DRAWDOWN RESPONSE OF A HYPEREUTROPHIC FLORIDA LAKE

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Abstract: A drawdown of Lake Carlton was conducted to evaluate complete dewatering as a method for rehabilitation of a severely eutrophic lake. The water level was lowered 4.1 m exposing 80.7% of the bottom (29.4% sand and 51.3% organic sediments). Substantial germination and growth of terrestrial and aquatic vegetation occurred on the exposed bottom. Following refill a layer of consolidated sediments persisted over most of the area where organic sediments had been exposed. Most new vegetation was established at too great a water depth and died. A net gain in area covered by rooted aquatic vegetation persisted only 2 years after refill. No improvement in water quality was accomplished. Increased standing crops of benthic invertebrates were only detected the winter following refill in areas where consolidation of organic sediments and extensive *Typha* growth occurred. Black crappie populations increased following refill while brown bullheads were substantially increased only the 1st year after refill. No substantial improvements were found for largemouth bass, bluegill, and redear sunfish populations.

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The lakes of the upper Oklawaha River, traditionally known for excellent sportfisheries, have suffered greatly from the effects of cultural and agricultural eutrophication and water level stabilization. These lakes are presently in stages of moderate to severe eutrophication as indicated by massive accumulations of flocculent organic sediment, periodic or continuous phytoplankton blooms, decline of rooted aquatic vegetation, and a reduction or elimination of diverse benthic invertebrate faunas. These factors have led to a loss of prime spawning and nursery areas for sportfish, particularly the largemouth bass. Concurrently other gamefish have declined and shad have increased in biomass. Overall, the net effects of these factors are expressed in a substantial decline in sportfishing and other recreational activities.

Lake rehabilitation procedures, including drawdown, have been summarized by Boyter and Wanielista (1973), Peterson et al. (1974), and Dunst et al. (1974). The value of drawdown for habitat and fisheries improvement has been reviewed by Holcomb et al. (1975), and Fox et al. (1977). The 1971 drawdown of Lake Tohopekaliga demonstrated the benefits that can be derived by lake drawdown in Florida. In addition to habitat improvement by compaction of organic sediments and expansion of rooted vegetation, invertebrate numbers increased and the sportfish population nearly doubled, increasing the value of the fishery resource by about $6,000,000 over 3 years (Wegener and Williams 1974).

Lake drawdown was the rehabilitation method chosen for this study because it was the only economically feasible technique which could be applied later to other larger lakes of the Oklawaha chain, and for which success in Florida has been demonstrated. It was recognized however, that the morphology of Lake Carlton is considerably different from that of Lake Tohopekaliga having greater average depth and no extensive shallow areas.

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METHODS

Lake Carlton is small [159 ha at 19.2 m MSL (mean sea level)] compared to the other lakes in the Oklawaha chain. The upper Oklawaha River Basin, located in central Florida, contains 8 principal lakes ranging from 448 to 12,396 ha, with a total area of 29,912 ha. Mainstream flow begins in Lake Apopka and proceeds through Lakes Beauclair, Dora, Eustis, and Griffin. Lake Carlton is connected to Lake Beauclair by a short canal.

During the drawdown the areas of exposed sand and organic sediments were mapped by aerial photographs.

Vegetation studies on the exposed bottom were conducted in May and June 1977. The locations of 0.3-m contours from elevation 18.9 m to 14.9 m MSL were determined on sand-bottom areas with a transit-level. Plants were identified and counted within 1-m^2 plots taken every 3 m along each transect on the sand-bottom contours and every 12 m on consolidated sediments.

After reflooding vegetation was mapped. Contour elevations of submerged and emergent vegetation were determined by measuring water depth to the nearest 3 cm and subtracting this measurement from the concurrent lake stage.

Benthic invertebrates were collected during the winter and summer with a screened Ekman dredge. Samples were taken at 0.3-m contour intervals along 2 transects extending from the shoreline (18.0 m MSL) to deep water basins (14.6 m MSL). Samples were washed through a standard 30-mesh screen, placed in bottles, refrigerated, and later counted while alive by using electrical stimuli.

Small fishes were seined monthly from 6 randomly selected sites in Lakes Carlton and in Beauclair, the control lake, from August 1978 - June 1980. Two timed hauls were taken at each site with a 4.6-m $\times$ 1.2-m seine, with a 3.2-mm mesh. Twenty-six Wegener ring samples (4.05 m^2) were taken periodically, at depths of 20 - 40 cm from November 1977 to June 1978 (Wegener et al. 1973).

Two limnetic and 2 or 3 littoral 0.4-ha blocknet-rotenone samples were collected in late summer of 1975, 1978, and 1979, to estimate fish standing crop.

A stratified random creel, with non-uniform probability sampling, (Ware et al. 1972) provided data for estimates of harvest, effort, and fishing success on Lake Carlton.

Bi-monthly water quality and phytoplankton samples were taken mid-lake from depths of 0, 2, and 4 m in Lake Carlton. One mid-lake composite was taken in Lake

Beauclair for control data. Values used in data analysis (analysis of variance) are averages of values obtained from 0, 2, and 4 m at the mid-lake sampling site. Chemical analysis was in accordance with Standard Methods (American Public Health Association et al. 1975). Phytoplankton was analyzed using methods described by Carter and Hestand (1977).

Hydrological Aspects of the Dewatering and Refill of Lake Carlton

An earthen-steel sheet piling dam was constructed to isolate Lake Carlton from Lake Beauclair. Pumps with a capacity of 189.3 m^3/min, were installed. Dewatering began March 3, 1977 at elevation 19.3 m MSL and most of the water (to 15.2 m MSL) was removed in 3 weeks as predicted (Anderson and Hughes 1977). The lowest elevation (14.9 m MSL) was reached May 26-31, 1977 but did not meet the objective of a complete dewatering (14.6 m MSL).

On the projected refill date, October 31, 1977, Lake Carlton was at elevation 16.8 m MSL or approximately 2.4 m behind schedule, due to below normal rainfall. In December 1977, a 76-cm culvert was installed to hasten refill Approximately 68 m^3/min was discharged by gravity from Beauclair through this culvert from December 15, 1977, to January 20, 1978; at which time the lake levels equalized at 19.1 m MSL. Removal of the dam was completed April 7, 1978.

RESULTS AND DISCUSSION

Organic Sediment Consolidation

A steeply sloped sand-bottom was present between 19.2 and 14.9 m MSL. From 14.9 m MSL the bottom rose on organic sediments to 15.2 m before again falling to 14.6 m MSL. Complete dewatering was not accomplished because the pump intake channel, dug through the sand, only extended to the shoreward edge of the organic sediments. As a result there was no way to pump the last of the water off the sediments. The area between 14.9 m and 15.2 m MSL comprised 51.9% (82.5 ha) of the lake bottom.

The drawdown exposed 80.7% (128.2 ha) of the bottom, of which 46.8 ha was sand and 81.5 ha was organic sediments. Approximately 17.4 ha of the exposed sediments remained wet. Ten hectares were moderately dried and supported vegetation which became uprooted during refill, and 54.1 ha were dried and consolidated sufficiently to hold down *Typha*, which grew to a height of 4.6 m, and other vegetation following refill.

Lake Carlton was no higher than 15.1 m MSL from April 10, 1977, to June 18, 1977, a total of 100 days. Organic sediments dried during this period totaled 54.1 ha. An exposure of 15 cm to 18 cm above the water level was required to dry sediment sufficiently to insure dense vegetation would remain rooted after refill. Consolidated organic sediments persisted following refill, although little effort was required to push through the dried layer with a pole. A dense mesh of roots contributed to the stability and firmness of this layer.

Aquatic Vegetation

During drawdown many terrestrial and aquatic vegetation species germinated and grew on the exposed sands and organic sediments. In sand areas dominant genera were *Salix* and *Ludwigia*. Dominant genera on consolidated organic sediments were *Typha*, *Salix*, and *Ludwigia* (Table 1). *Typha* was the only major genera to average more plants per m^2 on the consolidated sediments than on the sand.

Table 1. Average number plants per $1m^2$ from lake Carlton for sand-bottom (N = 95) and consolidated organic sediment (N = 30) areas, for combined transects, May 1977. Genera are listed according to their vertical distribution from elevation 18.9 - 14.9 m MSL.

	18.9 - 14.9 m MSL	15.2 - 14.9 m MSL
Genera	Sand	Consolidated sediments
Pancium	23.06[a]	0.1
Eupatorium	2.24	0.7
Ludwigia	14.22	3.7
Cyperus	3.08	0.3
Salix	13.95	5.9
Eichhornia	1.48	
Typha	2.18	6.9
Other[b]		
Total	63.28	17.9

[a] Includes plants present in the lake prior to the drawdown.
[b] Other genera found in average densities of $<1.0/m^2$ were *Erechtites, Eleusine, Setaria, Polygonum, Amaranthus, Solanum, Vitis, Hypericum, Eclipta, Baccharis, Urena, Phytolacca, Echinochloea, Hydrocotyle, Pontederia, Cynodon, Linaria, Scirpus, Lindernia, Diodia, Nuphar, Sonchus, Paspalum.*

About 60.7 ha of *Typha* growing on consolidated sediments, survived in 4.0 m of water 3 - 4 months after refill. An additional 8.1 ha of *Typha*, growing on unconsolidated sediments, uprooted during refill. Eight months after refill, *Panicum* and *Salix* were the only plants surviving on consolidated sediments or at depths greater than 3 m (16.2 m MSL).

Total vegetative coverage increased from 3.6 ha prior to drawdown to 9.0 ha in 1978, 1 year following refill (Table 2). Approximately 81% of the 9.0 ha was sparse *Panicum* and *Salix* located at lower elevations. Some vegetation present prior to the drawdown, was shaded out by floating *Typha*. Most *Typha* present along the shoreline prior to drawdown was killed by desiccation, but has since re-established at pre-drawdown levels.

Vegetation mapping in 1979 indicated an approximate 25% decrease in area for *Salix*, in addition to a decrease in density. *Panicum* located in deeper water showed no change in surface area between the 1978 and 1979 mappings, but density declined.

Table 2. Surface area and vertical distribution of principal aquatic plants (≥0.01 ha) in Lake Carlton prior to drawdown and for 2 years after refill.

	Area (ha)			Elevation range (m)		
	1976	1978	1979	1976	1978	1979
Panicum geminatum } *Panicum hemitomon*	1.27	7.58	7.66	1.6	3.9	3.7
Typha sp.	2.20	0.03	0.04	1.9	1.2	1.1
Nuphar advena	0.08	0.09	0.09	1.6	0.9	0.9
Cladium jamaicensis	*0.2*	<0.01	<0.01	1.0	0.2	0.5
Vallisneria americana[a]	0.01	0.00	0.00	0.7	0.0	0.0
Salix sp.	0.00	1.30	0.99		2.4	2.4
Total	3.58	9.00	8.78			

[a] Measured March 1977 as lake level fell.

Observations since 1979 indicated the drawdown was unsuccessful in permanently increasing aquatic vegetation. At the present time (1981) most of the deep water *Panicum* and *Salix* has disappeared and it is probable the remainder will not survive.

Benthic Invertebrates

Standing crops of benthic invertebrates were only increased at stations where consolidation of organic sediments and extensive *Typha* growth occurred during drawdown (14.9 m MSL). This area represented 52% of the lake. Invertebrates collected in February at 14.9 m MSL averaged 1722/m^2 in 1976, 2207/m^2 in 1977, 4456/m^2 in 1978, 818/m^2 in 1979, and 1098/m^2 in 1980. These results indicated that within 1 month following complete refill the number of organisms on consolidated sediments more than doubled compared to the winter sample before the drawdown or the average of the previous 2 winter samples. However, invertebrate population increases on consolidated sediments were short lived and were only detected the winter following refill. The loss of *Typha*, seasonal stratification, and the predation by strong year classes of black crappie and largemouth bass certainly contributed to this decline. Unlike Lake Carlton, invertebrate populations in Lake Tohopekaliga remained above pre-drawdown levels for 2 years following refill, but declining trends were also attributed to cropping by vertebrate predators (Wegener et al. 1974).

Fish Populations

Seine samples indicated that small fishes thrived in the marsh-like conditions created during the refill of Lake Carlton (Fig. 1). Largest catches were taken in December 1977 just prior to complete refill in January. The abundance of fishes was 4.7 times greater in Lake Carlton compared to Lake Beauclair from October 1977 through June 1978. Wegener ring samples taken during this period showed the fish density to average 143.6/m^2. The catch per minute by seine was equal between lakes from July 1978 - June 1979, but significantly greater ($P < 0.05$) in

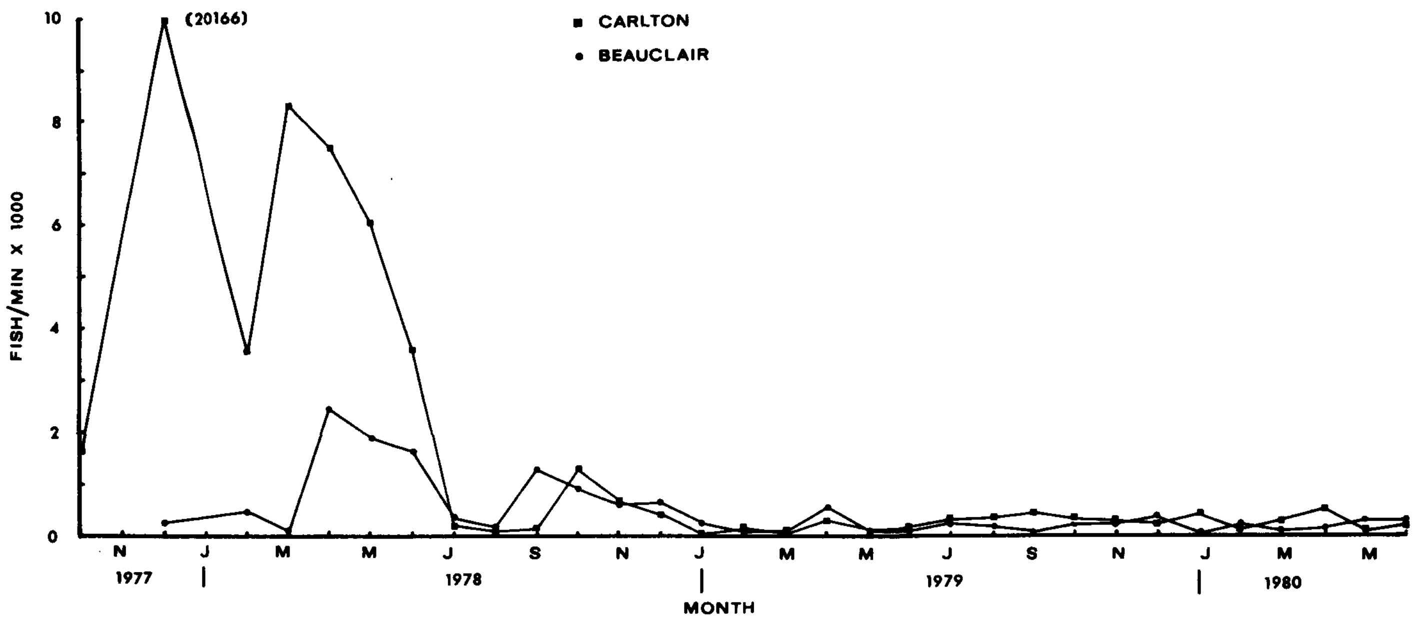

Fig. 1. Monthly variation in the abundance (fish/min) of all species seined in Lakes Carlton and Beauclair.

Carlton prior to July 1978 and for the year July 1979 - June 1980 ($P < 0.05$). With the loss of vegetative habitat the density decreased to the level observed in Lake Beauclair by July 1978.

Prior to July 1978, the species composition of Lake Carlton seine samples ranged from 95.9% to 99.9% mosquitofish. In Beauclair composition ranged from 65.7% to 96.9% tidewater silversides, but during May through July mosquitofish were dominant. The seasonal abundance and relative composition of dominant species were similar for Lakes Carlton and Beauclair after June 1978.

The most significant change in species composition in blocknet samples following the drawdown was for brown bullheads. Brown bullhead biomass increased 398.4 kg/ha and 33.6 kg/ha in littoral (Table 3) and limnetic (Table 4) samples respectively. Most of these fish were 8 - 13 cm in length. Dead juvenile brown bullheads were common along the shore during the fall of 1978 and spring 1979. In 1979 brown bullheads were nearly absent in blocknet samples.

Blocknet samples taken 8 months following refill (1978) showed increased numbers and biomass (mostly juvenile fish) of black crappie in littoral and limnetic samples. One year later (1979) more intermediate sized crappie (15 - 20 cm) per hectare were present than before the drawdown, or than were present 1 year before the record crappie harvest of 1975 in Lake Griffin. This strong year-class was produced as a result of a 1.2 m water fluctuation in January 1973 (Florida Game and Fresh Water Fish Comm., unpublished data). These values corresponded to a proportional average, for the lakes as a whole, of 189.3/ha in 1974 in Lake Griffin after drawdown and 251.3/ha in 1979 in Lake Carlton after drawdown.

Largemouth bass from the 1978 year class in Carlton were captured by seine at higher rates than in the following 2 years. Maximum values for young-of-the-year (YOY) largemouth bass captured for April or May were 8.3/min in 1978, 2.5/min in 1979, and 3.6/min in 1980. Bass seined from Lake Beauclair were collected at an average rate higher than Carlton, except for the 1978 year class (6.8/min, 5.6/min and 5.5/min, respectively). The number of YOY largemouth bass collected in late summer 1978, from littoral blocknets (221.1/ha) was similar to pre-drawdown numbers (207.6/ha) while the number collected from limnetic areas (39.5/ha) increased over 1975 (3.7/ha). Evidence of a strong 1978 year class was not detected in subsequent sampling.

With the exception of black crappie, gamefish populations declined in littoral samples (Table 3), while all game species increased in limnetic samples following the drawdown (Table 4). The percent of harvestable game species by total weight declined in littoral samples (54.7%, 1975; 15.2%, 1978; and 9.6%, 1979) and increased in limnetic samples (1.4%, 1975; 6.2%, 1978; and 15.9%, 1979) following the drawdown.

The biomass of threadfin shad appeared to decline in blocknet samples following drawdown while gizzard shad biomass increased (Tables 3 and 4). Electrofishing surveys confirmed the trend for gizzard shad.

During refill and for a few months following complete refill, what had previously been limnetic areas became an extensive littoral marsh. Most of the vegetation did not survive refill, and thus high forage and invertebrate production was not sustained. Black crappie populations increased following the drawdown while brown bullheads were substantially increased only the 1st year after refill. No clear improvements were found for largemouth bass, bluegill, and redear sunfish populations.

Table 3. Average number and kilograms of fish per hectare collected from littoral blocknets in Lake Carlton during late summer 1975, 1978, and 1979; tr = trace, <0.01 kg/ha.

	Average no./ha			Average kg/ha		
Species	(N=3) 1975	(N=2) 1978	(N=2) 1979	1975	1978	1979
Largemouth bass	231.5	250.8	40.8	22.76	18.69	12.48
Black crappie	518.9	4,142.6	127.3	26.53	44.48	5.02
Bluegill	9,370.0	3,023.3	8,827.6	339.72	89.88	43.38
Redear sunfish	895.2	572.0	265.6	43.12	18.72	18.42
Warmouth	402.0	1,157.7	12.4	2.52	25.87	0.37
Redbreast	19.0		181.6	0.11		0.71
Striped bass × white bass			1.2			0.09
Bowfin		8.6			7.66	
Florida gar	0.7	18.5	4.9	0.67	6.11	2.05
Gizzard shad	2,149.8	4,911.1	2,989.9	124.62	116.45	450.75
Threadfin shad	16,563.1	6,086.1	16,036.8	44.67	21.05	14.01
Lake chubsucker		3.7			2.13	
Golden shiner	2,550.0	4,184.6	358.3	25.22	16.46	5.13
Taillight shiner	446.5		695.6	0.26		0.50
White catfish	56.1	7.4		24.29	2.52	
Brown bullhead	593.0	34,606.4	1.2	2.75	401.26	tr
Yellow bullhead		6.2			1.21	
Tadpole madtom	0.7			tr		
Atlantic needlefish	9.1	12.4	3.7	0.19	0.31	0.11
Seminole killifish	156.4	1.2	25.9	0.64	0.03	0.11
Bluefin killifish	436.6	50.7		0.08	0.04	
Sheepshead minnow	1.7			tr		
Mosquitofish	1,617.8	379.3	139.6	0.30	0.26	0.17
Sailfin molly	23.0			tr		
Least killifish	14.1			tr		
Tidewater silverside	427.5	74.1	160.6	0.22	0.06	0.17
Swamp darter	7.4	61.8	2.5	tr	0.04	tr
Blue tilapia		14.8			0.48	
Total	36,490.5	59,573.3	29,875.6	658.69	773.73	553.48

Creel

Creel results indicated that values for harvest and effort were low during the 1st year after refill (Table 5). The following year, as a result of increased effort, harvest estimates for all game species increased substantially. Mean success estimates for largemouth bass and black crappie during the 2nd year following refill showed no substantial change when compared to data collected in recent years on the

Table 4. Average number and kilograms of fish per hectare collected from limnetic blocknets (N=2) in Lake Carlton, during the late summer 1975, 1978, and 1979; tr = trace, <0.01.

	Average no./ha			Average kg/ha		
Species	1975	1978	1979	1975	1978	1979
Largemouth bass	3.7	39.5	1.2	0.17	0.56	1.06
Black crappie	528.8	11,445.7	447.3	14.27	72.43	21.56
Bluegill	14.8	168.0	65.5	0.59	8.21	9.36
Warmouth		4.9			0.36	
Striped bass × white bass		1.2			0.08	
Florida gar		1.2	1.2		0.50	3.36
Longnose gar		1.2			2.52	
Gizzard shad	27.2	189.0	28.4	0.56	3.05	8.13
Threadfin shad	173,245.5	24,917.6	47,960.9	229.22	53.25	42.93
Golden shiner	16.1	1,010.6	61.8	0.50	5.94	1.66
Taillight shiner			1.2			tr
White catfish	28.4	3.7	1.2	12.36	1.40	0.15
Brown bullhead	38.3	2,634.1		16.48	50.14	
Atlantic needlefish	12.4			0.34		
Mosquitofish		1.2	1.2		tr	tr
Tidewater silverside		37.1	2.5		0.01	tr
Total	173,915.2	40,455.2	48,572.4	274.50	198.45	88.21

Oklawaha chain of lakes (Ware et al. 1972; Fla. Game and Fresh Water Fish Comm., unpubl. data). High success values were documented for the number of panfish (bluegill and redear sunfish) harvested per hour. Surveys taken the year after completion of this study (1980-81) indicated high success for largemouth bass (0.43/hr) while success rates for other species were lower than those taken the 2nd year after refill.

Phytoplankton

Phytoplankton populations in Carlton showed a steady decline from densities of 142.8×10^6/l (52% *Oscillatoria*) in July 1977 (when sampling began) until January 1978 (6.5×10^6/l) (Table 6). In addition, the percentage of blue-green algae decreased from 78% to 40%. In contrast, samples in January 1978, from Beauclair had a phytoplankton population almost 4 times as great as Carlton with 79% of the population blue-green algae (blue-green algae were dominant in Lake Beauclair throughout the study period). Secchi disc transparency in the 2 lakes were 178 cm in Lake Carlton and 51 cm in Lake Beauclair.

With increasing day-length and warmer water temperatures phytoplankton density began to increase in both lakes. By March 1978, phytoplankton density had more than quadrupled in Carlton and was 85% green algae (primarily *Ankistrodesmus).* Secchi disc visibilities in Lakes Carlton and Beauclair were 122 cm and 30 cm respectively.

Table 5. Estimates of annual harvest, effort, and success from Lake Carlton (159 ha), 1 July, 1978 through 30 June, 1979, and 1 July, 1979 through 30 June, 1980.

Species	Total harvest	Total man-hour effort	Average catch man-hour	Success estimate range for 2-week periods	Mean of available success estimates
		July 1, 1978 - June 30, 1979			
Largemouth bass	61	217	0.28	0.10-0.54	0.33
Black crappie	1,090	840	1.30	0.61-2.72	1.57
Bluegill & redear	362	20	18.10	0.76-4.34	2.22
Striped bass × white bass	2	0			
Catfish	93	2	46.50		
Other species		294			
Total	1,608	1,373	1.17		1.17
		July 1, 1979 - June 30, 1980			
Largemouth bass	566	2,126	0.26	0.15-0.56	0.36
Black crappie	5,033	4,931	1.02	1.28	1.28
Bluegill & redear	16,748	7,620	2.20	1.91-2.45	2.18
Striped bass × white bass	1,749	1,420	1.23		
Catfish	330	15	22.00		
Other species		1,138			
Total	24,426	17,250	1.42		1.42

Although phytoplankton numbers in Lake Carlton decreased slightly by May, blue-green algae accounted for 78% of the total population, an almost complete reversal of the situation in March. By July 1978, total phytoplankton numbers in Carlton surpassed those in Lake Beauclair. In July secchi disc values were 38 cm in Carlton and 30 cm in Beauclair. By September blue-green algae made up slightly more than 95% (primarily *Oscillatoria*) of the population in Carlton.

Water Chemistry

Analysis of variance indicated that F-ratios for total phosphate, ortho phosphate, filtered turbidity, conductivity, and dissolved organic nitrogen were significantly different ($P < 0.05$) for the refill period compared to pre-drawdown and 2 post-refill periods (Table 7). No significant differences among the pre-drawdown and 2 post-drawdown periods were found for any water quality parameter. These analyses indicated that drawdown and subsequent refill of Lake Carlton did not result in any improvement of any water quality, but actually resulted in short-term deterioration and eventual return of pre-drawdown eutrophication levels.

It should be kept in mind that poor quality water from Lake Beauclair was used to refill Carlton. After the drawdown on Lake Tohopekaliga water quality was not improved, but this was attributed to continued sewage discharge into the lake (Holcomb et al. 1975).

Many complex interactions occur in a lake as a result of a drawdown. Although it is not yet possible to define all of the mechanisms, it is evident from this and other Florida drawdowns that organic sediments can be improved by consolidation for invertebrate and vegetation communities. The littoral area can be increased by exposure which stimulates or permits germination of additional aquatic vegetation.

Many of the habitat improvements in Carlton which resulted following refill were short-lived. However, Lake Carlton has no extensive shallow areas, greater average depth, and was considerably more degraded than lakes where improvements have been more substantial and longer lasting.

This study has demonstrated that the drawdown techniques as a fisheries management tool is not a panacea for reclaiming all lakes degraded by the process of accelerated cultural eutrophication. Although black crappie and brown bullhead populations increased following the Lake Carlton drawdown, there was no clear evidence of improvement in the largemouth bass, bluegill, and redear populations. In Florida, sink hole type basins with no shoreline development, narrow littoral zones and exceptional average depth may not respond to this remedy. The Lake Carlton experience warns us that we cannot neglect aquatic resources too long, lest they become unrecoverable. It also points out that we must constantly look in all directions for creative management solutions.

LITERATURE CITED

American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1975. Standard methods for the examination of water and wastewater, 14th ed. New York.

Anderson, W., and G. H. Hughes. 1977. Hydrologic considerations in dewatering and refilling Lake Carlton, Orange and Lake Counties, Florida. U.S. Geol. Sur., Water-Resources Invest. 76-131. 31pp.

Boyter, C. J., and M. P. Wanielista. 1973. Review of lake restoration procedures. Water Res. Bull. 9:499-511.

Carter, C. C., and R. S. Hestand. 1977. The effects of selected herbicides on phytoplankton and sulfur bacteria populations. J. Aquatic Plant Manage. 15:47-56.

Dunst, R. C., S. M. Born, P. D. Uttormark, S. A. Smith, S. A. Nichols, J. O. Peterson, D. R. Knauer, S. L. Serns, D. R. Winter, and T. L. Wirth. 1974. Survey of lake rehabilitation techniques and experiences. Wis. Dept. Nat. Res. Tech. Bull. 75. 179pp.

Fox, J. L., P. L. Brezonik, and M. A. Keirn. 1977. Lake drawdown as a method of improving water quality. EPA-600/3-77-005. Corvalis Environ. Res. Lab. U. S. EPA, Corvalis, Oreg. 94pp.

Holcomb, D. E., W. L. Wegener, and V. P. Williams. 1975. Lake level fluctuation for habitat management: A case in point, p. 151-157. *in* P. L. Brezonik, and J. L. Fox, eds.; The proceedings of a symposium on water quality management through biological control. Dept. Env. Eng. Sci., Univ. FL, Gainesville.

Table 6. Average composite densities for major phytoplankton groups in Lakes Carlton and Beauclair. Values expressed as individuals/liter $\times 10^6$, July 1977 - November 1978.

Taxon	7-77	9-77	11-77	1-78	3-78	5-78	7-78	9-78	11-78
				Lake Carlton					
Green	23.5	10.4	6.9	3.9	24.4	2.8	11.4	10.1	11.8
Blue-green	110.9	86.3	6.9	2.6	3.4	17.8	146.6	260.0	147.1
Yellow-green	1.7	4.1	0.5	0	0.7	2.3	0.8	1.3	0
Flagellates	6.7	0	0	0	0.2	0	1.7	1.3	0.8
Total	142.8	100.8	14.3	6.5	28.7	22.9	160.5	272.7	159.7
				Lake Beauclair					
Green				3.8	21.6	25.0	22.9	42.8	0
Blue-green				18.9	30.7	84.4	60.6	203.0	290.3
Yellow-green				1.3	3.0	6.4	0	0	0
Total				24.0	55.3	115.8	83.5	245.8	290.3

Table 7. Selected water quality parameter means taken from Lake Carlton from 1975 through 1980, (data expressed as mg/l unless otherwise noted).

Parameter	(A)pre-drawdown	(B)during refill	(C)post-drawdown year one	(D)post-drawdown year two	F-ratio Periods compared A,B,C,D	A,C,D	C,D
Chlorophyll-a (mg/m^3)	54.6	107.1	97.3	64.1	1.39	3.57	3.05
Conductivity (microhos/cm)	389	440	397	364	3.28[a]	2.08	2.92
Filtered turbidity (JU)	7.8	11.3	5.8	6.2	3.36[a]	0.93	0.06
Unfiltered turbidity (JU)	30.5	50.9	32.0	32.5	1.90	0.14	0.03
Nitrate nitrogen	0.11	0.06	0.06	0.02	1.04	1.44	1.40
Ammonia nitrogen	0.06	0.44	0.11	0.14	1.79	1.47	0.28
Dissolved organic nitrogen	1.67	2.92	1.66	1.33	6.28[a]	0.98	1.03
Total organic nitrogen	3.01	4.86	3.58	4.23	2.35	3.39	1.37
Ortho phosphate (PO_4)	0.03	0.36	0.03	0.03	17.24[a]	0.02	0.07
Total phosphate	0.38	1.32	0.43	0.41	12.61[a]	0.28	0.04
Observations:	N=6	N=5	N=6	N=6			
Time interval:	7-75/5-76	5-77/1-78	7-78/5-79	7-79/5-80			

[a] Indicates significant difference at 0.05 level of probability.

Peterson, J. O., S. M. Born, and R. C. Dunst. 1974. Lake rehabilitation techniques and experiences. Water Res. Bull. 10:1228-1245.

Ware, F., J. W. Fish, and L. Prevatt. 1972. Five year creel survey of two Florida lakes. Quart. Journ. Fla. Acad. Sci. 35:31-48.

Wegener, W. L., D. E. Holcomb, and V. P. Williams. 1973. Sampling shallow water fish populations using the Wegener Ring. Proc. Ann. Conf. S.E. Assoc. Game and Fish Comm. 27:663-674.

__________, and V. P. Williams. 1974. Fish Population responses to improved lake habitat utilizing an extreme drawdown. Proc. Annu. Conf. S.E. Assoc. Game and Fish Comm. 28:144-161.

__________, and __________, and T. D. McCall. 1974. Aquatic macroinvertebrate responses to extreme drawdown. Proc. Annu. Conf. S.E. Assoc. Game and Fish Comm. 28:126-144.