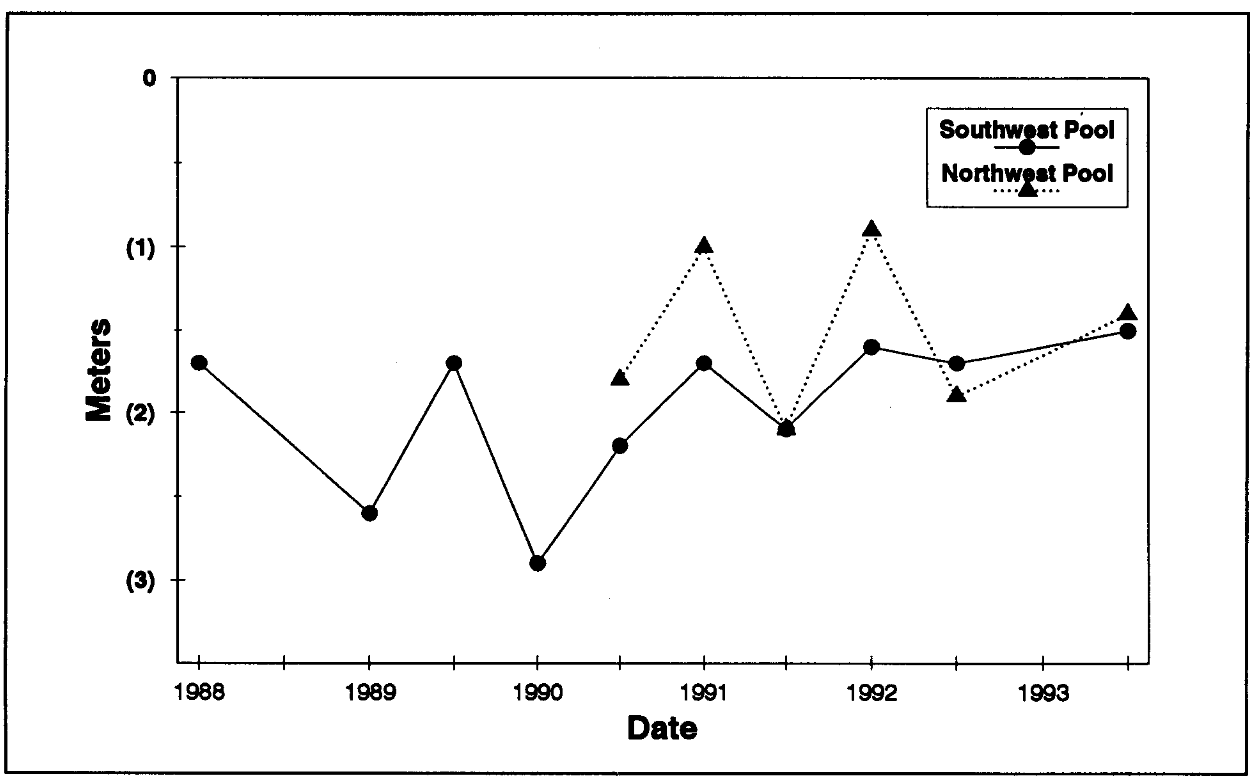

Figure 4. Secchi visibility readings in west Johns Lake by year

Table 4
Comparison of Materials Cost for Integrated Hydrilla Management in Johns Lake Versus Projected Costs for a Strictly Herbicidal Hydrilla Management Program Using Fluridone

	Integrated		
	Fish[1]	Contact Herbicides[2]	Fluridone[3]
1986		$608	$608
1987		$13,376	$13,376
1988	$18,240	$22,254	$100,000
1989	$13,280	$28,080	
1990	$5,012		
1991			$100,000
1992			
1993			
1994			$100,000
Total	$36,532	$64,318	$313,984
Total Integrated	$100,850		

[1] Actual expenditures for triploid grass carp stocked for hydrilla management in Johns Lake.
[2] Actual expenditures for contact herbicides used for hydrilla management in Johns Lake.
[3] Projected herbicide costs for fluridone based on conservative estimates of an 8.3-percent (81.2-ha) lake treatment at a rate of 4.7 L fluridone/hectare treated, cost of $1,000/3.8 L of fluridone, and repeated whole-lake fluridone treatments being required every third year in Johns Lake. The 1986 and 1987 figures are actual costs for contact herbicides, as the contact herbicides would have been utilized preliminary to the whole-lake fluridone treatments.

expenditures for future hydrilla control are expected in the current integrated program because of the suspected depletion of tuber reserves in the substrate and the residual population of triploid grass carp continuing to target any hydrilla that might regrow.

Although significant materials cost savings were realized with this integrated program, there are many other management considerations (Table 5). It is readily apparent that there are numerous advantages and disadvantages to both management techniques. Therefore, selection of a management technique depends heavily on established objectives, and materials cost may or may not be of prime consideration. The integrated approach relies more heavily on effective monitoring in order to plan ongoing herbicide treatments and triploid grass carp stockings (or removals). Timing and degree of herbicide treatments and triploid grass carp stockings are usually critical to the effectiveness and ultimate success of the integrated approach. However, proper timing is difficult to achieve (Sutton et al. 1986) because of unavailability of triploid grass carp, delays in funding for the purchase of herbicides, and many other factors. As

Table 5
Comparisons of Advantages and Disadvantages of Integrated Hydrilla Management and Hydrilla Management Using Strictly Herbicides (fluridone)[1]

Advantages	Disadvantages
Integrated	
* Fewer grass carp and less quantity and frequency of herbicide use than with either method used alone. * Significant reduction or sometimes elimination of the need for future and long-term hydrilla control. * Possible elimination of hydrilla from the water body. * Significant long-run cost savings. * Multiple uses of the water body maintained. * Extended benefits from contact herbicide treatments seen where more than 1 ha of hydrilla control is achieved for every hectare treated.	* Nontarget effects - temporary loss of habitat. * Proper timing and degree of integration is difficult to achieve. * Frequent monitoring required. * Removal of grass carp may be required, adding additional cost and effort. * Mortality of the triploid grass carp is not known, adding uncertainty to estimating long-term stocking rates and the need for ongoing hydrilla control operations.
Fluridone	
* Normally good selectivity for hydrilla - good chance to maintain native macrophytes. * Ease of application. * Minimal monitoring required. * Future technology to eliminate hydrilla from a water body?	* High cost. * High solubility - difficult to obtain partial control. * Regrowth of hydrilla occurs, and continual and costly retreatment necessary with current technology. * Some native plant species such as water lilies can be reduced or eliminated. * Some lake uses periodically impaired.

[1] This is not an exhaustive list, as there are many other considerations depending on the water body, environmental conditions, management objectives, etc.

seen in this example, the integrated approach can result in significant nontarget effects when hydrilla is either the dominant macrophyte or is increasing exponentially. A fluridone hydrilla management program in Johns Lake would have been more selective for hydrilla and most of the offshore maidencane community probably would have been maintained, but nontarget effects from fluridone can also occur and may be unavoidable in some cases (Farone and McNabb 1993). For example, fragrant water lily in Johns Lake could have been significantly reduced because of nontarget effects from fluridone (Farone and McNabb 1993), but was one of the species that increased in this integrated program. Monitoring programs to identify new infestations of hydrilla are extremely important. Much more effective results can be achieved in any hydrilla management program if hydrilla control measures are initiated before hydrilla begins increasing exponentially, as regrowth of hydrilla can only occur in rather limited areas because of the fact that a large tuber reserve in the substrate does not exist. Also, there is much less chance for nontarget effects when hydrilla populations are not allowed to expand.

The power of the integrated approach can be seen by evaluating results from the contact herbicide treatments. Johns Lake endothall treatments in 1988 resulted in 1 to 2 years of hydrilla control before regrowth was observed in the treatment plots. Without integration, only 2 to 6 months control is achieved with contact herbicides. With integration, control outside the endothall treatment plots were noted in Johns Lake, resulting in 0.6 to 0.8 ha of hydrilla controlled for every 0.4 ha treated (1.5 to 2:1 ratio). Similar results were seen in a smaller lake (unpublished data) where integrated endothall treatments (20.6 ha) resulted in 60.7 ha of hydrilla control (3:1 ratio). Without integration, the control to treatment ratio using contact herbicides usually is 1:1.

Largemouth bass response to habitat alteration

Canfield and Hoyer (1992) cited conflicting relationships between macrophyte abundance and largemouth bass abundance. Bettoli et al. (1992) related minimal macrophyte coverage with early piscivory and faster growth rates of largemouth bass. However, moderate to dense macrophyte coverage appears to be especially important for largemouth bass recruitment in large numbers and formation of quality year-class strength (Wiley et al. 1984; Durocher, Provine, Kraai 1984; Moxley and Langford 1985; Porak et al. 1990). Therefore, it is reasonable to expect that a significant reduction in macrophyte habitat would lead to significant changes in largemouth bass recruitment, abundance, food habits, and growth. Background data for largemouth bass populations in Johns Lake were not available, but electroshocking surveys were initiated in fall 1990 to obtain current data. Electroshocking has some severe limitations (Hardin and Conner 1992), especially for sampling open-water largemouth bass populations. However, electroshocking data should show some trends, at least for largemouth bass in a portion of Johns Lake.

Electrofishing CPUE for largemouth bass (Table 6) decreased from 1990 until fall 1993 when some recovery in CPUE was noted. Preliminary data from spring 1994 indicate the highest CPUE values for some largemouth bass size classes since sampling was initiated. Stock density indices for largemouth bass (Table 7) show PSD values within or near the preferred range (40 to 70) throughout the sampling period. Similarly, largemouth bass RSD-14 values were within or near the preferred range (10 to 40), but RSD-15 values were somewhat below the preferred range (10 to 40), especially during the fall sampling periods. The largemouth bass RSD-20 values were within the preferred range (1 to10). Relative weight values (W_r) from spring electrofishing surveys of largemouth bass (Table 8) were within or above the preferred range (95 to 105) for small fish (<20.3 cm), while W_r values for larger fish (>20.3 cm) were below the preferred range in spring 1991 and 1992, but improved during spring 1993. In fact, highest W_r values for all largemouth bass size classes were observed during spring 1993. Tournament angler catch data from fall 1993

Table 6
CPUE (number/minute) for Various Largemouth Bass Length Groups Collected from Johns Lake During Biannual Electrofishing Surveys 1990-1993[1]

Year	All Sizes	>20.3 cm	>30.5 cm	>35.6 cm	>38.1 cm	>50.8 cm
Fall 1990	1.6	0.7	0.3	0.1	0.1	—
Spring 1991	0.9	0.7	0.3	0.1	0.1	<0.1
Fall 1991	0.7	0.4	0.2	<0.1	<0.1	—
Spring 1992	0.7	0.5	0.2	0.1	<0.1	—
Fall 1992	0.6	0.4	0.2	<0.1	<0.1	<0.1
Spring 1993	0.8	0.4	0.2	<0.1	<0.1	—
Fall 1993	1.1	0.5	0.2	0.1	0.1	<0.1

[1] Unpublished data collected by Central Region Florida Game and Fresh Water Fish Commission Regional Fisheries project.

Table 7
Stock Density Indices (PSD and RSD) for Largemouth Bass Collected from Johns Lake During Biannual Electrofishing Surveys 1990-1993[1]

Year	PSD	RSD-14	RSD-15	RSD-20	RSD-24
Fall 1990	42	15	7	—	—
Spring 1991	61	20	13	4	—
Fall 1991	38	5	2	—	—
Spring 1992	38	13	4	—	—
Fall 1992	50	10	5	3	—
Spring 1993	42	10	10	—	—
Fall 1993	52	23	12	2	—

[1] Unpublished data collected by Central Region Florida Game and Fresh Water Fish Commission Regional Fisheries project. Objective range for PSD values is 40 to 70, 10 to 40 for RSD-14/RSD-15, and 1 to 10 for RSD-20.

Table 8
Mean Relative Weight Values (W_r) for Largemouth Bass Length Groups Collected from Johns Lake During Spring Electrofishing Surveys 1991-1993[1]

Year	<20.3 cm	20.3 to 27.9 cm	30.5 to 35.6 cm	38.1 to 48.3 cm	>50.8 cm
1991	103	86	85	85	95
1992	101	91	85	86	—
1993	118	101	91	95	—

[1] Unpublished data collected by Central Region Florida Game and Fresh Water Fish Commission Regional Fisheries project. Objective range for W_r values is 95 to 105.

(Table 9) show that the harvestable largemouth bass catch rates (0.17 fish/hour) were slightly below the statewide average of 0.25 fish/hour. CPUE for all size classes was 1.00 fish/hour. Mean weight of harvestable largemouth bass weighed in was 0.8 kg, and large fish weighed 3.8 kg.

These data indicate that largemouth bass in Johns Lake may be adapting to a changed forage base because of habitat alteration. During 1990, largemouth bass food habits probably were more closely related to a macrophyte-oriented forage base. By 1993, largemouth bass food habits appear to be more closely related to an open-water forage base (primarily shad, *Dorosoma petenense* and *D. cepedianum*). In fact, increased frequency of largemouth bass schooling behavior was noted during vegetation sampling trips in 1992 and 1993. However, recruitment may be depressed because of inadequate habitat, and the suspected open-water population of largemouth bass may not be able to withstand consistent harvest.[1] If

[1] Personal Communication, 1994, William Coleman.

Table 9
Angler Catch Data for Largemouth Bass Caught During a Mini-Bass Small Boat Tournament Trail Event During November 1993 in Johns Lake, Florida[1]

CPUE all sizes	1.00/hr
CPUE harvestable fish (≥35.6 cm)	0.17/hr
CPUE nonharvestable fish (<35.6 cm)	0.83/hr
Mean weight of harvestable fish (≥35.6 cm)	0.8 kg
Big fish	3.8 kg

[1] Unpublished data collected by Central Region Florida Game and Fresh Water Fish Commission Regional Fisheries project.

the predicted increase in native macrophytes occurs over the next 2 to 5 years, then largemouth bass food habits should gradually shift again toward a macrophyte-oriented forage base and recruitment should improve as well.

Conclusions

Although moderate coverages of hydrilla have been indicated to aid largemouth bass recruitment and forage production, hydrilla management is extremely costly and fast becoming unaffordable in the State of Florida. Long-term economic and political conditions can be expected to be much worse at the State level (Stocker 1993) and also nationally and internationally (Burkett 1991; Robertson 1991). Oligotrophic to moderately eutrophic lakes generally should be able to support adequate stands of native macrophytes valuable as largemouth bass habitat, without the need for the exotic macrophyte hydrilla as a habitat component and the associated expense for hydrilla management. This case study has indicated the possibility of using integrated hydrilla control to eliminate hydrilla from an individual water body, and this result was previously thought to be unattainable. In the long term, temporary loss of habitat, temporary decreases in largemouth bass recruitment rates, possible elimination of hydrilla, and significant cost savings incurred with integrated hydrilla management may be a more desirable management result than continual and costly treatments with herbicides alone. Charyev (1984) made similar observations, in that despite some negative effects from grass carp, the Kara Kum Canals in Turkmenistan were in much better condition than if grass carp had not been utilized as a management tool. Langeland (1990) stated that in most cases, the detrimental effects of hydrilla infestations far outweigh the potential benefits. However, management objectives must be clearly defined for an individual water body before accepting such trade-offs.

Acknowledgments

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