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Fifty Years of Fisheries Management in an Obstinate Prairie Lake

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Little Wall Lake, a shallow 104 ha glacial lake in Hamilton County, Iowa, has been manipulated for about 50 years by fishery managers in an attempt to provide a stable sport fishery. Managers have used dredging, water level manipulation, aquatic vegetation control, mechanical fish removal and fish eradication with toxicants, sport fish stocking, introduction of piscivorous fish, artificial habitat structures, and winter aeration. Attempts to stabilize the fishery have been unsuccessful, and because of overpopulation and stunting of panfishes, total fish eradications were conducted in 1977 and 1989. We review the history of management efforts on the lake, and suggest a series of changes in the habitat and fish community designed to achieve the goal of stabilizing the sport fishery. Proposed management actions include more extensive dredging, more intensive water level manipulations, moderate vegetation control, restrictive harvest regulations on largemouth bass (*Micropterus salmoides*), and aggressive use and stocking of piscivorous fish (game and non-game species) to prevent overpopulation of panfishes.

INDEX DESCRIPTORS: fishery management, fish, water resources

Managers of recreational fisheries often seek to provide anglers with numerous, acceptably large sport fish through the use of techniques such as catch limits, length limits, fish stocking or removal of undesirable species, hatchery production, and habitat improvement (Lichatowich 1985; Nielsen and Johnson 1983). There is no formal theory from which to prescribe use of such techniques. Application is usually based upon "muddling through" (successive limited comparisons; Lindblom 1973) with a combination of general ecological principles, past experiences, available natural and financial resources, and some sense of the interests of the anglers or society.

In some lakes, fisheries management has been judged to be successful with minimal intervention by managers. Other lakes are "problem" lakes where intense application of numerous techniques fails to achieve fisheries objectives for more than brief periods. A common symptom of ineffective management in problem lakes is that a particular management action may produce other problems rather than a satisfactory solution. One such problem lake is Little Wall Lake, a 104 ha glacial lake in central Iowa, when has been extensively manipulated physically and biologically in this century, yet has not provided the product sought by managers: a high-quality, sustainable recreational harvest of sport fishes. In this paper, we review the past management activities on the lake, summarize a recent fisheries renovation of it, and offer perspectives and possible new prescriptions for management of this and similar lakes in the Midwest.

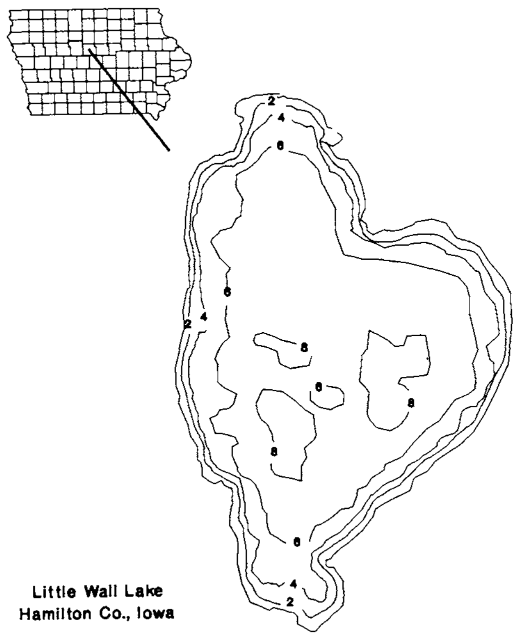

Fig. 1. Little Wall Lake, Iowa. Depth contours are in feet (0.304 m). Map Scale: 1 cm = approx. 0.16 km.

LITTLE WALL LAKE

Geology and physical limnology

Little Wall Lake is an oval-shaped, shallow, flat-bottomed, eutrophic lake located in Hamilton County, central Iowa (Sec 10, T 86 N; R 24 W; Latitude 42° 16′ N, Longitude 93° 38′ W; Bachmann 1980; Fig. 1). Bachmann (1980) estimated the mean depth to be 1.3 m, the maximum depth 1.7 m, shoreline length 4.7 km and the volume 1.3 x 10 exp6 m3. The lake lies within the Des Moines landform region, which was last glaciated in the Pleistocene epoch by the Wisconsin glaciation 14,000-13,000 years BP (Prior 1976). The land around the lake is characterized by a series of morainic mounds — scattered piles of drift and debris — and shallow lakes and depressions. Soils in the region are rich and poorly drained, classified as Clarion, Nicollet, Storden, and Webster. Land use around the lake as of 1980 was 81% cropland, 13% pasture, 2% forest, and 4% other (Bachmann 1980).

The estimated watershed to lake area ratio is only 0.8, and there are apparently no natural permanent inflows (Sprugel 1950; Bachmann 1980). Although mean annual precipitation in the basin is estimated to be 76 cm, wide variations in annual rainfall have resulted in the lake being nearly or completely dry in 1892 (Iowa State Highway Commission 1917), 1904 and 1905, and 1934 to 1941 (Sprugel 1950; Carlander and Sprugel 1955). The lake does not stratify thermally (Bachmann

1980), and shoreline erosion is negligible at most water levels.

Chemical and biological limnology

Bachmann (1980) summarized data on water chemistry collected in the summer of 1979 (Table 1). The lake is sometimes turbid from wave action, algal blooms, and, periodically, from the actions of foraging fishes (carp *Cyprinus carpio* and grass carp *Ctenopharyngodon idella*; Iowa Dep. Nat. Resour., unpubl. data). Extensive submerged aquatic vegetation has at times impeded angling and boating (Carlander and Sprugel 1955). No point sources of pollution have been identified, but non-point sources include nutrients (phosphorus and ammonia nitrogen) from surrounding fertilized agricultural lands. In late winter, dissolved oxygen concentrations often drop below that acceptable for sport fish (Sprugel 1950), and Bachmann (1980) estimated that winterkills historically occurred on average every 4 years. After a winter aeration system was installed in 1980, however, only one minor winterkill has occurred during the period 1980-1991.

Fish community and stocking

Stocking of sport fish into the lake has long been a major emphasis of managers (Appendix Table 1). Inasmuch as the lake has periodically dried up completely, the fish community consists entirely of numerous species introduced intentionally or incidentally. Fishes introduced include bluegill *Lepomis macrochirus*, green sunfish *L. cyanellus*, pumpkinseed *L. gibbosus*, largemouth bass *Micropterus salmoides*, black crappie *Pomoxis nigromaculatus*, white crappie *P. annularis*, walleye *Stizostedion vitreum vitreum*, black bullhead *Ictalurus melas*, channel catfish *I. punctatus*, northern pike *Esox lucius*, tiger muskellunge *E. masquinongy* x *E. lucius*, yellow bass *Morone mississippiensis* and, in 1989, flathead catfish *Pylodictus olivaris*. Other species introduced intentionally or incidentally into the lake at one time or another have included carp, grass carp, white sucker *Catostomus commersoni*, fathead minnow *Pimephales promelas*, and creek chub *Semotilus atromaculatus*.

HISTORY OF MANAGEMENT INTERVENTIONS IN THE LAKE

Managers have used numerous fisheries techniques in Little Wall Lake during the last century in an attempt to improve and stabilize the fishery, including dredging, water level manipulation, aquatic vegetation control (chemical and biological), intentional fish removal via netting, fish eradication with toxicants, sport fish restocking, introduction of predaceous fish species, use of artificial habitat structures, and winter aeration. Management activities and results are summarized chronologically.

Historical to 1933

Early in this century, MacBride (1909:117) described Little Wall Lake as "...a picturesque little pond...nearly surrounded by steep wall-like hills. Had it depth, Little Wall Lake would be the attraction of the landscape, but its shallowness makes it simply a great marsh filled from side to side with aquatic plants". The Iowa State Highway Commission (1917:84) also reported it to be a shallow lake with "...a large part of its surface...grown up to rushes". Carlander and Sprugel (1955) reported that in the late 1940s, most limnologists would still have classified Little Wall Lake as a marsh, as Errington (1963) later classified it.

In the early 1900s, there was debate about whether this shallow marsh should be drained, deepened, or otherwise altered. As early as 1917, the Iowa State Highway Commission (1917:85) reported that "people living in the vicinity are in favor of keeping the lake and they very much wish to see it improved". The shallowness has always been considered a problem from the standpoint of fishing, boating, and related recreation. The recommendations in 1917 were either to place a dam at the outlet and raise the water level or, preferably, to dredge, using the dredged spoil in a public park on the lake. Dredging records for the lake are sketchy. The only recorded dredging was in 1953, when the Iowa State Conservation Commission dredged 23 ha of the lake for recreational purposes (Carlander and Sprugel 1955). Fish stocking records were not recorded by water body before 1943, so the early stocking history of the lake cannot be accurately reconstructed.

Table 1. Chemical and physical characteristics of Little Wall Lake, Iowa (Bachmann 1980).

Parameter	n	Mean
pH	2	8.2
Alkalinity (mg/L $CaCO_3$)	9	192.3
Specific conductance (μmohs/cm)	10	385.0
Total hardness (mg/L $CaCO_3$)	9	201.6
Secchi disc depth (m)	5	1.0
Turbidity (JTU)	9	7.5
Total phosphorus (mg/m^3)	9	171.9
Kjeldahl nitrogen (mg/L)	2	1.8
Ammonia nitrogen (mg/L)	2	0.3
Chlorophyll a (mg/m^3)	9	50.3

1934-44

The lake was dry or nearly so during the period 1934 to 1941. Errington (1963) reported that the lake surface area dropped to about 40 ha during the summer of 1936, and dried up completely by November of that year. It began to refill in 1941, but did not refill completely until 1944. By then, "most of the cattails which had been present at the lower water levels died out... . In 1943 and 1944 [before fish were stocked], tadpoles and frogs were reportedly very abundant..." (Carlander and Sprugel 1955:556). No fish were reported to have been stocked during this period, but, based upon later sampling, at least bullheads were present.

1945-53

Carlander and Sprugel (1955) and Sprugel (1950, 1955) summarized the fish community and management on the lake up to 1953, when it was dredged. Over the period 1945 to 1949, after the water level had risen, the Iowa Conservation Commission stocked largemouth bass, bluegills, and, in 1949, northern pike to reestablish a sport fishery (Iowa Conservation Commission, unpubl. data). Such a stocking program, which was to be repeated with minor variations in subsequent decades, was implemented under the rationale that all species would provide quality angling, and that the pike and bass would control the reproduction and density of bluegills, allowing them to reach a size desirable to anglers. This simple fish community was supplemented by bullheads and green sunfish, somehow also introduced unofficially, from 1942 to 1944. The 1942-44 year classes of bullheads were reported to grow faster than later year classes, perhaps because of their lower densities in the earlier years. Green sunfish also grew rapidly and had become large enough (commonly 17.8 to 21.6 cm total length (TL); Carlander and Sprugel 1955; Sprugel 1955) by 1948 to provide a well-received fishery.

During most of the period 1945-1953, excessive aquatic vegetation became a management problem in the lake. In 1948, local sportsmen kept open two parallel channels about 15 meters wide in a north-south direction across the west end, but the lake was otherwise heavily vegetated. Decomposition of this extensive vegetation resulted in oxygen depletion and high fish mortality (winterkill) in the winters of 1948-49 and 1949-50 (Sprugel 1950). Although "no detailed observations were made in the succeeding winters...the water levels were low and dead bullheads and fathead minnows were found when the ice went out in 1951, 1952, and 1953" (Carlander and Sprugel 1955:557).

1954-77

During 1953-54, crappies and bluegills were stocked (Appendix

Table 1) along with largemouth bass and northern pike, again to insure a mixture of predaceous and prey sport fishes. From 1955 to 1957, additional northern pike and largemouth bass were stocked to increase predation on the smaller sport fishes. Although precise stocking records were not recorded by lake from 1959 to 1968, some black bullheads were stocked in the spring of 1961 and crappies were stocked in the spring of 1962 (Iowa Conservation Commission, unpubl. manage. rep. 1964). These fish were reported to have reproduced well, and by 1962, numerous white and black crappies, and young-of-the-year black bullheads were found (Iowa Conservation Commission, unpubl. manage. rep. 1962). From 1962 through 1967, bullheads and crappies remained abundant (Iowa Conservation Commission, unpubl. manage. rep. 1962 through 1967).

Slow growth and stunting problems of crappies and bullhead exacerbated from 1965 through 1967, so that by 1967, the dominant year class of bullheads, aged 6+, averaged only 14.6 cm TL (range 13.5-17.0 cm) and 41 g in weight. The dominant age class of crappies, aged 5+, averaged only 12.7 cm TL (range 13.5-14.5 cm) and 27 g (Iowa Conservation Commission, unpubl. manage. rep. 1967). Fish of these species smaller or larger than these ranges were essentially absent.

Yellow bass, first recorded in the management survey in 1969, were reported in 1974 as having "all age classes represented — growth of all age classes adequate" (Iowa Conservation Commission, unpubl. manage. rep. 1974). By 1977, however, yellow bass growth was perceived to be poor (J. Wahl, letter to T. Gengerke, 10 May 1989), along with that of crappies and bullheads. By 1977, none of these three species was providing quality angling.

Reproduction of largemouth bass during 1965-1967 was reported to be extremely limited. Northern pike, although providing angling, were apparently not effectively reducing abundance of prey species. From 1969 through 1975, northern pike fingerlings and adults were stocked to help control stunted bullheads and crappies. In 1975, 350,000 walleye fry were stocked as a potential piscivore and sport fish (Appendix Table 1). As of 1977, neither of these coolwater piscivores had successfully depleted prey populations (J. Wahl, letter to T. Gengerke, 10 May 1989).

In addition, carp, somehow introduced into the lake, increased in numbers from 1970 through 1977 (Ennor 1976). Although angling from shore was reported to be difficult in 1972 because of dense aquatic vegetation, planned chemical control of the vegetation was not conducted because vegetation problems had subsided by May 1973 (Moeller 1973). No major aquatic vegetation problems were reported from 1974-1977, perhaps because of increased turbidity (Moeller 1973) commonly associated with high densities of carp.

By 1977, the combination of a large carp population, overabundance of stunted panfish and the near absence of predators (despite repeated stockings) led to a decision to eradicate the entire fish population. Managers applied rotenone at a concentration of 3.5 mg/l during the fall of 1977, and on the next two days collected and buried an estimated 55,000 kg of large carp (215 fish/ha; 188 kg/ha). The numerous crappies, bullheads, and yellow bass killed were not counted. Incredibly only 20 largemouth bass and 8 northern pike were collected (Iowa Conservation Commission, unpubl. data). Although a "total kill" was sought, it was not achieved. A post-eradication survey crew sampling with fyke nets captured one adult bullhead (Iowa Conservation Commission, unpubl. manage. rep. 1977). Other bullheads undoubtedly survived.

1978-88

After the near-elimination of fish in 1977, a mixture of bluegills, largemouth bass, crappies, channel catfish, largemouth bass and northern pike was stocked from 1978-1980 to reestablish sport fish populations (Appendix Table 1). The channel catfish, popular with Iowa's anglers, were to provide additional angling and eat invertebrates. Fingerlings (as large as 20.3 cm TL in 1980) were stocked yearly from 1977 through 1986. Tiger muskellunge, a coolwater piscivore and desirable sport fish, were also stocked as juveniles (10.2-17.8 cm TL) from 1983 to 1987, and northern pike were again introduced in 1988. Largemouth bass were stocked as advanced fry in 1978 and 1979, after the eradication, and were stocked as fingerlings (10.2-12.7 cm TL) from 1985 through 1988 (Appendix Table 1).

In an attempt to increase habitat diversity and concentrate fish for anglers, oak stake bed and pallet crib structures were placed in eight locations in the lake in 1982. Subsequent surveys by electrofishing have shown that the structures are used frequently by bass, bluegills, crappies, and channel catfish.

From 1977 until 1990, water has been pumped into the lake on an irregular basis from a nearby drainage ditch during periods of low water. The volume of water pumped has ranged from 9 million liters in 1980 to more than 305 million liters in 1985. In 3 of the 14 years during this period, no water was pumped. In most cases, the water available to pump was insufficient to substantially increase water levels. In addition, managers have been concerned about the accidental introduction of undesirable larval fish species from the ditch. The pump was damaged in 1990 and is not in use as of 1991.

As in the 1970s, and despite the introduction of pike, tiger muskellunge, and bass, an overpopulation of crappies and bullheads in the 1980s again posed management problems. A survey conducted with fyke nets during 1980 revealed numerous large bullheads from 22.9 to 30.2 cm TL, numerous young-of-the-year bullheads from 2.5 to 6.1 cm TL, but none in between these lengths, which indicated that many bullheads had survived the 1977 renovation and had reproduced effectively in 1980. Some bullhead reproduction apparently occurred from 1981 to 1983 as well, so that in 1984, many small bullheads (7.6 to 15.0 cm TL) were present (Iowa Conservation Commission, unpubl. manage. rep. 1984). By 1985, both crappies and bullheads exhibited poor growth, and by 1986, nearly all bullheads sampled in management surveys were 10.2 to 15.0 cm TL, and all crappies sampled were between 12.7 and 15.0 cm TL, indicating an overpopulated, stunted mixture of these species. The stunting problems and shortages of piscivores exacerbared in 1987 and 1988 (Iowa Conservation Commission, unpubl. manage. rep. 1985 through 1988). A decade after the 1977 renovation, the fish community in Little Wall Lake was once again dominated by many small, slow growing bullheads and crappies, and piscivores were few (J. Wahl, letter to T. Gengerke, 10 May 1989).

During the spring of 1988, managers attempted to mechanically remove large numbers of stunted panfish with an extensive fyke netting program. A total effort of 242 fyke net days resulted in the removal of more than 172,000 bullheads and crappies. About 4,300 kg of fish (33 kg/ha) were removed. These efforts were discontinued because of low catch rates and insufficient manpower. The efforts did not appear to result in increased growth rates of panfishes.

After the removal of carp in the eradication of 1977, water clarity had again improved so that aquatic vegetation proliferated and problems for anglers and boaters again worsened. In response, 2,500 grass carp (20.3 cm TL) were stocked in 1983 (at a rate of 24.0 fish/ha) to deplete the aquatic vegetation and improve fishing opportunities (Appendix Table 1). The grass carp controlled vegetation well; by 1988, essentially no submerged or emergent aquatic vegetation remained in Little Wall Lake.

In April 1989, the Hamilton County Conservation Board contacted the Iowa Department of Natural Resources (DNR) fishery manager and requested that the existing fish assemblage in Little Wall Lake be chemically eradicated, and that the lake be restocked with sport fishes (B.P. Holt, letter to J. Wahl, 18 April 1989). Camping revenues had been halved as angling success had declined. State fishery managers concurred, and in the fall of 1989, the lake was chemically treated with 3.0 ppm rotenone. Dead fish were collected for three days thereafter.

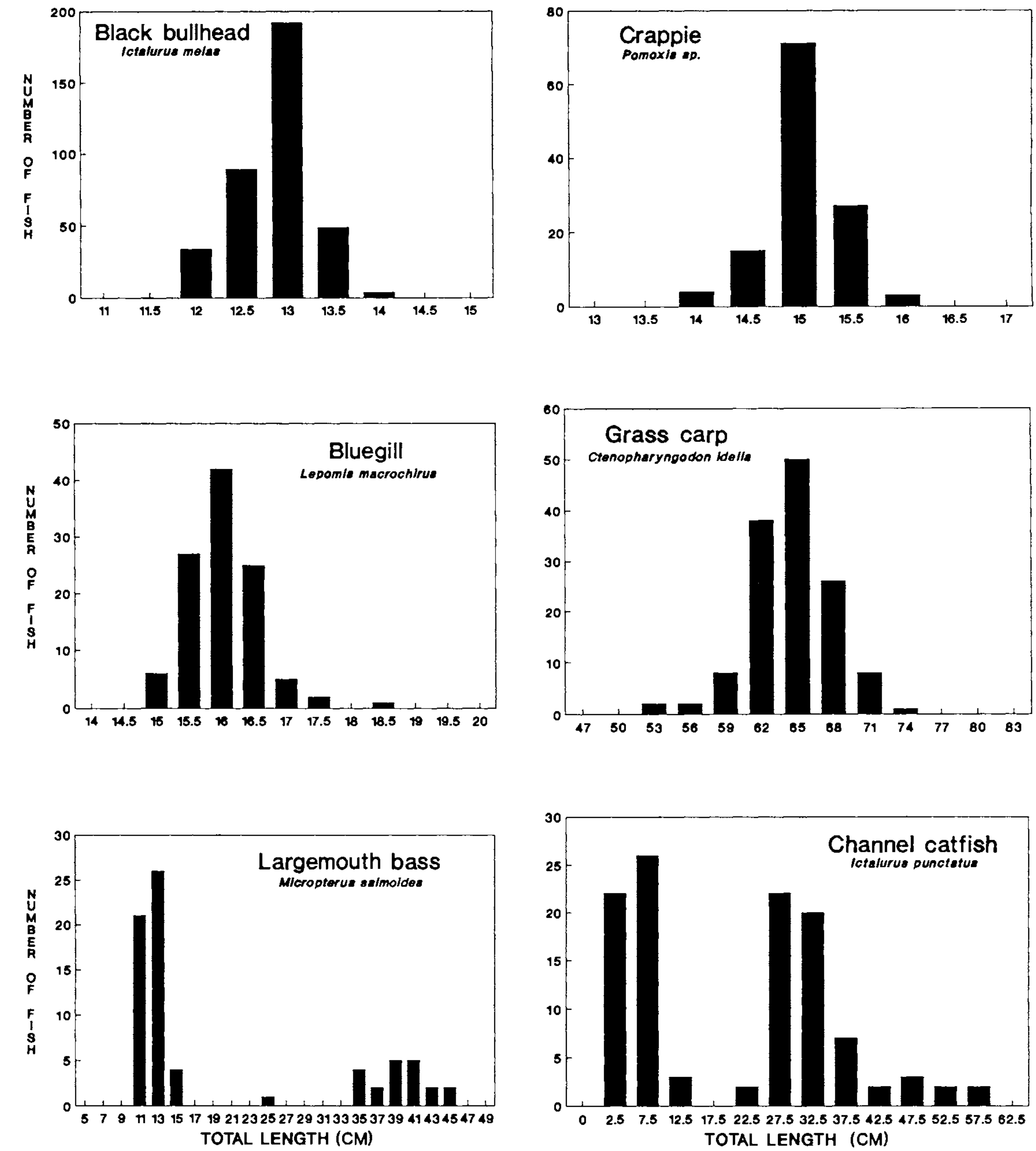

Fig. 2. Length frequencies for species sampled during the fish eradication of September 5-8, 1989.

Status of the fish community at time of the most recent eradication (1989).

Immediately prior to the addition of rotenone, a total of 120 largemouth bass (0.9 to 2.7 kg) and 20 channel catfish (0.5 to 3.6 kg) was salvaged and restocked in nearby lakes. It was estimated that about 45,000 kg of dead fish were removed following the application of rotenone. Although populations were not estimated, shoreline transects were sampled to estimate species composition and to obtain additional data for fisheries management according to established methods (Lagler 1956; Wege and Anderson 1978; Anderson 1980). Bullheads (82% of transect samples) and crappies (14% of transect samples) constituted most of the fish in the lake at the time of the eradication. Other species present included grass carp, bluegills, channel catfish, and largemouth bass.

Bullheads displayed a remarkable uniformity of length; all but one of 2,725 fish sampled were within the narrow range of 12 to 14 cm TL (Fig. 2). Crappies also displayed a narrow range of lengths; essentially all of them were 14 to 17 cm TL (Fig. 2). Scales from crappies showed a rapid growth up to the first two annuli, after which annuli became so closely spaced that separation was impossible. Evidently the fish grew well for the first two years after stocking but then became stunted. These two species, which constituted more than 95% of the fish in the transects by number, were not reproducing and provided no quality fishing (Proportional Stock Density (PSD) = 0 for both species; Anderson 1980). Similarly, although bluegills constituted fewer than 1% of the fish sampled in the transects, all sampled bluegills but one were between 15 and 17.5 cm long, indicating stunting and a lack of reproduction (Fig. 2). Grass carp also exhibited a narrow range of lengths (56 cm to 73 cm TL; Fig. 2), and their mean weight was 3.1 kg.

Largemouth bass exhibited no reproduction despite the presence of some large specimens (35 to 48 cm TL) of reproductive size. In addition, few bass were found in the intermediate length range of 16 to 34 cm, indicating either that growth of the fingerlings (10.2 to 12.7 cm) stocked from 1985 to 1988 was poor, or survival was poor, or both (Fig. 2). The largest bass, aged 5 to 8, had grown much more rapidly and had been much larger at ages 2 and 3 than were fish of that age sampled in 1989, indicating that conditions for growth of bass were evidently much better in the early 1980s (soon after the eradication of 1977) than in 1986-88, when stunting of bullheads and crappies became acute (Fig. 3). Bass of the larger group (35.0-46.6 cm TL; n = 20) were in good condition (mean Relative Weight (Wr) = 102.5; Wege and Anderson 1978), whereas bass of the smaller group (11.9-15.2 cm TL; n = 51) were not (Wr = 88.4).

Channel catfish was the only fish in the lake that showed evidence of successful reproduction (Fig. 2). Fish less than 9 cm constituted nearly 50% of the catfish sampled in the transects, even though no channel catfish that small had been stocked in recent years. Some channel catfish had also reached quality size (PSD = 22%).

Although tiger muskellunge had been stocked from 1983 to 1987, none was found in the transects, nor were any seen in netting operations. Only one northern pike was identified during the netting, and that fish (740 mm TL) was severely emaciated.

1989 to 1991

Following the fish eradication of September 1989, the DNR stocked fingerling bluegills, mid-sized (12.7-15.2 cm) largemouth bass, and channel catfish (Appendix Table 1) at densities prescribed by the agency (Hill and Schwartz, undated) to again establish a sport fish community. Soon afterward, managers sampled the lake near the shore with fyke nets and electrofishing and recovered the stocked species plus one white crappie and one white bass *Morone chrysops*. (Iowa Department of Natural Resources, unpubl. manage. rep. 1989). These fish either survived the eradication or were introduced unofficially soon thereafter. In 1990, northern pike fry and fingerlings, largemouth bass, and 675 flathead catfish were introduced into the lake. As of 1990, it was again hoped that the bass, pike, and flathead catfish would reduce bluegill populations so that all species would provide quality angling. During summer, 1990, sampling with fyke nets and an electrofisher yielded some stocked bass, channel catfish, pike, and bluegills, but also yielded two bullheads that either survived the fish eradication or were unofficially stocked (Iowa Department of Natural Resources, unpubl. manage. rep. 1990). In an attempt to suppress the reestablishment of a large bullhead population, an aggressive approach to stocking piscivores was begun early in the stocking program. The plan calls for stocking of fingerling largemouth bass and flathead catfish in the first three years following renovation.

SYNOPSIS OF EVENTS

The management approach on Little Wall Lake has been to develop a sport fishery by starting with a lake full of water but nearly empty of fish, either recently after drought (1930s), after winterkill (1949-50), or after intentional eradication (1977, 1989), and restock a mixture of smaller sport species such as bluegills and crappies and piscivores such as largemouth bass and northern pike. Stocked fish, as well as fish such as bullheads surviving the winterkills and eradication programs, have been able to reproduce well in subsequent years by spawning in the extensive shallows of the lake. Low densities and high growth rates of all species have resulted in quality fishing for 3-4 years, until one or more successful year classes of crappies or bullheads became extremely abundant. These fish have become stunted (Alm 1946), resulting in a narrow range of length-frequencies (Fig. 2), little or no annual growth (Fig. 3), and poor reproduction and recruitment (Fig. 2). The result has been a large fraction of the fish remaining too small to interest anglers. Introduction of lake aeration devices by managers has reduced the winterkill problems, but non-piscivorous species such as bullheads and crappies have then suffered low overwinter mortality and further overpopulated.

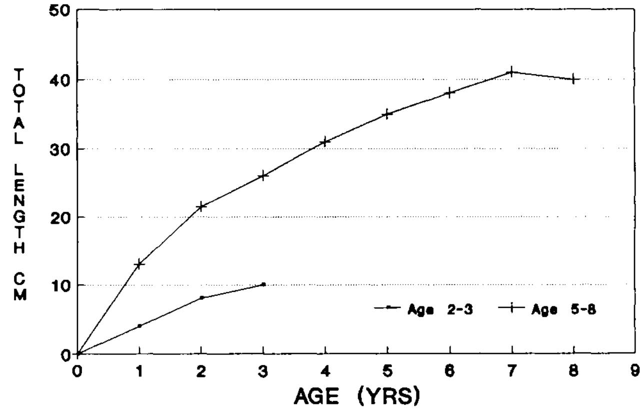

Fig. 3. Size at age for largemouth bass ages 2 and 3, compared with size at age for fishes ages 5 through 8. Size at ages 2 and 3 for fishes 5 through 8 was estimated from back-calculation, using the simple Dahl-Lea method, of lengths based on scale samples (Lagler 1956).

Piscivores stocked to control bullheads, crappies, and bluegills have not done so. The coolwater species — northern pike, tiger muskellunge, and walleye — have been especially ineffective. Although detailed temperature records are unavailable for the lake, water temperatures in summer frequently exceed 30 C, especially during years of warm air temperatures and low water levels. Such temperatures are probably unacceptably high for these species. The absence of any significant inflows of cooler water would make it even more difficult for coolwater species to survive stress periods. Stocking has continued in part because these species are much-desired by Iowa anglers (IMR Systems 1986). Largemouth bass, the only warmwater piscivore used (other than flathead catfish in 1990) have grown well in the lake (Fig. 3), but harvest of them by an enthusiastic angling public has continually reduced their numbers.

A particular management action on the lake has often solved one problem but created one or more other problems of equal or greater severity. Lake aeration has improved overwinter survival and probably exacerbated overpopulation. Carp and grass carp have alleviated the aquatic vegetation problem but increased turbidity and eliminated cover for juvenile fishes. Elimination of carp and grass carp has improved water clarity but, combined with nutrient inputs, has resulted in excessive aquatic vegetation and increased the likelihood of winterkill.

WHY HAS MANAGEMENT FAILED?

The goal of fishery management in Little Wall Lake has been to develop a stable, sustainable recreational fishery and boating site. Achieving this goal has been a challenge because habitat quality for fish and other organisms in Little Wall Lake is naturally highly variable, not stable. For example, in the late 1930s, the lake was nearly always dry, whereas by the mid-1940s, it overflowed. Because the drainage basin surrounding the lake is so small, the lake level is greatly affected not only by region-wide climatic factors, but also by local weather events, such as brief, intense summer rains (Errington 1963). Wildly unstable water levels in the lake have instigated abrupt habitat quality changes, and resulted in population explosions and crashes of fish as well as other fauna and flora. In 1942, Errington wrote that recurrent exposures and flooding of the lake bottom had resulted in a nearly solid stand of cattails, nearly all of which was killed in 1944 as high water made the marsh lake-like. A severe population crash of muskrats *Ondatra zibethica* followed soon thereafter from a combination of factors, including food shortages, loss of shelter, and disease (Errington 1963). Die-offs of fishes through winterkill (Bachmann 1980) and other factors have been documented associated with changing water levels (Carlander and Sprugel 1955). Our conclusion is that with the existing natural habitat variations, a stable sport fishery is unlikely, and periodic eradications and restockings will be continually required.

PERSPECTIVES AND PRESCRIPTIONS

Lake fishery or marsh?

In this century, Little Wall Lake has been viewed as a fishing lake, as a marsh (Errington 1963) suitable for muskrats, and potentially, as farmland. How should the lake be managed, and why? The argument favoring fishing is supported by the small supply and large demand in Iowa for recreational waters for fishing and boating (IMR Systems 1986). As for supply, although many glacial lakes were formed in northwest and north-central Iowa during the Pleistocene, most of these lakes at the time of settlement were small and shallow (Prior 1976). Where deeper lakes are more plentiful, as in neighboring Minnesota, lakes similar to Little Wall are generally managed as wetlands rather than as fisheries (Minnesota Department of Natural Resources 1982). But in Iowa, lakes such as Little Wall may provide the best fishing opportunity available. As for demand, the large number of licensed anglers (425,000) in Iowa greatly exceeds the number of licensed waterfowl hunters (15,000), so the reestablishment of a marsh is unlikely on those grounds. There are, however, other non-game benefits of marsh development (natural water treatment benefits, non-game wildlife habitat, etc.) that have not been considered in Little Wall Lake, and perhaps should be, before the idea of marsh reestablishment is dismissed. That assessment is outside the scope of this paper, and our recommendations below are designed to address the long-time goal of a stable sport fishery.

The need for an integrated management plan

In our opinion, simple, one-dimensional management actions (such as stocking fish) in Little Wall Lake are unlikely to achieve the management goal for any but brief periods, and a more integrated fisheries management plan is needed. Such a plan would involve reducing variations in between-year and within-year habitat quality, and diversifying the fish community in the lake. Our approach here is not to create a detailed plan per se, but to outline an integrated series of habitat management and fish community management actions likely to stabilize the habitat and the fishery.

Habitat management

Dredging — Inasmuch as Little Wall Lake is shallow, dredging to increase water depth would increase water volume and decrease the likelihood of winterkill. Increased depth near shore might also reduce the extensive beds of submerged vegetation that develop in shallow water (Dillard, undated).

Improved land use practices — Before any dredging is implemented, all land within the watershed should be protected by implementing "best land use management practices" (Moore and Thornton 1988) or the equivalent. As of 1980, only 56% of the watershed was in approved soil conservation practices (Bachmann 1980). With better land use practices, nutrient inputs would be reduced and nearshore turbidity would decrease, resulting in better water quality, less aquatic vegetation, and reduced likelihood of winterkill.

Water level stabilization — Because of its small watershed to lake area ratio, Little Wall Lake is heavily dependent upon local rainfall. The loss of 1 m of water depth in a lake with a maximum depth of less than 3 m can devastate a fish population (Iowa Department of Natural Resources, unpubl. manage. rep. 1990). Stabilizing the water level with a supplemental water supply such as a deep well could substantially improve fish habitat quality and stability, especially during drought years, when water levels would otherwise drop 1 to 2 m or more. This approach was used in Lake Cornelia, Iowa, during the drought from 1987 through 1989. In that lake, which is similar in area to Little Wall, stable water levels were maintained within 0.3 m of crest, whereas other lakes in the area dropped 1-1.3 m below crest (Bruce Lindner, Wright County (Iowa) Conservation Board, Pers. Commun.).

Vegetation Control — Rooted aquatic vegetation has returned to Little Wall Lake as expected after eradication of the grass carp in 1989. Inasmuch as water quality and fish growth are often enhanced by the presence of aquatic vegetation (Gabelhouse et al. 1982), vegetation control should be approached cautiously in the future. If vegetation becomes too excessive, moderate chemical or mechanical control should be considered. If chemical and mechanical control are not sufficiently effective, biological control with grass carp remains an option. Fish should be stocked, however, at a much lower density (perhaps 5 to 7.5 fish/ha) rather than the 24 fish/ha stocked in 1983. Nearshore dredging, better land use practices in the watershed, and public access fishing jetties should all reduce the need for vegetation control.

Fish community management

Emphasis on piscivore stocking and maintenance — Historical events have shown that after a stunted panfish community has developed, stocking piscivores has been ineffective, and it has been too late to reverse the stunting. We support the idea of establishing healthy populations of piscivores early in a restocking program and maintaining them to suppress overpopulation of bluegills and bullheads. One method of keeping sufficient numbers of large bass in the system would be to establish a 46 cm (18 inch) or longer minimum length to protect large bass from harvest. Bass typically grow well in Iowa lakes after eradication projects (Hill 1990), but many are harvested quickly after they reach the statewide minimum length of 38 cm (15 inches; Paragamian 1977). A 46 cm minimum length limit would not only keep them in the lake, it would allow more large bass to serve as broodstock to spawn in years when stocking does not occur. Anglers would still be able to enjoy high-quality catch-and-release fishing for bass, and would probably accept the regulation if they could harvest large panfish. Flathead catfish, another warm water piscivore, might also alleviate overpopulation problems in the lake if they are not harvested too heavily (Davis 1985; Hudson 1990).

Other prospective piscivores (besides bass and the flathead catfish) might be northern pike, tiger muskellunge, gars (*Lepisosteus* spp.), and bowfin (*Amia calva*). Tiger muskellunge stocked in the 1980s did not provide a trophy fishery nor act as effective predators, and we do not recommend them. Northern pike have, in our opinion, functioned sporadically as effective predators, and have contributed to the fishery in cooler, higher water years. Although reproduction of pike has been observed in the lake when sufficient aquatic vegetation existed, pike will probably not sustain themselves without stocking. Consistent supplies of fingerling-sized pike have not been available in the past, but the refurbishment of the Beeds Lake State Park rearing ponds in nearby Franklin County may result in a consistent source of fish to stock throughout the 1990s. If northern pike stocking is pursued, significant annual mortality might be expected in unusually warm years, when water temperatures can exceed 30 C for several days. Impacts of warm water should be lessened if water levels can be increased by pumping from wells during warm years.

Fish community diversity

In our opinion, too much emphasis has been placed on re-establishing "game fish only" fish communities, and too little emphasis on establishing diverse fish communities of a mixture of game and nongame species. It seems plausible to us that more diverse communities would be less prone to stunting. Experimental stocking of warmwater, non-game piscivores such as shortnose gars *Lepisosteus platostomus* and bowfin deserve some consideration. Both species have historically been found in Iowa, and no rare species would be threatened by their introduction into Little Wall Lake. Gars and bowfin are well adapted to warm, shallow, vegetated lakes (Becker 1983), and can tolerate low dissolved oxygen concentrations common in the lake. They may be much more effective predators on bullheads and centrarchids in the warm days of summer than would the coolwater piscivores. Both species would be harvested lightly, and would therefore be a continual presence affecting prey species. Fishing for these species might be promoted if they became too abundant. But reproductive capabilities of these fishes are relatively low, and they feed high in the food web, so the chance of overpopulation is less than for other non-game fishes such as carp and buffalo (*Ictiobus* spp.). Their potential usefulness may be impeded because they are not widely distributed in Iowa, and numbers of fish available for stocking may be small. In addition, considerable research is needed on the use of holosteans as management tools (Scarnecchia 1992). The introduction of some non-game species such as minnows (Cyprinidae) that remain small is also worth considering.

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Appendix Table 1. History of fish introductions in Little Wall Lake, Iowa, 1943 to 1990. Stocking records before 1943 were reported by county and are not available by water body. Stocking records from 1959 to 1969 were reported only statewide and are not available by water body.

Year	Species	Number stocked	Length (cm) or size
1990	Flathead catfish	675	12.7-30.5
	Largemouth bass	26,000	2.5
	Northern pike	1,300	5.1
	Northern pike	350,000	fry
1989	(after renovation)		
	Bluegill	90,000	2.5-5.1
	Channel catfish	26,000	5.1
	Largemouth bass	7,500	12.7-15.2
1988	Largemouth bass	6,315	10.2-12.7
	Northern pike	1,360	3.8-10.2
1987	Largemouth bass	7,500	10.2-12.7
	Tiger muskellunge	1,300	15.2
1986	Channel catfish	2,600	14.0
	Largemouth bass	5,000	10.2-12.7
	Tiger muskellunge	300	15.2
1985	Channel catfish	2,600	12.7-15.2
	Largemouth bass	5,000	11.4
	Tiger muskellunge	210	12.7-15.2
1984	Channel catfish	2,600	12.7-17.8
	Tiger muskellunge	255	10.2-17.8
1983	Channel catfish	2,600	17.8
	Grass carp	2,500	20.3
	Tiger muskellunge	300	15.2
1982	Channel catfish	2,600	17.8
1981	Channel catfish	2,600	17.8
1980	Bluegill	300	adults
	Channel catfish	2,700	15.2-20.3
	Crappie	300	adults
	Northern Pike	1,375	5.1
1979	Bluegill	100	adult
	Channel catfish	3,000	15.2-20.3
	Crappie	100	adult
	Largemouth bass	27,500	advanced fry
	Northern pike	1,375	5.1
1978	Bluegill	100	adult
	Black crappie	101	adult
	Channel catfish	3,000	17.8
	Largemouth bass	27,500	advanced fry
	Northern pike	5,500	5.1-7.6
1977	(after renovation)		
	Bluegill	162,000	2.5-5.1
	Channel catfish	9,400	15.2-25.4
1976		No stocking	
1975	Walleye	350,000	fry
1974		No stocking	
1973	Northern Pike	1,370	45.7
1972		No stocking	
1971		No stocking	
1970	Northern pike	100	adult
1969	Northern pike	100	fingerling
1959-68		Data unavailable	
1958		No stocking	
1957	Northern pike	25	adult
	Northern pike	100,000	fry
1956	Northern pike	100,000	fry
1955	Largemouth bass	9,400	fingerlings
	Northern pike	200	adult
1954	Bluegill	1,850	adult
	Crappie	1,350	adult
	Largemouth bass	30	adult
	Northern pike	10	adult
1953		No stocking	
1952		Data unavailable	
1951		Data unavailable	
1950		No stocking	
1949	Bluegill	8,000	fingerlings
	Northern pike	50,000	fry
1948	Bluegill	10,400	fingerlings
	Bluegill	1,000	yearlings
	Largemouth bass	2,500	fingerlings
	Largemouth bass	508	yearlings
	Largemouth bass	30	adult
1947	Largemouth bass	30	adult
1946	Bluegill	100	adult
	Bluegill	1,400	yearlings
	Largemouth bass	500	fingerlings
1945		No stocking	
1944		No stocking	
1943		No stocking	
Before 1943		Not available	