July 1, 1993

LCMR Final Status Report – Summary – Research
LCMR Work Program 1991

# I. Lake Minnetonka Bass Tracking

Program Manager: Tim Goeman
Fisheries Research
Minnesota Department of Natural Resources
1601 Minnesota Drive
Brainerd, MN 56401
218/828-2246

A. M.L. 91 Chap. 254 Art. I Sec. 14 Subd. 8 (f) Appropriation: $85,000
Balance: $0

This appropriation is to the Commissioner of Natural Resources to study the impacts of bass fishing contests. The study must be done in cooperation with the Minnesota Sportfishing Congress and other interested groups.

B. Compatible Data: During the biennium ending June 30, 1993, the data collected by projects funded under this section that have common value for natural resource planning and management must conform to information architecture as defined in guidelines and standards adopted by the Information Policy Office. In addition, the data must be provided to and integrated with the Minnesota Land Management Information Center's geographic data bases with the integration costs borne by the activity receiving funding under this section.

C. Match Requirement: $0

## II. Narrative

Tournament-caught largemouth bass (*Micropterus salmoides*) are frequently transported substantial distances to a weigh-in site, where they are later released. Fish mortality at weigh-in sites is easily measured and well documented, but effects on post-release survival and behavior are largely unknown for northern latitudes. Survival (determined by holding fish) and movement of tournament-displaced bass (determined using radio telemetry) will address the impacts of tournament angling. Collection of tournament mortality data will define the extent of the impact and provide information for improving tournament procedures and sustaining fish survival. Tournament fishing is becoming increasingly popular in Minnesota with largemouth bass serving as the most popular tournament species. Greater numbers of tournaments are taking place on a finite number of Minnesota waters. Assessment of the success of tournament live release and the impacts associated with displacement of tournament-caught fish will provide an educated basis for operating tournaments to allow optimum use of the fishery resource statewide.

## III. Objectives

### A. Dispersal of tournament-caught largemouth bass.

A.1. Narrative: Determine the extent and time required for dispersal of displaced tournament-caught largemouth bass using radio telemetry.

A.2. Procedures: Radio transmitters with a 6-month battery life will be surgically implanted into fish following one tournament in September 1991 and another in May 1992. Minnesota Bass Federation (MBF) representatives will select weigh-in sites that have not previously been used. In addition, MBF members will provide capture sites when weigh-in occurs. Prior to each tournament, transmitters will be implanted in up to 5 fish collected and released near the weigh-in site. Following each tournament, transmitters will be implanted into 10 tournament-caught fish to be released at the weigh-in site and 5 tournament-caught fish released at their site of capture. This will yield a total of 20 radio-tagged fish for study after each tournament.

A.3. Budget:

| | LCMR Funds | Matching Funds |
|---|---|---|
| a. Amount budgeted: | $73,000 | $0 |
| b. Balance: | $0 | $0 |

A.4. Timeline for Products/Tasks

| | July 91 | Jan. 92 | June 92 | Jan. 93 | June 93 |
|---|---|---|---|---|---|
| Design program | *************** | | | | |
| Conduct study | ****************************************** | | | | |
| Analyze data | | ********************************** | | | |
| Final report | | | | ***************** | |

A.5. Status:

A.5.1. Study Area and Dates

This study was conducted on Lake Minnetonka, MN, a 5900-ha lake located in the western suburbs of Minneapolis. The first fishing tournament that we studied took place over two days on September 6-7, 1991. The Minnetonka Boat Works facility, on Browns Bay in the City of Orono, was selected as the weigh-in site for this tournament. The second tournament took place on May 16, 1992, and the Power

Squadron Picnic Area on Big Island was used as the weigh-in site. Neither facility had previously been used for weigh-in activities.

A.5.2. Completed Procedures

Largemouth bass for radio telemetry studies were provided by anglers participating in both tournaments. Anglers also confidentially supplied the catch locations of selected fish. Two sizes of resin-coated radio transmitters with trailing antennas, which operate at a frequency of 49 MHz, were surgically implanted into fish. A total of 22 largemouth bass were radio tagged in association with the first tournament: 3 fish were collected by electrofishing near the weigh-in site prior to the tournament and were released at their capture site, 5 tournament-caught fish were released at their capture site, and 14 tournament-caught fish were released at the weigh-in site. Biologists tracked radio-tagged fish daily by boat, using a programmable receiver and loop antenna, for two weeks following the first tournament, but all fish were not located every day. Thereafter, fish were tracked weekly. After fish were located, the following ancillary information was collected at the site: location (UTM coordinates), air temperature and weather conditions, depth, secchi disk reading, profiles of water temperature and dissolved oxygen, bottom type, and associated plants. Transmitter pulse rate was timed at each fish location to estimate the temperature of the transmitter (and thus the fish). Because of ice formation on the lake, fish could not be tracked for an extended period of over two months beginning early November, 1991. Similarly, fish could not be tracked during March and early April, 1991, due to ice break-up. During ice break-up, batteries expired in transmitters that were powered by a smaller battery (2 fish). As of June 1, 1992, 8 transmitters in fish from the first tournament, powered by larger batteries, continued to operate. Those batteries failed shortly thereafter, and only sporadic tracking of fish from the first tournament was possible during June, 1992.

A total of 29 largemouth bass were radio tagged in studies of the second tournament. On May 7, 1992 (9 days prior to the second tournament), 10 largemouth bass were collected by electrofishing near the weigh-in site for the upcoming tournament. They were surgically implanted with radio transmitters, and then released at their sites of capture. On the day of the tournament, 14 tournament-caught fish were surgically implanted with transmitters and released at the weigh-in site. An additional 5 tournament-caught fish were fitted with experimental externally attached radio transmitters and were returned to their site of capture. The external transmitters were used with this group of fish (radio-tagged, tournament-caught fish released at capture sites) in an attempt to reduce surgery-related stress, because we observed high subsequent mortality with this group in studies following the first tournament (5 of 5 fish died, see below). Radio-tagged fish from the second tournament were tracked on a schedule similar to that described above for the first tournament with similar procedures. Fish from the second tournament were tracked through October, 1992.

A.5.3 Results and Discussion

Cooperation by Minnesota Bass Federation tournament officials and anglers was excellent. An ample number of fish with known capture locations was available for radio transmitter implanting during both tournaments. It was difficult, however, to attain resident largemouth bass from the Browns Bay area near the weigh-in site for implanting before the first tournament. Over 12 hours of electrofishing effort yielded only three largemouth bass large enough to be implanted with radio transmitters. Electrofishing was conducted both during light and dark hours on three occasions; Minnesota Department of Natural Resources biologists accompanied the investigators on two of these collections. In addition, approximately 20 members of the MBF volunteered to attempt to catch fish by hook and line to be used in telemetry studies before the tournament, but no sizable fish were collected. The difficulty in collecting sizable largemouth bass in the Browns Bay area in the fall was presumably due to the habitat in the immediate area and behavioral effects of weather conditions and season. Fish were more readily collected by electrofishing prior to the second tournament presumably because of site tenacity and habitat use associated with spawning during that collection.

Survival and Status of Radio-Tagged Fish

Radio transmitters were implanted into the body cavity of fish while they were anesthetized with benzocaine (88 mg/L), and all fish were in surgery for less than 16 minutes. Fish were held for at least 1 hour to assure an adequate recovery from surgery, and then were released. All fish radio tagged during the first tournament appeared healthy at the time of release. By October 1, 1991, 7 of those radio-tagged fish were known to have died. Five transmitters were recovered in dead fish. One transmitter was found under a bridge near a popular shoreline fishing area with no sign of a dead fish and was likely caught by an angler who then discarded the transmitter. Another transmitter (and presumably the fish) was ingested by a common snapping turtle; the turtle was captured, held, and eventually voided the transmitter. The observed initial mortality rate (31.8%) is higher than expected under normal study conditions and was probably due to cumulative stress effects. Whereas the stress involved with tournament angling (capture, transport, and weigh-in) or the surgical procedure for implanting transmitters may not, as single factors, cause high mortality, the combination of these two procedures and the associated cumulative stress effects likely led to the observed rate of mortality. Furthermore, the water temperatures following the first tournament were generally decreasing and thus did not create an optimal environment for incisions to heal and tissue damage related to surgery to repair.

On June 11, 1992, SCUBA divers recovered 3 transmitters from fish that were radio-tagged during the first tournament. The death of a fourth fish from that tournament was also confirmed, but the transmitter was not recovered. Two of these fish showed substantial winter movements, and thus behavioral data from these two fish, until ice break-up (through February 25, 1992), were included in analyses. Of the 22 radio-tagged fish from the first tournament, 12 survived until ice break-up (spring 1992), and 10 survived the period of the entire study.

As of June 1, 1992, 2 radio-tagged fish from the second tournament had died. These fish were tournament-caught and released at the weigh-in site. Of the 29 fish radio-tagged in association with the second tournament, 16 survived until ice formation (late October 1992), 6 died (21%), 2 were not tracked because of radio interference at the specific frequencies, and the status of 5 missing fish remained unknown at ice formation. Two possible explanations for missing fish are transmitter failure or unreported harvest by anglers. Anglers reported (by telephone) catching and releasing three radio-tagged fish during June and July, 1992. One additional radio-tagged fish was killed during a tournament in June, 1992, but that fish was not trackable due to radio interference. All behavioral data from missing fish were included in analyses until the time of their last known location.

Mortality of radio-tagged, tournament-caught, displaced fish ("displaced" experimental group) at the termination of tracking was identical between the two tournaments (35.7%). Mortality of fish collected near the weigh-in site by electrofishing that were radio-tagged and released at their capture site ("resident" group) showed lower mortality (0 and 10%) — a finding that suggests collection by electrofishing induces less physiological stress on fish than does angling and subsequent activities associated with tournaments. The highest mortality of radio-tagged fish (100%) occurred in the group of tournament-caught fish in the first tournament that were surgically implanted with transmitters and then returned to their capture location ("returned" group). No fish of this group died associated with the second tournament, when transmitters were externally attached rather than surgically implanted. This result suggests that externally attached transmitters may reduce stress associated with radio tagging, but the signal from the smaller externally attached transmitters was much weaker, and those fish were difficult to locate. Until externally attached transmitters can be engineered to transmit a stronger signal without increasing size or weight, we suggest that surgical implantation remains the optimal method of radio tagging.

## Dispersal of Radio-Tagged Fish

By October 8, 1991 (1 month after the first tournament), 4 of 9 (44%) of the surviving displaced tournament-caught fish that were released at the weigh-in site had dispersed beyond radio-signal range (approx. 0.75 km) from the release site (Figure 1). From that time until ice formation on the lake, the number of displaced fish within radio-signal range from the release site fluctuated between 4 and 6 (44% and 67%). These fish displayed three general behavior patterns after their release at the weigh-in site: 1) most fish appeared to have established home ranges near the release site in Browns Bay, 2) others moved relatively long distances without establishing an apparent home range, and 3) one fish appeared to have established a home range in an area over 5 km from the release site. After ice break-up on April 15, 1992, 3 of 6 (50%) surviving and trackable (extant battery power) displaced tournament-caught fish remained within radio-signal range from the release site, but by May 22, 1992, all displaced fish had dispersed beyond radio-signal range from the release site. This dispersal of the remaining displaced fish during spring was likely associated with reproduction.

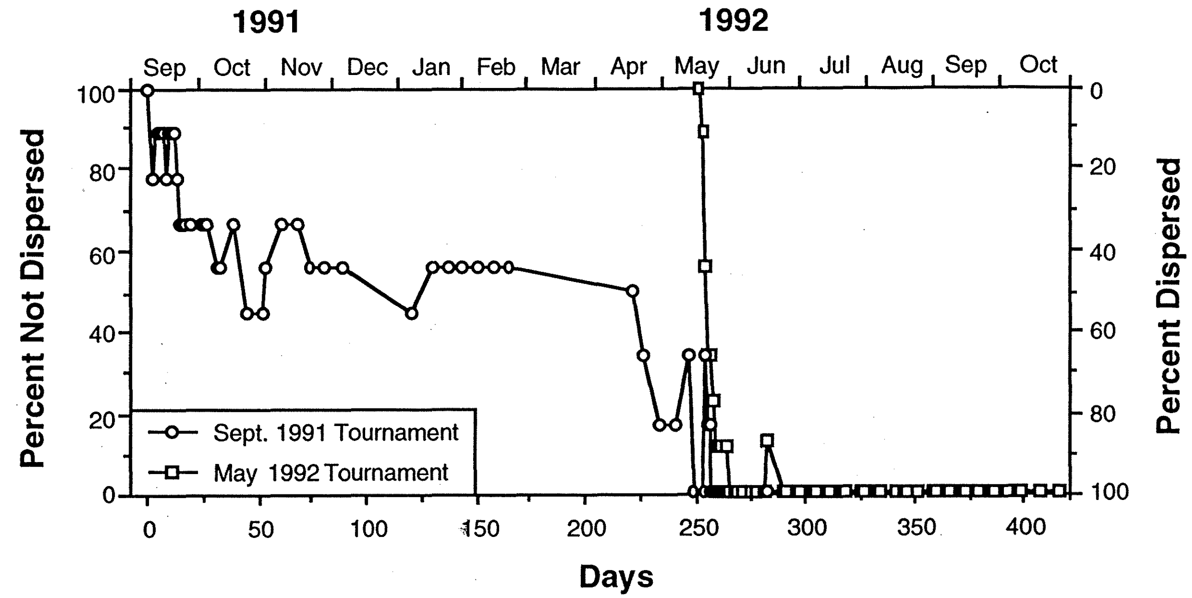


Figure 1. Plot of dispersal rate over time of displaced, tournament-caught largemouth bass for two tournaments.

The three resident fish of Browns Bay that were radio-tagged before the first tournament survived the entire study and remained in Browns Bay and maintained home ranges near their capture sites. All five tournament-caught fish that were returned to their capture site during the first tournament died early in the study, and thus no behavior data were collected.

Largemouth bass that were collected by electrofishing near the weigh-in site before the second tournament, then radio tagged and released at their capture site (resident fish), dispersed from the weigh-in site at a slower rate than tournament-displaced fish released at the same location. Resident fish had been radio tagged 9 days prior to the tournament, and by the tournament day (May 16, 1992), 2 of the 9 (22%) surviving resident fish had dispersed beyond radio-signal range from the weigh-in site. One week after the tournament (May 23), 5 of 9 (56%) resident fish had dispersed from the weigh-in site, as had 7 of 9 (78%) tournament-displaced fish (Figure 1). Two weeks after the tournament (May 30), 4 of 9 (44%) resident fish had dispersed from the weigh-in site, but all 8 (100%) of the surviving tournament-displaced fish had dispersed beyond radio-signal range from the weigh-in site (excluding missing fish). Beyond that date, the number of resident fish remaining within radio-signal range of the weigh-in site varied from 0 to 5 fish (0–56%), and at the last tracking of the study (October 28), 3 of 6 (50%) resident fish remained near the weigh-in site (excluding missing fish).

The movement patterns of resident fish from the second tournament were variable, but most fish established one or more home ranges near Big Island. One resident fish moved relatively long distances without establishing an apparent home range, and another appeared to have established a home range in an area over 2.5 km from the release site. Movements of tournament-displaced fish associated with the second tournament also varied, but most established one or more home ranges away from Big Island, often preceded by a period (up to 9 weeks) of substantial movements. One displaced fish moved relatively long distances without establishing an apparent home range, as did another displaced fish before it appeared missing (after 8 weeks). Another missing, displaced, fish was located near the release site for 3 weeks before its disappearance. The three tournament-caught fish released at their capture site (excluding 2 with radio interference), also showed variation in behavior. One established a home range at its release (and capture) site, another established a home range after an initial large movement from its release site (over 3.5 km), and the third stayed in a home range near its release site for 11 weeks, then moved to a another bay (2 km distance) for the remainder of the tracking period (13 weeks).

Because the observed largemouth bass behavior associated with the both tournaments may be related to reproduction, we recorded observations of spawning fish in Lake Minnetonka and other behaviors associated with reproduction to document spawning chronology during 1992. We observed large aggregations of largemouth bass (12-15 fish) in shallow bays on May 5, and a largemouth bass pair was observed spawning over a nest on May 13. We observed largemouth bass guarding nests (presumably males) continuously from May 13 through June 8, and males were observed guarding fry from June 23 through June 29. One radio-tagged fish (presumably a male) was observed guarding a nest and subsequently guarding fry. This fish was guarding a large school of fry (over ca. 5000 fry) on June 29 in a shallow bay of Big Island, but the following week (July 6) the same fish was located in deep open water off a point on Big Island, likely marking the end of the largemouth bass reproductive season that year in Lake Minnetonka.

Only 2 of the 16 displaced fish that survived the entire study returned to the site where they were captured. One fish that was captured by angling during the first tournament in Forest Lake, a small bay in the north-central portion of Lake Minnetonka, returned to within 0.4 km of its capture site. The fish was not located near its capture site until the following spring (May 24, 1992) and remained in the general area of its capture for the remainder of the study (until June 9, 1992). The capture site of that fish was 9 km from the weigh-in site (release point), and the fish had navigated through at least three narrow channels separating larger bays to complete its return. One displaced tournament-caught fish from the second tournament returned to its capture site in St. Albans Bay, 3.6 km south of the weigh-in site. This fish returned to its capture site five weeks after its release. It was again located at its capture site one week later (six weeks after release), but then left the area. These two occurrences of homing indicate that displaced largemouth bass have the ability to navigate to a home range when displaced, and nest-site fidelity in some individuals is further suggested. The preponderant result, however, is that displaced largemouth bass in this study did not return to their capture site, and reproductive activities were interrupted by displacement, and presumably not resumed, following the spring tournament. The extent of this impact on reproduction and recruitment at the population level is beyond the scope of this study and would require further research.

It should be noted, however, that the second tournament which took place during the largemouth bass spawning season was conducted prior to the open fishing season for bass in Minnesota specifically for this study to assess tournament impacts, and the bass fishing season in Minnesota does not open for approximately two weeks after the date of the May tournament that we studied. Therefore, under normal circumstances, tournament fishing in Minnesota would not interfere with largemouth bass spawning activity on Lake Minnetonka, but may overlap with the period when adult males are guarding fry.

Our results from largemouth bass in Lake Minnetonka indicated that tournament-caught fish displaced during late summer do not disperse well until the following spring, but fish displaced during the spring dispersed rapidly. These findings strongly suggest that fish dispersal and activity is associated with spawning and other reproductive behaviors. It is reasonable to suggest that there may be a critical time after spawning, but some time before September, after which dispersal of displaced fish will be delayed until the following spring. We are unable to temporally define that critical period more precisely based on the results of this study — further study would be required.

## Habitat Use

Radio-tagged largemouth bass were always found in the relatively shallow littoral zone of the lake, usually associated with aquatic macrophytes, and were never located in the deep open-water limnetic zone. Such habitat requirements may be an important influence on fish dispersal. Fish were most frequently located over bottom materials composed of fine particles (silt or clay 52% of locations; sand 39% of locations), but were occasionally located over rock substrates (9% of locations). Average habitat measurements were 3.26 m depth, 14.62˚C water temperature (mid-column), and 9.84 mg/L dissolved oxygen concentration (mid-column). Fish occupied areas 1.0–5.5 m deep most frequently (86% of locations), and habitat use was evenly distributed among that range of depth. Fish most frequently occupied habits with mid-water-column dissolved oxygen concentrations of 9.0–9.9 mg/L with lower frequencies of use above or below this modal range.

Largemouth bass habitat use varied widely among individuals and seasonally. Depths at fish locations during the period shortly after ice break-up in the spring were markedly lower than depth of habitat used the remainder of the year. Depths were lowest (mean = 1.3 m) during the second week in May, a period when largemouth bass were observed spawning in Lake Minnetonka. Depths gradually increased during the remainder of the reproductive season (through June). Variation among individuals in water temperature at locations was minimal, and the trend over time is probably more indicative of seasonal changes in water temperature of the lake as a whole rather than habitat selection by fish. Dissolved oxygen concentrations at fish locations varied among individuals and over time, and the lowest concentrations were observed during late summer (August and September).

Largemouth bass were associated with aquatic or semiaquatic plants at 90.7% of locations measured. Submersed macrophytes were present at 86.2% of locations, and emersed plants were found at 5.6% of locations. Associated plants included 27 taxa. Watermilfoil (*Myriophyllum* spp.) was the dominant plant taxon present at 59% of fish locations, followed by coontail (*Ceratophyllum demersum*), which was dominant at 22% of locations. Eurasian watermilfoil (*Myriophyllum spicatum*) was discovered in Lake Minnetonka in 1986, and this introduced species has since reached nuisance-level proportions. Eurasian watermilfoil coexists with the native northern watermilfoil (*Myriophyllum exalbescens*) in Lake Minnetonka, but Eurasian watermilfoil is clearly dominant in biomass over all other plant taxa in that lake. We did not distinguish between Eurasian watermilfoil and northern watermilfoil in collection of plant association data, and both plant species were found at fish locations. The high frequency with which largemouth bass were found associated with watermilfoil in our study should not be misinterpreted as an indication of preference for that plant taxon over other taxa as cover by largemouth bass. The close association between largemouth bass and watermilfoil that we observed is more likely owing to the widespread distribution of the plant group throughout Lake Minnetonka, and plant species may actually be used by largemouth bass for cover in proportion to their occurrence. Because no quantitative surveys of the aquatic plants of Lake Minnetonka were conducted concurrent with our study, we are unable to quantify suitability or preference of plant taxa for cover use by largemouth bass.

A.6. Benefits: Results will reveal if displacement of tournament-caught fish is a potential problem associated with tournament angling and will provide information on behavior, movement, and dispersal rate.

**B. Survival and Population Characteristics**

B.1. Narrative: Determine the short-term post-release survival of tournament-caught fish and describe the population structure of largemouth bass in Lake Minnetonka. Population parameters will include age, size, and growth characteristics.

B.2. Procedures: Mortality at weigh-in will be recorded for all tournament-caught fish, and a subsample of fish will be held in submersed on-site holding pens for 3 days to determine post-release delayed mortality. A subsample of anglers will be interviewed regarding their fish holding techniques, and several water quality parameters will be measured in boat livewells. Length and weight will be recorded from bass and scales will be removed to estimate age. These population characteristics will be compared to similar data from the early 1980's to assess changes in population structure which will be related to previous population estimates.

B.3. Budget:

| | LCMR Funds | Matching Funds |
|---|---|---|
| a. Amount budgeted: | $12,000 | $0 |
| b. Balance: | $0 | $0 |

B.4. Timeline for Products/Tasks

| | July 91 | Jan. 92 | June 92 | Jan. 93 | June 93 |
|---|---|---|---|---|---|
| Collect data | ************************************** | | | | |
| Analyze data | ****************************************** | | | | |
| Final report | | | | ***************** | |

B.5. Status:

B.5.1. Completed Procedures

Fish mortality at weigh-in was determined independently by a biologist and tournament officials at both tournaments. Fish were considered dead if no opercular movement was observed. We also recorded the number of fish at weigh-in that were considered weak and not likely to survive — fish that were appeared inordinately stressed and would probably die soon, but for which opercular movement was observed. This group included fish that showed only intermittent opercular movement or had obvious physical injuries. A subsample of 296 largemouth bass (150 from day-1 fishing, 146 from day-2) was held in on-site holding cages (described above) for three days following their catch in the first tournament. A sample of 200 fish was held for three days following the second tournament. The holding cages were checked by SCUBA divers to assure that no extraneous factors influenced fish mortality.

Total lengths, weights, and a sample of scales (for age determination) of tournament-caught fish were collected on the first day of the first tournament; only total lengths were measured on the second day. Total length was measured for all fish caught in the second tournament, and weights and scales were collected from a subsample of those fish. Subsamples of 36 and 33 anglers were interviewed on the first and second days of the first contest, respectively, and 64 anglers were interviewed during the second tournament. A series of questions were asked regarding livewell capacity, conditions, and fish density. Water temperature, dissolved oxygen, pH, conductivity, and total ammonia were measured in the livewells of these subsamples of anglers.

Concentration of the more toxic unionized form of ammonia was calculated from equilibrium equations, which incorporate the effects of pH and temperature. Data collected from livewells was related to weigh-in mortality associated with the second tournament. It was possible to link livewell and interview data to mortality data by collecting anglers' names concurrently with data during the second contest.

B.5.2. Results and Discussion

Tournament Catch and Population Characteristics

The angler catch during the first tournament was 469 fish (403 kg) for the first day of fishing and 451 fish (411 kg) on the second day, yielding a total catch of 920 fish (including 23 smallmouth bass, *Micropterus dolomieu*) weighing 814 kg. Catch rate during the second tournament was much higher than that of the 1991 contest. Anglers caught 870 largemouth bass weighing a total of 847 kg during the second tournament in only one day of fishing. Tournament rules excluded smallmouth bass from the creel of the second tournament. The greater catch rate of the second tournament is likely due to seasonal differences related to fish behavior (spawning activity). Average fish size was also greater during the second tournament.

The average size of fish caught during the first tournament (376 mm total length) was slightly higher than mean lengths of fish caught in tournaments that took place in 1981–1983 (350–368 mm) and equivalent to mean lengths obtained by electrofishing during the same years (360–375 mm). Mean length of bass caught in the second tournament (396 mm) was higher than that of the first tournament or of fish collected by electrofishing or tournaments during 1981–1983. Maximum fish lengths of catch from both the first (557 mm) and second (550 mm) tournaments were greater than the maximum of fish collected during 1981–1983 (536 mm).

Length-frequency histograms of the catch from both tournaments showed continuous size distributions of fish except at the upper extremes. The modal length range of fish from day 1 of the first tournament was 320–369 mm; 350–360 mm for day 2 of the first tournament; and 350–399 mm for the second tournament. These modes in the length distribution are similar to those obtained during 1981–1983.

The length–weight relationship of largemouth bass collected in tournaments conformed well to a least-squares logarithmic regression function with few outliers ($P < 0.0001$). The equations describing the relationship were similar in both slope and intercept between the two tournaments. Slopes from the length–weight relationships of largemouth bass in our study were equivalent at 3.30 and 3.31. Most slopes for similar relationships determined in other studies fall within a range of 2.7–3.3. The slopes in our study lie on the upper end of the range found in other studies, supporting an observed trend that weight to length ratios tend to be higher for largemouth bass populations in the northern portions of its range, compared to those in southern portions.

Results of age determinations using largemouth bass scales collected from fish caught in the two tournaments that we studied indicated considerable overlap in fish size among age groups. Relationships between fish size (length and weight) and age that we determined for Lake Minnetonka largemouth bass were similar to those reported from other populations in the northern portion of that species' distribution. Fish over age 10 were relatively common in our study and one fish's age was estimated at 14 years. The longevity of largemouth bass that we encountered for Lake Minnetonka fish is in accord with the trend noted by others that northern largemouth bass are longer lived than southern fish, which rarely live beyond 5 years. Our results revealed that Lake Minnetonka largemouth bass growth over the winter of 1991–1992 was minimal in some age groups, and other age groups lost weight over winter. The lack of winter growth in Lake Minnetonka is an expected finding, because largemouth bass cease growing at water temperatures below 10˚C, and temperatures recorded at fish locations in our study were well below the 10˚C threshold for nearly the entire interval between the two tournaments.

Age determinations indicated that the catch of the two tournaments that we studied was dominated by fish of age 6–8 in late summer and age 7–9 in spring, corresponding to the 1983–1985 year classes. Specific age–size relationships of largemouth bass from Lake Minnetonka were not reported for 1981–1983, but a dominant 1977 year class of fish (age 4–6 during 1981–1983) was present in that study. Age-class dominance is a common phenomenon in largemouth bass, that has been attributed to variable survival of young during the first few weeks of life related to environmental temperature and wind action during that critical period.

It was beyond the scope of this study to validate the aging technique using scales for largemouth bass in Lake Minnetonka. Thus, the age determinations that we present should be considered tentative and may only be approximate. Accuracy and precision of those results may be variable, especially in the oldest age groups, and we advise caution in interpretation.

Tournament Mortality

Mortality at weigh-in during the first contest was low, with 7 (1.5%) and 1 (0.2%) dead fish on the first and second days, respectively (Table 1). Total weigh-in mortality was therefore 8 fish (0.9%). After being held for 3 days, 3 fish (2.0%) from the first day died and another 2 (1.3%) had lost equilibrium, showed only intermittent opercular movement, and would likely die shortly thereafter. Three fish (2.1%) held from the second day had died. Three-day delayed mortality from both days combined was thus 8 fish (2.7%), including the 2 fish too weak to release. Fourteen fish (1.5%) were judged at weigh-in to be weak and not likely to survive. Mortality (both weigh-in and delayed) associated with the second tournament was similarly low, but higher (approximately double), compared to that of the first tournament. Weigh-in mortality was 17 dead fish (2.0%), and 3-day delayed mortality was 8 dead of 200 retained fish (4.0%). At weigh-in, another 27 fish (3.1%) were considered weak and not likely to survive. Delayed mortality of both tournaments was over twice as high as that recorded at weigh-in.

Table 1. Mortality associated with two bass tournaments held on Lake Minnetonka. Data are number of dead fish and percent mortality.

| Measure | 2-day Sept. 1991 tournament | | | |
|---|---|---|---|---|
| | Sept. 6 | Sept. 7 | Total | May 16, 1992 |
| Weigh-in mortality | 7 (1.49%) | 1 (0.22%) | 8 (0.87%) | 17 (1.95%) |
| Weak at weigh-in[1] | 10 (2.13%) | 4 (0.89%) | 14 (1.52%) | 27 (3.10%) |
| 3-day delayed mortality | 5[2] (3.33%) | 3 (2.05%) | 8 (2.70%) | 8 (4.00%) |
| Estimated total mortality[3] | 22 (4.77%) | 10 (2.27%) | 33 (3.55%) | 51 (5.87%) |

[1] Not included in mortality estimates.

[2] Includes two fish that lost equilibrium and showed only intermittent opercular movement.

[3] Total mort. (percent) calculated as: Weigh-in mort. + [3-day delayed mort. x (100 – weigh-in mort.)]. Total mort. (number) calculated as: (Total catch x percent total mort.) ÷ 100.

A previous investigator estimated the number of largemouth bass over 305 mm total length in Lake Minnetonka to range from 21,000 to 29,000 fish during 1981–1983, using a mark-recapture method. He also estimated an average total instantaneous mortality rate (Z) of 0.69 and a natural instantaneous mortality rate (M) of 0.27 for fish over 305 mm. Converting those average instantaneous rates to annual rates, total annual mortality was 0.50 (50%), and natural annual mortality was 0.24 (24%). Thus, annual angling mortality would be 0.26 (26%). Assuming a relatively stable population over time and an average abundance of largemouth bass over 305 mm to be 25,000 fish, an estimated 12,500 fish die in a typical year, with 6,000 deaths due to natural causes and 6,500 attributable to angling.

During the 1992 fishing season, 11 bass tournaments took place on Lake Minnetonka that were permitted by the MN DNR (MN DNR unpublished data). The reported total cumulative catch of bass in those 11 tournaments was 5,135 fish. Applying an average total tournament mortality rate (including weigh-in and delayed) of 4.71%, that we determined from the two tournaments studied in 1991 and 1992, to the annual catch in tournaments (5,135 fish), yields an estimated annual tournament mortality of 242 fish for Lake Minnetonka during the 1992 season. The estimated proportion of the total annual angling mortality that occurred during 1992 permitted tournaments for largemouth bass over 305 mm in Lake Minnetonka amounts to 3.72%. These empirical estimates should be considered approximations, and the estimates of tournament-related mortality that we present do not include estimates from the many smaller contests that do not require state permits, but are known to occur on Lake Minnetonka each season. Nonetheless, the proportion of total angling mortality due to tournament fishing is clearly small.

Potential Influences on Mortality

Mean number (and range) of fish in livewells examined during the first tournament was 3.9 (1-9), and mean well capacity was 59.4 L (15.7 gal) and ranged 18.9-189.2 L (5-50 gal). Most anglers had livewells located in the stern of the boat (65%) with freshwater input (84%), a concentrated water stream aeration system (67%), no cooling system or insulation (52%), and used no chemical additives (88%). Means (and ranges) for water quality variables measured in livewells were 23.2°C (22.0-25.6°C) water temperature, 5.7 mg/L (1.4-7.7 mg/L) dissolved oxygen, 7.4 (6.9-8.1) pH, 475 µS/cm (400-625 µS/cm) conductivity, 1.0 mg/L (0.2-12.7 mg/L) total ammonia as nitrogen, and 0.010 mg/L (0.003-0.049 mg/L) unionized ammonia as nitrogen ($NH_3$). Temperature in Lake Minnetonka at the weigh-in site during the first tournament was equivalent (23.0°C) to the mean of that found in livewells; dissolved oxygen was higher (8.5 mg/L); pH was slightly higher (7.6); conductivity was lower (450 µS/cm); and total and unionized ammonia were lower (0.3 mg/L and 0.006 mg/L, respectively).

Mean number (and range) of fish in livewells examined during the second tournament was 6.6 (2-12), and mean well capacity was 80.5 L (21.3 gal) and ranged 15.1-151.4 L (4-40 gal). Most anglers had livewells located in the stern of the boat (70%) with freshwater input (69%), a concentrated water stream aeration system (70%), no cooling system or insulation (75%), and used no chemical additives (94%). Means (and ranges) for water quality variables measured in livewells were 17.0°C (14.0-19.6°C) water temperature, 6.6 mg/L (1.9-13.6 mg/L) dissolved oxygen, 8.0 (7.1-9.2) pH, 460 µS/cm (400-540 µS/cm) conductivity, 0.6 mg/L (0.2-2.6 mg/L) total ammonia as nitrogen, and 0.029 mg/L (0.001-0.160 mg/L) unionized ammonia as nitrogen ($NH_3$). Temperature in Lake Minnetonka at the weigh-in site on the day of the second tournament was lower (15.0°C) than the mean of that found in livewells; dissolved oxygen was higher (9.9 mg/L); pH was slightly lower (7.8); conductivity was lower (440 µS/cm); and total and unionized ammonia were lower (0.2 mg/L and 0.002 mg/L, respectively).

Mortality of tournament-caught fish in this study may not be attributable to any single water quality variable from livewells. Water temperatures in livewells were well below the range of thermal tolerances for adult largemouth bass that range from 28.9°C to 38.9°C (upper incipient lethal limits determined in other studies). Dissolved oxygen concentrations below or approaching 1.0 mg/L are frequently lethal to largemouth bass, but only the lowest extreme found in livewells (1.4 mg/L) approached lethal concentration. Largemouth bass are known to have survived acidic waters with pH as low as 3.9, but generally this species is not found in waters below pH 4.7. These critical pH values are much lower than any encountered in livewells in our study. However, the toxicity of many substances is affected by pH; consequently, it is difficult to identify the direct effects of pH on fish. For example, ammonia toxicity increases with increasing pH, but low pH can indicate high carbon dioxide concentrations, which reduce the oxygen carrying capacity of fish's blood regardless of ambient oxygen concentrations. Unionized ammonia (toxic form) concentrations from livewells were also well below the range of tolerance limits determined for largemouth bass in laboratory studies (0.7–1.2 mg/L).

Even though our water quality investigations revealed no obvious single acute stressor to fish that may have directly caused mortality, fish physiologists agree that the cumulative effects of sublethal stress factors may eventually lead to death, even if the individual factors do not exceed physiological tolerance limits. Although the scales of measured water quality variables may not be directly comparable, the general trends and magnitude of comparisons between livewell water and water found in Lake Minnetonka may add insight into the relative influences of variables on fish in livewells. Relative differences in ammonia concentration (both total and unionized form) were substantially greater than for any measured variable, suggesting that stress related to ammonia toxicity may be an important contributing factor to cumulative stress and mortality during tournaments.

Correlation analyses between continous-scale variables (water quality variables, fish density in livewells, and livewell capacity) and the number of dead or weak fish in livewells of the second tournament revealed one significant finding. The number of dead or weak fish in livewells was positively correlated with pH of livewell water ($P = 0.029$). Interpretation of this result is difficult and complicated by interactions with other factors as discussed above. If the correlation between pH and dead or weak fish indicates a cause and effect relationship, it is more likely related to carbon dioxide concentrations and respiration or interactive effects of other substances, than directly to pH toxicity. No significant effect of categorical variables including livewell location on boat, use of chemical additives, or livewell circulation, aeration, or cooling system on the number of dead or weak fish was detected (one-way analysis of variance, $P > 0.05$).

B.6. Benefits: Results will quantify tournament mortality and provide a basis for comparisons with other tournaments and guidelines. Recent changes in largemouth bass population structure will be defined.

## C. Summary of Impacts and Recommendations.

### C.1 Summary of Impacts

1. Our results from studying largemouth bass in Lake Minnetonka indicated that tournament-caught fish displaced during late summer did not disperse well until the following spring, but fish displaced during the spring dispersed rapidly. These findings strongly suggest that fish dispersal and activity is associated with spawning and other reproductive behaviors.

2. Most displaced fish did not return to their capture site, and reproductive activity was interrupted by displacement that occurred during the spawning season. The extent of this impact on reproduction and recruitment at the population level is beyond the scope of this study and would require further research.

3. Fish were always found in the relatively shallow littoral zone of the lake, usually over fine-particle substrates and associated with aquatic macrophytes; fish were never located in the deep open-water limnetic zone. Such habitat requirements may be an important influence on fish dispersal patterns and rate.

4. Total mortality associated with the two tournaments studied was low, averaging 4.71% of the catch. Mortality associated with the spring tournament was approximately double that of the late-summer tournament, and delayed mortality was over twice as high as that recorded at weigh-in of both tournaments. Estimated annual mortality associated with state permitted tournaments was 3.72% of estimated annual total angling mortality of largemouth bass on Lake Minnetonka.

5. Analysis of fish holding techniques and livewell water quality identified no single cause for fish mortality. Changes in livewell water relative to lake water were greatest for ammonia concentration, but the number of dead or weak fish in a livewell was positively correlated with pH of livewell water. Fish mortality associated with tournaments is most likely due to cumulative effects of sublethal stressors of water quality and handling, as well as physical injuries related to angling.

### C.2 Recommendations

We propose the following recommendations to mitigate biological and behavioral impacts associated with fishing tournaments. These recommendations are based on our observations, results of this study, and current knowledge of the subject. They were specifically developed for Minnesota waters, but may apply to other north-central states with some application to fishing tournaments in general.

1. Continue point incentives for live-release tournaments.

Although many tournament anglers and promoters exhibit a conservation ethic toward fisheries resources, penalties for weighing in dead fish at tournaments appears to be strong incentive for minimizing mortality.

2. Continue minimum-impact weigh-in procedures.

We observed organized procedures at weigh-in which minimized the impact on fish. These included conducting weigh-in activities in a shaded area, concluding the contest in shifts so that smaller groups of anglers arrive at any one time, providing large tanks available as holding stations before and after weighing, and operating the weigh-in in a timely, organized manner.

3. Change or dilute livewell water frequently.

Livewell water should be changed or diluted with lake water as frequently as possible throughout the fishing day to maintain favorable water quality. Aeration systems or chemical additives should not be relied upon solely to maintain suitable environmental conditions in livewells.

4. Rotate use of weigh-in sites.

On lakes where more than one tournament takes place within a fishing season, different weigh-in sites should be selected and used to minimize the unnaturally high concentrations of displaced fish that will result, particularly late in the season. In large lakes with disjunct areas of suitable littoral habitat for bass, tournament-caught fish may be dispersed by boat provided that adequate transporting facilities are available. In lakes with abundant and continuous littoral zones, dispersal by boat is not recommended to avoid stress related to additional handling and transport.

5. Do not conduct traditional tournaments during spawning.

Until impacts at the population level can be assessed, tournaments should not take place during the spawning season, because reproduction is interrupted by displacement. Additional research may reveal that the impact to the population is negligible, or tournaments with immediate release of each fish at its catch site may mitigate the impact. However, until further study suggests otherwise, tournaments during the spawning season should be avoided.

It is our intention that the results of this study and the recommendations that we offer will improve tournament guidelines and fisheries management to contribute to the common goals of anglers, fisheries managers, and the public — understanding, conservation, and wise use of the fisheries resources.

IV. Evaluation: For the FY 92-93 the program can be evaluated by :

1) Analyzing and summarizing the population characteristics of the Lake Minnetonka largemouth bass population and comparing the present structure to that of recent years; and
2) documenting tournament mortality and dispersal patterns of tournament-displaced fish with conclusions concerning statewide implications for tournament operations.

V. Context:

A. Tournament-related mortality and dispersal of caught fish and their impact on fish near the weigh-in sites has not been documented thoroughly in Minnesota. Educated mitigation measures and guideline procedures for tournaments cannot be established with the presently available information.

B. The information that will be obtained from this study will provide a foundation for implementation of informed mitigation procedures and guideline improvements to assure maximum survival and the sustainability and wise use of the fisheries resource. Fisheries management in Minnesota is undergoing a change in philosophy in response to increases in fishing intensity. Incorporating a balance of goals to provide anglers optimum recreational opportunity, yet maintain the integrity and sustainability of the resource is an immediate challenge. An observed and continuing change in angler ethics that includes catch-and-release fishing is paramount to achieving management goals. Fishing tournaments serve as ideal environmental laboratories and have been the proving grounds for some types of catch-and-release practices. This study will be a unique opportunity to gain some solid knowledge of catch-and-release impacts so that a factual basis for the future direction of tournament fishing can be established.

C. The effects of tournaments on Minnesota fish populations have gone largely unevaluated. In the past two years, live release following professional walleye tournaments in Minnesota has been evaluated without LCMR funding. Future LCMR funding could be used to examine the impact of recreational (non-tournament) catch-and-release angling.

D. Not applicable.

E. APID 316027513 AID 329821.

VI. Qualifications

1. Program Manager: Tim Goeman
Senior Fisheries Research Biologist
Section of Fisheries, Minnesota Dept. of Natural Resources
M.S. Fisheries, University of Wisconsin, 1981

The program manager has conducted pioneering research in survival of tournament-caught walleye in Minnesota, and results of his study have been accepted for publication in the North American Journal of Fisheries Management. In addition, he has collected and analyzed data from many bass tournaments and is presently conducting a radio telemetry study of muskellunge. The primary role of the program manager was coordination of the work described under the objectives.

2. Major Cooperators:

| | |
|---|---|
| Dr. Mary Henry<br>Leader, Minnesota Fish and Wildlife Cooperative Research Unit<br>University of Minnesota | Dr. Tom Kwak<br>Research Fellow<br>Department of Fisheries and Wildlife<br>University of Minnesota |
| Ph.D., Iowa State University<br>Department of Animal Ecology, 1984 | Ph.D., University of Minnesota<br>Department of Fisheries and Wildlife, 1993 |

The project was conducted by faculty, staff, and students of the Minnesota Cooperative Fish and Wildlife Research Unit, directed by Dr. Henry. She has published extensively on fish behavior, biological impacts of human disturbance on fish communities, and trophic relations in aquatic systems. She has employment experience as a fisheries project leader, Section Chief with the National Fisheries Research Center, Fisheries Biologist, and university instructor. Dr. Kwak has a great deal of experience in fisheries field techniques, including radio telemetry. He has conducted research for 5 years at the Illinois Natural History Survey and has published on fish ecology and behavior. The primary role of the Minnesota Cooperative Unit was to specifically plan, conduct the study, and report results.

The Minnesota Sportfishing Congress

VII. Reporting Requirements

Semiannual status reports were submitted not later than January 1 1992, July 1 1992, January 1 1993, and a final status report by June 30 1993.

**1991 RESEARCH PROJECT ABSTRACT**
FOR THE PERIOD ENDING JUNE 30, 1993

This project was supported by the MN Future Resources Fund

| | |
|---|---|
| **TITLE:** | Lake Minnetonka Bass Tracking |
| **PROGRAM MANAGER:** | Tim Goeman |
| **ORGANIZATION:** | MN Department of Natural Resources |
| **LEGAL CITATION:** | M.L. 91 Chap. 254 Art. I Sec. 14 Subd. 8 (f) |
| **APPROP. AMOUNT:** | $85,000 |

## STATEMENT OF OBJECTIVES

The goal of this research was to assess the biological and behavioral impacts of fishing tournaments on largemouth bass. Our primary objective was to determine the dispersal rate and patterns of largemouth bass that were caught and displaced during fishing tournaments on Lake Minnetonka, Minnesota. Radio telemetry techniques were employed to meet this objective. Secondary objectives were to quantify fish mortality (both at weigh-in and post-release) associated with live-release bass fishing tournaments and to identify potential influences on mortality.

## RESULTS

Tournament-caught largemouth bass displaced during late summer did not disperse well until the following spring, but fish displaced during the spring dispersed rapidly, suggesting that fish dispersal is associated with reproductive behavior. Most displaced fish did not return to their capture site, and reproductive activity was interrupted by displacement that occurred during the spawning season. Fish were always found in the littoral zone of the lake, usually over fine-particle substrates and associated with aquatic macrophytes. Total mortality associated with two tournaments studied averaged 4.71% of the catch. Mortality associated with a spring tournament was approximately double that of a late-summer tournament, and 3-day delayed mortality was over twice as high as that recorded at weigh-in of both tournaments. Estimated annual mortality associated with state permitted tournaments was 3.72% of the estimated annual total angling mortality of largemouth bass on Lake Minnetonka. Analysis of fish holding techniques and livewell water quality identified no single cause for fish mortality. Changes in livewell water relative to lake water were greatest for ammonia concentration, but the number of dead or weak fish in a livewell was positively correlated with pH of livewell water. Fish mortality associated with tournaments is most likely due to cumulative effects of sublethal stressors of water quality and handling, as well as physical injuries related to angling. We recommend (1) continuing point incentives for live-release tournaments, (2) continuing minimum-impact weigh-in procedures, (3) changing or diluting livewell water frequently during tournaments, (4) rotating use of weigh-in sites on lakes for multiple tournaments within a season, and (5) traditional tournaments be avoided during the spawning season.

## PROJECT RESULTS USE AND DISSEMINATION

The results and recommendations of this study may be used to improve tournament guidelines and fisheries management of Minnesota waters. Dr. Tom Kwak and Dr. Mary Henry presented preliminary results at the joint meeting of the Minnesota and North Dakota Chapters of the Wildlife Society (February 1992, Fargo, ND) and final results at the annual meeting of the Minnesota Chapter of the American Fisheries Society (January 1993, Brainerd, MN) and at a seminar at the Minnesota Department of Natural Resources (January 1993, St. Paul, MN). In addition, Dr. Kwak has presented results to the membership of the Minnesota Bass Federation and Minnesota Sportfishing Congress on two occasions at their annual conventions (April 1992, St. Paul, MN and April 1993, New Ulm, MN) and to academic colleagues at the Illinois Natural History Survey (April 1992, Champaign, IL) and San Diego State University (February 1993, San Diego, CA). Publication of results in addition to the final report to the MN State Legislature (see legal citation above) will follow.

July 1, 1993

LCMR Final Status Report – Detailed for Peer Review – Research
LCMR Work Program 1991

I. **Lake Minnetonka Bass Tracking**

Program Manager: Tim Goeman
Fisheries Research
Minnesota Department of Natural Resources
1601 Minnesota Drive
Brainerd, MN 56401
218/828-2246

A. M.L. 91 Chap. 254 Art. I Sec. 14 Subd. 8 (f) Appropriation: $85,000
Balance: $0

This appropriation is to the Commissioner of Natural Resources to study the impacts of bass fishing contests. The study must be done in cooperation with the Minnesota Sportfishing Congress and other interested groups.

B. Compatible Data: During the biennium ending June 30, 1993, the data collected by projects funded under this section that have common value for natural resource planning and management must conform to information architecture as defined in guidelines and standards adopted by the Information Policy Office. In addition, the data must be provided to and integrated with the Minnesota Land Management Information Center's geographic data bases with the integration costs borne by the activity receiving funding under this section.

C. Match Requirement: $0

II. Narrative

Background and Importance

Tournament fishing is becoming increasingly popular in Minnesota with largemouth bass (*Micropterus salmoides*) as the most popular tournament species. Greater numbers of tournaments are taking place on a finite number of Minnesota waters. The number of tournaments permitted by the Minnesota Department of Natural Resources (MN DNR) has increased from 116 in 1986 to 215 in 1992 (Figure 1, MN DNR unpublished data). Similar increases in fishing tournaments and their popularity have been reported in other states as well (Shupp 1979).



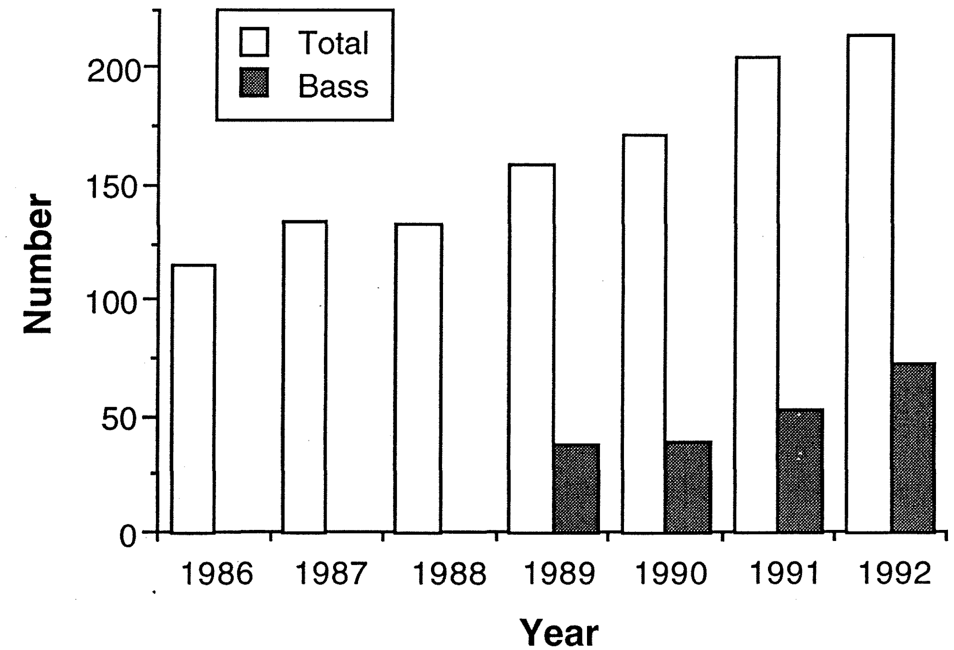


Figure 1. Number of fishing tournaments (multiple species and bass) permitted by the MN DNR according to year (MN DNR unpublished data).

While many tournaments take place in Minnesota each year, a large proportion of them are held on a few popular lakes. In 1981 and 1982, 44 and 38%, respectively, of Minnesota bass tournaments were held on only six lakes (MN DNR, unpublished data). More bass tournaments are held each year on Lake Minnetonka than any other lake in Minnesota. Lake Minnetonka is a 5,900-hectare lake located in east-central Minnesota with an irregular shape made up of 15 basins. The popularity of this lake is presumably due to the abundance of quality habitat that supports a healthy largemouth bass population within close proximity to the Minneapolis-St. Paul metropolitan area. Eight permitted bass tournaments were held on Lake Minnetonka in 1990, and the MN DNR has compiled results of five of these eight contests. The five tournaments were conducted on various dates from May 27 to August 29. Anglers fished a total of 8,392 hours during those five tournaments and produced 3,238 bass weighing a total of 6,359 pounds at official weigh-in sites. Although advances in sportfishing technology and equipment continue to evolve, the efficiency of tournament anglers appears relatively stable over the last decade. The 1990 tournament catch rate of 0.39 bass per hour and a 910-g (2-lb) average size is equivalent to corresponding data for 1982 and 1983.

Bass tournaments are generally well organized, and contestants are required to follow a set of rules that is strictly enforced by tournament officials. Emphasis is placed on conservation and minimizing fish mortality by maintaining the fish in boat livewells until they can be weighed and released at official weigh-in sites. Anglers are awarded an additional incentive of bonus points for live fish. Regardless of measures taken to avoid fish mortality in tournaments, a small proportion do not survive. The MN DNR monitored 31 major bass tournaments from 1981 to 1983 and found that 4% of fish at weigh-in were either dead or too weak to release. Fish mortality at weigh-in sites is easily measured and well documented, but data on post-release survival are more difficult to attain and hence is largely unknown for largemouth bass in northern latitudes. Delayed post-release mortality may substantially add to the total tournament-related mortality, as indicated by a study of walleye tournaments in Minnesota, where Goeman (1991) found ranges of 1.0% to 6.2% and 5.7 to 47.1% weigh-in and post-release mortality, respectively.

In addition to lethal effects, impacts on fish behavior are also associated with tournament angling. Tournament-caught bass are frequently transported substantial distances to a weigh-in site for processing and subsequent release. Weighed fish are usually all released at the weigh-in site, creating an artificially high density of fish in a small area. Fish tagging studies have yielded rather anecdotal findings on the dispersal patterns of tournament-caught displaced largemouth bass. Lantz and Carver (1975) recaptured 94% of tagged and recaptured tournament-caught bass within 3 km of the release site with most of these recaptures occurring within one month of the tournament. Similarly, Blake (1981) found 44% and 52% of tagged tournament-caught bass within 1.5 km of the release site for up to 50 days after release.

Tagging studies may provide some useful information on movement and distribution, but the results on fish behavior remain inconclusive. Largemouth bass are known to establish a home range and in some cases may display a homing ability, i.e., the ability to return to a home range following displacement (Hasler and Wisby 1958, Parker and Hasler 1959, Lewis and Flickinger 1967). Tagging studies, however, cannot adequately determine if displaced tournament-caught bass return to their home range. A tagging study on displaced tournament-caught largemouth bass in Lake Minnetonka showed that 23 of 28 (74%) of recaptured tagged bass failed to show a homing tendency (Ebbers 1987, MN DNR unpublished data). However, the time between release and recapture of these fish ranged from 7 to 274 days in this study, a fact which may limit conclusions.

The development of radio and ultrasonic telemetry equipment provided the technology needed to study movements, habitat use, home range and homing ability, and other behavior of fishes. Studies of displaced radio tagged largemouth bass have shown variable results. Mesing et al. (1981) found that all eight largemouth bass that were displaced up to 4.5 km from their home range returned to that area. Another study found only two of four largemouth bass returned to their site of capture (Peterson 1975). A largemouth bass that was transplanted from one lake to another did not establish a home range, while three other indigenous fish in the same lake did establish home ranges (Winter 1977). Although the results of these studies may be conflicting, they illustrate the usefulness of radio telemetry as a behavioral study technique.

Need For Study

It is clear that more information regarding the biological impacts of bass tournaments in Minnesota is needed. Mortality rates due to fishing are an integral component required to form a reasonable management plan. Tournament-related mortality both at weigh-in and post-release will be addressed to contribute information to lake managers and to determine this aspect of the impact of bass tournaments. Post-release delayed mortality will be ascertained by holding tournament-caught fish for a period after the tournament. Lake Minnetonka is typical of many of the larger Minnesota lakes where tournaments occur, in that, sites suitable for administration and weigh-in are scarce. Consequently, over the length of a multi-tournament fishing season, hundreds of fish may be released at one or two locations on a lake. The dispersal patterns of these displaced tournament-caught largemouth bass will be determined using radio telemetry. In addition, the behavior of resident fish in the area of a weigh-in site can be studied by the same techniques. Assessment of the success of tournament live release and the impacts associated with displacement of tournament-caught fish will provide an educated basis for operating tournaments to allow optimum use of the fishery resource statewide.

## III. Objectives

### A. **Dispersal of tournament-caught largemouth bass.**

A.1. Narrative

The extent and time required for dispersal of displaced tournament-caught largemouth bass will be determined using radio telemetry. This technique also allows the investigators to determine if released tournament-caught fish return to their home range by monitoring their activity and location after release at the weigh-in site. A reference group of tournament-caught bass will be subject to weigh-in procedures, implanted with transmitters, and returned to their site of capture. This second group may serve as a control to assess the effects of displacement only. By implanting transmitters in a third group of bass with home ranges near the weigh-in site prior to a tournament, the behavioral impact of tournaments on resident fish will also be assessed; these fish may also serve as a control group to be compared with displaced fish released in the same general location.

A.2. Procedures

Studies will be conducted on two tournaments which will take place on Lake Minnetonka, one in September 1991 and another in May 1992. Minnesota Bass Federation (MBF) representatives will select weigh-in sites that have not previously been used. In addition, MBF members will provide capture sites of fish when weigh-in occurs.

Radio transmitters, equipped with single-stage lightweight lithium or mercury batteries with a 6-month life, will be surgically implanted into fish prior to and following each tournament. Transmitters will operate on a low frequency 49 MHz and will emit a pulsed radio signal. A clear waterproof electrical resin will encapsulate each transmitter, and the stainless steel antenna cable will be coated with nylon. Transmitters will weigh less than 2% of the fish's body weight in air to avoid altering fish behavior.

One week prior to each tournament, up to 5 largemouth bass will be collected by angling near the future weigh-in site. Transmitters will be surgically implanted into these fish, and they will be released at the weigh-in site. These fish will be tracked daily for the week before the tournament. On the day of the tournament, transmitters will be implanted into 10 tournament-caught fish to be released at the weigh-in site after weigh-in procedures are completed. An additional 5 tournament-caught fish will be weighed in, implanted with transmitters, and released at their site of capture. This will yield a total of 20 radio-tagged fish for each tournament study.

Radio-tagged largemouth bass will be tracked daily for two weeks following each tournament and weekly thereafter as weather permits, for the duration of the battery life of each transmitter (approximately 6 months). A programmable receiver connected to either a ground-use loop antenna or a boat-mounted yagi antenna will be employed to determine fish locations by signal triangulation. Once a precise fish location is determined, the following physical data will be recorded: water temperature, air temperature, dissolved oxygen concentration, a secchi disc reading, habitat type, and weather conditions.

Data analysis will include mapping fish locations over time and determining dispersal rates and patterns. A comparison of displaced tournament-caught fish and those released at their capture site provide an assessment of the impacts of displacement. Differential behavior of resident fish in the area of a weigh-in site before and after the tournament will document the impact of tournament weigh-in on resident fish. Habitat use will be quantified, and seasonal comparisons will be made.

A.3. Budget:

| | LCMR Funds | Matching Funds |
|---|---|---|
| a. Amount budgeted: | $73,000 | $0 |
| b. Balance: | $0 | $0 |

A.4. Timeline for Products/Tasks

| | July 91 | Jan. 92 | June 92 | Jan. 93 | June 93 |
|---|---|---|---|---|---|
| Design program | **************** | | | | |
| Conduct study | ***************************************** | | | | |
| Analyze data | | ********************************* | | | |
| Final report | | | | ***************** | |

A.5. Status:

A.5.1. Study Area and Dates

This study was conducted on Lake Minnetonka, MN, a 5900-ha lake located in the western suburbs of Minneapolis (Figure 2). The first fishing tournament that we studied took place over two days on September 6-7, 1991. The Minnetonka Boat Works facility, on Browns Bay in the City of Orono, was selected as the weigh-in site for this tournament. The second tournament took place on May 16, 1992, and the Power Squadron Picnic Area on Big Island was used as the weigh-in site. Neither facility had previously been used for weigh-in activities.

A.5.2. Completed Procedures

Largemouth bass for radio telemetry studies were provided by anglers participating in both tournaments. Anglers also confidentially supplied the catch locations of selected fish. Two sizes of resin-coated radio transmitters with trailing antennas, which operate at a frequency of 49 MHz, were surgically implanted into fish. A total of 22 largemouth bass were radio tagged in association with the first tournament: 3 fish were collected by electrofishing near the weigh-in site prior to the tournament and were released at their capture site, 5 tournament-caught fish were released at their capture site, and 14 tournament-caught fish were released at the weigh-in site (Figure 2). Biologists tracked radio-tagged fish daily by boat, using a programmable receiver and loop antenna, for two weeks following the first tournament, but all fish were not located every day. Thereafter, fish were tracked weekly. After fish were located, the following ancillary information was collected at the site: location (UTM coordinates), air temperature and weather conditions, depth, secchi disk reading, profiles of water temperature and dissolved oxygen, bottom type, and associated plants. Transmitter pulse rate was timed at each fish location to estimate the temperature of the transmitter (and thus the fish). Because of ice formation on the lake, fish could not be tracked for an extended period of over two months beginning early November, 1991. Similarly, fish could not be tracked during March and early April, 1991, due to ice break-up. During ice break-up, batteries expired in transmitters that were powered by a smaller battery (2 fish). As of June 1, 1992, 8 transmitters in fish from the first tournament, powered by larger batteries, continued to operate. Those batteries failed shortly thereafter, and only sporadic tracking of fish from the first tournament was possible during June, 1992.

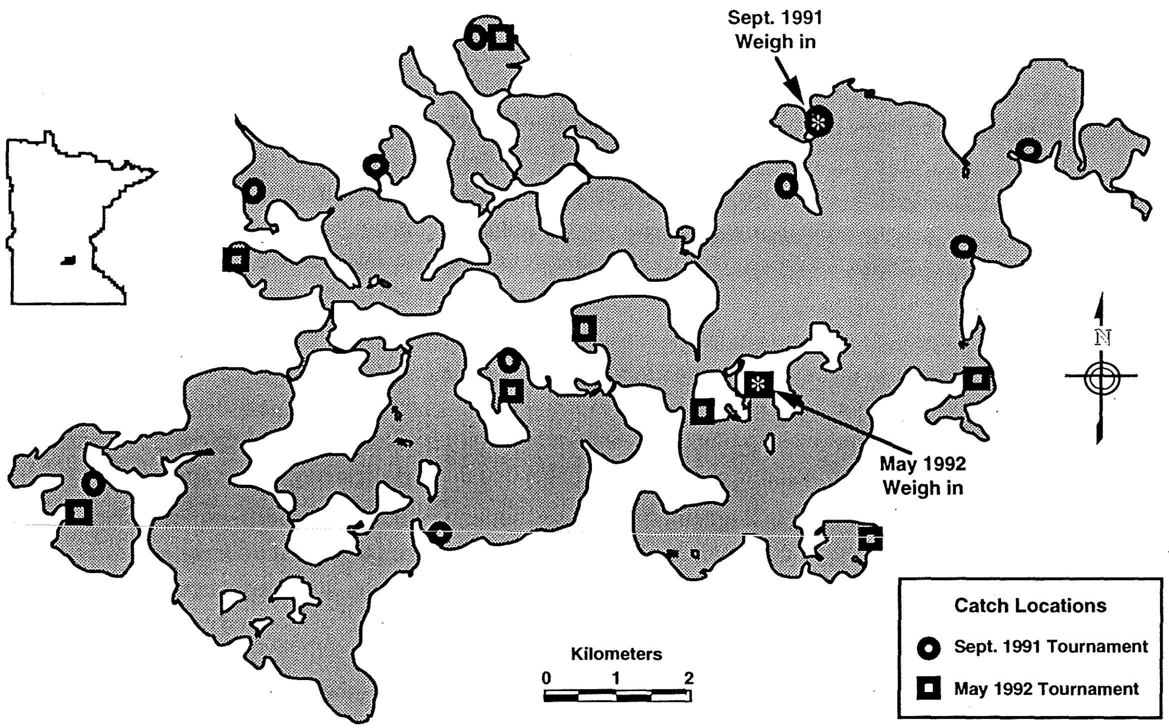


Figure 2. Map of Lake Minnetonka showing capture locations of radio-tagged, tournament-displaced largemouth bass that survived the entire study and weigh-in sites for two tournaments.

A total of 29 largemouth bass were radio tagged in studies of the second tournament. On May 7, 1992 (9 days prior to the second tournament), 10 largemouth bass were collected by electrofishing near the weigh-in site for the upcoming tournament. They were surgically implanted with radio transmitters, and then released at their sites of capture. On the day of the tournament, 14 tournament-caught fish were surgically implanted with transmitters and released at the weigh-in site (Figure 2). An additional 5 tournament-caught fish were fitted with experimental externally attached radio transmitters and were returned to their site of capture. The external transmitters were used with this group of fish (radio-tagged, tournament-caught fish released at capture sites) in an attempt to reduce surgery-related stress, because we observed high subsequent mortality with this group in studies following the first tournament (5 of 5 fish died, see below). Radio-tagged fish from the second tournament were tracked on a schedule similar to that described above for the first tournament with similar procedures. Fish from the second tournament were tracked through October, 1992.

A.5.3 Results and Discussion

Cooperation by Minnesota Bass Federation tournament officials and anglers was excellent. An ample number of fish with known capture locations was available for radio transmitter implanting during both tournaments. It was difficult, however, to attain resident largemouth bass from the Browns Bay area near the weigh-in site for implanting before the first tournament. Over 12 hours of electrofishing effort yielded only three largemouth bass large enough to be implanted with radio transmitters. Electrofishing was conducted both during light and dark hours on three occasions; Minnesota Department of Natural Resources biologists accompanied the investigators on two of these collections. In addition, approximately 20 members of the MBF volunteered to attempt to catch fish by hook and line to be used in telemetry studies before the tournament, but no sizable fish were collected. The difficulty in collecting sizable largemouth bass in the Browns Bay area in the fall was presumably due to the habitat in the immediate area and behavioral effects of weather conditions and season. Fish were more readily collected by electrofishing prior to the second tournament presumably because of site tenacity and habitat use associated with spawning during that collection.

Survival and Status of Radio-Tagged Fish

Radio transmitters were implanted into the body cavity of fish while they were anesthetized with benzocaine (88 mg/L), and all fish were in surgery for less than 16 minutes. Fish were held for at least 1 hour to assure an adequate recovery from surgery, and then were released. All fish radio tagged during the first tournament appeared healthy at the time of release. By October 1, 1991, 7 of those radio-tagged fish were known to have died. Five transmitters were recovered in dead fish. One transmitter was found under a bridge near a popular shoreline fishing area with no sign of a dead fish and was likely caught by an angler who then discarded the transmitter. Another transmitter (and presumably the fish) was ingested by a common snapping turtle; the turtle was captured, held, and eventually voided the transmitter. The observed initial mortality rate (31.8%) is higher than expected under normal study conditions and was probably due to cumulative stress effects. Whereas the stress involved with tournament angling (capture, transport, and weigh-in) or the surgical procedure for implanting transmitters may not, as single factors, cause high mortality, the combination of these two procedures and the associated cumulative stress effects likely led to the observed rate of mortality. Furthermore, the water temperatures following the first tournament were generally decreasing and thus did not create an optimal environment for incisions to heal and tissue damage related to surgery to repair.

On June 11, 1992, SCUBA divers recovered 3 transmitters from fish that were radio-tagged during the first tournament. The death of a fourth fish from that tournament was also confirmed, but the transmitter was not recovered. Two of these fish showed substantial winter movements, and thus behavioral data from these two fish, until ice break-up (through February 25, 1992), were included in analyses. Of the 22 radio-tagged fish from the first tournament, 12 survived until ice break-up (spring 1992), and 10 survived the period of the entire study.

As of June 1, 1992, 2 radio-tagged fish from the second tournament had died. These fish were tournament-caught and released at the weigh-in site. Of the 29 fish radio-tagged in association with the second tournament, 16 survived until ice formation (late October 1992), 6 died (21%), 2 were not tracked because of radio interference at the specific frequencies, and the status of 5 missing fish remained unknown at ice formation. Two possible explanations for missing fish are transmitter failure or unreported harvest by anglers. Anglers reported (by telephone) catching and releasing three radio-tagged fish during June and July, 1992. One additional radio-tagged fish was killed during a tournament in June, 1992, but that fish was not trackable due to radio interference. All behavioral data from missing fish were included in analyses until the time of their last known location.

The final survival status of radio-tagged fish at the termination of tracking for each tournament is summarized according to experimental group in Table 1. Mortality of radio-tagged, tournament-caught, displaced fish ("displaced" experimental group) was identical between the two tournaments (35.7%). Mortality of fish collected near the weigh-in site by electrofishing that were radio-tagged and released at their capture site ("resident" group) showed lower mortality (0 and 10%) — a finding that suggests collection by electrofishing induces less physiological stress on fish than does angling and subsequent activities associated with tournaments. The highest mortality of radio-tagged fish (100%) occurred in the group of tournament-caught fish in the first tournament that were surgically implanted with transmitters and then returned to their capture location ("returned" group). No fish of this group died associated with the second tournament, when transmitters were externally attached rather than surgically implanted. This result suggests that externally attached transmitters may reduce stress associated with radio tagging, but the signal from the smaller externally attached transmitters was much weaker, and those fish were difficult to locate. Until externally attached transmitters can be engineered to transmit a stronger signal without increasing size or weight, we suggest that surgical implantation remains the optimal method of radio tagging.

Table 1. Survival status of radio-tagged largemouth bass at the termination of tracking for each tournament.

| Experimental Group | Status: Survived | Dead | Missing | Radio interference | Total |
|---|---|---|---|---|---|
| **September 1991 Tournament** | | | | | |
| Displaced | 9 (64.3%)[1] | 5 (35.7%) | 0 | 0 | 14 (100%) |
| Resident | 3 (100.0%) | 0 | 0 | 0 | 3 (100%) |
| Returned | 0 | 5 (100%) | 0 | 0 | 5 (100%) |
| All Fish | 12 (54.5%) | 10 (45.5%) | 0 | 0 | 22 (100%) |
| **May 1992 Tournament** | | | | | |
| Displaced | 7 (50.0%) | 5 (35.7%) | 2 (14.3%) | 0 | 14 (100%) |
| Resident | 6 (60.0%) | 1 (10.0%) | 3 (30.0%) | 0 | 10 (100%) |
| Returned | 3 (60.0%) | 0 | 0 | 2 (40.0%) | 5 (100%) |
| All Fish | 16 (55.2%) | 6 (20.7%) | 5 (17.2%) | 2 (6.9%) | 29 (100%) |

[1] Includes two fish that died at least 6 months after tournament.

Dispersal of Radio-Tagged Fish

By October 8, 1991 (1 month after the first tournament), 4 of 9 (44%) of the surviving displaced tournament-caught fish that were released at the weigh-in site had dispersed beyond radio-signal range (approx. 0.75 km) from the release site (Figures 3 and 4). From that time until ice formation on the lake, the number of displaced fish within radio-signal range from the release site fluctuated between 4 and 6 (44% and 67%). These fish displayed three general behavior patterns after their release at the weigh-in site: 1) most fish appeared to have established home ranges near the release site in Browns Bay, 2) others moved relatively long distances without establishing an apparent home range, and 3) one fish appeared to have established a home range in an area over 5 km from the release site. After ice break-up on April 15, 1992, 3 of 6 (50%) surviving and trackable (extant battery power) displaced tournament-caught fish remained within radio-signal range from the release site, but by May 22, 1992, all displaced fish had dispersed beyond radio-signal range from the release site. This dispersal of the remaining displaced fish during spring was likely associated with reproduction.

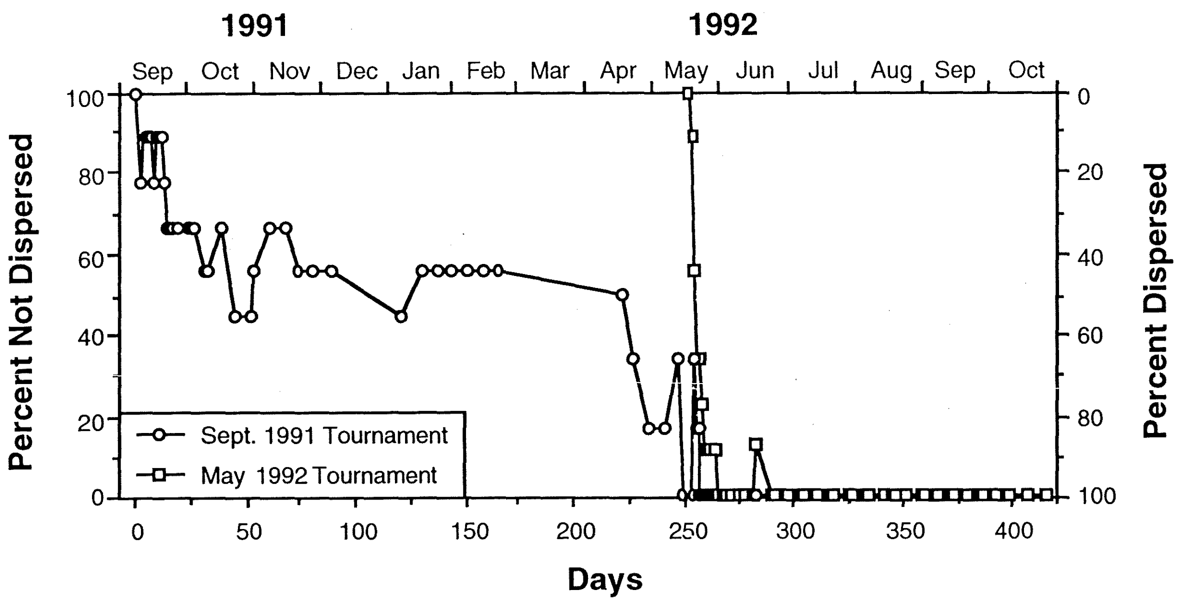


Figure 3. Plot of dispersal rate over time of displaced, tournament-caught largemouth bass for two tournaments.

The three resident fish of Browns Bay that were radio-tagged before the first tournament survived the entire study and remained in Browns Bay and maintained home ranges near their capture sites, but one resident fish was located beyond signal range (ca. 0.75 km) within Browns Bay on several dates during May–July, 1992 (Figure 4a). All five tournament-caught fish that were returned to their capture site during the first tournament died early in the study, and thus no behavior data were collected.

Largemouth bass that were collected by electrofishing near the weigh-in site before the second tournament, then radio tagged and released at their capture site (resident fish), dispersed from the weigh-in site at a slower rate than tournament-displaced fish released at the same location (Figure 4b). Resident fish had been radio tagged 9 days prior to the tournament, and by the tournament day (May 16, 1992), 2 of the 9 (22%) surviving resident fish had dispersed beyond radio-signal range from the weigh-in site. One week after the tournament (May 23), 5 of 9 (56%) resident fish had dispersed from the weigh-in site,



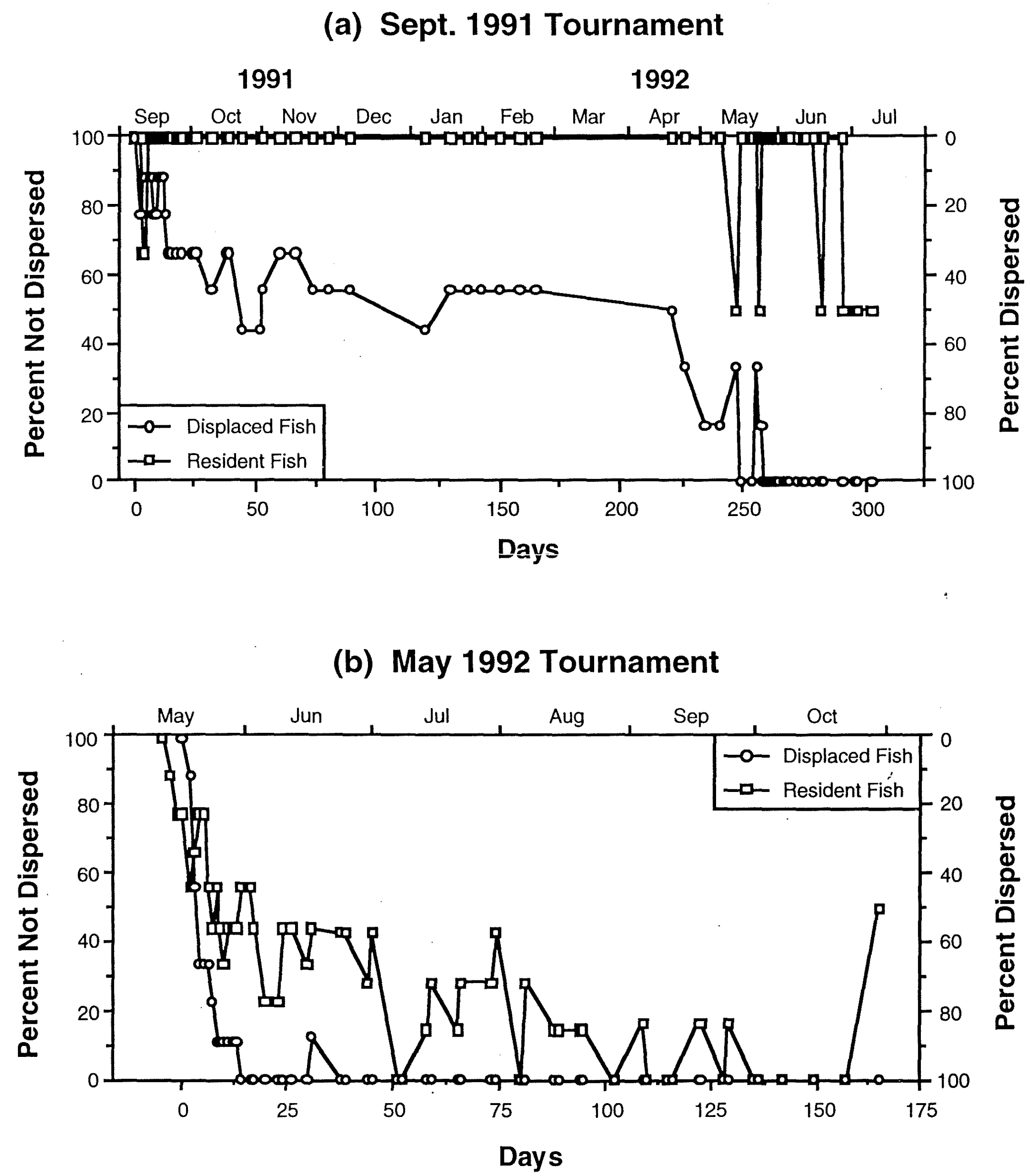


Figure 4. Plot of dispersal rate over time of resident fish and displaced, tournament-caught largemouth bass for tournaments held in (a) September 1991 and (b) May 1992.

as had 7 of 9 (78%) tournament-displaced fish. Two weeks after the tournament (May 30), 4 of 9 (44%) resident fish had dispersed from the weigh-in site, but all 8 (100%) of the surviving tournament-displaced fish had dispersed beyond radio-signal range from the weigh-in site (excluding missing fish). Beyond that date, the number of resident fish remaining within radio-signal range of the weigh-in site varied from 0 to 5 fish (0–56%), and at the last tracking of the study (October 28), 3 of 6 (50%) resident fish remained near the weigh-in site (excluding missing fish).

The movement patterns of resident fish from the second tournament were variable, but most fish established one or more home ranges near Big Island. One resident fish moved relatively long distances without establishing an apparent home range, and another appeared to have established a home range in an area over 2.5 km from the release site. Movements of tournament-displaced fish associated with the second tournament also varied, but most established one or more home ranges away from Big Island, often preceded by a period (up to 9 weeks) of substantial movements. One displaced fish moved relatively long distances without establishing an apparent home range, as did another displaced fish before it appeared missing (after 8 weeks). Another missing, displaced, fish was located near the release site for 3 weeks before its disappearance. The three tournament-caught fish released at their capture site (excluding 2 with radio interference), also showed variation in behavior. One established a home range at its release (and capture) site, another established a home range after an initial large movement from its release site (over 3.5 km), and the third stayed in a home range near its release site for 11 weeks, then moved to a another bay (2 km distance) for the remainder of the tracking period (13 weeks).

Because the observed largemouth bass behavior associated with the both tournaments may be related to reproduction, we recorded observations of spawning fish in Lake Minnetonka and other behaviors associated with reproduction to document spawning chronology during 1992. We observed large aggregations of largemouth bass (12-15 fish) in shallow bays on May 5, and a largemouth bass pair was observed spawning over a nest on May 13. We observed largemouth bass guarding nests (presumably males) continuously from May 13 through June 8, and males were observed guarding fry from June 23 through June 29. One radio-tagged fish (presumably a male) was observed guarding a nest and subsequently guarding fry. This fish was guarding a large school of fry (over ca. 5000 fry) on June 29 in a shallow bay of Big Island, but the following week (July 6) the same fish was located in deep open water off a point on Big Island, likely marking the end of the largemouth bass reproductive season that year in Lake Minnetonka.

Only 2 of the 16 displaced fish that survived the entire study returned to the site where they were captured. One fish that was captured by angling during the first tournament in Forest Lake, a small bay in the north-central portion of Lake Minnetonka, returned to within 0.4 km of its capture site. The fish was not located near its capture site until the following spring (May 24, 1992) and remained in the general area of its capture for the remainder of the study (until June 9, 1992). The capture site of that fish was 9 km from the weigh-in site (release point), and the fish had navigated through at least three narrow channels separating larger bays to complete its return. One displaced tournament-caught fish from the second tournament returned to its capture site in St. Albans Bay, 3.6 km south of the weigh-in site. This fish returned to its capture site five weeks after its release. It was again located at its capture site one week later (six weeks after release), but then left the area. These two occurrences of homing indicate that displaced largemouth bass have the ability to navigate to a home range when displaced, and nest-site fidelity in some individuals is further suggested. The preponderant result, however, is that displaced largemouth bass in this study did not return to their capture site, and reproductive activities were interrupted by displacement, and presumably not resumed, following the spring tournament. The extent of this impact on reproduction and recruitment at the population level is beyond the scope of this study and would require further research.

It should be noted, however, that the second tournament which took place during the largemouth bass spawning season was conducted prior to the open fishing season for bass in Minnesota specifically for this study to assess tournament impacts, and the bass fishing season in Minnesota does not open for approximately two weeks after the date of the May tournament that we studied. Therefore, under normal circumstances, tournament fishing in Minnesota would not interfere with largemouth bass spawning activity on Lake Minnetonka, but may overlap with the period when adult males are guarding fry.

Our results from largemouth bass in Lake Minnetonka indicated that tournament-caught fish displaced during late summer do not disperse well until the following spring, but fish displaced during the spring dispersed rapidly. These findings strongly suggest that fish dispersal and activity is associated with spawning and other reproductive behaviors. It is reasonable to suggest that there may be a critical time after spawning, but some time before September, after which dispersal of displaced fish will be delayed until the following spring. We are unable to temporally define that critical period more precisely based on the results of this study — further study would be required.

Habitat Use

Physical habitat measurements collected at sites where radio-tagged largemouth bass were located are summarized in Table 2. Fish were always found in the relatively shallow littoral zone of the lake, usually associated with aquatic macrophytes, and were never located in the deep open-water limnetic zone. Such habitat requirements may be an important influence on fish dispersal. Fish were most frequently located over bottom materials composed of fine particles (silt or clay 52% of locations; sand 39% of locations), but were occasionally located over rock substrates (9% of locations). Average habitat measurements were 3.26 m depth, 14.62°C water temperature (mid-column), and 9.84 mg/L dissolved oxygen concentration (mid-column). Fish occupied areas 1.0–5.5 m deep most frequently (86% of locations), and habitat use was evenly distributed among that range of depth (Figure 5a). Fish most frequently occupied habits with mid-water-column dissolved oxygen concentrations of 9.0–9.9 mg/L with lower frequencies of use above or below this modal range (Figure 5b).

Table 2. Summary statistics of physical habitat measurements collected where radio-tagged largemouth bass were located (N = 674 locations).

| Habitat variable | Mean | Standard deviation | Range |
|---|---|---|---|
| Depth (m) | 3.26 | 1.58 | 0.4 – 8.4 |
| Surface water temperature (°C) | 14.78 | 7.41 | –1.8 – 24.7 |
| Surface dissolved oxygen (mg/L) | 9.94 | 1.93 | 0.3 – 18.1 |
| Mid-column water temperature (°C) | 14.62 | 6.91 | –1.3 – 24.5 |
| Mid-column dissolved oxygen (mg/L) | 9.84 | 1.83 | 4.1 – 15.6 |
| Bottom water temperature (°C) | 14.48 | 6.30 | – 0.5 – 17.4 |
| Bottom dissolved oxygen (mg/L) | 7.49 | 2.87 | 0.1 – 17.4 |

Largemouth bass habitat use varied widely among individuals and seasonally (Figure 6). Depths at fish locations during the period shortly after ice break-up in the spring were markedly lower than depth of habitat used the remainder of the year (Figure 6a). Depths were lowest (mean = 1.3 m) during the second week in May, a period when largemouth bass were observed spawning in Lake Minnetonka. Depths gradually increased during the remainder of the reproductive season (through June). Variation among individuals in water temperature at locations was minimal (Figure 6b), and the trend over time is probably more indicative of seasonal changes in water temperature of the lake as a whole rather than habitat selection by fish. Dissolved oxygen concentrations at fish locations varied among individuals and over time, and the lowest concentrations were observed during late summer (August and September, Figure 6c).

Largemouth bass were associated with aquatic or semiaquatic plants at 90.7% of locations measured. Submersed macrophytes were present at 86.2% of locations, and emersed plants were found at 5.6% of locations. Associated plants included 27 taxa (Table 3). Watermilfoil (*Myriophyllum* spp.) was the dominant plant taxon present at 59% of fish locations, followed by coontail (*Ceratophyllum demersum*), which was dominant at 22% of locations (Table 4). Eurasian watermilfoil (*Myriophyllum spicatum*) was discovered in Lake Minnetonka in 1986, and this introduced species has since reached nuisance-level proportions (Smith et al. 1991). Eurasian watermilfoil coexists with the native northern watermilfoil

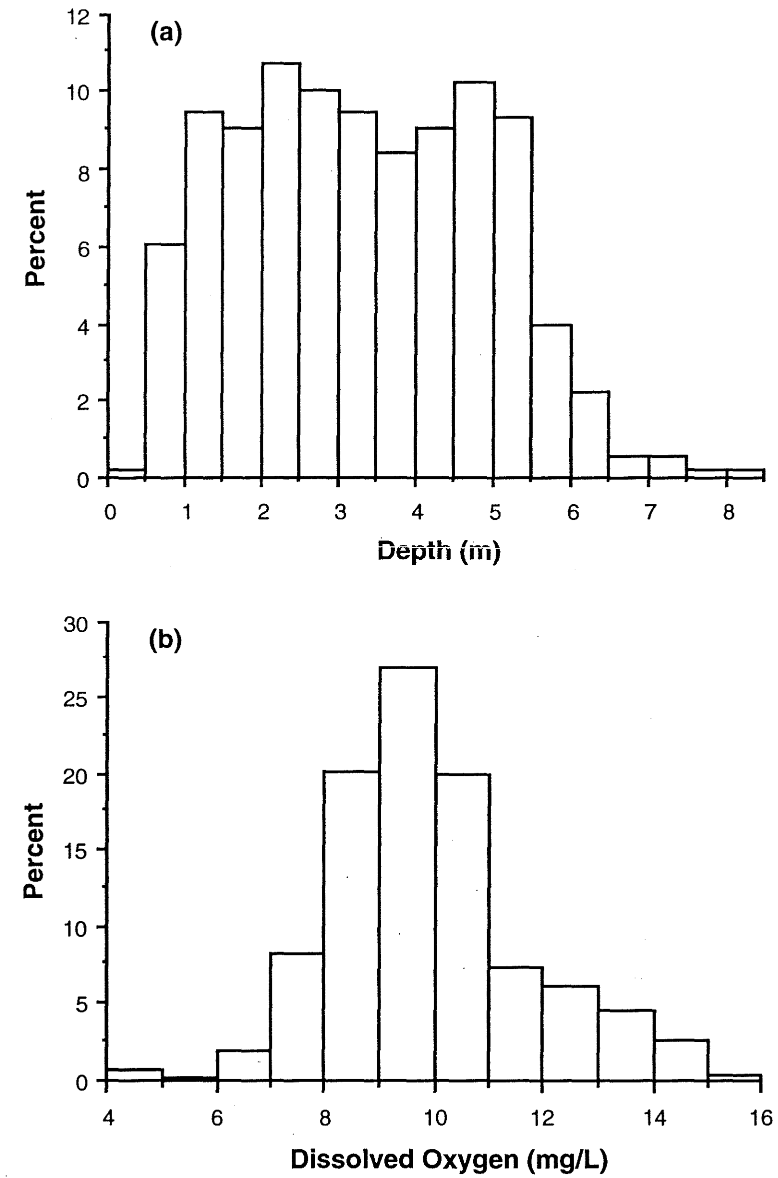


Figure 5. Frequency distributions for (a) depth and (b) dissolved oxygen concentration for habitats occupied by radio-tagged largemouth bass.

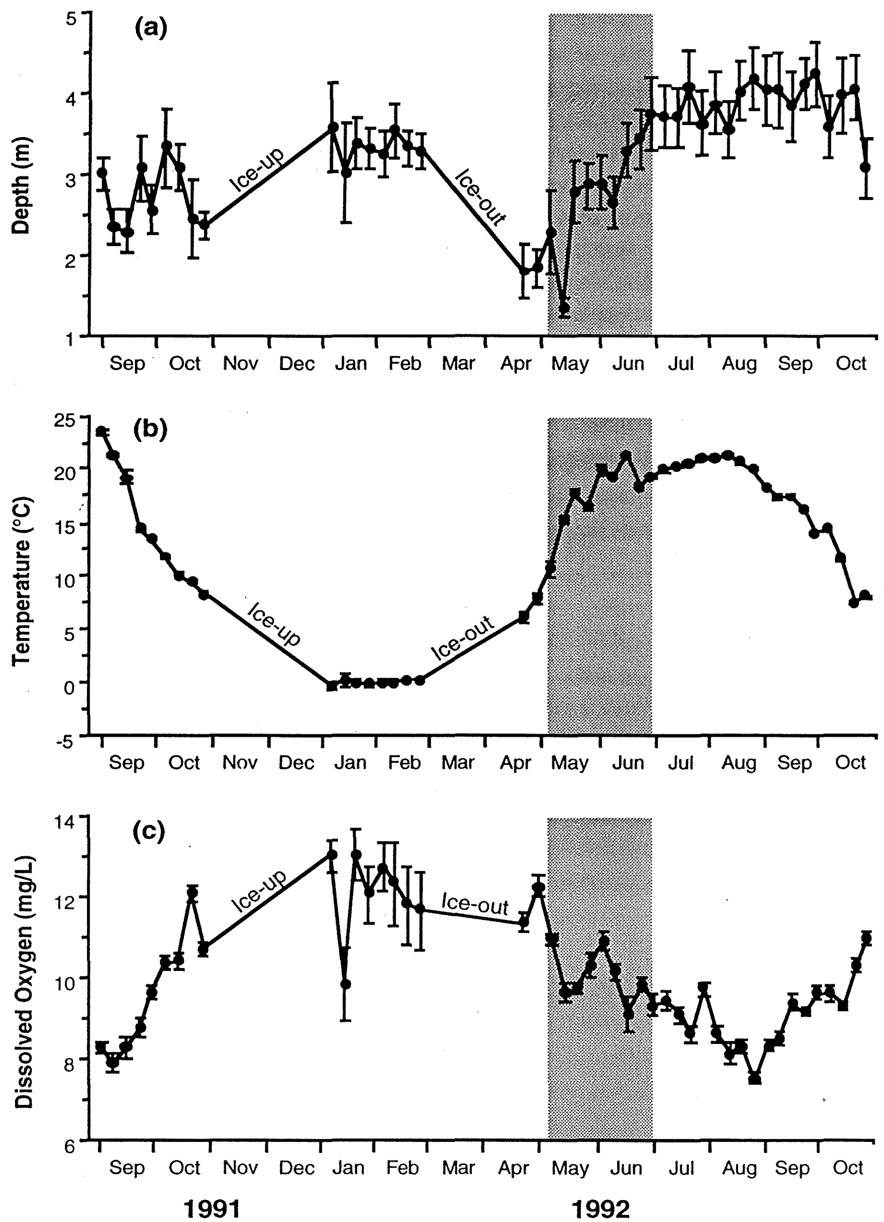


Figure 6. Mean (± SE) (a) depth, (b) water temperature, and (c) dissolved oxygen concentration at habitats occupied by radio-tagged largemouth bass according to week (reproductive season shaded).

(*Myriophyllum exalbescens*) in Lake Minnetonka, but Eurasian watermilfoil is clearly dominant in biomass over all other plant taxa in that lake (Crowell 1992). We did not distinguish between Eurasian watermilfoil and northern watermilfoil in collection of plant association data, and both plant species were found at fish locations. The high frequency with which largemouth bass were found associated with watermilfoil in our study should not be misinterpreted as an indication of preference for that plant taxon over other taxa as cover by largemouth bass. The close association between largemouth bass and watermilfoil that we observed is more likely owing to the widespread distribution of the plant group throughout Lake Minnetonka, and plant species may actually be used by largemouth bass for cover in proportion to their occurrence. Because no quantitative surveys of the aquatic plants of Lake Minnetonka were conducted concurrent with our study, we are unable to quantify suitability or preference of plant taxa for cover use by largemouth bass.

Table 3. List of aquatic or semiaquatic plant taxa found at largemouth bass locations in Lake Minnetonka.

| Scientific name | Common name |
|---|---|
| *Carex* spp. | Sedge |
| *Ceratophyllum demersum* | Coontail |
| *Chara* spp. | Muskgrass |
| *Elodea* spp. | Waterweed |
| *Equisetum* spp. | Horsetail |
| *Lemna* spp. | Duckweed |
| *Lythrum salicaria* | Purple loosestrife |
| *Megalodonta beckii* | Water marigold |
| *Myriophyllum* spp. | Watermilfoil |
| *Najas flexilis* | Northern naiad |
| *Najas* spp. | Naiad |
| *Nuphar luteum pumilum* | Little yellow waterlily |
| *Nuphar luteum variegatum* | Yellow waterlily |
| *Nymphaea tetragona* | Little white waterlily |
| *Nymphaea tuberosa* | White waterlily |
| *Potamogeton crispus* | Curly pondweed |
| *Potamogeton friesii* | Fries' pondweed |
| *Potamogeton natans* | Floating pondweed |
| *Potamogeton pectinatus* | Sago pondweed |
| *Potamogeton richardsonii* | Claspingleaf pondweed |

Table 3 (continued).

| | |
|---|---|
| *Potamogeton strictifolius* | Narrowleaf pondweed |
| *Potamogeton* spp. | Pondweed |
| *Rumex* spp. | Dock |
| *Salix* spp. | Willow |
| *Scirpus* spp. | Bulrush |
| *Typha* spp. | Cattail |
| *Vallisneria americana* | Wild celery |

Table 4. Dominant plant taxon occurrence at largemouth bass locations.

| | Locations of dominant occurrence | |
|---|---|---|
| Plant taxon | Number | Percent |
| *Myriophyllum* spp. | 346 | 58.84 |
| *Ceratophyllum demersum* | 129 | 21.94 |
| *Typha* spp. | 22 | 3.74 |
| *Chara* spp. | 9 | 1.53 |
| *Potamogeton crispus* | 7 | 1.19 |
| *Potamogeton richardsonii* | 5 | 0.85 |
| *Najas* spp. | 4 | 0.68 |
| *Lythrum salicaria* | 3 | 0.05 |
| *Potamogeton* spp. | 3 | 0.05 |
| *Potamogeton pectinatus* | 1 | <0.01 |
| *Potamogeton strictifolius* | 1 | <0.01 |
| *Vallisneria americana* | 1 | <0.01 |
| No Plants | 57 | 9.69 |



A.6. Benefits: Results will reveal if displacement of tournament-caught fish is a potential problem associated with tournament angling and the extent of any associated impacts. The effects of a sudden drastic increase in fish density on resident fish will also be determined. Basic knowledge on the homing ability of largemouth bass will be gained in this portion of the study, in addition to information on behavior, movement, dispersal rate, and habitat use by this species.

## B. Survival and Population Characteristics

B.1. Narrative

The weigh-in mortality and short-term post-release survival of tournament-caught fish will be determined. The population structure of largemouth bass in Lake Minnetonka will be described by measuring tournament-caught fish and analyzing hard parts (scales). Population parameters will include age, size, and growth characteristics. The mortality results and the population structure of largemouth bass will be put into perspective by a comparison with population structure data and population estimates collected and analyzed from 1981 to 1983 on Lake Minnetonka. In addition, fish density and water quality parameters will be measured from angler boat livewells to determine sources of fish stress and form a basis for mitigation of mortality.

B.2. Procedures

Mortality at weigh-in will be determined and recorded by a biologist, independent of tournament officials for all tournament-caught fish. A subsample of tournament-caught bass will be held in submersed on-site holding pens for 3 days to determine post-release delayed mortality. Fish will be held in mesh cages constructed from modified hoop-net samplers with a 2.5-cm mesh. Each cage will be 4-m long and have a volume of 1.7 $m^3$. The cages will be anchored on the lake bottom in an area with a firm substrate and will be periodically checked by a diver. This relatively short holding duration and ample space in pens will minimize holding stress on fish to provide an accurate measure of post-release mortality.

Weigh-in stress, weather conditions during tournaments, and livewell densities were implicated as potential causes of tournament-related fish mortality in a study of Minnesota walleye tournaments (Goeman 1991). Accordingly, our study will address these factors as potential influences on mortality. A subsample of anglers will be interviewed regarding their fish holding techniques. Fish density and water quality parameters including temperature, concentrations of dissolved oxygen and ammonia, pH, and conductivity will be measured in boat livewells. Weather on the day of each tournament will also be recorded.

Length and weight will be recorded from bass, and scales will be removed from a subsample to

1981 to 1983 using three methods of data collection: electrofishing, tournaments, and angler diaries. Analyses of these data by collection method yielded similar results. It is beyond the scope of our study to estimate the total largemouth bass population of Lake Minnetonka, but these data are available from the study by Ebbers (1987). Within-season Petersen mark-recapture largemouth bass population estimates for fish over 305 mm (12 in) in length ranged from 21,000 to 29,000 fish, varying with the data collection method. There were no significant differences among years or sources of data, which justifies the application of those results to our study. The population characteristics determined from tournament data in our study will be compared to similar data from Ebbers (1987) to assess changes in population structure over time which will be related to previous population estimates. Expression of mortality data from this study as a proportion of the total largemouth bass population will demonstrate more clearly the extent of impacts.

The MN DNR has conducted a thorough creel survey of all anglers on Lake Minnetonka during 1975 and found that anglers caught and removed an estimated 10,500 bass that year. A comparison of tournament mortality from our study and the total fishing mortality (estimated from the MN DNR survey) will provide a reasonable assessment of tournament mortality impacts.

B.3. Budget:

| | LCMR Funds | Matching Funds |
|---|---|---|
| a. Amount budgeted: | $12,000 | $0 |
| b. Balance: | $0 | $0 |

B.4. Timeline for Products/Tasks

| | July 91 | Jan. 92 | June 92 | Jan. 93 | June 93 |
|---|---|---|---|---|---|
| Collect data | ************************************** | | | | |
| Analyze data | ****************************************** | | | | |
| Final report | | | | ***************** | |

B.5. Status:

B.5.1. Completed Procedures

Fish mortality at weigh-in was determined independently by a biologist and tournament officials at both tournaments. Fish were considered dead if no opercular movement was observed. We also recorded the number of fish at weigh-in that were considered weak and not likely to survive — fish that were appeared inordinately stressed and would probably die soon, but for which opercular movement was observed. This group included fish that showed only intermittent opercular movement or had obvious physical injuries. A subsample of 296 largemouth bass (150 from day-1 fishing, 146 from day-2) was held in on-site holding cages (described above) for three days following their catch in the first tournament. A sample of 200 fish was held for three days following the second tournament. The holding cages were checked by SCUBA divers to assure that no extraneous factors influenced fish mortality.

Total lengths, weights, and a sample of scales (for age determination) of tournament-caught fish were collected on the first day of the first tournament; only total lengths were measured on the second day. Total length was measured for all fish caught in the second tournament, and weights and scales were collected from a subsample of those fish. Subsamples of 36 and 33 anglers were interviewed on the first and second days of the first contest, respectively, and 64 anglers were interviewed during the second tournament. A series of questions were asked regarding livewell capacity, conditions, and fish density. Water temperature, dissolved oxygen, pH, conductivity, and total ammonia were measured in the livewells of these subsamples of anglers.

Ammonia in aqueous solutions exists in two forms — the ionized form ($NH_4^+$) and the unionized form ($NH_3$). The unionized form is generally considered more toxic to fish than the ionized form (Russo 1985). Concentration of the unionized form of ammonia was calculated from equilibrium equations developed by Emerson et al. (1975), which incorporate the effect of pH and temperature on relative proportions of each form. Data collected from livewells was related to weigh-in mortality associated with the second tournament. It was possible to link livewell and interview data to mortality data by collecting anglers' names concurrently with data during the second contest.

B.5.2. Results and Discussion

Tournament Catch and Population Characteristics

The angler catch during the first tournament was 469 fish (403 kg) for the first day of fishing and 451 fish (411 kg) on the second day, yielding a total catch of 920 fish (including 23 smallmouth bass, *Micropterus dolomieu*) weighing 814 kg (Table 5). Catch rate during the second tournament was much higher than that of the 1991 contest. Anglers caught 870 largemouth bass weighing a total of 847 kg during the second tournament in only one day of fishing. Tournament rules excluded smallmouth bass from the creel of the second tournament. The greater catch rate of the second tournament is likely due to seasonal differences related to fish behavior (spawning activity). Average fish size was also greater during the second tournament.

Table 5. Summary of tournament catch from Lake Minnetonka.

| Statistic | 2-day Sept. 1991 tournament | | | May 16, 1992 |
|---|---|---|---|---|
| | Sept. 6 | Sept. 7 | Total | |
| Number fish | 469 | 451 | 920 | 870 |
| Total weight (kg) | 402.87 | 411.26 | 814.13 | 846.58 |
| Total length (mm) | | | | |
| Mean | 373 | 379 | 376 | 396 |
| Standard deviation | 49 | 46 | 48 | 49 |
| Range | 300 – 557 | 301 – 551 | 300 – 557 | 304 – 550 |
| Mean weight (g) | 859 | 912 | 885 | 973 |

The average size of fish caught during the first tournament (376 mm total length, Table 5) was slightly higher than mean lengths of fish caught in tournaments that took place in 1981–1983 (350–368 mm, Ebbers 1987) and equivalent to mean lengths obtained by electrofishing during the same years (360–375 mm, Ebbers 1987). Mean length of bass caught in the second tournament (396 mm) was higher than that of the first tournament or of fish collected by electrofishing or tournaments during 1981–1983. Maximum fish lengths of catch from both the first (557 mm) and second (550 mm) tournaments were greater than the maximum of fish collected by Ebbers (1987) during 1981–1983 (536 mm).

Length-frequency histograms of the catch from both tournaments show continuous size distributions of fish except at the upper extremes (Figures 7 and 8). The modal length range of fish from day 1 of the first tournament was 320–369 mm; 350–360 mm for day 2 of the first tournament; and 350–399 mm for the second tournament. These modes in the length distribution are similar to those obtained during 1981–1983 (Ebbers 1987).

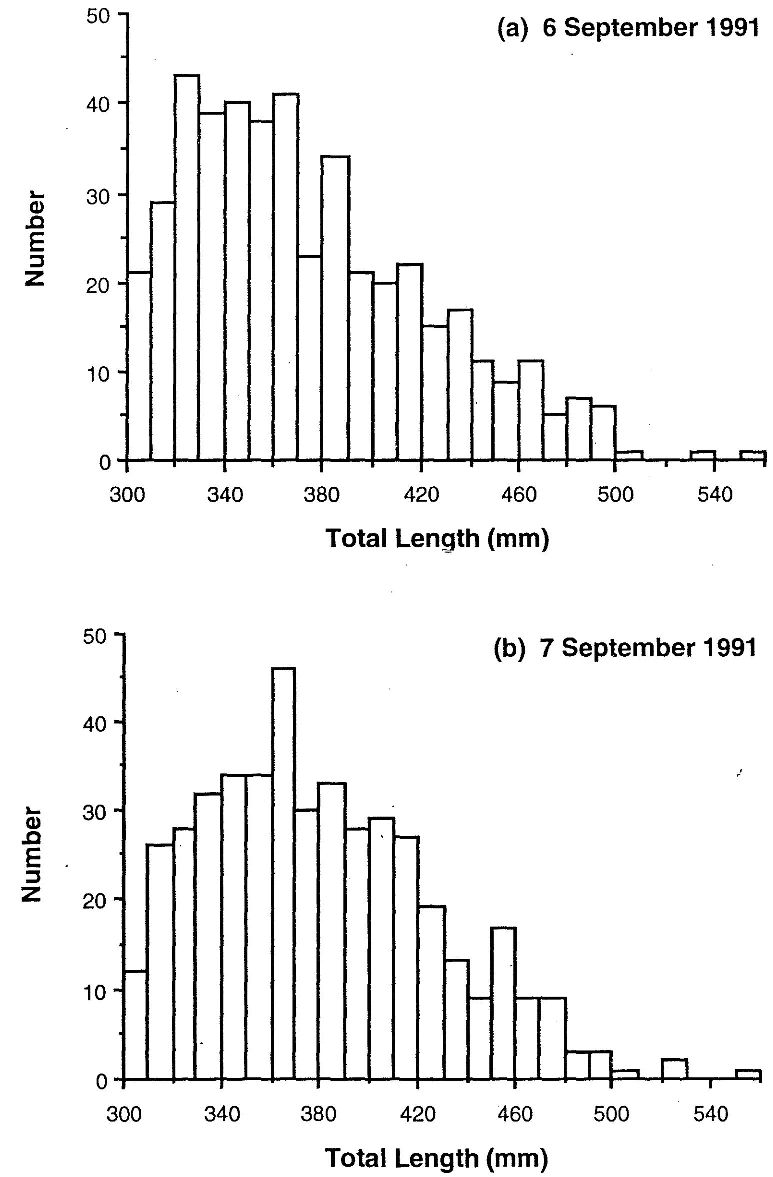


Figure 7. Length frequency distributions for catch of bass during a two-day tournament held in September 1991.

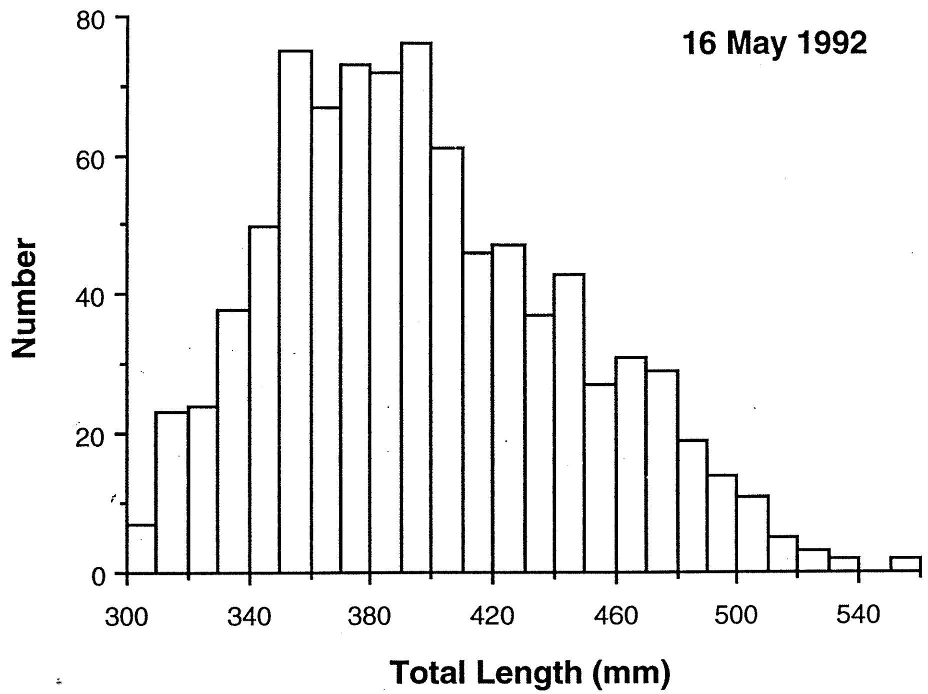


Figure 8. Length frequency distribution for catch of bass during a tournament held in May 1992.

The length–weight relationship of largemouth bass collected in tournaments conformed well to a least-squares logarithmic regression function with few outliers ($P < 0.0001$, Figure 9). The equations describing the relationship were similar in both slope and intercept between the two tournaments. Slopes from the length–weight relationships of largemouth bass in our study were equivalent at 3.30 and 3.31. Most slopes for similar relationships determined in other studies fall within a range of 2.7–3.3 (Carlander 1977). The slopes in our study lie on the upper end of the range found in other studies, which adds support to Carlander's (1977) observation that weight to length ratios tend to be higher for largemouth bass populations in the northern portions of its range, compared to those in southern portions.

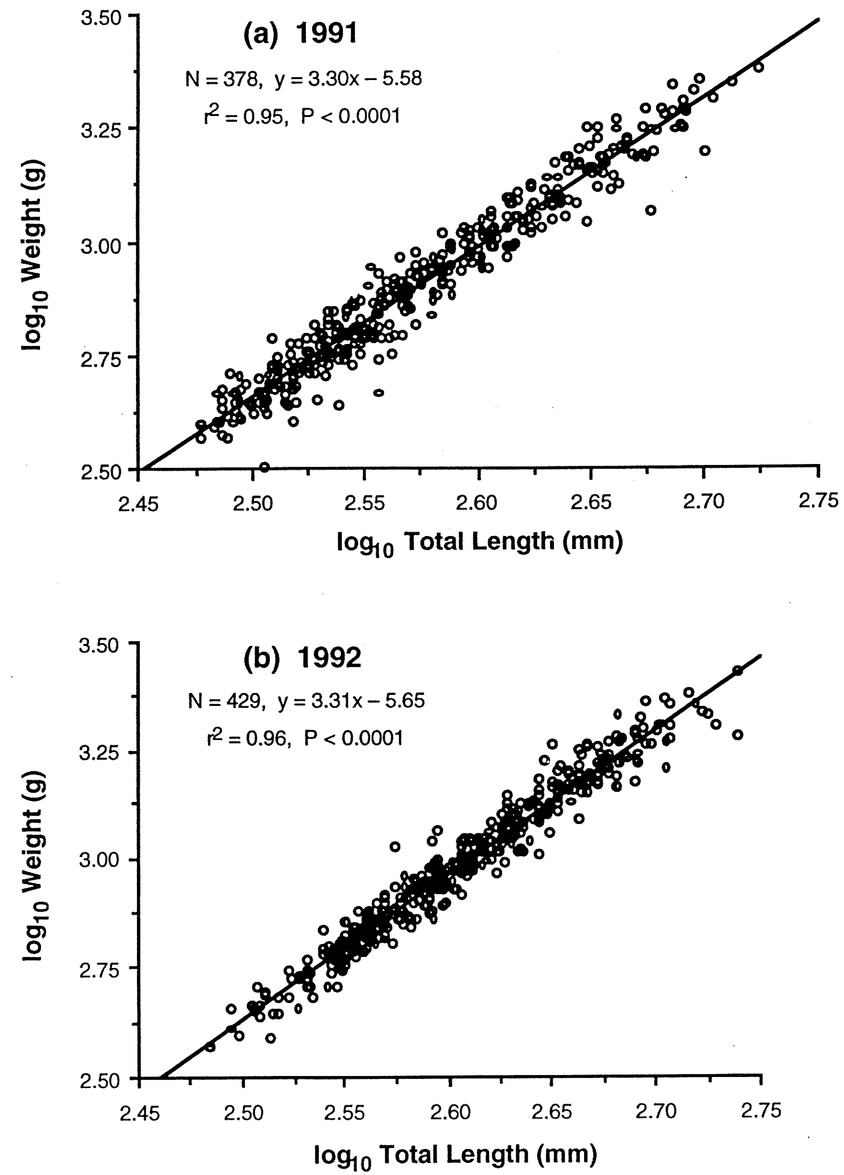


Figure 9. Length–weight relationships for largemouth bass collected in two tournaments held in (a) September 1991 and (b) May 1992.

Results of age determinations using largemouth bass scales collected from fish caught in the two tournaments that we studied indicated considerable overlap in fish size among age groups (Tables 6 and 7). Relationships between fish size (length and weight) and age that we determined for Lake Minnetonka largemouth bass were similar to those reported from other populations in the northern portion of that species' distribution (Carlander 1977, Becker 1983). Fish over age 10 were relatively common in our study and one fish's age was estimated at 14 years. The longevity of largemouth bass that we encountered for Lake Minnetonka fish is in accord with the trend noted by others that northern largemouth bass are longer lived than southern fish, which rarely live beyond 5 years (Carlander 1977, Becker 1983). Our results revealed that Lake Minnetonka largemouth bass growth over the winter of 1991–1992 was minimal in some age groups, and other age groups lost weight over winter. The lack of winter growth in Lake Minnetonka is an expected finding, because largemouth bass cease growing at water temperatures below 10°C (Becker 1983), and temperatures recorded at fish locations in our study were well below the 10°C threshold for nearly the entire interval between the two tournaments (Figure 6b).

Age determinations indicated that the catch of the two tournaments that we studied was dominated by fish of age 6–8 in late summer and age 7–9 in spring, corresponding to the 1983–1985 year classes. Ebbers (1987) did not report specific age–size relationships of largemouth bass from Lake Minnetonka in 1981–1983, but he noted a dominant 1977 year class of fish (age 4–6 during 1981–1983) in that study. Age-class dominance is a common phenomenon in largemouth bass, that has been attributed to variable survival of young during the first few weeks of life related to environmental temperature and wind action during that critical period (Summerfelt 1975).

It was beyond the scope of this study to validate the aging technique using scales for largemouth bass in Lake Minnetonka. Thus, the age determinations that we present should be considered tentative and may only be approximate. Accuracy and precision of those results may be variable, especially in the oldest age groups, and we advise caution in interpretation.

Table 6. Summary of age analysis determined from scales of largemouth bass collected during a tournament that took place on September 6, 1991 on Lake Minnetonka.

| | | Total length (mm) | | Weight (g) | |
|---|---|---|---|---|---|
| Age | N | Mean ± SD | Range | Mean ± SD | Range |
| 4 | 20 | 322.2 ± 12.7 | 300 – 342 | 491.8 ± 72.0 | 375 – 656 |
| 5 | 42 | 327.9 ± 16.7 | 305 – 388 | 503.8 ± 84.4 | 320 – 765 |
| 6 | 39 | 346.8 ± 28.8 | 300 – 413 | 651.2 ± 209.1 | 370 – 1,215 |
| 7 | 51 | 373.0 ± 26.8 | 329 – 461 | 791.8 ± 219.9 | 535 – 1,615 |
| 8 | 45 | 402.7 ± 40.9 | 346 – 491 | 1,066.8 ± 375.2 | 540 – 1,940 |
| 9 | 19 | 426.9 ± 31.5 | 368 – 493 | 1,259.0 ± 323.4 | 763 – 1,925 |
| 10 | 9 | 465.2 ± 20.6 | 434 – 502 | 1,469.1 ± 258.1 | 1,100 – 1,905 |
| 12 | 2 | 499.0 ± 9.9 | 492 – 506 | 2,006.0 ± 93.3 | 1,940 – 2,072 |

Table 7. Summary of age analysis determined from scales of largemouth bass collected during a tournament that took place on May 16, 1992 on Lake Minnetonka.

| | | Total length (mm) | | Weight (g) | |
|---|---|---|---|---|---|
| Age | N | Mean ± SD | Range | Mean ± SD | Range |
| 5 | 3 | 331.3 ± 23.1 | 305 – 348 | 486.7 ± 106.9 | 370 – 580 |
| 6 | 20 | 341.4 ± 24.2 | 305 – 398 | 540.5 ± 135.6 | 372 – 858 |
| 7 | 50 | 361.3 ± 24.4 | 313 – 430 | 677.3 ± 155.0 | 435 – 1,169 |
| 8 | 56 | 383.0 ± 29.6 | 321 – 461 | 832.1 ± 221.8 | 447 – 1,475 |
| 9 | 57 | 410.2 ± 31.0 | 334 – 467 | 1,033.7 ± 269.4 | 550 – 1,565 |
| 10 | 29 | 425.1 ± 30.4 | 351 – 484 | 1,176.8 ± 295.3 | 620 – 1,872 |
| 11 | 17 | 438.8 ± 37.6 | 378 – 502 | 1,308.5 ± 382.3 | 817 – 2,110 |
| 12 | 11 | 455.1 ± 39.8 | 407 – 528 | 1,463.1 ± 423.2 | 945 – 2,259 |
| 13 | 2 | 479.0 ± 43.8 | 448 – 510 | 1,922.5 ± 130.8 | 1,830 – 2,015 |
| 14 | 1 | 450 | | 1290 | |

Tournament Mortality

Mortality at weigh-in during the first contest was low, with 7 (1.5%) and 1 (0.2%) dead fish on the first and second days, respectively (Table 8). Total weigh-in mortality was therefore 8 fish (0.9%). After being held for 3 days, 3 fish (2.0%) from the first day died and another 2 (1.3%) had lost equilibrium, showed only intermittent opercular movement, and would likely die shortly thereafter. Three fish (2.1%) held from the second day had died. Three-day delayed mortality from both days combined was thus 8 fish (2.7%), including the 2 fish too weak to release. Fourteen fish (1.5%) were judged at weigh-in to be weak and not likely to survive. Mortality (both weigh-in and delayed) associated with the second tournament was similarly low, but higher (approximately double), compared to that of the first tournament. Weigh-in mortality was 17 dead fish (2.0%), and 3-day delayed mortality was 8 dead of 200 retained fish (4.0%). At weigh-in, another 27 fish (3.1%) were considered weak and not likely to survive. Delayed mortality of both tournaments was over twice as high as that recorded at weigh-in.

Table 8. Mortality associated with two bass tournaments held on Lake Minnetonka. Data are number of dead fish and percent mortality.

| | 2-day Sept. 1991 tournament | | | |
|---|---|---|---|---|
| Measure | Sept. 6 | Sept. 7 | Total | May 16, 1992 |
| Weigh-in mortality | 7 (1.49%) | 1 (0.22%) | 8 (0.87%) | 17 (1.95%) |
| Weak at weigh-in[1] | 10 (2.13%) | 4 (0.89%) | 14 (1.52%) | 27 (3.10%) |
| 3-day delayed mortality | 5[2] (3.33%) | 3 (2.05%) | 8 (2.70%) | 8 (4.00%) |
| Estimated total mortality[3] | 22 (4.77%) | 10 (2.27%) | 33 (3.55%) | 51 (5.87%) |

[1] Not included in mortality estimates.

[2] Includes two fish that lost equilibrium and showed only intermittent opercular movement.

[3] Total mort. (percent) calculated as: Weigh-in mort. + [3-day delayed mort. x (100 – weigh-in mort.)]. Total mort. (number) calculated as: (Total catch x percent total mort.) ÷ 100.

Ebbers (1987) estimated the number of largemouth bass over 305 mm total length in Lake Minnetonka to range from 21,000 to 29,000 fish during 1981–1983, using a mark-recapture method. He also estimated an average total instantaneous mortality rate (Z) of 0.69 and a natural instantaneous mortality rate (M) of 0.27 for fish over 305 mm. Converting those average instantaneous rates to annual rates according to Ricker (1975), total annual mortality was 0.50 (50%), and natural annual mortality was 0.24 (24%). Thus, annual angling mortality would be 0.26 (26%). Assuming a relatively stable population over time and an average abundance of largemouth bass over 305 mm to be 25,000 fish, an estimated 12,500 fish die in a typical year, with 6,000 deaths due to natural causes and 6,500 attributable to angling.

During the 1992 fishing season, 11 bass tournaments took place on Lake Minnetonka that were permitted by the MN DNR (MN DNR unpublished data). The reported total cumulative catch of bass in those 11 tournaments was 5,135 fish. Applying an average total tournament mortality rate (including weigh-in and delayed) of 4.71%, that we determined from the two tournaments studied in 1991 and 1992, to the annual catch in tournaments (5,135 fish), yields an estimated annual tournament mortality of 242 fish for Lake Minnetonka during the 1992 season. The estimated proportion of the total annual angling mortality that occurred during 1992 permitted tournaments for largemouth bass over 305 mm in Lake Minnetonka amounts to 3.72%. These empirical estimates should be considered approximations, and the estimates of tournament-related mortality that we present do not include estimates from the many smaller contests that do not require state permits, but are known to occur on Lake Minnetonka each season. Nonetheless, the proportion of total angling mortality due to tournament fishing is clearly small.

Potential Influences on Mortality

Mean number (and range) of fish in livewells examined during the first tournament was 3.9 (1-9), and mean well capacity was 59.4 L (15.7 gal) and ranged 18.9-189.2 L (5-50 gal). Most anglers had livewells located in the stern of the boat (65%) with freshwater input (84%), a concentrated water stream aeration system (67%), no cooling system or insulation (52%), and used no chemical additives (88%). Means (and ranges) for water quality variables measured in livewells were 23.2°C (22.0-25.6°C) water temperature, 5.7 mg/L (1.4-7.7 mg/L) dissolved oxygen, 7.4 (6.9-8.1) pH, 475 µS/cm (400-625 µS/cm) conductivity, 1.0 mg/L (0.2-12.7 mg/L) total ammonia as nitrogen, and 0.010 mg/L (0.003-0.049 mg/L) unionized ammonia as nitrogen ($NH_3$). Temperature in Lake Minnetonka at the weigh-in site during the first tournament was equivalent (23.0°C) to the mean of that found in livewells; dissolved oxygen was higher (8.5 mg/L); pH was slightly higher (7.6); conductivity was lower (450 µS/cm); and total and unionized ammonia were lower (0.3 mg/L and 0.006 mg/L, respectively).

Mean number (and range) of fish in livewells examined during the second tournament was 6.6 (2-12), and mean well capacity was 80.5 L (21.3 gal) and ranged 15.1-151.4 L (4-40 gal). Most anglers had livewells located in the stern of the boat (70%) with freshwater input (69%), a concentrated water stream aeration system (70%), no cooling system or insulation (75%), and used no chemical additives (94%). Means (and ranges) for water quality variables measured in livewells were 17.0°C (14.0-19.6°C) water temperature, 6.6 mg/L (1.9-13.6 mg/L) dissolved oxygen, 8.0 (7.1-9.2) pH, 460 µS/cm (400-540 μS/cm) conductivity, 0.6 mg/L (0.2-2.6 mg/L) total ammonia as nitrogen, and 0.029 mg/L (0.001-0.160 mg/L) unionized ammonia as nitrogen ($NH_3$). Temperature in Lake Minnetonka at the weigh-in site on the day of the second tournament was lower (15.0˚C) than the mean of that found in livewells; dissolved oxygen was higher (9.9 mg/L); pH was slightly lower (7.8); conductivity was lower (440 μS/cm); and total and unionized ammonia were lower (0.2 mg/L and 0.002 mg/L, respectively).

Mortality of tournament-caught fish in this study may not be attributable to any single water quality variable from livewells. Water temperatures in livewells were well below the range of thermal tolerances for adult largemouth bass that range from 28.9˚C to 38.9˚C (upper incipient lethal limits, Wismer and Christie 1987). Dissolved oxygen concentrations below or approaching 1.0 mg/L are frequently lethal to largemouth bass (Bulkley 1975), but only the lowest extreme found in livewells (1.4 mg/L) approached lethal concentration. Largemouth bass are known to have survived acidic waters with pH as low as 3.9, but generally this species is not found in waters below pH 4.7 (Bulkley 1975). These critical pH values are much lower than any encountered in livewells in our study. However, the toxicity of many substances is affected by pH; consequently, it is difficult to identify the direct effects of pH on fish (Bulkley 1975). For example, ammonia toxicity increases with increasing pH, but low pH can indicate high carbon dioxide concentrations, which reduce the oxygen carrying capacity of fish's blood regardless of ambient oxygen concentrations (Bulkley 1975, Piper et al. 1983). Unionized ammonia (toxic form) concentrations from livewells were also well below the range of tolerance limits determined for largemouth bass in laboratory studies (0.7–1.2 mg/L, Roseboom and Richey 1977).

Even though our water quality investigations revealed no obvious single acute stressor to fish that may have directly caused mortality, the cumulative effects of sublethal stress factors may eventually lead to death, even if the individual factors do not exceed physiological tolerance limits (Wedemeyer et al. 1990). Although the scales of measured water quality variables may not be directly comparable, the general trends and magnitude of comparisons between livewell water and water found in Lake Minnetonka may add insight into the relative influences of variables on fish in livewells (Table 9). Relative differences in ammonia concentration (both total and unionized form) were substantially greater than for any measured variable, suggesting that stress related to ammonia toxicity may be an important contributing factor to cumulative stress and mortality during tournaments.

Correlation analyses between continous-scale variables (water quality variables, fish density in livewells, and livewell capacity) and the number of dead or weak fish in livewells of the second tournament revealed one significant finding. The number of dead or weak fish in livewells was positively correlated with pH of livewell water ($P = 0.029$). Interpretation of this result is difficult and complicated by interactions with other factors as discussed above. If the correlation between pH and dead or weak fish indicates a cause and effect relationship, it is more likely related to carbon dioxide concentrations and respiration or interactive effects of other substances, than directly to pH toxicity. No significant effect of categorical variables including livewell location on boat, use of chemical additives, or livewell circulation, aeration, or cooling system on the number of dead or weak fish was detected (one-way analysis of variance, $P > 0.05$).

Table 9. Comparison of mean water quality variables measured from livewell water compared to those measured in Lake Minnetonka at weigh-in sites during two bass tournaments.

| | Sept. 1991 Tournament | | | May 1992 Tournament | | |
|---|---|---|---|---|---|---|
| Variable | Lake | Livewells | Comparison[1] | Lake | Livewells | Comparison[1] |
| Temperature[2] (˚C) | 23.0 | 23.2 | + 0.9% | 15.0 | 17.0 | + 13.3% |
| Dissolved oxygen (mg/L) | 8.50 | 5.73 | – 32.6% | 9.90 | 6.60 | – 33.3% |
| pH | 7.60 | 7.40 | – 2.6% | 7.75 | 7.99 | + 3.1% |
| Conductivity (μS/cm) | 450 | 475 | + 5.6% | 440 | 460 | + 2.2 |
| Total ammonia (mg/L) | 0.30 | 1.02 | + 240.0% | 0.15 | 0.62 | + 313.3% |
| $NH_3$ ammonia (mg/L) | 0.006 | 0.010 | + 66.7% | 0.002 | 0.029 | + 1350.0% |

[1] Livewell/lake comparison expressed as percent of lake value.

[2] Note that degrees Centigrade is not an absolute scale.

B.6. Benefits: Results will quantify immediate and delayed tournament mortality and provide a basis for comparisons with other tournaments and guidelines. The causes or influencing factors in mortality may also be determined by angler interviews and ancillary measurements of livewell water quality and environmental conditions and may lead to recommendations for mitigation to minimize mortality. Recent changes in largemouth bass population structure will be defined, and mortality and population results will be compared to previously collected relevant data to assess tournament impacts.

## C. Summary of Impacts and Recommendations.

### C.1 Summary of Impacts

1. Our results from studying largemouth bass in Lake Minnetonka indicated that tournament-caught fish displaced during late summer did not disperse well until the following spring, but fish displaced during the spring dispersed rapidly. These findings strongly suggest that fish dispersal and activity is associated with spawning and other reproductive behaviors.

2. Most displaced fish did not return to their capture site, and reproductive activity was interrupted by displacement that occurred during the spawning season. The extent of this impact on reproduction and recruitment at the population level is beyond the scope of this study and would require further research.

3. Fish were always found in the relatively shallow littoral zone of the lake, usually over fine-particle substrates and associated with aquatic macrophytes; fish were never located in the deep open-water limnetic zone. Such habitat requirements may be an important influence on fish dispersal patterns and rate.

4. Total mortality associated with the two tournaments studied was low, averaging 4.71% of the catch. Mortality associated with the spring tournament was approximately double that of the late-summer tournament, and delayed mortality was over twice as high as that recorded at weigh-in of both tournaments. Estimated annual mortality associated with state permitted tournaments was 3.72% of estimated annual total angling mortality of largemouth bass on Lake Minnetonka.

5. Analysis of fish holding techniques and livewell water quality identified no single cause for fish mortality. Changes in livewell water relative to lake water were greatest for ammonia concentration, but the number of dead or weak fish in a livewell was positively correlated with pH of livewell water. Fish mortality associated with tournaments is most likely due to cumulative effects of sublethal stressors of water quality and handling, as well as physical injuries related to angling.

### C.2 Recommendations

We propose the following recommendations to mitigate biological and behavioral impacts associated with fishing tournaments. These recommendations are based on our observations, results of this study, and current knowledge of the subject. They were specifically developed for Minnesota waters, but may apply to other north-central states with some application to fishing tournaments in general.

1. Continue point incentives for live-release tournaments.

Although many tournament anglers and promoters exhibit a conservation ethic toward fisheries resources, penalties for weighing in dead fish at tournaments appears to be strong incentive for minimizing mortality.

2. Continue minimum-impact weigh-in procedures.

We observed organized procedures at weigh-in which minimized the impact on fish. These included conducting weigh-in activities in a shaded area, concluding the contest in shifts so that smaller groups of anglers arrive at any one time, providing large tanks available as holding stations before and after weighing, and operating the weigh-in in a timely, organized manner.

3. Change or dilute livewell water frequently.

Livewell water should be changed or diluted with lake water as frequently as possible throughout the fishing day to maintain favorable water quality. Aeration systems or chemical additives should not be relied upon solely to maintain suitable environmental conditions in livewells.

4. Rotate use of weigh-in sites.

On lakes where more than one tournament takes place within a fishing season, different weigh-in sites should be selected and used to minimize the unnaturally high concentrations of displaced fish that will result, particularly late in the season. In large lakes with disjunct areas of suitable littoral habitat for bass, tournament-caught fish may be dispersed by boat provided that adequate transporting facilities are available. In lakes with abundant and continuous littoral zones, dispersal by boat is not recommended to avoid stress related to additional handling and transport.

5. Do not conduct traditional tournaments during spawning.

Until impacts at the population level can be assessed, tournaments should not take place during the spawning season, because reproduction is interrupted by displacement. Additional research may reveal that the impact to the population is negligible, or tournaments with immediate release of each fish at its catch site may mitigate the impact. However, until further study suggests otherwise, tournaments during the spawning season should be avoided.

It is our intention that the results of this study and the recommendations that we offer will improve tournament guidelines and fisheries management to contribute to the common goals of anglers, fisheries managers, and the public — understanding, conservation, and wise use of the fisheries resources.

## IV. Evaluation: For the FY 92-93 the program can be evaluated by :

1) documenting the dispersal patterns of tournament displaced fish and the impact of high fish density at weigh-in release sites on resident fish,

2) analyzing and summarizing the population characteristics of the Lake Minnetonka largemouth bass population and comparing the present structure to that of recent years,

3) documenting tournament mortality at weigh-in and post-release as related to estimates of the largemouth bass population and total annual angling mortality,

4) attempting to define environmental conditions that influence mortality, and

5) summarizing results with conclusions concerning statewide implications for tournament operations.

V. Context:

A. Tournament-related mortality of largemouth bass and dispersal of caught fish and their impact on resident fish near the weigh-in sites has not been documented thoroughly in Minnesota (see Section II). Educated mitigation measures and tournament guideline procedures to maximize sustainable fishing cannot be established with the presently available information.

B. The information that will be obtained from this study will provide a foundation for implementation of informed mitigation procedures and guideline improvements to assure maximum survival and the sustainability and wise use of the fisheries resource. Fisheries management in Minnesota is undergoing a change in philosophy in response to increases in fishing intensity. Incorporating a balance of goals to provide anglers optimum recreational opportunity, yet maintaining the integrity and sustainability of the resource is an immediate challenge. The availability of reliable quantitative information is crucial to an informed management effort. The observed and continuing change in angler ethics that includes catch-and-release fishing is also paramount to achieving management goals. Fishing tournaments serve as ideal environmental laboratories and have been the proving grounds for some types of catch-and-release practices. This study will be a unique opportunity to gain some solid knowledge of catch-and-release impacts so that a factual basis for the future direction of tournament fishing can be established.

C. The effects of tournaments on Minnesota fish populations have gone largely without evaluation. In the past two years, live release following professional walleye tournaments in Minnesota has been evaluated without LCMR funding (Goeman 1991). Future LCMR funding could be used to examine the impact of recreational (non-tournament) catch-and-release angling. Social aspects of catch-and-release angling including attitudes and perceptions of anglers and the public regarding the practice could also be investigated.

D. Not applicable.

E. APID 316027513 AID 329821.

VI. Qualifications

1. Program Manager: Tim Goeman
Senior Fisheries Research Biologist
Section of Fisheries, Minnesota Dept. of Natural Resources
M.S. Fisheries, University of Wisconsin, 1981

The program manager has conducted pioneering research in survival of tournament-caught walleye in Minnesota, and results of his study have been accepted for publication in the North American Journal of Fisheries Management. In addition, he has collected and analyzed data from many bass tournaments and is presently conducting a radio telemetry study of muskellunge. The primary role of the program manager was coordination of the work described under the objectives.

2. Major Cooperators:

Dr. Mary Henry
Leader, Minnesota Fish and Wildlife Cooperative Research Unit
University of Minnesota
Ph.D., Iowa State University
Department of Animal Ecology, 1984

Dr. Tom Kwak
Research Fellow
Department of Fisheries and Wildlife
University of Minnesota
Ph.D., University of Minnesota
Department of Fisheries and Wildlife, 1993

The project was conducted by faculty, staff, and students of the Minnesota Cooperative Fish and Wildlife Research Unit, directed by Dr. Henry. She has published extensively on fish behavior, biological impacts of human disturbance on fish communities, and trophic relations in aquatic systems. She has employment experience as a fisheries project leader, Section Chief with the National Fisheries Research Center, Fisheries Biologist, and university instructor. Dr. Kwak has a great deal of experience in fisheries field techniques, including radio telemetry. He has conducted research for 5 years at the Illinois Natural History Survey and has published on fish ecology and behavior. The primary role of the Minnesota Cooperative Unit was to specifically plan, conduct the study, and report results.

The Minnesota Sportfishing Congress

VII. Reporting Requirements

Semiannual status reports were submitted not later than January 1 1992, July 1 1992, January 1 1993, and a final status report by June 30 1993.

VIII. Acknowledgments

This study was designed, conducted, and findings reported by Mary Henry and Tom Kwak (MN Coop. Unit) with the assistance of many other individuals to whom we are grateful. Tim Goeman (MN DNR) served as project manager and contributed many helpful suggestions at all stages of the study, loaned equipment, reviewed draft reports, and provided administrative assistance. Don Jaschke (MN Coop. Unit) provided technical assistance in many facets; he gathered data during tournaments, diligently radio tracked fish, aged fish scales in the laboratory, and assisted in data compilation. Dick Nelson, of the Minnesota Sportfishing Congress (MSC) and Minnesota Bass Federation (MBF), served as liaison between researchers and angling groups. He, along with other members of the MSC and MBF including Don Knutson, Gary Larson, and John Schneider, contributed insightful discussion, useful suggestions, and were accommodating in supporting and assisting in research at their tournaments.

Other MN DNR personnel provided assistance in the field, offered suggestions, and shared their unpublished data freely; they are Wayne Christopher, Henry Drewes, Jerry Johnson, Taylor Polomis, Duane Shodeen, and Dave Zappatillo. Tom Heming (Univ. Texas – Galveston) assisted in data collection during tournaments and provided constructive technical and methodological suggestions. Jon Ross' (Univ. MN) expertise was invaluable in refining surgical techniques for implanting radio transmitters, and Dick Huempfner, Larry Kuechle, and Mike Schuster (ATS, Inc.) assisted in engineering and implementing radio telemetry equipment and improving techniques.

Many faculty, staff, and students from the Department of Fisheries and Wildlife at the University of Minnesota, along with other colleagues and friends, graciously volunteered to assist with the intensive task of collecting field data during tournaments; their time and effort is appreciated. We also thank Minnetonka Boat Works for donating boat dockage at their Orono facility on Browns Bay. Finally, we thank the many anglers of Minnesota that cooperated with this study. They enthusiastically provided fish for study, responded to interviews, assisted in tournament operations, and allowed and encouraged us to study their avocation. Their cooperation and insightful comments and questions improved the quality of this research.

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