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**US Army Corps of Engineers**
Waterways Experiment Station

JOHN D. MADSEN

*Aquatic Plant Control Research Program*

# Ecological Assessment of Kirk Pond

*by John D. Madsen, Gary O. Dick, David Honnell, Judy Shearer, R. Michael Smart*
*Environmental Laboratory*

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Prepared for Headquarters, U.S. Army Corps of Engineers
and U.S. Army Engineer District, Portland

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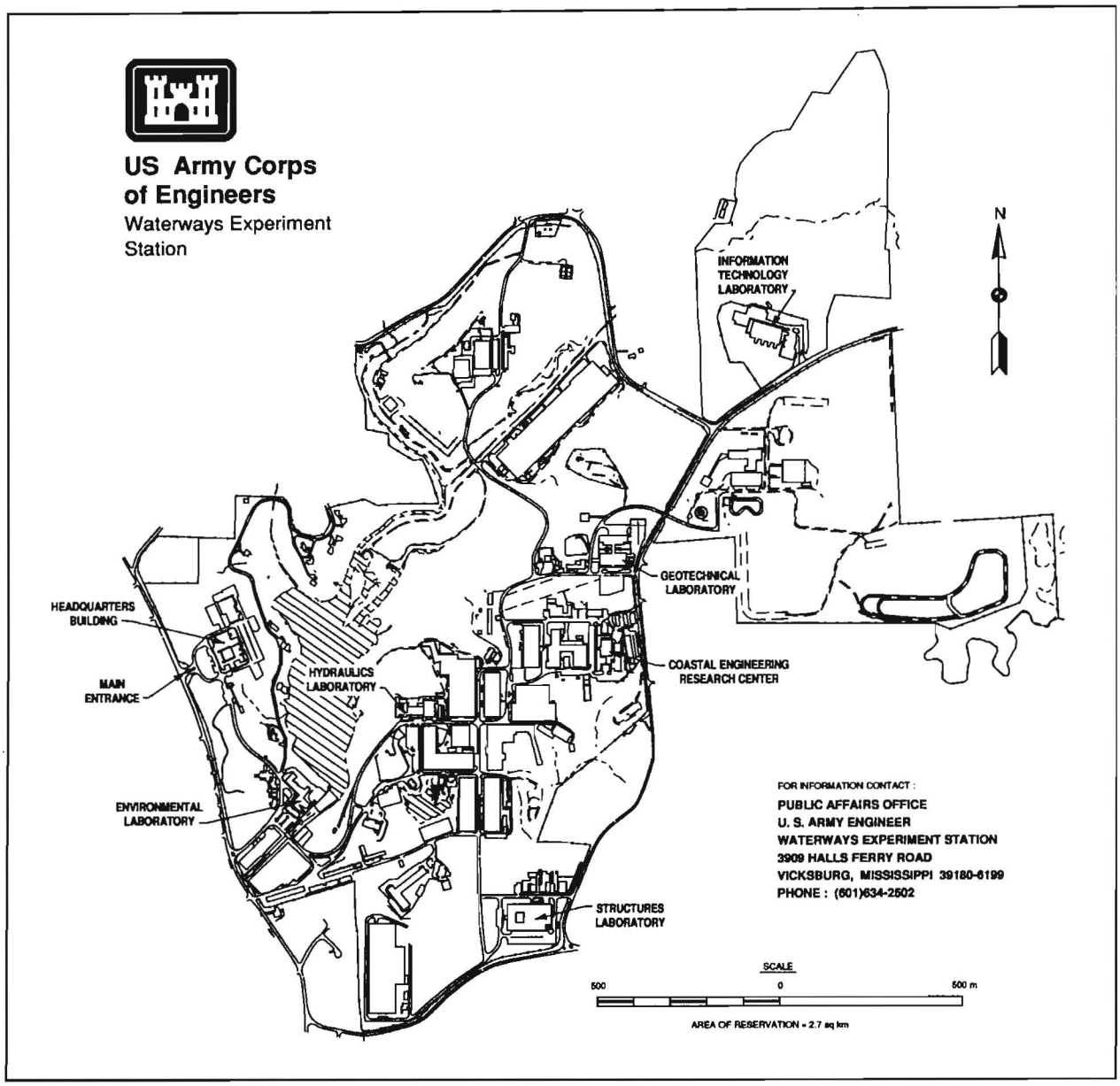


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# Preface

The work reported herein was sponsored by the U.S. Army Engineer District, Portland, and by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Aquatic Plant Control Research Program (APCRP). The APCRP is assigned to the U.S. Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). Funding was provided under Department of the Army Appropriation No. 96x3122, Construction General. The APCRP is managed under the Environmental Resources Research and Assistance Programs (ERRAP), Mr. J. L. Decell, Manager. Mr. Robert C. Gunkel was Assistant Manager, ERRAP, for the APCRP. Technical Monitor during this study was Ms. Denise White, HQUSACE.

This ecological assessment was performed for the USACE District, Portland, to provide baseline data on environmental conditions and the ecological state of Kirk Pond to aid in the preparation of an aquatic plant management plan for the Kirk Pond management unit.

The study was conducted and the report prepared by Dr. R. Michael Smart, Ecologist; Dr. Gary O. Dick, IPA; Mr. David Honnell, Scientist, AScI Corporation; and Dr. John D. Madsen, Research Biologist of the Ecological Processes and Effects Branch (EPEB), Environmental Processes and Effects Division (EPED); and Dr. Judy Shearer, IPA, of the Aquatic Ecology Branch (AEB), Ecological Research Division (ERD). Both groups are within the Environmental Laboratory (EL), WES.

Field assistance was provided by Dr. Richard Castenholz, University of Oregon, Eugene, and his students: Tanya Leatham, Athena Perry, and Amy Schneider. Jim Beal and the staff of USACE Fern Ridge Reservoir Project, Portland District, performed bathymetry measurements and provided logistical support and information. Jeff Ziller of the Oregon Department of Fish and Wildlife and Joe Snow (EPEB) assisted during fishery assessment sample collections. The study was coordinated by Dan Troglin, USACE, Portland District, and Dr. Al Cofrancesco, WES.

The principal investigator for this study was Dr. R. Michael Smart of EL. The study was performed under the general supervision of Dr. John Harrison,

Director, EL, and Mr. Donald L. Robey, Chief, EPED, and under the direct supervision of Dr. Richard E. Price, Acting Chief, EPEB.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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# 1 Introduction and Objectives

## Introduction

Kirk Pond is a 24-ha pond located in western Oregon near Eugene, created by clay removal for the construction of the dam for Fern Ridge Reservoir (Figure 1). The pond is the main feature of Kirk Park, a 92-ha park operated by the U.S. Army Corps of Engineers (USACE). The west end of the park has developed picnic and trail facilities and is heavily utilized for day use activities. The park includes 36 ha of deciduous trees, 19 ha of grassland (formerly agricultural land), 2 ha of disturbed land along the Long Tom River, 2 ha of emergent aquatic vegetation, and 24 ha of water surface area (Kirk Pond).

The primary water source for Kirk Pond is through a pipe located at the outflow of Fern Ridge Reservoir. Pond outflow is through Coyote Creek, which then flows back into the Long Tom River (the source of water for Fern Ridge Reservoir) and then into the Willamette River.

The pond supports a warmwater fishery and stocked trout. Public sport fishing is the primary use of the pond, which receives heavy fishing pressure.

The shallow pond is heavily populated with the exotic submersed aquatic plant Eurasian watermilfoil (*Myriophyllum spicatum* L.), but also supports other submersed aquatic plants such as curly-leaf pondweed (*Potamogeton crispus* L.), elodea (*Elodea canadensis* Michx.), and coontail (*Ceratophyllum demersum* L.). The heavy growth of aquatic plants (particularly *M. spicatum*) interferes with full utilization of the fishery resource by obstructing both bank fishing and nonpower boating access; full utilization of the fishery is the primary management objective of the pond.

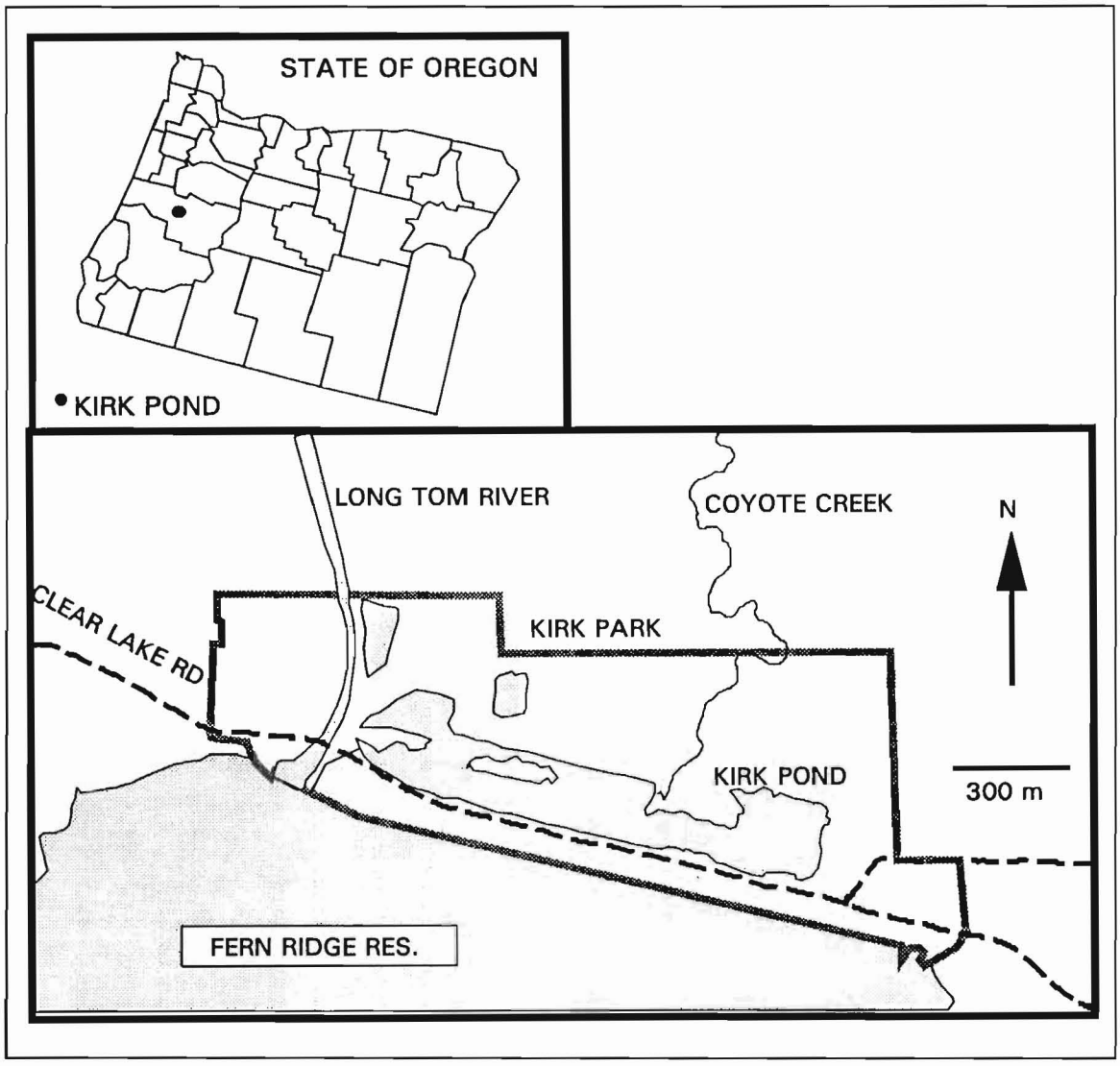


Figure 1. General location map indicating the location of Kirk Pond in the state of Oregon (inset) and Kirk Park

## Management Objectives

Kirk Pond is managed for multiple uses in a park setting. Management goals and objectives include the following from the Fern Ridge Project Management Plan:[1]

*a.* Control aquatic weed problems in Kirk Pond and other water bodies in the unit.

[1] Unpublished.

*b.* Protect and interpret cultural resource sites.

*c.* Provide opportunities for low density and dispersed recreation use focused on fishing, picnicking and wildlife viewing.

*d.* Manage wildlife habitat for wildlife species richness and diversity and to provide wildlife viewing opportunities.

*e.* Maintain the unique brown cyprus (*Cyperus melanostachys*) community adjacent to Kirk Pond.

Preliminary assessments of potential aquatic plant control techniques indicated that Kirk Pond might be a potential candidate for the field application of *Mycoleptodiscus terrestris* (Gerdemann) Ostazeski, or Mt, which is a fungal pathogen of *M. spicatum.* To prepare for field application, an initial survey for the presence of Mt in Kirk Pond, as well as other fungal pathogens or symbiotes was required.

## Study Objectives

The objectives of this study are as follows:

*a.* To determine the role of environmental factors, such as water depth, sediment and water composition, and light availability in affecting the present and future distribution and abundance of submersed aquatic plants (particularly *M. spicatum*) in Kirk Pond.

*b.* To assess the condition of the Kirk Pond ecosystem, including the water quality as well as the distribution, abundance, and species diversity of fish populations.

*c.* To document the existence of any endemic populations of the pathogenic fungus *Mycoleptodiscus terrestris.*

# 2 Physical and Chemical Environmental Factors

Physical and chemical environmental factors were analyzed to determine which may be important in limiting the distribution and abundance of the nonnative nuisance aquatic plant, *M. spicatum*. Pond morphometry was measured to determine the potential depth range and areal coverage of this species. Sediment composition was determined to further evaluate possible nutritional limitations of aquatic plants in the pond. Light extinction with depth was examined to estimate the potential depth distribution of aquatic plants in the pond. A monitoring program was initiated to assess water chemistry both spatially and temporally in Kirk Pond. Monitoring objectives were to assess potential limitations of aquatic plant growth or distribution, to assess the pond habitat potential, and to determine possible effects of vegetation on water chemistry.

## Methods

### Bathymetry

Depth was measured in 0.1-m increments using a calibrated staff at 5-m intervals along 36 transects extending from the south to the north bank of the pond. Transects were positioned every 25 m in the eastern half of the pond and every 50 m in the western half of the pond. Bathymetry data were collected and bathymetric maps were generated during the summer of 1991. Bathymetry data were analyzed on SAS version 6.03 (SAS Institute 1988).

### Sediment composition

Sediment samples were collected at 25-m intervals along 19 transects, which were also used for vegetation assessment. A total of 118 samples were collected using a 5-cm-diameter hand core, sampling to a maximum depth of 30 cm. After each sample collection, a visual classification of sediment type and the measured core sediment thickness were recorded. Visual estimates were later confirmed by laboratory analyses. Sediments were classified as

gravel if gravel-sized cobbles dominated at the surface. Sand, silt, and clay sediments were defined as more than 50 percent distributions of one particle size. Organic sediments were defined as more than 10 percent organic matter. Particle size definitions (USDA system) used were: gravel, > 2 mm; sand, 0.5 to 2 mm; silt, 0.002 to 0.05 mm; clay, < 0.002 mm (Foth 1978). Samples were placed in a Whirl-pac, stored on ice, and shipped to the Lewisville Aquatic Environment Research Facility (LAERF), Lewisville, TX, for analysis. Sediments were analyzed for particle size distribution, moisture, organic matter, calcium carbonate, bulk density, and exchangeable $NH_4$. Methods used for these analyses are summarized in Table 1.

**Table 1**
**Summary of Sediment Analytical Techniques**

| Analysis | Method/Instrument | Reference |
|---|---|---|
| Particle size distribution | Hydrometer (settling) | Day 1956 |
| Moisture | Gravimetric<br>Drying at 105 °C | APHA et al. 1989 |
| Organic matter | Gravimetric<br>Combustion at 550 °C | APHA et al. 1989 |
| $CaCO_3$ | Gravimetric<br>Combustion at 950 °C | APHA et al. 1989 |
| Bulk density | Gravimetric | Day 1956 |
| Exchangeable $NH_4$ | NaCl extraction followed by $NH_4$ analysis with a specific-ion electrode | Bremner 1965 |

## Light availability

Light measurements were taken at all six biomass sample sites (Figure 2, I to VI), where vegetation had reached the surface. Additional light measurements were taken at open water sites L1 to L3, where vegetation was not at the surface (Figure 2). Sites L1, L2, and L3 correspond to water chemistry sample stations 2, 3, and 5; respectively. Light intensity was measured with a Li-Cor LI-1000 data logging meter using both a terrestrial quantum sensor ("deck cell") and a submersible underwater quantum sensor. Light intensity was measured as light quanta of photosynthetically active radiation (PAR). Measurements at each site were taken at the surface and every 0.25 m to a depth of 1 m, then every 0.5 m to the bottom. Two or three profiles were measured at each site, and values averaged. Light penetration or transmittance was calculated as percent of surface light intensity. In addition, light extinction coefficients ($K_d$) were calculated for every depth interval measured to indicate depths at which most light was restricted. Light extinction coefficient is calculated as:

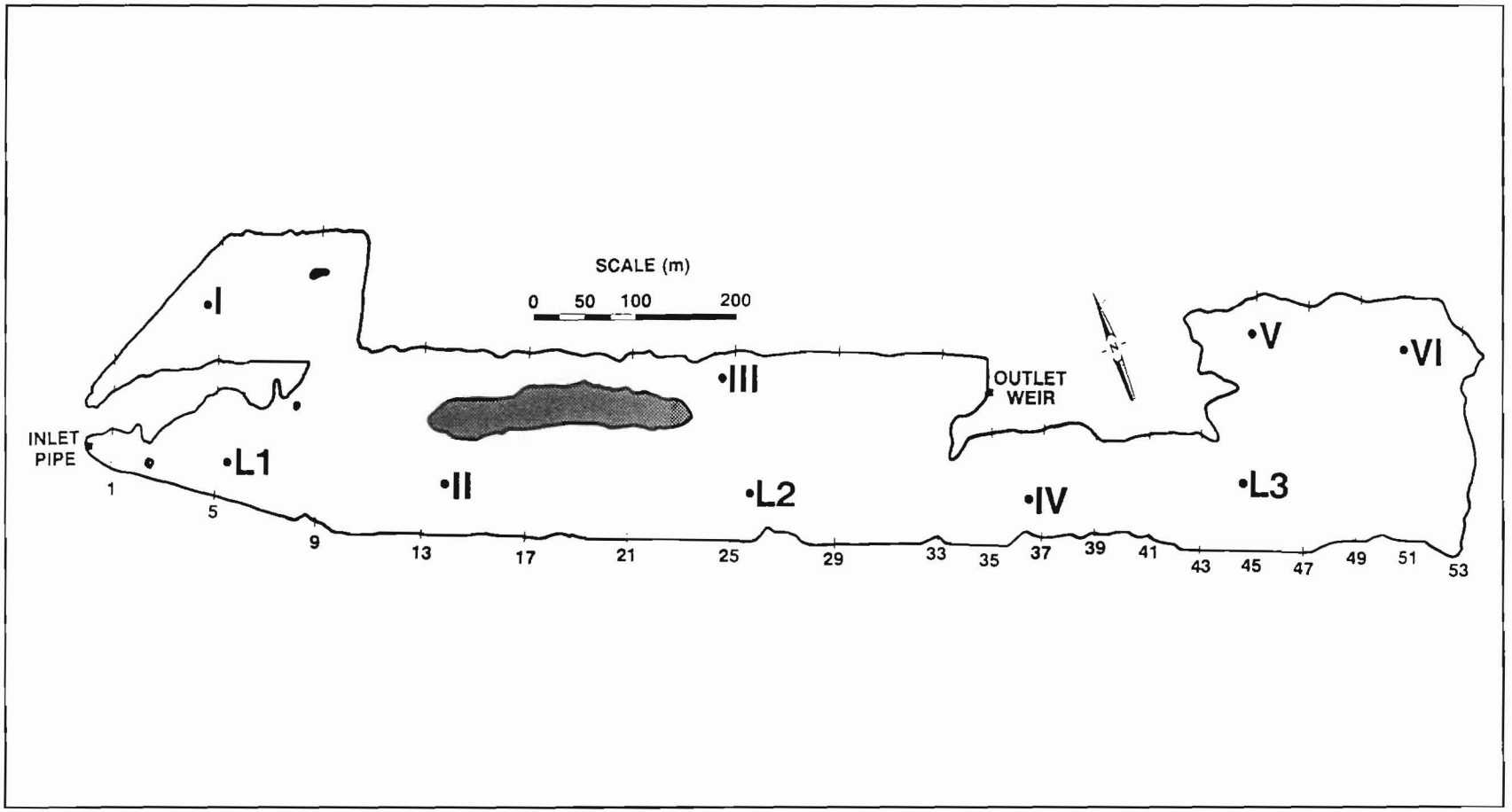


Figure 2. Map of Kirk Pond indicating light profile measurement sites, which included six vegetated sites (I-VI) and three unvegetated sites (L1-L3)

$$K_d = [\ln(I_{z_1}) - \ln(I_{z_2})]/(z_2 - z_1) \quad (1)$$

where $I$ is light intensity (PAR) and $z_n$ is the depth at either the first or second interval. Light profiles were obtained on 10 September 1991 at or near the time of peak plant biomass.

### Water chemistry

A total of 10 sample sets from six stations were taken every 2 weeks from 21 May through 24 September 1991 (Figure 3). Pond elevation at all in-lake stations remained constant throughout the study. Station 1 represents the inflow to the impoundment and station 6 represents the outflow. Stations 2 and 3 are in-lake sites located in the western portion of the pond where there was little submersed vegetation. Sampling depths at stations 2 and 3 were 2.5 m and 1.5 m, respectively. Stations 4 and 5 are in-lake sites located in the eastern portion of the pond, which was densely populated with submersed vegetation, dominated by *M. spicatum*. Sampling depths at stations 4 and 5 were 2.0 m and 2.5 m, respectively.

Each sampling trip included measurements of water temperature, dissolved oxygen, pH, and conductivity prior to water sampling. In-lake stations were profiled at 0.5-m intervals from subsurface to the bottom. Water samples from in-lake stations were procured by taking a 1.5-m depth-integrated sample, mixing the sample in a bucket, then distributing different aliquots to the appropriate sample bottles for preservation. Laboratory samples were obtained from inflow and outflow stations by grab sampling, then distributed and preserved in the same fashion as in-lake samples. Preservation techniques and sampling methods are outlined in Tables 2 and 3. Samples were stored on ice and shipped by air to arrive at the LAERF laboratory the following day. Once samples were received, each set was checked and logged in. Laboratory analyses included alkalinity, turbidity, total phosphorous, soluble reactive phosphorous, $NH_3$-N, $NO_3$-N, dissolved Na, K, Ca, Mg, Fe, and Mn, and total suspended solids. All samples collected were handled, preserved, and analyzed according to APHA et al. (1989) protocols.

## Results and Discussion

### Bathymetry

The bottom contours of Kirk Pond are highly irregular (Figure 4), particularly in the eastern end of the pond, in large part due to the "borrow" activities during the construction of Fern Ridge Dam. Most shallow areas in the pond are gravel ridges that were not desirable material for dam construction.

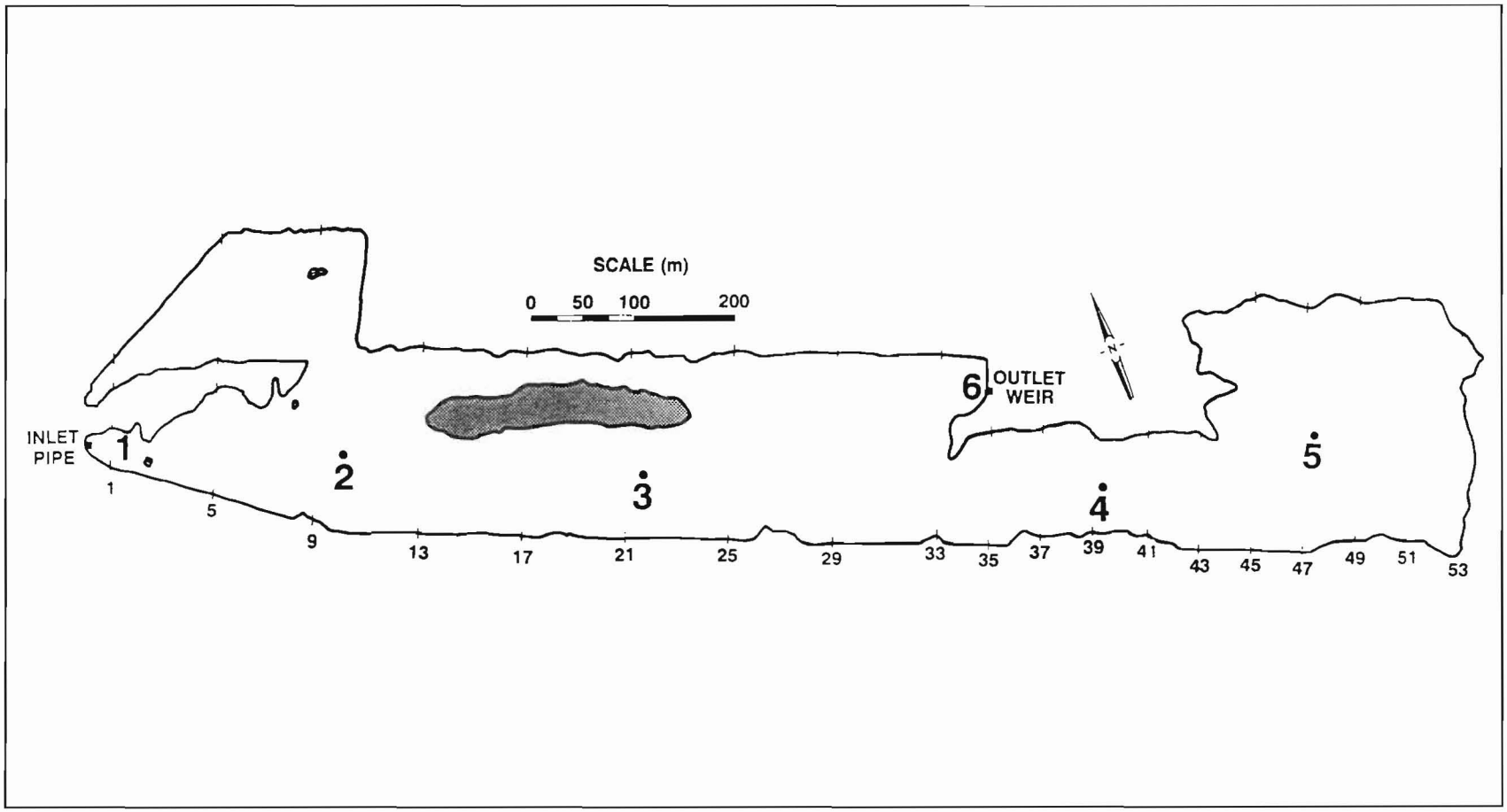


Figure 3. Map of Kirk Pond indicating water sampling stations 1 through 6

**Table 2**
**Sample Preservation Methods and Selected Parameters**

| Preservation Technique | Bottle | Water Type | Preserving Acid | Refrigerated |
|---|---|---|---|---|
| A | 500 mL, plastic | Raw | None | Yes |
| B | 250 mL, plastic | Raw | 1:1 $H_2SO_4$ | Yes |
| C | 175 mL, plastic | Filtered, 0.45µ | None | Yes |
| D | 60 mL, plastic | Filtered, 0.45µ | 1:1 HC1 | No |

Note: Each sampling station includes the above-listed set of sample bottles and preservation techniques.

**Table 3**
**Selected Parameters, Preservation Techniques, and Analytical Methods**

| Selected Parameters | Preservation Technique (from Table 2) | Method[1] |
|---|---|---|
| Alkalinity (mg $CaCO_3$ $L^{-1}$) | A | Electrometric titration |
| Turbidity (NTU) | A | Nephelometric |
| Total phosphorous (µg $L^{-1}$) | B | Persulfate digestion, spectrometric analysis |
| Ammonia nitrogen (mg $L^{-1}$) | B | Specific ion electrode |
| Soluble reactive phosphorous (µg $L^{-1}$) | C | Ascorbic acid, spectrometric analysis |
| Nitrate nitrogen (mg $L^{-1}$) | C | Cd reduction |
| Dissolved sodium (mg $L^{-1}$) | D | AA spectroscopy |
| Dissolved potassium (mg $L^{-1}$) | D | AA spectroscopy |
| Dissolved calcium (mg $L^{-1}$) | D | AA spectroscopy |
| Dissolved magnesium (mg $L^{-1}$) | D | AA spectroscopy |

[1] All analytical methods are derived from APHA et al. 1989.

A graph of cumulative depths is shown in Figure 5. Kirk Pond is very shallow, with a mean depth of 1.6 m and a median depth of 1.4 m. The maximum depth measured in the pond was 4.4 m. Few sites were deeper than 3.0 m, and these were "holes" of limited area. Deep "holes" are found along transects 11, 31, 41 to 48, and 51 to 52.

## Sediment characteristics

The distribution of sediment types in Kirk Pond is shown in Figure 6. Sediment classification provides a convenient method for distinguishing

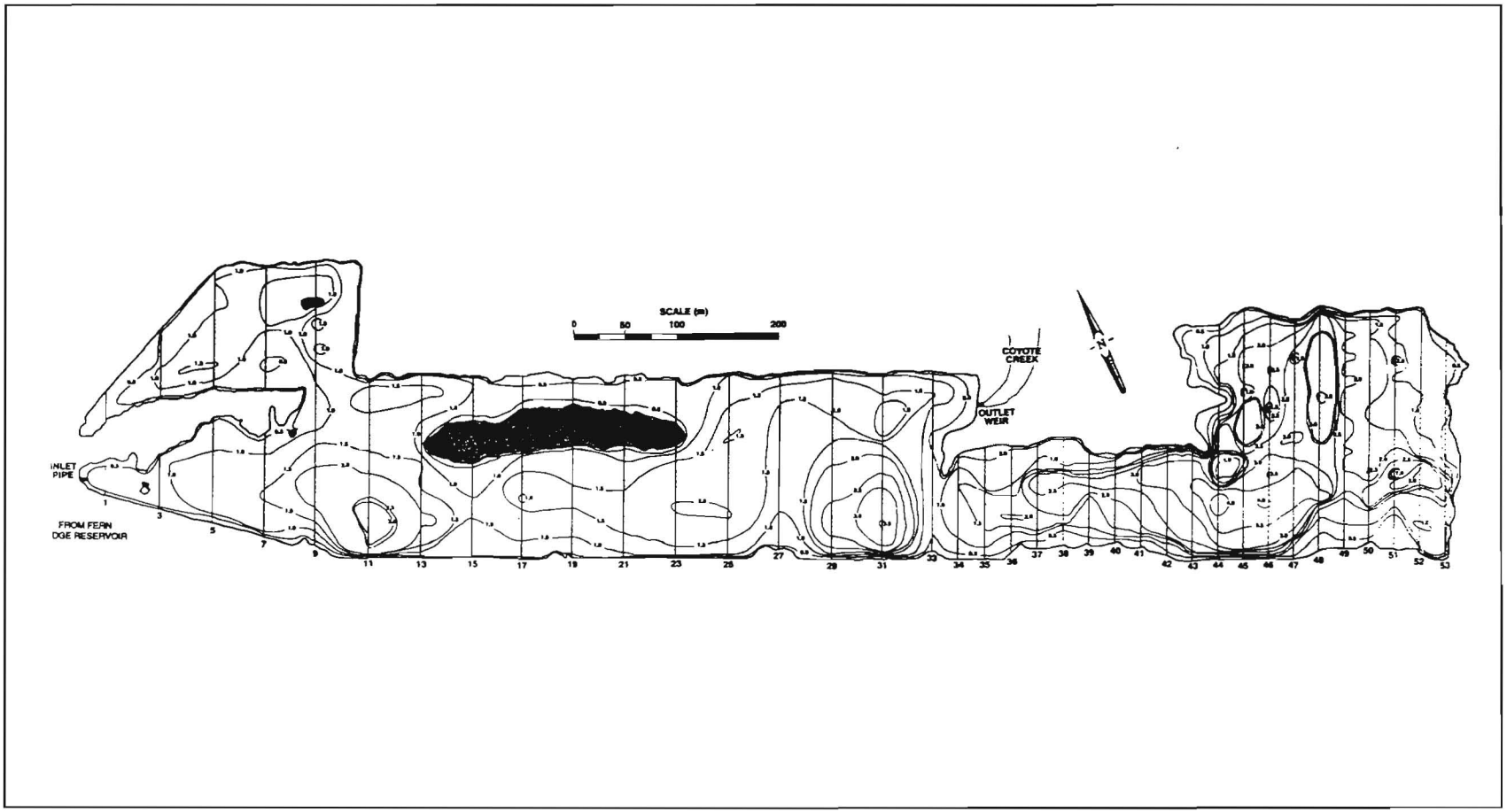


Figure 4. Map of Kirk Pond indicating depth intervals every 0.5 m and transects along which the depths were measured

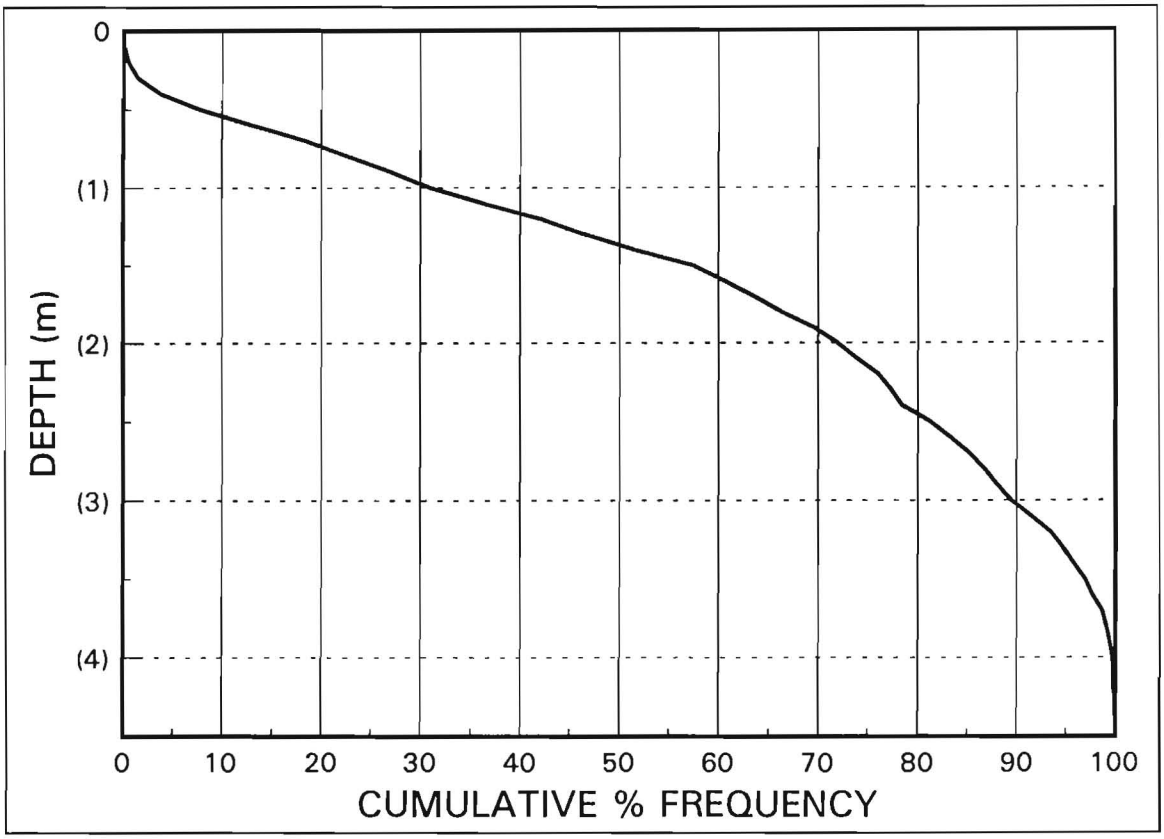


Figure 5. Cumulative frequency of depth in Kirk Pond

sediments. A summary of sediment type distributions and the characteristics of each sediment are found in Table 4.

Gravel substrates composed 16.1 percent of the bottom area sampled. These sediments were very difficult to core, often having large cobbles that obstructed the core sampler; therefore, the average core depth was significantly less than other classes. Once the gravel-size "particles" were removed, sediments were similar to those of other sediment classes. Sandy substrates composed 35.6 percent of the bottom area sampled, which is typical of many aquatic environments. Sand class sediments were significantly higher in sand-size particles and lower in silt-size particles than other sediment classes measured, but clay-size particles did not change in relative abundance. Silt sediments covered 13.6 percent of the bottom area sampled. These were typically found in protected areas out of wave-driven water movement or the flow from inlet to outlet.

Clay sediment class was found at only 4.2 percent of the bottom area, which may be a tribute to the effectiveness of the borrow activities. This material was very cohesive, and almost as difficult to sample as the gravel. Because of problems with sampling and technique in handling the material, particle size analysis was not performed. However, the clay was similar in many parameters to other sediments. Organic sediments were found over

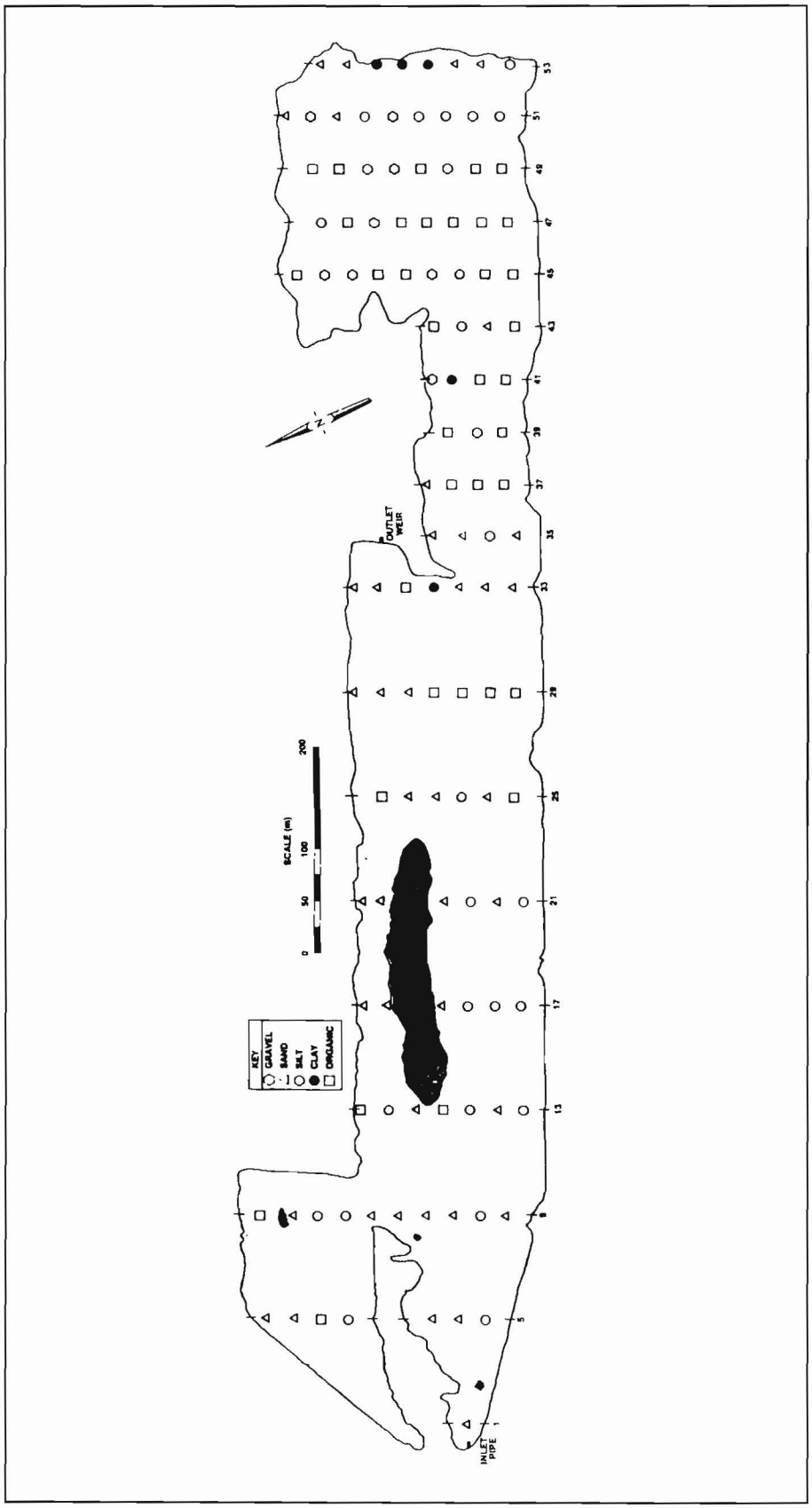


Figure 6. Distribution of sediment types in Kirk Pond

**Table 4**
**Relative Frequency of Sediment Classes in Kirk Pond and Their Chemical and Physical Characteristics**

| Characteristic (range) | Gravel (> 50%) | Sand (> 50%) | Silt (> 50%) | Clay (> 50%) | Organic (> 10%) | All |
|---|---|---|---|---|---|---|
| Frequency (Percent) | 19 (16.1) | 42 (35.6) | 16 (13.6) | 5 (4.2) | 36 (30.5) | 118 (100) |
| % Sand | [1] | 70.5[2] | 26.3 | [1] | 22.5 | 49.4 |
| % Silt | [1] | 14.7[2] | 53.9 | [1] | 63.4 | 34.9 |
| % Clay | [1] | 14.9 | 19.8 | [1] | 17.5 | 16.6 |
| Core depth (cm) | 6.4[2] | 18.0 | 22.5 | 17.8 | 19.4 | 17.3 |
| Density ($g\ L^{-1}$) | 1.5 | 1.5 | 1.4 | 1.7 | 1.3[2] | 1.4 |
| % Organic matter | 7.4 | 4.7 | 6.6 | 5.6 | 13.5[2] | 8.0 |
| % Calcium carbonate | 6.0 | 3.9 | 6.0 | 4.2 | 8.0[2] | 5.6 |
| Extractable $NH_4^+$-N ($\mu g\ g^{-1}$) | 1.0 | 4.1 | 8.2 | 1.5 | 2.6 | 4.5 |

[1] No data collected for this class due to lack of adequate samples.
[2] Significantly different from other classes at the p = 0.05 level using a one-way ANOVA.

30.5 percent of pond bottom area, typically in deeper waters, and were the result of allochthonous and autochthonous plant material inputs, with decomposition altering the character of the sediment. Organic sediments were significantly less dense and, as expected, higher in organic matter than other sediment classes. Organic sediments were also significantly higher in calcium carbonate than other classes, possibly as the result of aquatic plant material inputs. Aquatic plants, such as *Myriophyllum spicatum*, actively create a carbonate coating through photosynthetic activity (Wetzel 1960; Smart 1990).

## Light availability

Average light profiles for the nine sites measured are shown in Figure 7. Light intensity, as shown by percent of surface light transmitted, decreased very rapidly within plant canopies and was generally reduced to around 1 percent of surface light intensity within the upper 50 cm of the canopy. Light intensity decreased more slowly at unvegetated sites 1 and 2, in the western and central portions of the pond. Light transmission was highest at site 3 located in the eastern portion of Kirk Pond, due to the absence of a vegetated canopy and low turbidity. The rate of light extinction ($K_d$) was highest at the vegetated sites, and peaked within the canopy of *M. spicatum*. The peak of $K_d$ ranged from 10 to 17 in the vegetated sites, while unvegetated sites had a $K_d$

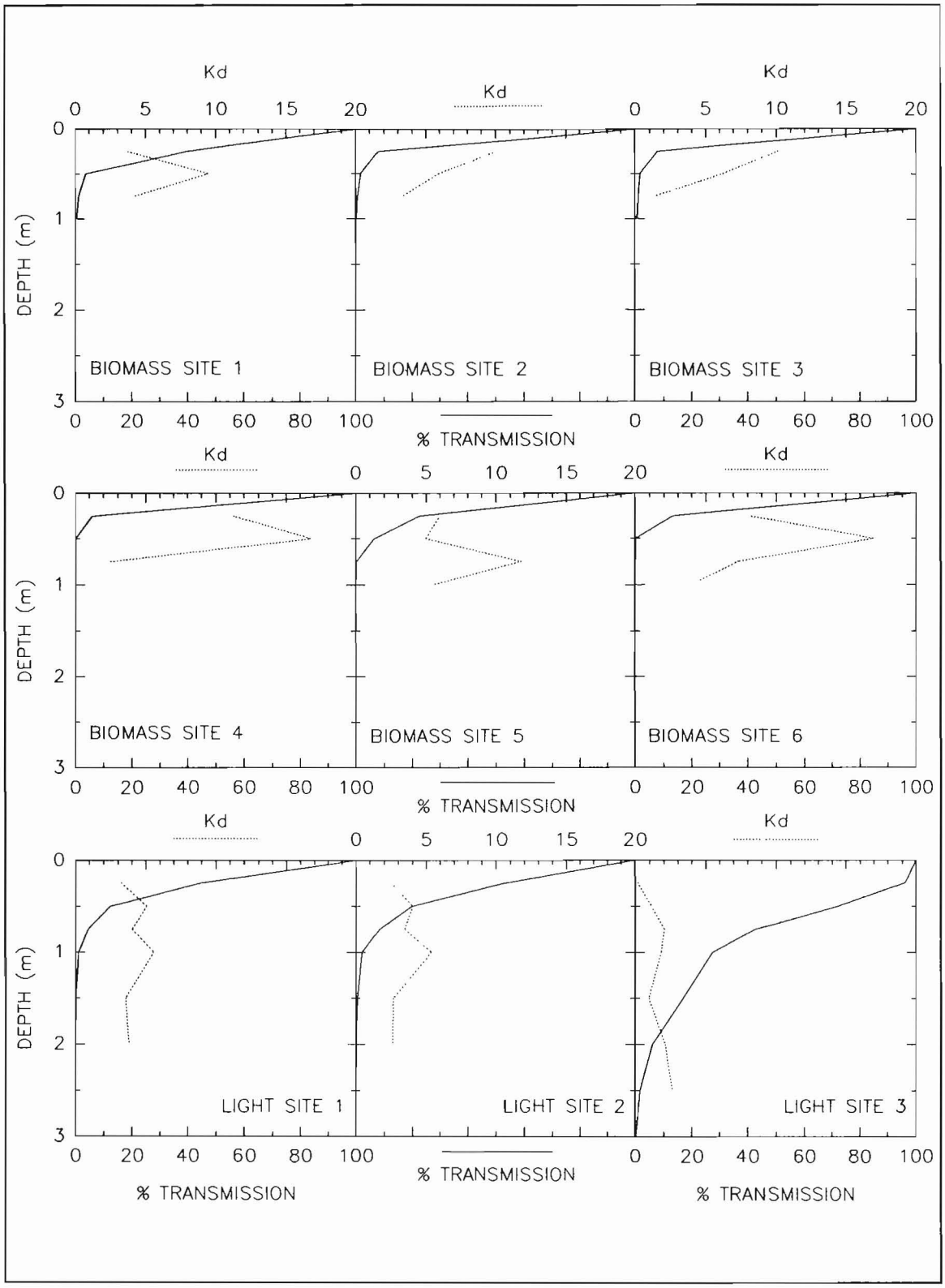


Figure 7. Light profiles for six vegetated sites (I - VI) and three unvegetated sites (L1 - L3) for Kirk Pond. Solid line, percent light transmission; dotted line, light extinction coefficient ($K_d$)

of around 5 in the western and central portions of the pond, and 1 to 3 in the eastern portion of the pond. Although light penetration was greater in unvegetated sites, particularly in the eastern end of the pond, light intensities equivalent to 1 percent of surface light intensity did not reach the sediment surface at any of the sites. Open water sites differed significantly in light penetration; however, the vegetated sites were very similar despite substantial difference in water clarity. Therefore, plant canopy was the most significant component of light reduction in vegetated sites.

Unvegetated sites had an average $K_d$ of 3.42, with a range of 1.83 to 4.61. The average depth of 10 percent of surface light was 0.95; thus, an average depth of 1 m where 10 percent of surface light intensity was present could be expected for the pond, with the western end having a range of 0.57 to 0.68 m and the eastern end having 2.5 times that light penetration. Light penetration under vegetated canopies (dominated by *M. spicatum*) was, on average, less than one-third of this value, with no pattern between different regions of the pond. *Myriophyllum spicatum* effectively preempted light, precluding other plant species from occurring beneath its dense canopy.

Light was rapidly extinguished under plant canopies of predominantly *M. spicatum*, with light extinction rates in the canopy ranging from 10 to 17 $m^{-1}$. The depth at which ambient light reached 10 percent of full sun ranged from 0.2 to 0.4 m. The *M. spicatum* canopy could effectively shade native plants, suppressing their growth (Madsen et al. 1991a,b). At the unvegetated, open water sites, light penetration was greater. In the western and central portions of the pond, sufficient light (10 percent of full sun) to support plant growth reached depths of approximately 0.7 m, which corresponds to the maximum depth of plants observed in the western end. In the eastern end of the pond, 10 percent of full sun penetrated to approximately 2.0 m, which corresponds to the maximum depth of *M. spicatum* in this area. Coontail was found to a maximum depth of 3.5 m, which corresponded to 0.2 percent full sun. Coontail has a lower light requirement than *M. spicatum*, allowing it to grow at greater depths (Titus 1977). The higher light penetration in the eastern end of the pond allows plant growth to deeper areas, with plants growing to the deepest point of this end of the pond.

## Water chemistry

Water chemistry differed significantly between the eastern portion (stations 4, 5) of the pond, which was hydrodynamically isolated from the western and central portions of the pond (stations 1, 2, 3, and 6). The western and central portions of the pond were strongly influenced by the inflow water quality, and tended to be more turbid than the eastern end of the pond.

Temperature of the water flowing into Kirk Pond increased from 15 °C in late May to a maximum of 23.5 °C on 1 August, and then declined to 18 °C by the end of September (Figure 8). Temperature at the outflow from the pond

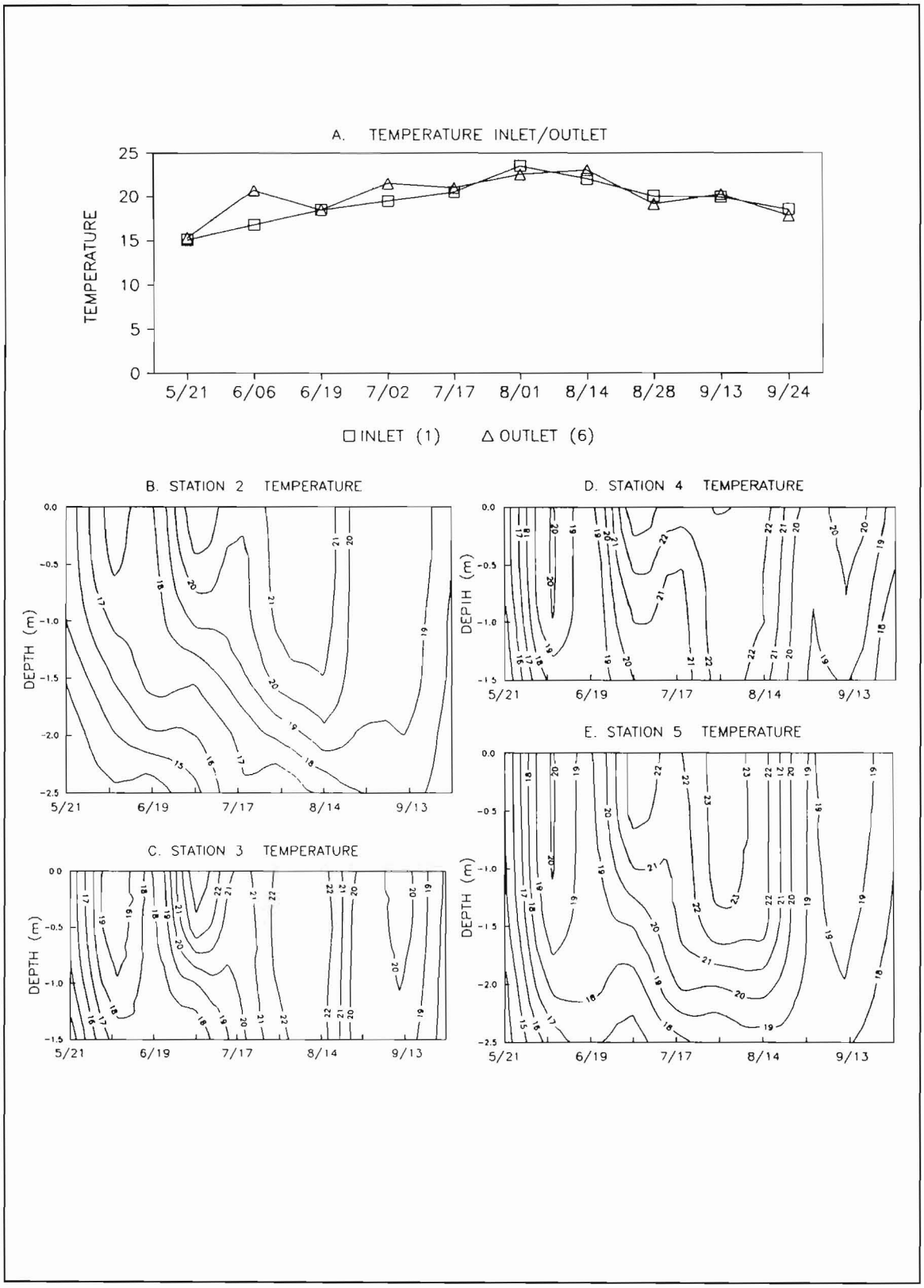


Figure 8. Water temperature (°C) in Kirk Pond at the inflow and outflow, stations 1 and 6, respectively (A), and temperature isopleths for stations 2 through 5 (B through E)

was usually within ½ or 2 °C of the inflow, except during early June when the water flowing out of the pond was about 4 °C warmer than the inflow.

Stations 2 and 3, in the western and central portions of the pond, respectively, exhibited weak stratification early in the sample period (May through June), with surface temperatures that ranged from 16 to 22 °C. Inflow temperatures increased from 15 to 18 °C during the same period. Inflow water was cooler and denser than Kirk Pond surface water in early May, but was the same temperature and density as pond water by the end of June. Surface temperatures at stations 2 and 3 peaked in July at about the same time the inflow water reached its highest temperature. Between July and late September, temperatures at stations 2 and 3 were more uniform and did not differ appreciably either between stations or with depth.

Stations 4 and 5, located in the eastern portion of the pond, were more isothermal early in the measurement period, with both surface and bottom temperatures increasing from 16 °C to 18 or 20 °C by mid-July. Surface water temperatures at stations 4 and 5 peaked in early August, later than stations 2 and 3, and at a time when the inflow temperature was declining. Station 5 exhibited stratification during the period July through August. Differences in thermal profiles between the western and eastern portions of the pond are attributable to the influence of the inflow of water into the western end of the pond and a lack of mixing in the eastern portion due to dense aquatic plant growth.

Inflow water pH was consistently one to two units below that of the outflow from May through late August (Figure 9). After late August, pH of the inflow and outflow waters were similar. As this water flowed through the pond it was aerated, resulting in a steady increase in pH and dissolved oxygen.

Profiles of pH at stations 2 and 3 showed little difference with depth or season, which was consistent with the observation that these stations were in a flowing water zone in which the pond acts as a conduit for inflow water to the outflow (Figure 9). pH values at stations 4 and 5 were considerably higher than those at stations 2 and 3, reflecting the influence of photosynthetic activity of the macrophytes.

Dissolved oxygen concentrations in the inflow and outflow waters were consistent with temperature-mediated saturation levels (Figure 10). Inflow dissolved oxygen varied from 9.9 mg $L^{-1}$ in May to a low of 4.4 mg $L^{-1}$ in mid-July. Outflow dissolved oxygen ranged from 11.2 mg $L^{-1}$ to a low of 4.5 mg $L^{-1}$ in September. Stations 2 and 3, in the zone of water flow-through, exhibited a weak stratification of dissolved oxygen. Stations 4 and 5, in the eastern portion of the pond, exhibited higher surface water oxygen levels, reflecting the influence of the vegetation. Dissolved oxygen at station 5 exhibits a strong gradient of high dissolved oxygen at the surface to low dissolved oxygen near the bottom, again reflecting the influence of vegetation and reduced hydraulic exchange.

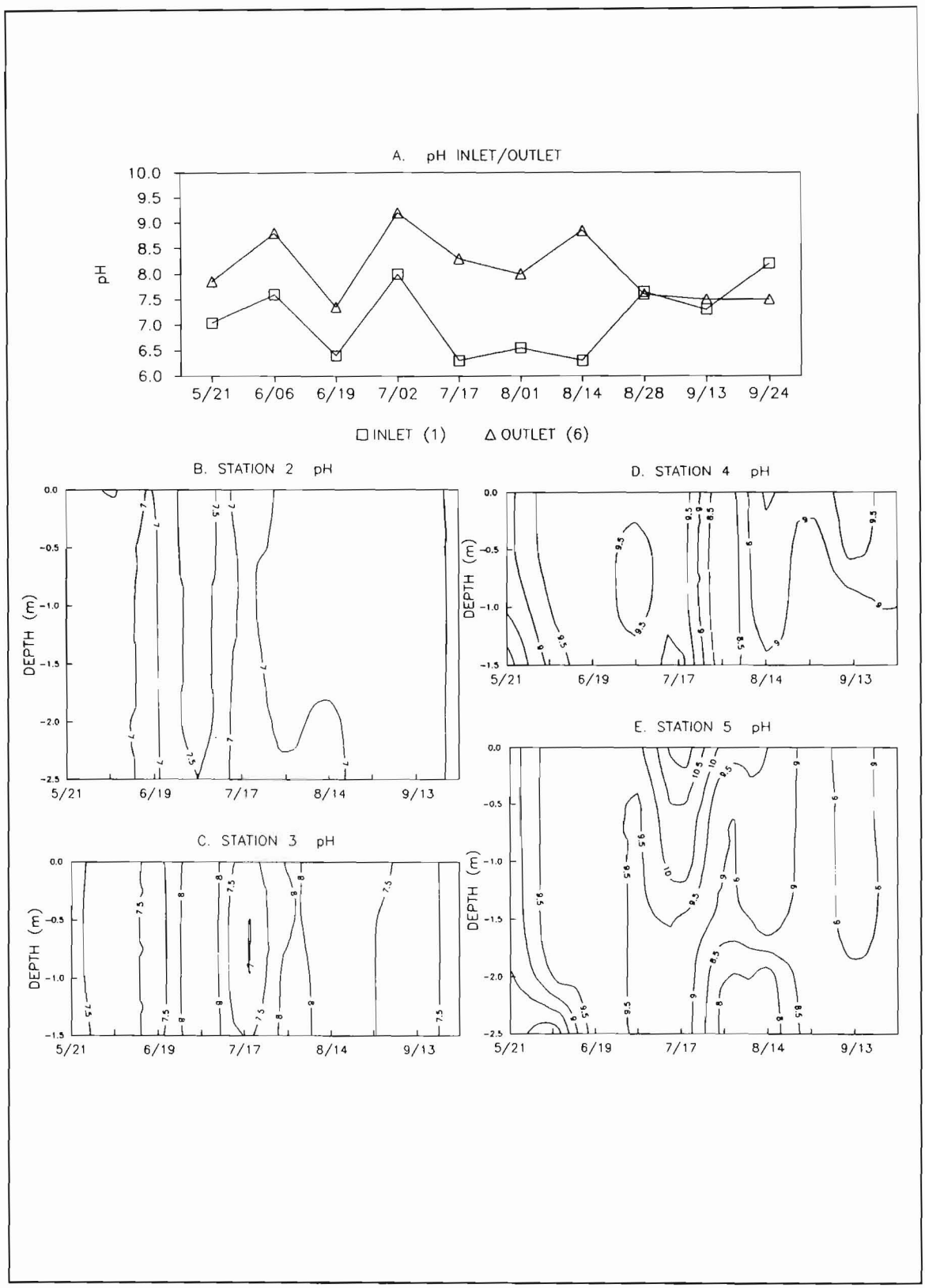


Figure 9. Water pH (units) in Kirk Pond at the inflow and outflow, stations 1 and 6, respectively (A), and pH isopleths for stations 2 through 5 (B through E)

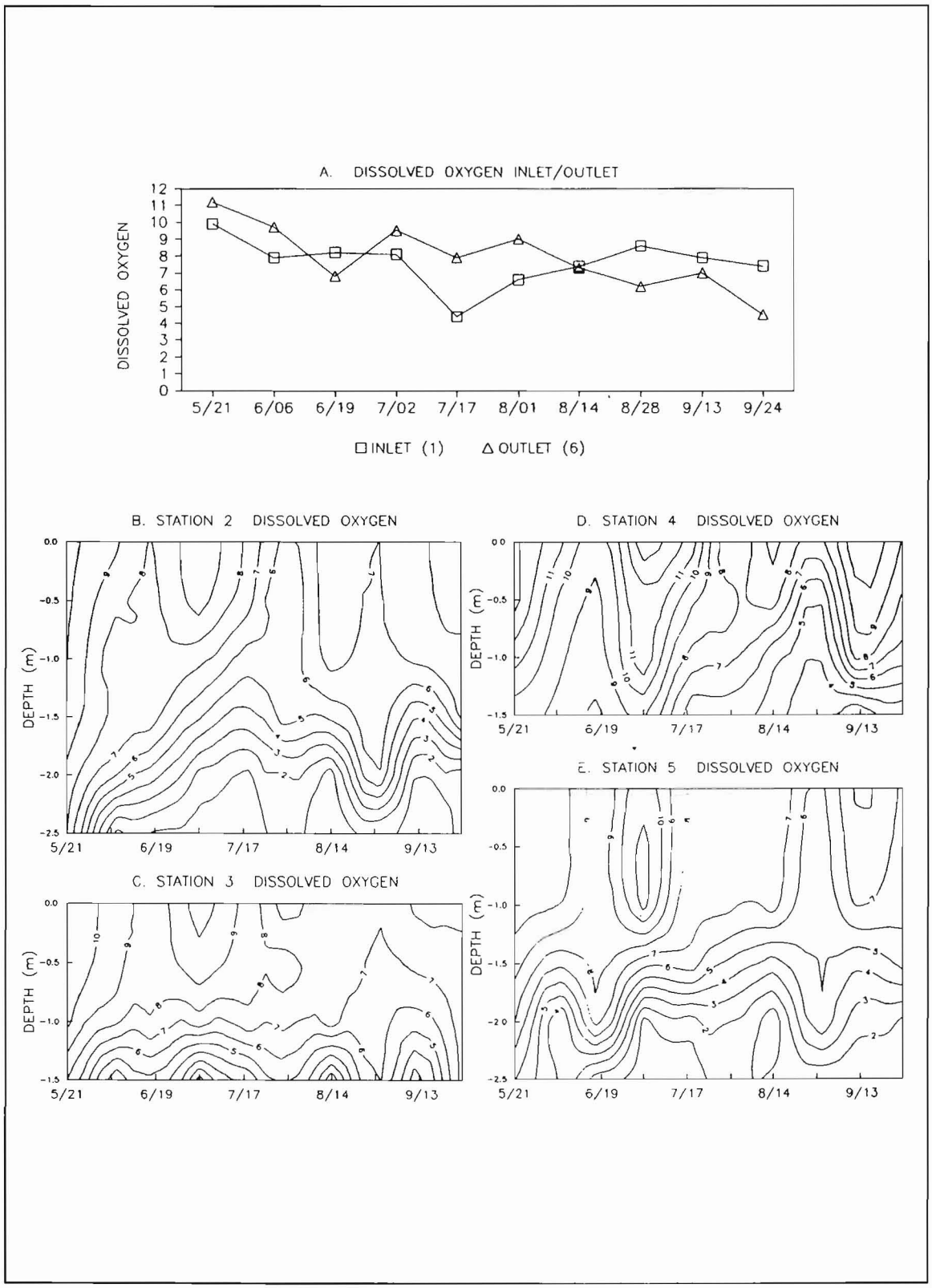


Figure 10. Dissolved oxygen (mg $L^{-1}$) in Kirk Pond at the inflow and outflow, stations 1 and 6, respectively (A), and dissolved oxygen isopleths for stations 2 through 5 (B through E)

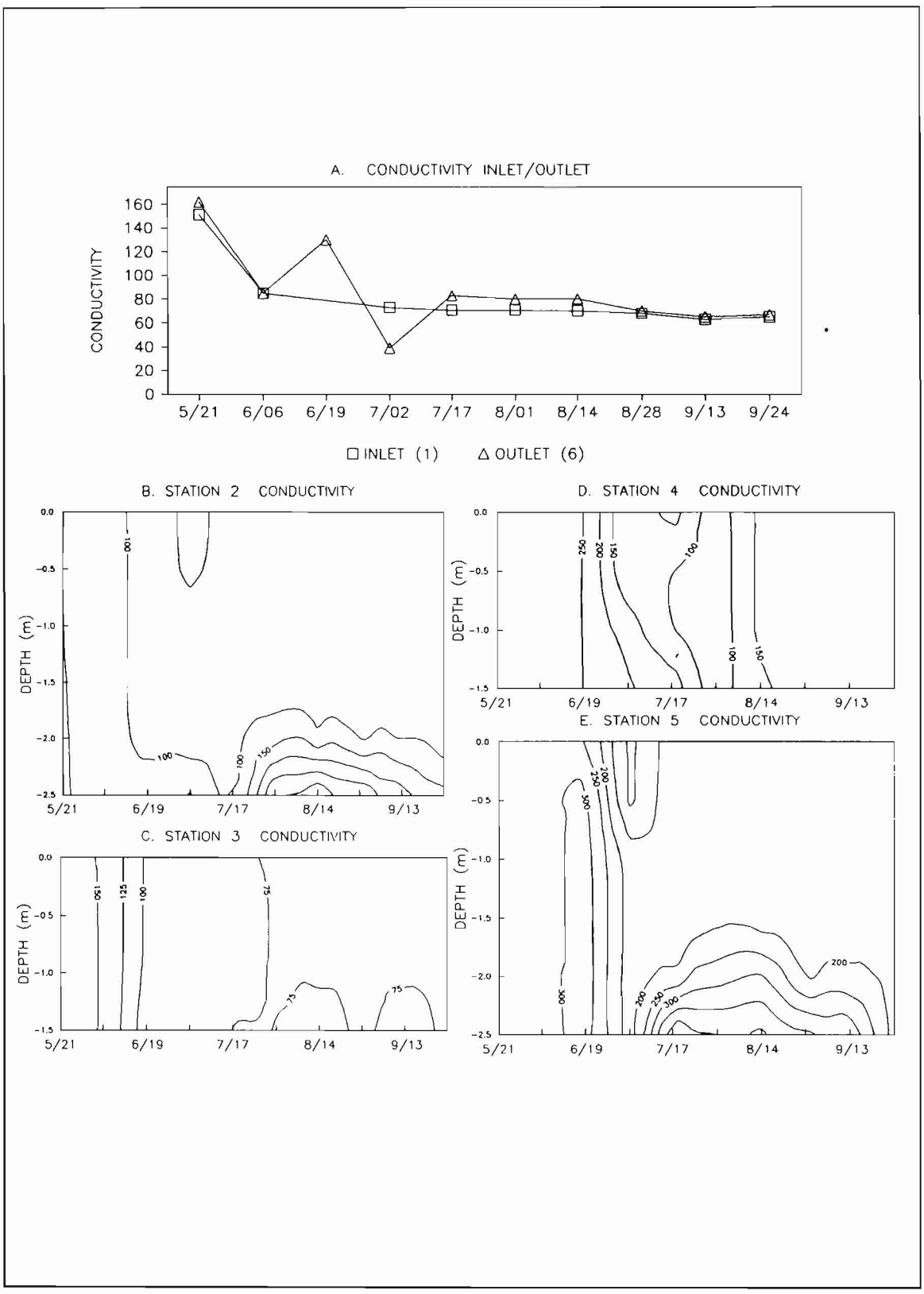


Figure 11. Conductivity (μS $cm^{-1}$) in Kirk Pond at the inflow and outflow, stations 1 and 6, respectively (A), and conductivity isopleths for stations 2 through 5 (B through E)

Specific conductance of inflow and outflow waters was almost identical throughout the sampling period (Figure 11). Conductivity was highest in May, at 150 µS $cm^{-1}$, and stabilized throughout most of the sampling period at about 80 µS $cm^{-1}$. Conductivity at stations 2 and 3 was consistent with these values. Stations 3 and 4 showed little vertical stratification throughout the sample period. In contrast, stations 2 and 5 showed strong vertical gradients in conductivity from July through the end of the sampling season. The values at station 5 were consistently above those of the inflow and the other stations, averaging 194 µS $cm^{-1}$ (Table 5). The vertical gradient observed at station 5 and high values at both stations 4 and 5 may have been related to groundwater input in the eastern end of the pond.

Alkalinity exhibited differences between the inflow and the outflow, and the eastern and western sections of the pond. Alkalinity averaged between 24 and 30 mg $CaCO_3$ $L^{-1}$ in the flow-through zone (inflow, stations 2 and 3, and outflow), and 91 to 94 mg $CaCO_3$ $L^{-1}$ in the eastern portion of the pond (Table 5). These alkalinity values were consistent with conductivity measurements discussed previously. The eastern portion of the pond was higher in dissolved constituents than water flowing from the inflow to the outflow in the western and central portions of the pond.

Turbidity was an order of magnitude higher in the inflow, outflow, and western portions of the pond than in the eastern portion (Table 5). Stations 1 through 3 averaged turbidity of 27.3 to 28.6 NTU, and station 6 (outflow) averaged slightly lower at 17.1 NTU, perhaps due to settling of particulate material. Turbidity averages in the eastern portion of the pond were much lower, reflecting the lack of significant influx of turbid water and the filtering effects of the vegetation. Total suspended solids (TSS) also substantiated observations on turbidity; TSS was a major component of turbidity in Kirk Pond (Table 5).

The seasonal variation in turbidity is interesting to note (Figure 12). Turbidity of inflow water was consistently between 25 and 35 NTU. Outflow water had similar turbidity during the period of June through mid-July, but was substantially lower from early August through the end of the sampling period. This could be related to the development of a topped-out plant canopy near the outflow, which may have trapped some particulate matter. Turbidity values at stations 2 and 3 were higher than inflow values early in the season, and equivalent to the inflow values for the remainder of the sampling period. High values at these stations early in the season likely reflect the influence of resuspension of recently deposited sediments, since the sediments in the western portion of the pond were largely composed of depositional silt from the inflow water.

Ammonium concentrations were relatively low in the inflow and outflow waters, averaging 30 µg $L^{-1}$, but were elevated in the pond water, particularly at stations 2 and 3, where the averages were 80 and 60 µg $L^{-1}$, respectively (Table 5). Although the high averages at the two stations were largely attributable to single occurrences of very high ammonium concentrations (440 and

**Table 5**
**Average of Water Chemistry Parameters for the Six Monitoring Stations in Kirk Pond**

| Parameter | Station | | | | | |
|---|---|---|---|---|---|---|
| | 1 Inflow | 2 In-lake | 3 In-lake | 4 In-lake | 5 In-lake | 6 Outflow |
| Water temperature (°C) | 19.4 (0.3) | 19.4 (0.7) | 20.0 (0.9) | 20.5 (0.9) | 20.1 (0.8) | 20.0 (0.7) |
| pH (units) | 7.1 (0.2) | 7.3 (0.1) | 7.7 (0.1) | 9.4 (0.2) | 9.6 (0.3) | 8.1 (0.2) |
| Dissolved oxygen (mg $L^{-1}$) | 7.6 (0.4) | 8.2 (0.4) | 8.6 (0.4) | 10.4 (0.8) | 8.4 (0.5) | 7.9 (0.6) |
| Conductivity (µS $cm^{-1}$) | 79.7 (8.2) | 75.0 (9.2) | 83.3 (8.4) | 184.8 (21.3) | 194.0 (18.1) | 81.2 (10.0) |
| Alkalinity (mg $CaCO_3$ $L^{-1}$) | 24.0 (1.4) | 25.9 (1.5) | 29.7 (1.4) | 91.1 (2.5) | 93.6 (2.8) | 29.2 (1.3) |
| Turbidity (NTU) | 27.8 (1.9) | 27.3 (2.2) | 28.6 (2.9) | 2.1 (0.2) | 1.9 (0.2) | 17.1 (2.6) |
| Total suspended solids (mg $L^{-1}$) | 22.8 (2.8) | 21.6 (1.9) | 38.0 (13.0) | 7.7 (1.8) | 4.7 (1.6) | 18.7 (3.2) |
| Ammonium-N (mg $L^{-1}$) | 0.03 (0.01) | 0.08 (0.04) | 0.06 (0.03) | 0.04 (0.01) | 0.03 (0.02) | 0.03 (0.01) |
| Nitrate-N (mg $L^{-1}$) | 0.05 (0.01) | 0.03 (<0.01) | 0.02 (<0.01) | 0.03 (0.01) | 0.03 (0.01) | 0.03 (0.01) |
| Total phosphorus (µg $L^{-1}$) | 48 (4) | 58 (6) | 60 (9) | 26 (2) | 20 (2) | 40 (3) |
| Soluble reactive phosphorus (µg $L^{-1}$) | 6 (0.3) | 8 (0.6) | 8 (0.1) | 10 (0.9) | 4 (0.6) | 7 (0.9) |
| Dissolved calcium (mg $L^{-1}$) | 2.8 (0.2) | 3.3 (0.3) | 3.9 (0.3) | 13.9 (0.7) | 13.8 (0.5) | 4.3 (0.5) |
| Dissolved magnesium (mg $L^{-1}$) | 2.5 (0.1) | 2.9 (0.1) | 3.5 (0.3) | 12.6 (0.5) | 12.8 (0.3) | 3.4 (0.2) |
| Dissolved sodium (mg $L^{-1}$) | 4.0 (0.4) | 4.3 (0.3) | 4.7 (0.3) | 9.7 (0.8) | 10.5 (0.9) | 4.7 (0.2) |
| Dissolved potassium (mg $L^{-1}$) | 1.1 (0.1) | 1.3 (0.2) | 1.0 (0.1) | 0.9 (0.1) | 1.0 (0.1) | 0.9 (0.0) |

Note: Standard error of the mean is given in parentheses.

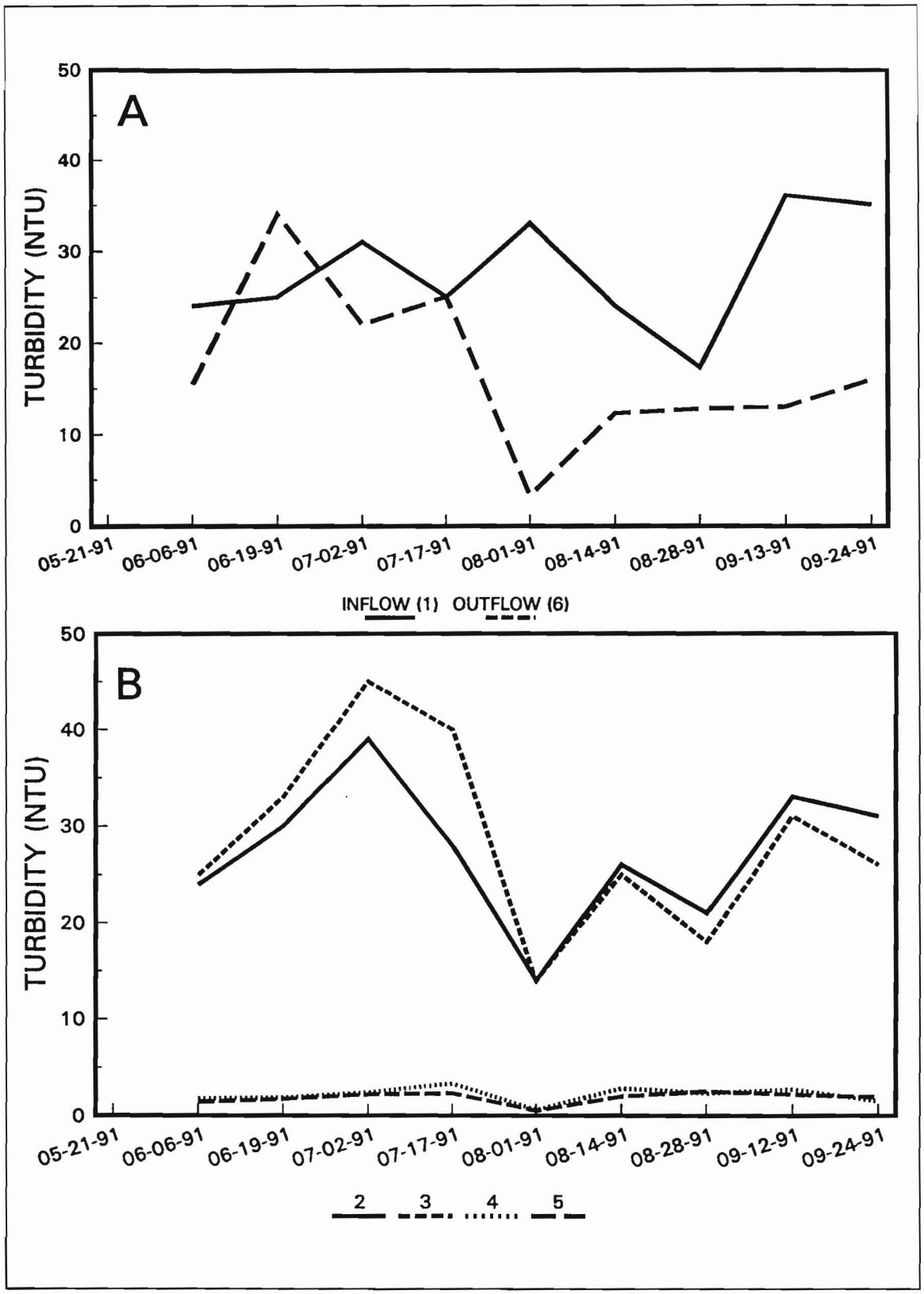


Figure 12. Turbidity (NTU) in Kirk Pond at the inflow and outflow stations (A; 1 and 6, respectively) and at sites 2 through 5 (B)

320 µg $L^{-1}$, respectively), these stations tended to be higher throughout the study period. Taken in a larger context, the ammonium concentrations were low throughout the pond compared to other water bodies, reflecting low loading rates and the influence of macrophytes. In contrast, nitrate was highest in the inflow water (50 µg $L^{-1}$) and averaged 20 to 30 µg $L^{-1}$ at the other stations (Table 5). Nitrate is readily taken up by phytoplankton and macrophytes.

Total phosphorus was substantially higher in the inflow and stations 2 and 3 than at stations 4 and 5. Total phosphorus concentrations in the outflow were intermediate to those of the eastern and western stations. Soluble reactive phosphorus, a form of phosphorus readily available to plants and algae, exhibited a similar, but less pronounced, pattern (Table 5). Total phosphorus throughout the sample period was very similar between the inflow and outflow stations (Figure 13). Total phosphorus values measured at stations 2 and 3 were similar to those of inflow, except for one high value at station 3 (140 µg $L^{-1}$) in mid-July. Total phosphorus fluctuated little at either station 4 or 5.

Dissolved metal cations (Ca, Mg, Na, and K) concentrations gave strong evidence for groundwater influx to the eastern end of Kirk Pond (Table 5). Average concentrations of calcium, magnesium, and sodium at the inflow, outflow, and eastern stations ranged from 2.5 to 5 mg $L^{-1}$. The concentrations of these cations were several times higher in the eastern end of the pond than at stations 4 and 5. In contrast, potassium concentrations were similar throughout. Potassium is readily absorbed by submersed macrophytes, so relatively low values may reflect uptake by plants.

In summary, the western portion of the pond, from station 1 at the inflow to stations 2 and 3 in the pond to station 6 at the outflow, represents a flow-through system of discharge from the reservoir flowing to Coyote Creek. It is highly turbid, with a high load of total suspended solids. Because of this, light does not penetrate deeply, and plant growth is restricted. In contrast, the eastern portion of the pond has much lower turbidity and higher levels of alkalinity and cations. These differences in water chemistry suggest that groundwater inputs may dominate over surface water exchange in the eastern end of the pond. The greater water clarity allows plant growth throughout the eastern portion of the pond.

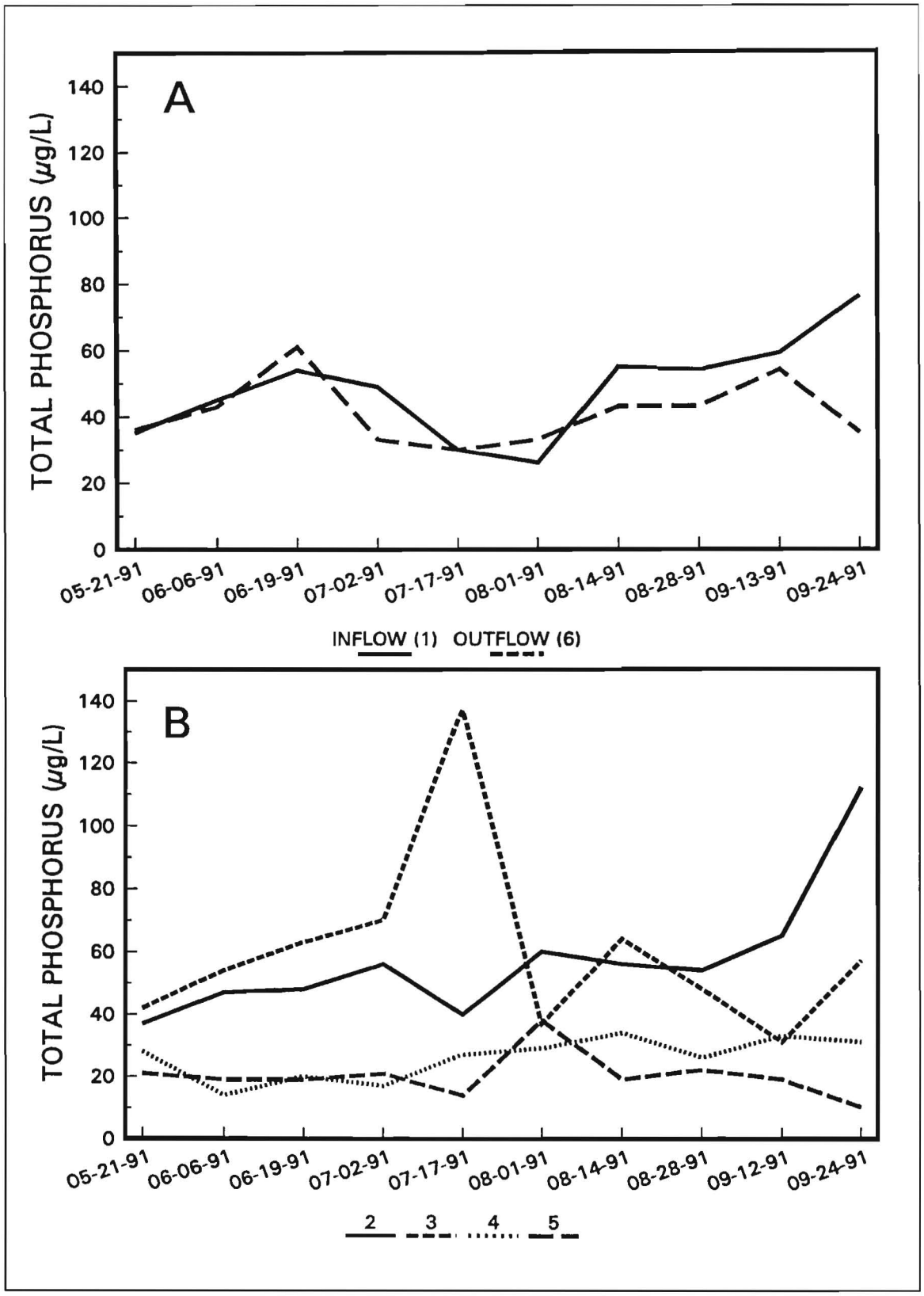


Figure 13. Total phosphorus (µg $L^{-1}$) in Kirk Pond at the inflow and outflow stations (A; 1 and 6, respectively) and at sites 2 through 5 (B)

# 3 Vegetation

## Introduction

The distribution and abundance of aquatic vegetation is controlled by a variety of environmental, ecological, and biological factors. Light penetration, water temperature, sediment and water chemistry, and the chance introduction of plants and animals all affect species composition of aquatic plant communities. In man-made Kirk Pond, mining of clay for dam construction has resulted in irregular bottom contours and patchy distribution of sediments. In addition, the input of highly turbid Fern Ridge Reservoir water to the west end of the pond results in decreased light penetration and a shallower maximum depth limit of plant growth, compared to the eastern end which is not influenced by the inflow of turbid water. All of these factors result in variations in plant distribution.

Perhaps the single biggest influence on the distribution of submersed vegetation in Kirk Pond has been the introduction of Eurasian watermilfoil (*Myriophyllum spicatum* L.), a nonnative submersed species. Its ability to form a surface canopy not only makes it successful in growing in the highly turbid waters of the western end, but this same canopy makes it a highly competitive plant, able to displace many native North American species (Madsen et al. 1991b). Near-monospecific stands of a *M. spicatum* with extensive surface canopies or mats are quite common and these infestations can severely restrict the use of water resources.

In 1991, a study was initiated to determine the present distribution and abundance of all aquatic plant species in Kirk Pond and to examine environmental factors that potentially affect plant distribution and abundance. This study was to provide information necessary to proceed with aquatic plant management planning.

# Materials and Methods

## Vegetation distribution

The distribution and species composition of aquatic plants was measured using a line-intercept method during 11-13 June 1991. Nineteen transects (Figure 14) were positioned across the entire pond from the south to north sides. Each transect was divided into 1-m intervals. Observers familiar with aquatic plant identification examined each interval per transect and marked the species found under or above the transect (e.g., intersecting the vertical plane made by the transect interval). A total of 3,161 transect intervals were examined. Using these data, percent cover of each species was calculated, and vegetation maps for Kirk Pond were produced. For simplicity, vegetation maps were prepared by pooling 1-m data for each species into 5-m intervals. Chi-square analyses using SAS statistical software (SAS Institute 1988) were used in pairwise two-by-two comparisons of the presence or absence of each species with the presence or absence of *M. spicatum*, measuring the effect of this invasive species.

## Biomass

Biomass was sampled at six locations in Kirk Pond (Figure 15) distributed across depth ranges and from the eastern to western portion of the pond during 8-9 September 1991. In all locations, *M. spicatum* was the dominant species. At each site, ten biomass samples were collected in a stratified-random pattern within 10,000-$m^2$ site plots using a 0.1-$m^2$ quadrat. Shoot material only was collected; root biomass was not included in the measurements. Biomass samples were separated by species and dried for 48 hours at 55 °C to a constant weight.

Dried plant samples were ground to pass a 0.4-mm mesh and then digested using a sulfuric acid/hydrogen peroxide method (Allen et al. 1974). Total plant nitrogen was determined by analysis of the digest for ammonium using a specific ion method, phosphorus using the ascorbic acid method, and potassium using atomic absorption spectrophotometry (APHA et al. 1989).

# Results and Discussion

## Vegetation distribution

The distribution of aquatic plant species in Kirk Pond is shown in Figures 16 and 17. A total of 85 percent of the pond area sampled was covered with aquatic plants; only 15 percent was bare substrate (based on 1-m-interval data from the transects). Bare substrate sites were found only in the western and central parts of the pond, where high turbidity prevented plants from growing at depths greater than 1.5 m in the western portion and 2.5 m in

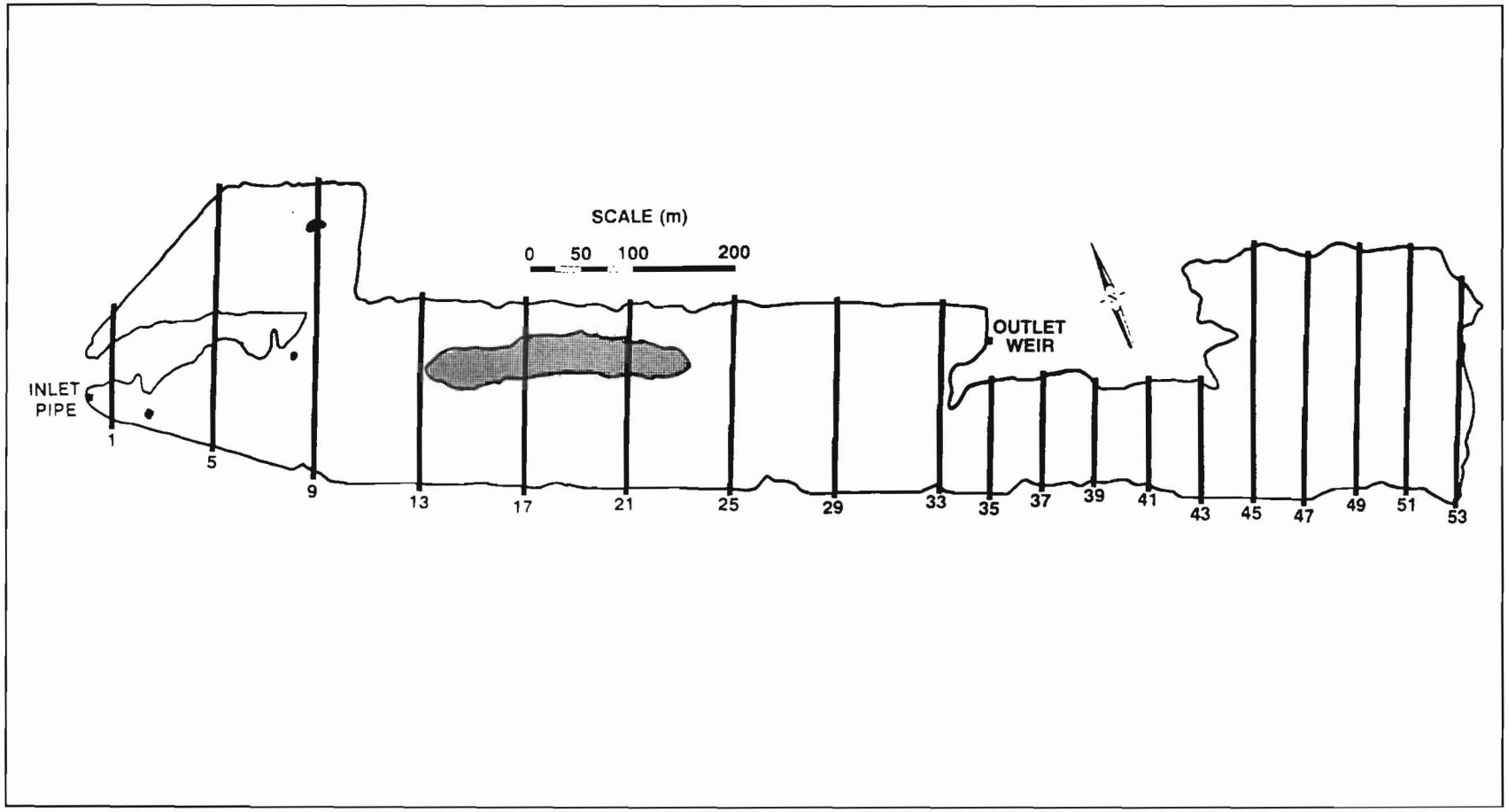


Figure 14. Map of Kirk Pond showing vegetation transect locations

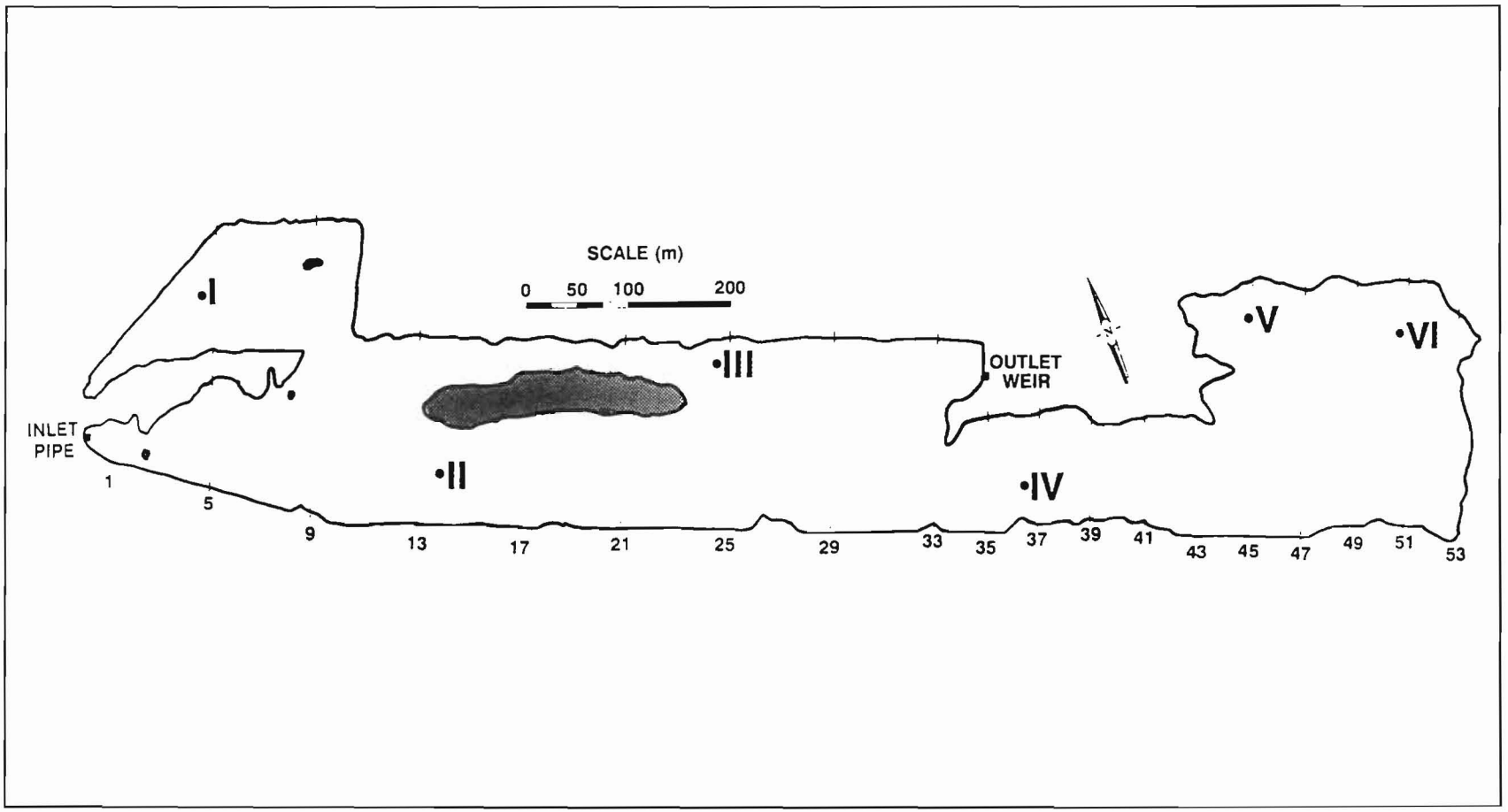


Figure 15. Map of Kirk Pond showing the six biomass sampling locations, I through VI

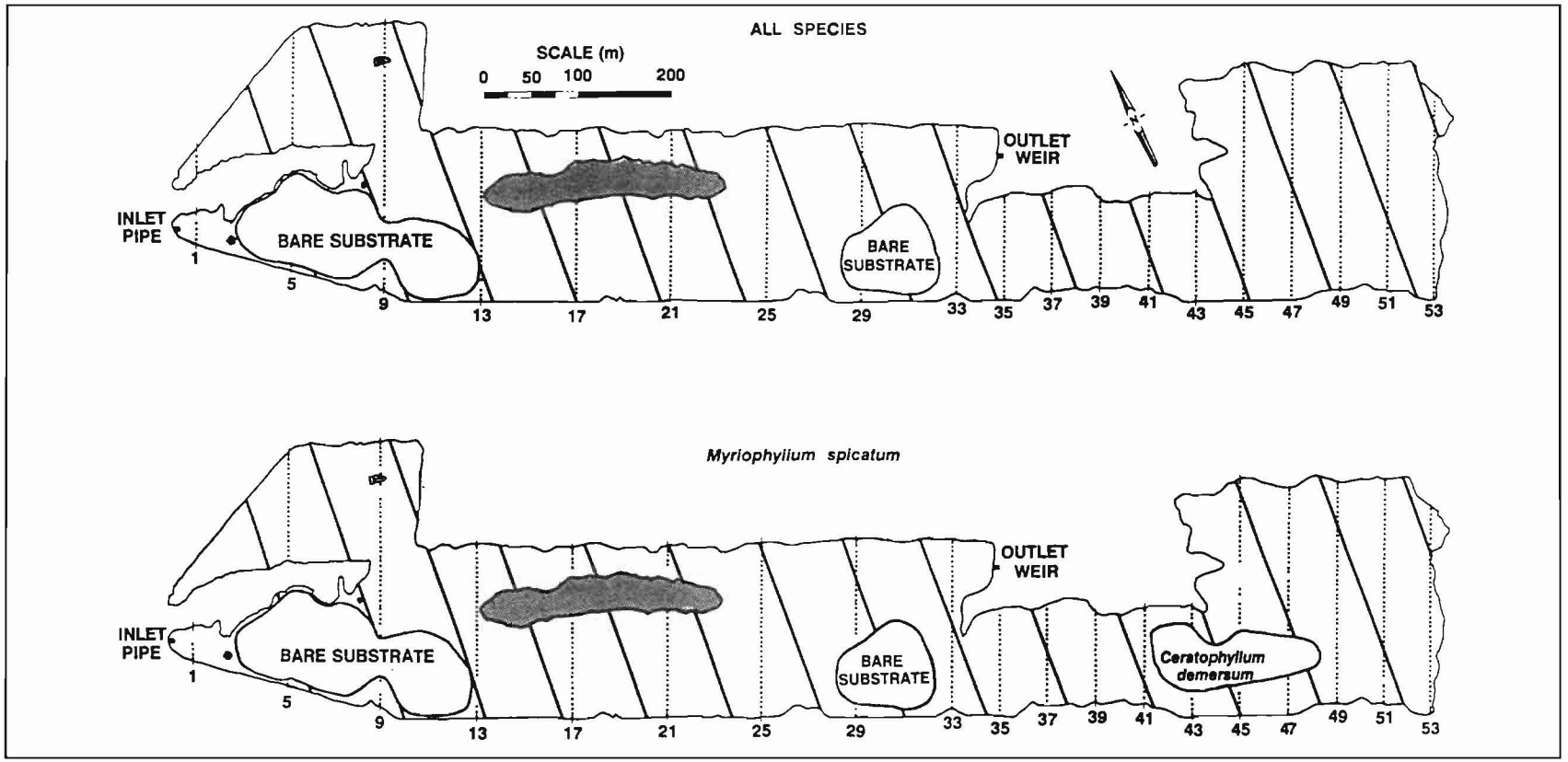


Figure 16. Maps of Kirk Pond showing the distributions of all species (right) and *Myriophyllum spicatum* (left). Closed circles indicate the occurrence of the species in that 5-m interval

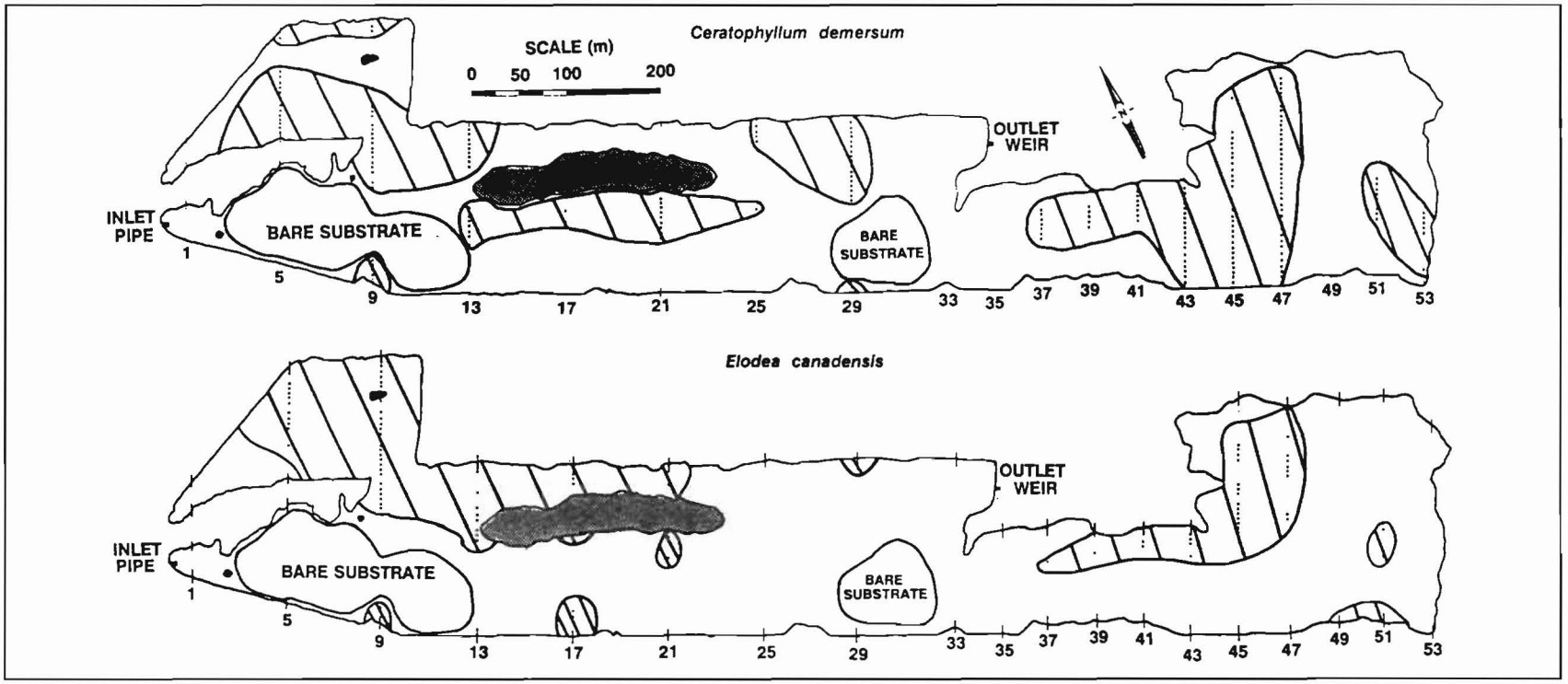


Figure 17. Maps of Kirk Pond showing the distributions of *Ceratophyllum demersum* (right) and *Elodea canadensis* (left). Closed circles indicate the occurrence of the species in that 5-m interval

the central portion. *Myriophyllum spicatum* occurred in 68.9 percent of the intervals, and was the dominant species in most of that area (Table 6). Of the vegetated portion of the pond, *M. spicatum* was absent only in a small, deep (>3 m) area in the eastern portion of the pond, which was dominated by *Ceratophyllum demersum*. This species also co-occurred with *M. spicatum* in many areas of the pond, and was the next most common species at 24.7 percent cover. *Elodea canadensis* also occurred with *M. spicatum*, and was observed in 9 percent of the transect intervals. *Elodea canadensis* often occurred among *M. spicatum* plants, generally around the edges of the pond, and was particularly common along the northern shore of the pond in both the western and the eastern ends. Other species occurred in less than 5 percent of the transect intervals (Table 6).

A total of 14 aquatic plant species were found rooted at or below the water surface; 5 were submersed, 3 were floating-leaved, and 6 were emergent

**Table 6**
**Percent Cover of Aquatic Plant Species in Kirk Pond**

| Scientific Name[1] | Common Name | Growth Form | Percent Cover |
|---|---|---|---|
| *Ceratophyllum demersum* | Coontail | Submersed | 24.7 |
| *Cyperus* sp. | Rush | Emergent | 0.4 |
| *Elodea canadensis* | Elodea | Submersed | 9.0 |
| *Juncus* sp. | Rush | Emergent | 1.0 |
| *Myriophyllum spicatum* | Eurasian watermilfoil | Submersed | 68.9 |
| *Nuphar* sp. | Yellow pond lily | Floating-leaved | 0.1 |
| *Polygonum* sp. | Smartweed | Emergent | 1.1 |
| *Potamogeton nodosus* | American pondweed | Floating-leaved | 0.3 |
| *Potamogeton crispus* | Curly-leaf pondweed | Submersed | 0.5 |
| *Potamogeton epihydrus* | Leafy pondweed | Submersed/Floating-leaved | 0.1 |
| *Scirpus* sp. | Bulrush | Emergent | 1.5 |
| *Sparganium* sp. | Bur-reed | Emergent | 0.9 |
| *Typha* sp. | Cattail | Emergent | 1.0 |
| *Utricularia vulgaris* | Common bladderwort | Submersed | 0.3 |
| None (bare sediment) | -- | -- | 15.0 |

[1] Species identified to generic level only because of the absence of flowering structures or other identifying features required for proper identification.

species (Table 6). Species diversity was low, with an average of 1.5 species found per interval. The breakdown of species co-occurrence based on the presence or absence of Eurasian watermilfoil indicates that *M. spicatum* occurred alone 72 percent of the time, and a single species was found in 65 percent of intervals (Figure 18). Few species occurred regularly with *M. spicatum*, perhaps due to the dense canopy formed (Madsen et al. 1991a,b); however, *M. spicatum* can preempt most of the available favorable environments, thus excluding most plants from all but peripheral environments.

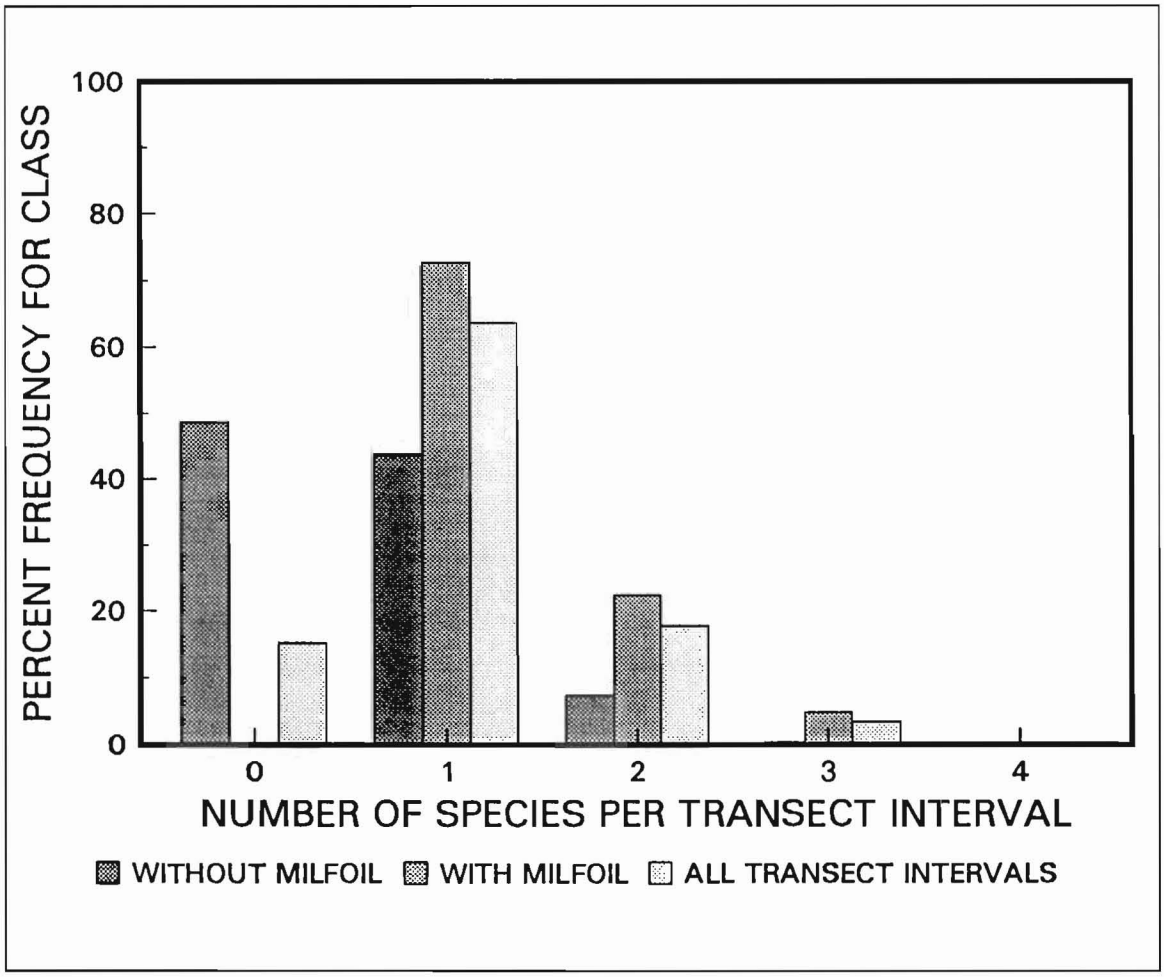


Figure 18. Percent frequency of species number per transect interval for intervals in which *M. spicatum* is present, for intervals in which *M. spicatum* is absent, and for all transect intervals

An analysis of the occurrence of native species with or without *M. spicatum* indicated that most species showed no difference in occurrence; or, as often happened, species occurred too infrequently for any statistical analysis (Table 7). *Ceratophyllum demersum* often occurred at greater depths than *M. spicatum*, and occurred at 45 percent of the intervals without *M. spicatum*, but only 16 percent of intervals with *M. spicatum*. Both *Potamogeton nodosus*

**Table 7**
**Percent Frequency of Plant Species Pairwise Two-by-Two Comparisons of Presence or Absence in the Presence or Absence of *Myriophyllum spicatum***

| Species | Without *M. spicatum* | | With *M. spicatum* | | Chi-sq. p-value and +/- Association |
|---|---|---|---|---|---|
| | Absent | Present | Absent | Present | |
| *Ceratophyllum demersum* | 543 (55) | 441 (45) | 1838 (84) | 339 (16) | 0.001 - |
| *Elodea canadensis* | 918 (93) | 66 (7) | 1959 (90) | 218 (10) | 0.003 + |
| *Potamogeton nodosus* | 979 (99) | 5 (1) | 2148 (99) | 29 (1) | 0.038 + |
| *Potamogeton crispus* | 983 (>99) | 1 (<1) | 2168 (>99) | 9 (<1) | 0.148 |
| *Potamogeton epihydrus* | 980 (>99) | 4 (<1) | 2166 (99) | 11 (1) | 0.708 |
| *Sparganium* sp. | 972 (99) | 12(1) | 2141 (98) | 36 (2) | 0.355 |
| *Typha* sp. | 973 (99) | 11 (1) | 2159 (99) | 18 (1) | 0.427 |
| *Ultricularia vulgaris* | 970 (99) | 14 (1) | 2158 (99) | 19 (1) | 0.159 |
| Native plants [1] | 478 (49) | 506 (51) | 1582 (73) | 595 (27) | <0.001 - |

[1] Cross-classification based on the occurrence of any native species in the presence or absence of *M. spicatum*; thus it excludes both *M. spicatum* and *P. crispus*.
Note: Species with too few occurrences for statistical comparisons were eliminated.

and *Elodea canadensis* occurred more frequently in the presence of *M. spicatum* than in its absence, possibly because of a similarity in preferred habitats. Because of the overall importance of *C. demersum* to the native community (comprising 441 of 506 occurrences), native plants were more frequent in the absence of *M. spicatum* than where *M. spicatum* was found.

## Biomass

Depth at biomass sample sites ranged from 90 to 186 cm, with site 5 being the deepest and site 4 the shallowest (Figure 19). Total biomass varied from 236 g DW $m^{-2}$ (site 3) to 553 g DW $m^{-2}$ (site 5), with biomass higher in the eastern end of the pond and lower in the western and central portions (Figure 20). Since *M. spicatum* comprised an average of 95 percent of the total biomass, the values for this species are very similar to that of total biomass. No species other than *M. spicatum* were found in biomass samples at sites 4 through 6 located in the eastern portion of the pond. Ceratophyllum *demersum* comprised 3 percent of biomass at site 1, 8 percent at site 2, and 9 percent at site 3. *Elodea canadensis* comprised 4 percent at site 1 and 8 percent at site 2, but only 0.2 percent at site 3.

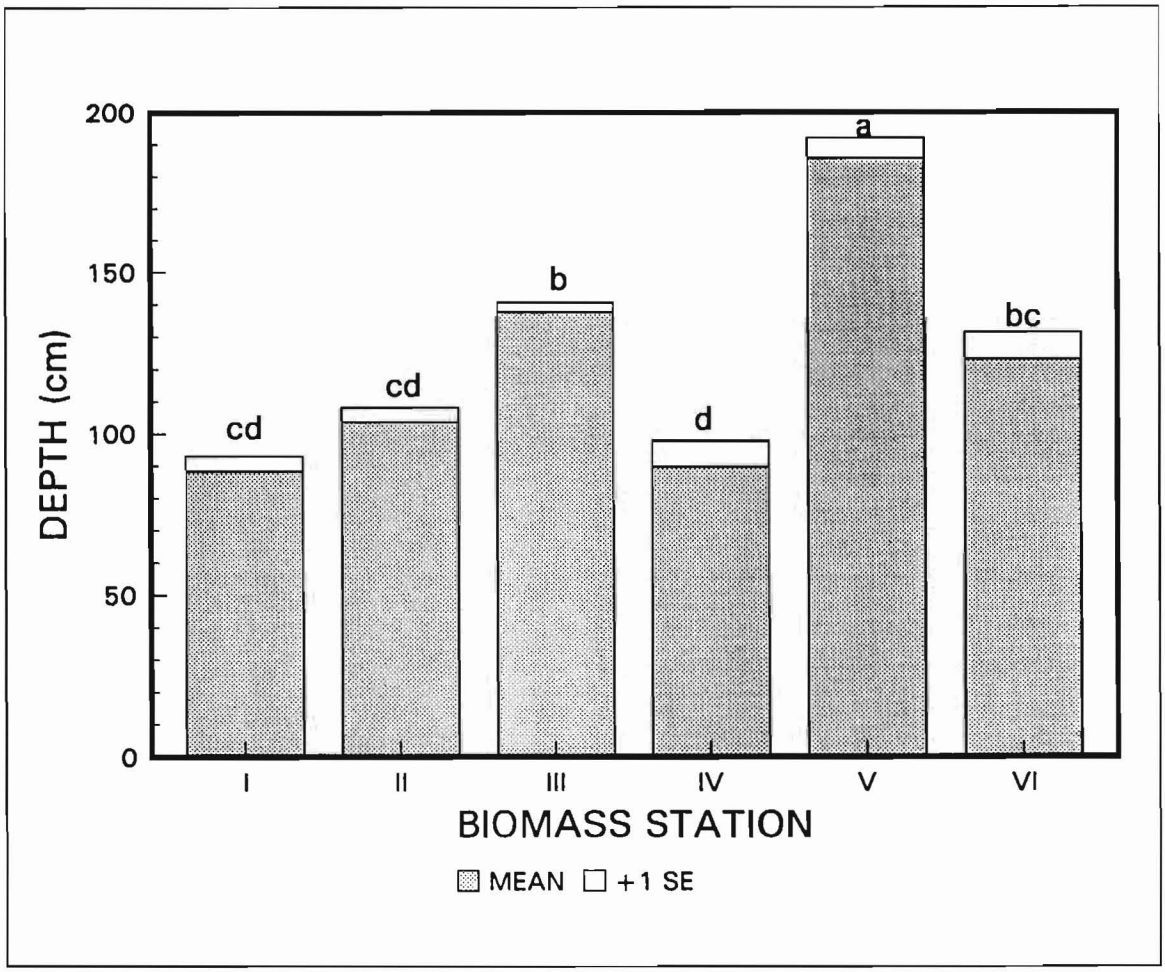


Figure 19. Mean water depth (cm) at each biomass sample site, plus one standard error of the mean. Different letters indicate that the means are different at the p = 0.05 level for a Bonferroni significant difference test, ANOVA

Tissue nutrients were measured for all three species, but sufficient samples were only available for *M. spicatum* to perform statistical analyses (Figure 21). Therefore, although native plant concentrations (*C. demersum* and *E. canadensis*) are shown, they will not be discussed below. Initial critical concentrations for *M. spicatum* were derived by Gerloff and Krombholz (1966) from cultured plants, but these critical concentrations were later shown to be too low (Colman et al. 1987). A "critical range" was applied to all nutrient measurements to ascertain if nutrients might be limiting plant growth. The "critical range" is a calculated tissue content zone encompassing known and calculated tissue concentrations limiting to plant growth (Gerloff and Krombholz 1966; Colman et al. 1987, Madsen 1991). Using these tissue levels, it appears that nitrogen was not limiting to *M. spicatum* growth at western sites, but may have been limiting at the eastern sites. Tissue P did not appear to be limiting growth at any site. Like N, K may also have been limiting growth of *M. spicatum* at eastern sites, but not at western sites. In spite of possible growth limitation by either N or K, biomass production in the eastern portion of the pond was quite

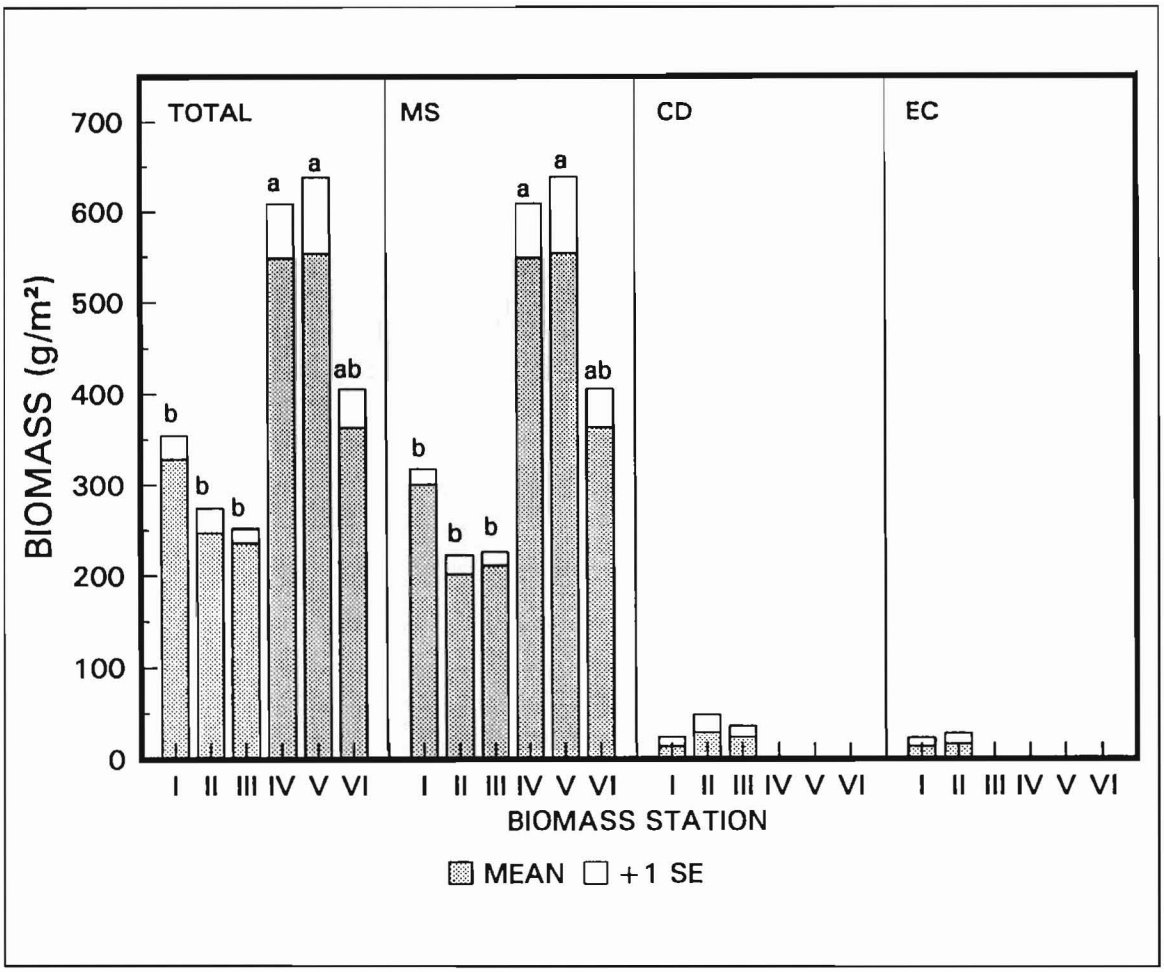


Figure 20. Mean biomass (g dry weight $m^{-2}$) plus one standard error of the mean at the six biomass sample stations for all species (TOTAL), *Myriophyllum spicatum* (MS), *Ceratophyllum demersum* (CD), and *Elodea canadensis* (EC). Different letters indicate that the means are different at the p = 0.05 level for a Bonferroni significant difference test, ANOVA

high. In the western portion of the pond biomass production did not appear to be limited by nutrients (with the possible exception of K at site 1), but may have been limited by light availability.

In summary, the plant community in Kirk Pond was overwhelmingly dominated by *M. spicatum*, with 69 percent of the pond covered by *M. spicatum*. Only 15 percent of the pond did not have vegetation, these sites being in the western portion where turbidity was high. Only two other species are found with more than 5 percent cover in the pond: *C. demersum* (25 percent) and *E. canadensis* (9 percent). *Myriophyllum spicatum* comprised 95 percent of plant biomass at selected stations. In the turbid western pond waters, *M. spicatum* biomass averaged 238 g $m^{-2}$and appeared to be light-limited. In the

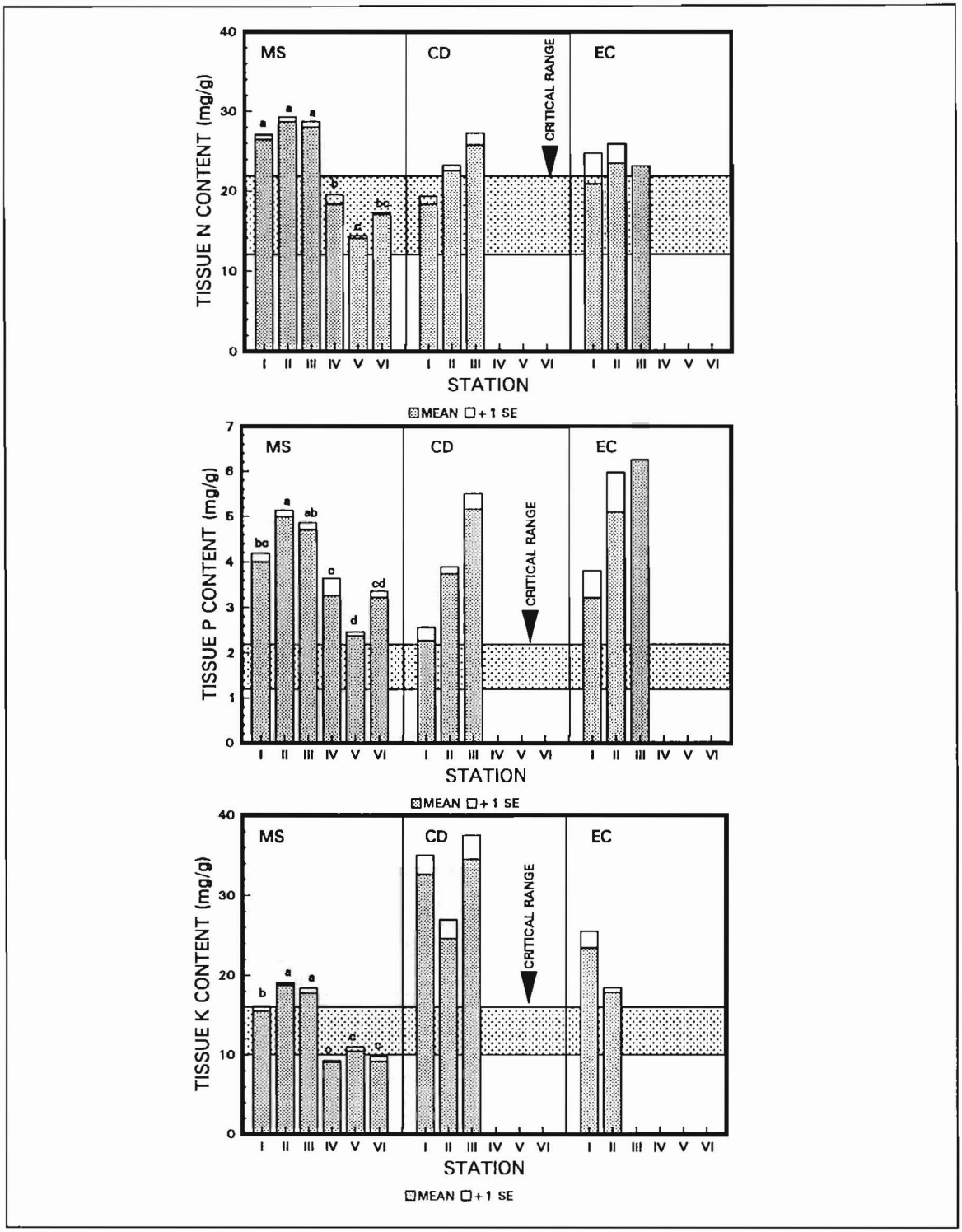


Figure 21. Mean tissue nutrient content (mg $g^{-1}$ dry weight) plus one standard error of the mean for nitrogen (top), phosphorus (middle), and potassium (bottom) at the six biomass sample stations for *Myriophyllum spicatum* (MS), *Ceratophyllum demersum* (CD), and *Elodea canadensis* (EC). Different letters indicate that the means are different at the p = 0.05 level for a Bonferroni significant difference test, ANOVA.

eastern part of the pond, where water was much less turbid, *M. spicatum* biomass was more than twice as high (488 g $m^{-2}$), and appeared to be nutrient-limited.

# 4 Kirk Pond Fishery Assessment

## Introduction

Traditionally, Kirk Pond has been used extensively as a recreational fishery for a small variety of gamefish, mostly centrarchids (sunfish and black bass) and ictalurids (bullheads). The Oregon Department of Fish and Wildlife (ODFW) has maintained an additional "put-and-take" cutthroat trout (*Salmo-clarki*) fishery over the past 15 years. Invasion by Eurasian watermilfoil (*Myriophyllum spicatum*) in recent years has led to the termination of this practice, although ODFW stocked approximately 4,000 cutthroat fingerlings and excess broodfish in early May 1991. Verifiable records have not been kept, but lore indicates that the fishery has declined subsequent to the establishment and proliferation of *M. spicatum* both in terms of numbers and sizes of fish taken.

The objectives of this study were to provide baseline information on the fish assemblage and species composition in Kirk Pond, evaluate the vigor of the fishery, and predict some potential impacts and benefits of aquatic plant management on the fishery.

The data presented here are from samples taken in 1991 and 1992, and include species identified, frequency, size class distributions, and length-weight relationships of selected species. These two data sets are used to ascertain the pre-treatment condition of the fish assemblage in Kirk Pond.

A 1993 or 1994 post-treatment sample collection is planned for data comparison with pre-treatment fish populations. This final collection will allow researchers to identify changes that may occur in the fishery due to the vegetation management demonstration using the fungal pathogen to be undertaken in 1992.

## Fishery Study Site Description

Similar to many man-made impoundments in the northwest, Kirk Pond has developed a fishery dominated by introduced eastern and southern U.S. species, primarily centrarchids. Bluegill (*Lepomis macrochirus*), crappie (*Poxomis spp.*), and largemouth bass (*Micropterus salmoides*) are frequently the most abundant species in water bodies of the area[1]. Many native species (primarily *Salmo spp.*) populations are maintained only through the efforts of conservation organizations, due to both disruption of habitats and displacement by introduced fishes.

## Methods

Late May sampling was chosen as most desirable due to several factors, including: (1) prespawn of fish species known to be present, (2) relatively low submersed plant densities due to low temperatures, and (3) coordination of sampling between WES and ODFW personnel.

### Sample sites

Sample sites were initially selected with the aid of maps and site visits. Three general habitat zones were identified in the pond, and three collection sites were assigned per zone (Figure 22):

Zone 1. The western portion of the pond was heavily influenced by inflow water from Fern Ridge Lake, with relatively deep, turbid, and lotic conditions. Submersed vegetation was evident throughout most of the area.

Zone 2. The central portion of the pond, at which the outlet weir is located, was also influenced by water flow from the reservoir, but was shallower with submersed vegetation visible from most points.

Zone 3. The eastern portion of the pond was static in relation to water flow, with deep, clear water and large stands of submersed plants.

### Collections and measurements

Preliminary sampling with an 8.3-m by 1.3-m common sense seine net of 6-mm mesh indicated that electrofishing would be the most practical nonselective method for sample collection due to dense vegetation present in the pond.

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[1] Personal communication, ODFW personnel.

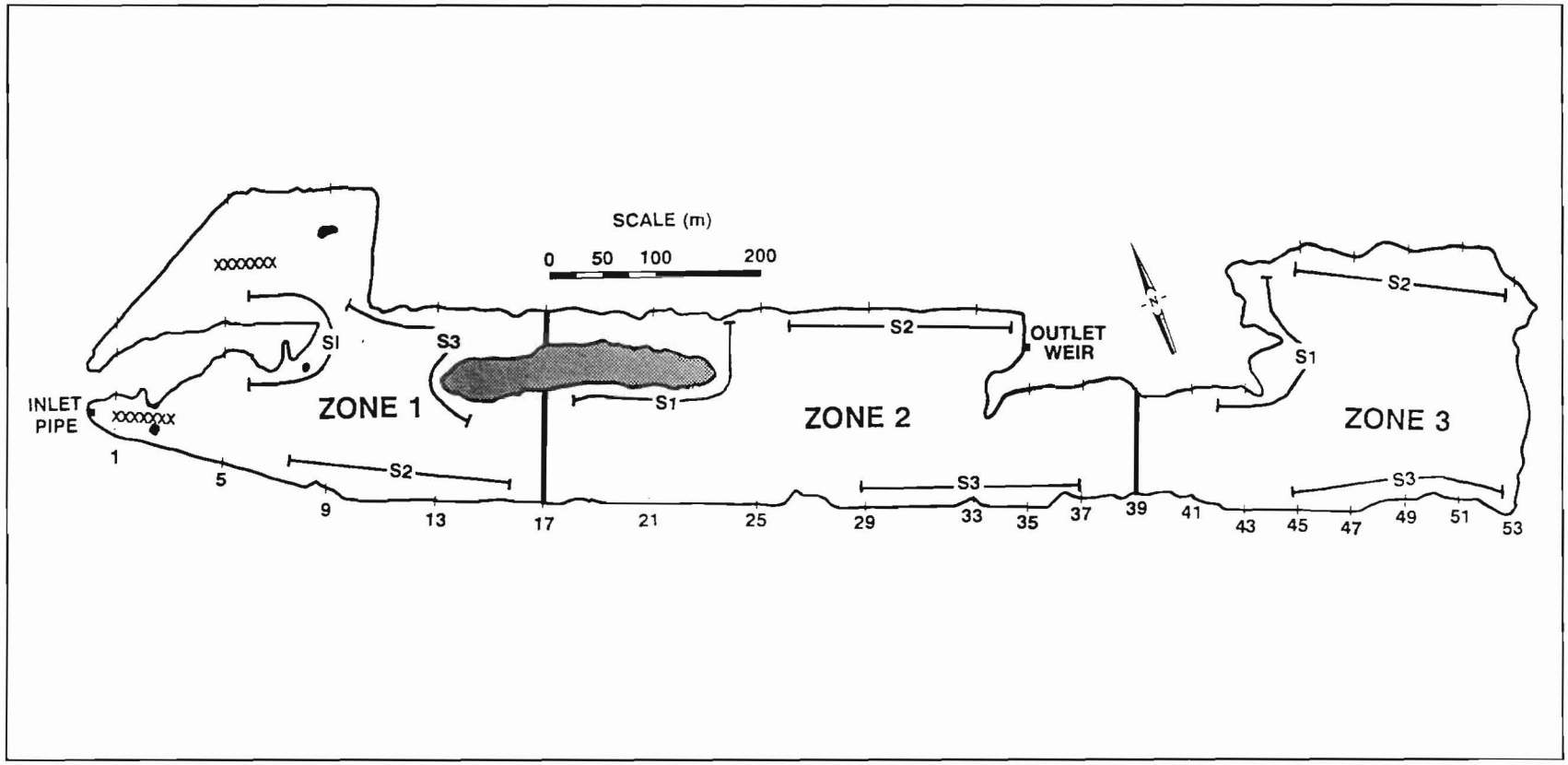


Figure 22. Kirk Pond electrofishing collection sites. Transects denoted with an "S" number are sample transects; transects denoted with "X" are calibration runs

On 22 and 23 May 1991 WES and ODFW personnel performed electrofishing runs on the nine selected sites between 20:00 and 23:30 hr using a 5.7-m aluminum boat driven by a 50-hp outboard motor. The boat was rigged with a commercial circular boom electrode electrofishing unit and adequate lighting for night sampling. The electroshocker was set to provide a constant output of 300-400 V at 5-7 A. One driver and two netters were present for each run, with each site sampled for 300 sec (5 min). Distance covered by each run was approximately 200 m. Area covered by each run was estimated at 600 $m^2$, with all nine runs equalling about 5,400 $m^2$, or roughly 2 percent of the pond by area. All electrofishing runs were conducted in water less than 2 m deep to increase efficiency of the collection technique. The procedure was repeated on 26 and 27 May 1992 utilizing the same equipment, techniques, and sample sites described for 1991 collections.

Stunned fish were netted and kept on ice during the course of the collection period. Upon completion of all nine runs, fish were preserved in 10 percent formalin for transport to the LAERF for identifications and measurements. Fish were identified using binomial keys, primarily Pflieger (1975), weighed to the nearest 0.1 g on an electronic balance and measured for total and standard lengths to the nearest 1 mm with a standard fish measuring board. Size class distributions of selected species were based on standard length and assigned according to those commonly found in the literature (Carlander 1977). No attempt was made to relate size class to age class in this study. Length-weight relationships for selected species were developed by calculating condition coefficients, K, (Hile 1936) and plotting linear regressions (slopes) of log-transformed length and weight data. Both techniques are common in the literature, and K factors and slopes are frequently used to assess the vigor of individuals within a population. K factors were compared between years for species collected in adequate numbers (n = 20+) using Student's t-tests. One-way ANOVAs and Duncan's Multiple Range Tests were performed on species frequency per described habitat zone for species collected in adequate numbers (n = 20+) using SAS (SAS Institute 1988).

## Results

Eleven species of fish representing six families were collected from Kirk Pond in 1991 (Table 8). Ten species representing four families were collected in 1992 (Table 9). Total number of fish collected in both years was similar, with 326 taken in 1991 and 310 taken in 1992. Centrarchids, primarily sunfish (*Lepomis* spp.) and crappie (*Poxomis* spp.), dominated the assemblage both years, together comprising over 93 percent (1991) and 84 percent (1992) of fish collected (Figure 23). Significant increases were seen in number of common carp (*Cyprinus carpio*) and white crappie (*Poxomis annularis*) collected in the second year, while decreases in number occurred in most other species. The largescale sucker (*Catostomus macrocheilus*) and yellow bullheads (*Ictalurus natalis*) were the least common species encountered in 1991, with only one and two individuals collected, respectively. A single largescale sucker was

**Table 8**
**Species List and Frequencies from 1991 Kirk Pond Electrofishing Samples**

| Family | Scientific Name | Common Name | *f* | *rf* |
|---|---|---|---|---|
| Salmonidae | *Salmo clarki* | Cutthroat trout | 6 | 0.018 |
| Cyrinidae | *Cyprinus carpio* | Common carp | 13 | 0.040 |
| Catostomidae | *Catostomus machrocheilus* | Largescale sucker | 1 | 0.003 |
| Ictaluridae | *Ictalurus natalis* | Yellow bullhead | 2 | 0.006 |
| Poeciliidae | *Gambusia affinis* | Mosquitofish | [1] | [1] |
| Centrarchidae | *Micropterus salmoides* | Largemouth bass | 21 | 0.064 |
| | *Lepomis gibbosus* | Pumpkinseed | 4 | 0.012 |
| | *Lepomis gulosus* | Warmouth | 17 | 0.052 |
| | *Lepomis macrochirus* | Bluegill | 126 | 0.387 |
| | *Poxomis annularis* | White crappie | 126 | 0.387 |
| | *Poxomis nigromaculatus* | Black crappie | 10 | 0.031 |
| | | Totals | 326 | 1.000 |

[1] Collected only during preliminary sampling.
Note: *f* is the number of each species collected and *rf* is the relative frequency within all samples.

collected in 1992, and a previously uncollected species, the goldfish (*Carassius auratus*), was also taken. Cutthroat trout were collected in 1991, but not in 1992. Mosquitofish (*Gambusia affinis*) were not taken during the electrofishing runs, but numerous individuals were collected during preliminary seining both years.

Common carp represented the greatest biomass component of the samples collected (Figure 24). Although only 13 individuals were taken in 1991 (4 percent of fish collected), these equalled 47.5 percent of the total weight of all samples. Twenty-nine (9 percent of fish collected) individuals taken in 1992 represented nearly 90 percent of the total biomass in those samples. Bluegills dominated the centrarchid biomass in 1991, representing 44 percent of their weight and nearly 20 percent of the total biomass (Figure 25). White crappie dominated the centrarchid biomass in 1992, representing 64 percent of their weight, but only 8 percent of the total biomass.

Size class distributions of the three most common centrarchids (largemouth bass, bluegill, and white crappie) are given in Table 10 and Figures 26-28. Largemouth bass were dominated by the smallest size class during both years, which comprised 56 percent of the population in 1991 and 81 percent in 1992. Bluegill size class frequencies were evenly distributed in 1991, with no class exceeding 30 percent of the population. Size classes were less evenly distributed in 1992, with shifts toward smaller classes, but dominance by any single

**Table 9**
**Species List and Frequencies from 1992 Kirk Pond Electrofishing Samples**

| Family | Scientific Name | Common Name | *f* | *rf* |
|---|---|---|---|---|
| Cyrinidae | *Carassuis auratus* | Wild goldfish | 1 | 0.003 |
| | *Cyprinus carpio* | Common carp | 29 | 0.094 |
| Catostomidae | *Catostomus machrocheilus* | Largescale sucker | 1 | 0.003 |
| Poeciliidae | *Gambusia affinis* | Mosquitofish | [1] | [1] |
| Centrarchidae | *Micropterus salmoides* | Largemouth bass | 17 | 0.055 |
| | *Lepomis gibbosus* | Pumpkinseed | 1 | 0.003 |
| | *Lepomis gulosus* | Warmouth | 5 | 0.016 |
| | *Lepomis macrochirus* | Bluegill | 51 | 0.165 |
| | *Poxomis annularis* | White crappie | 202 | 0.652 |
| | *Poxomis nigromaculatus* | Black crappie | 3 | 0.009 |
| | | Totals | 310 | 1.000 |

[1] Collected only during preliminary sampling.
Note: *f* is the number of each species collected and *rf* is the relative frequency within all samples.

class (>50 percent *n*) (Anderson 1973) did not occur. White crappie were dominated by an intermediate size class in 1991, which represented about 70 percent of the number collected. In 1992, the white crappie population was dominated by the smallest size class (65 percent total). Low numbers (less than 20) of other species collected precluded size class evaluations, although most exhibited multiple size classes.

Log-transformed linear regressions of standard lengths (SL) in millimeters and weights in grams of selected species were calculated, and regression coefficients (slopes) and standard errors are given in Tables 11 and 12. Condition factors, K(SL), calculated for selected centrarchids are compared with ranges found in the literature (Table 13) and between years (Figure 29). Mean standard lengths and weights are given for all species in Table 14.

One-way ANOVAs performed on species frequency by zone indicated no significant habitat preference by each tested species, showing that the fish were well-distributed throughout the pond during 1991 (Table 15). Significant differences were found in bluegill and white crappie distributions during 1992 (Table 16), with bluegill occurring more frequently in Zone 3 and white crappie more frequently in Zone 1. Species taken in low numbers were not tested for zone preferences, but appeared evenly distributed both years, with most species collected taken from all three zones.

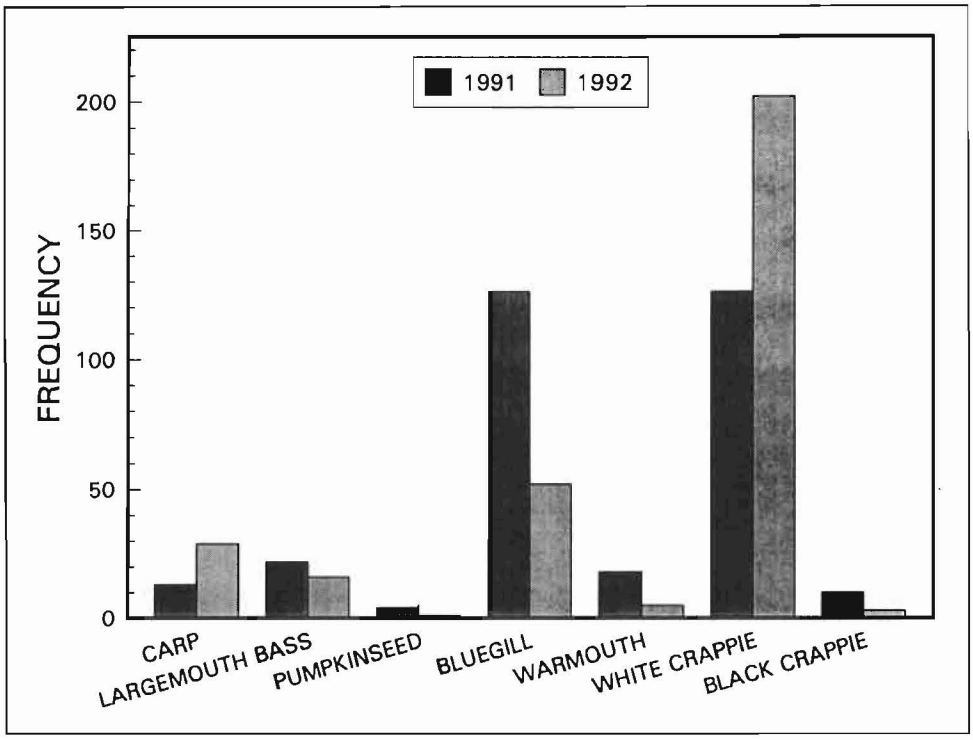


Figure 23. Frequencies of commonest species collected during 1991 and 1992

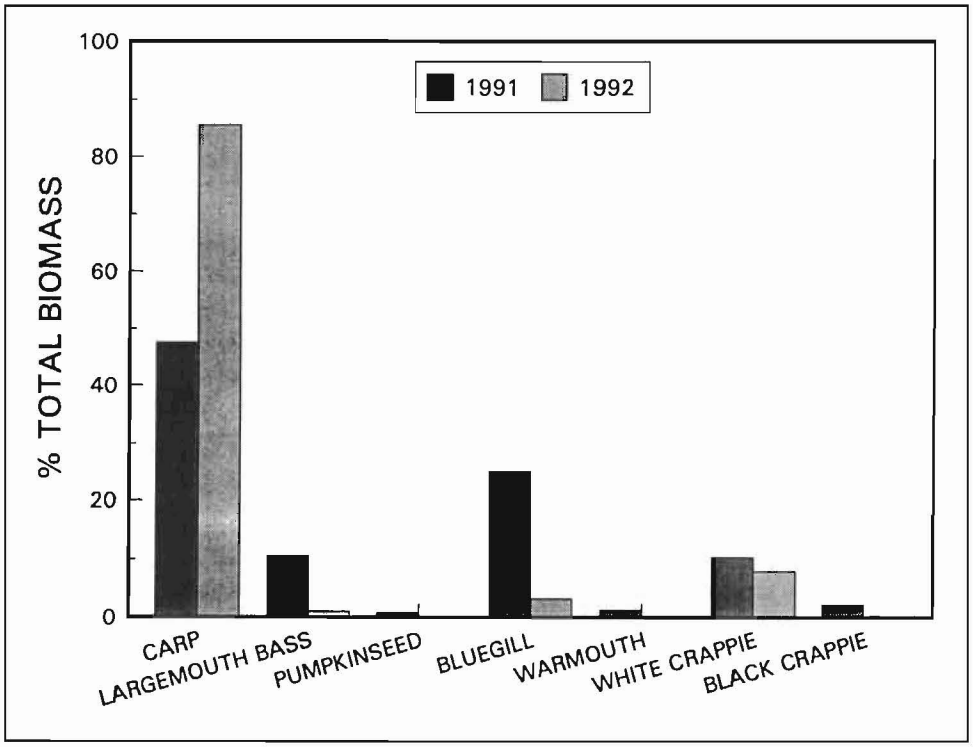


Figure 24. Biomass distribution of commonest species collected from Kirk Pond

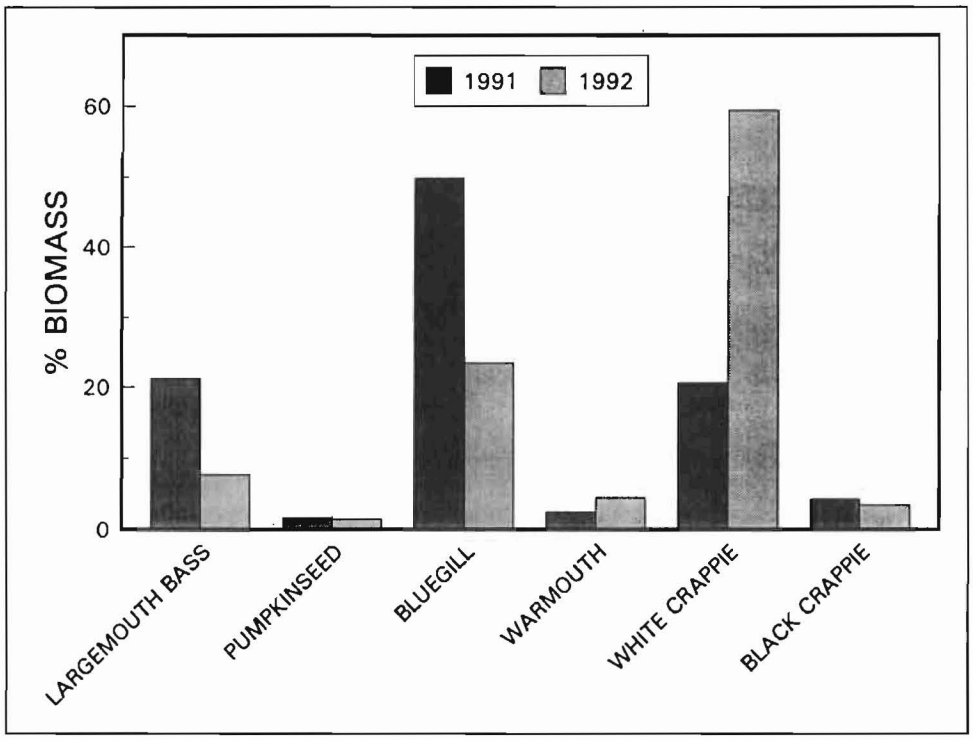


Figure 25. Biomass distribution of centrarchids collected from Kirk Pond

**Table 10**
**Size Class Distributions of Selected Species**

| Species (Common Name) | Size Class SL (mm) | 1991 | | 1992 | |
|---|---|---|---|---|---|
| | | *f* | *rf* | *f* | *rf* |
| *Micropterus salmoides* (Largemouth bass) | 51-75 | 12 | 57.1 | 14 | 82.4 |
| | 76-125 | 5 | 23.8 | 2 | 11.8 |
| | 126-175 | 2 | 9.5 | 1 | 5.8 |
| | 176-225 | 1 | 4.8 | --- | --- |
| | >226 | 1 | 4.8 | --- | --- |
| *Lepomis macrochirus* (Bluegill) | 25-50 | 37 | 29.3 | 13 | 25.5 |
| | 51-75 | 16 | 12.8 | 22 | 43.1 |
| | 76-100 | 30 | 23.8 | 10 | 19.6 |
| | 101-125 | 38 | 30.1 | 5 | 9.9 |
| | 126-150 | 5 | 4.0 | 1 | 1.9 |
| *Poxomis annularis* (White crappie) | 50-75 | 31 | 24.6 | 133 | 65.8 |
| | 76-100 | 92 | 73.0 | 60 | 29.7 |
| | 101-125 | 2 | 1.6 | 6 | 3.0 |
| | 126-150 | 1 | 0.8 | 2 | 1.0 |
| | >151 | --- | --- | 1 | 0.5 |

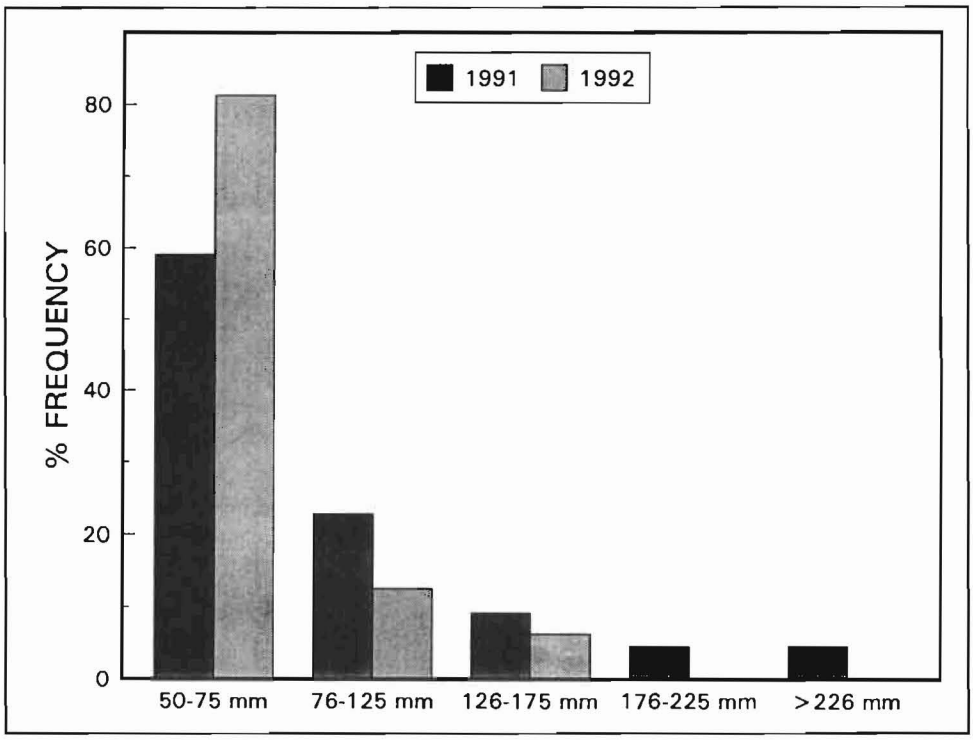


Figure 26. Largemouth bass size class distribution

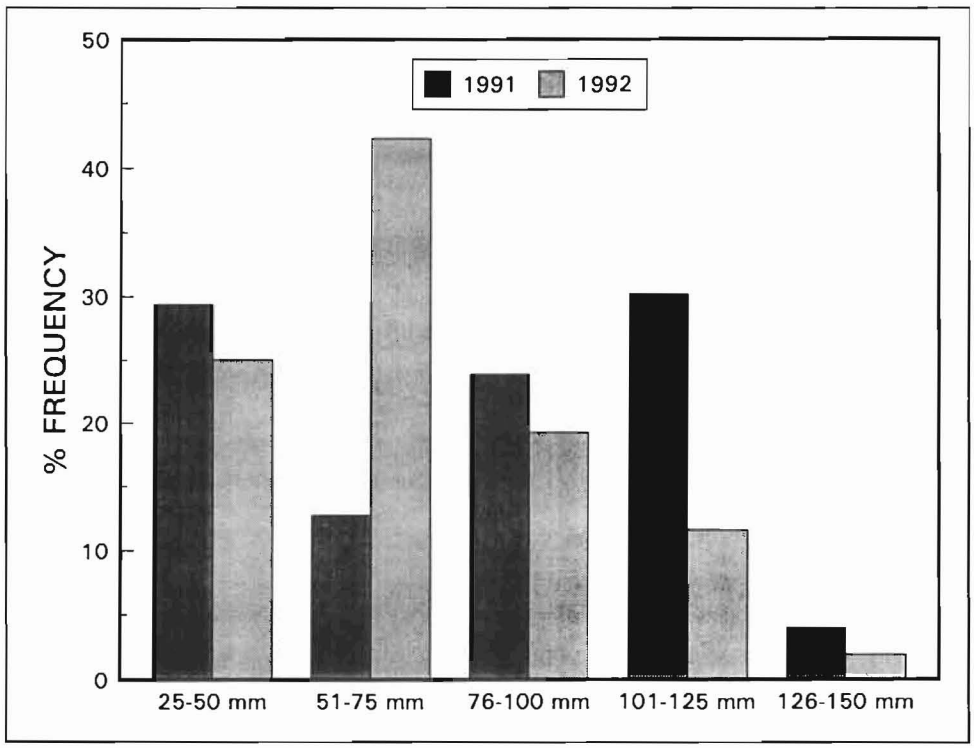


Figure 27. Bluegill size class distribution

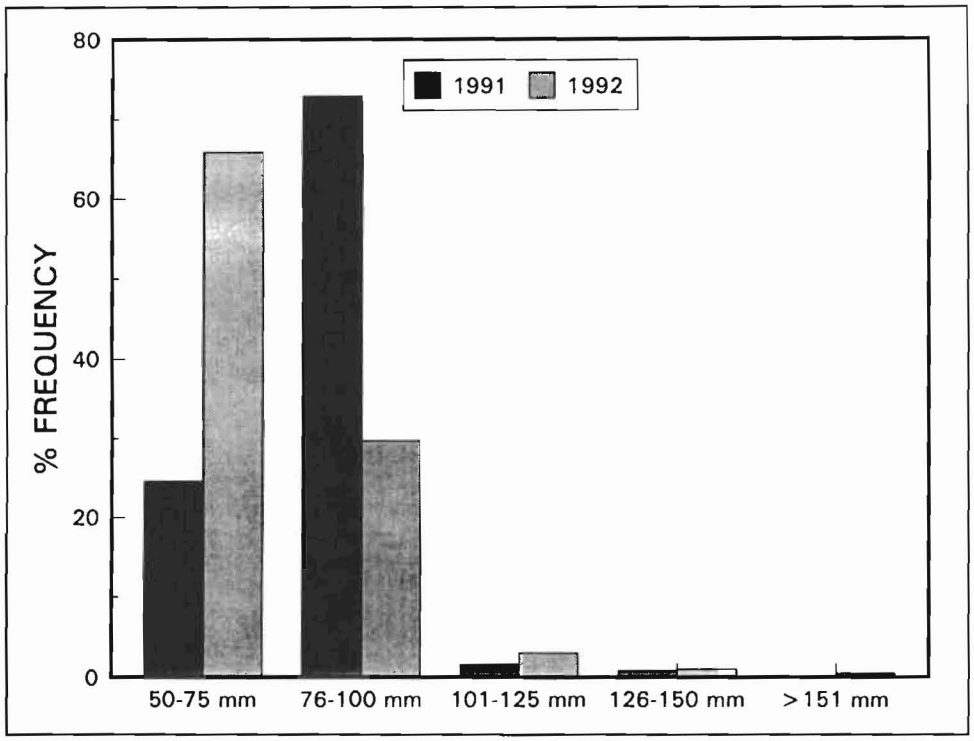


Figure 28. White crappie size class distribution

**Table 11**
**Log-Transformed Linear Regression Coefficients (Slopes) Calculated for Selected Species ($n$ > 15) During 1991**

| Species | df | $r^2$ | Slope | SE |
|---|---|---|---|---|
| *Micropterus salmoides* | 20 | 0.9928 | 3.024 | 0.058 |
| *Lepomis macrochirus* | 124 | 0.9960 | 3.073 | 0.017 |
| *Lepomis gulosus* | 16 | 0.9927 | 2.863 | 0.061 |
| *Poxomis annularis* | 124 | 0.9842 | 2.891 | 0.033 |

# Discussion

Kirk Pond exhibited a typical warmwater fishery, with centrarchids comprising the most abundant forage and predator species present. Although not native to the area, many centrarchid species, including those taken from Kirk Pond, are now widespread throughout most of the U.S. due to past and current stocking practices (Lee et al. 1980). Conditions in the pond (lentic and

**Table 12**
**Log-Transformed Linear Regression Coefficients (Slopes) Calculated for Selected Species ($n$ > 15) Collected During 1992**

| Species | df | $r^2$ | Slope | SE |
|---|---|---|---|---|
| *Micropterus salmoides* | 15 | 0.9863 | 2.860 | 0.087 |
| *Lepomis macrochirus* | 49 | 0.9910 | 3.160 | 0.043 |
| *Poxomis annularis* | 200 | 0.9367 | 2.938 | 0.053 |

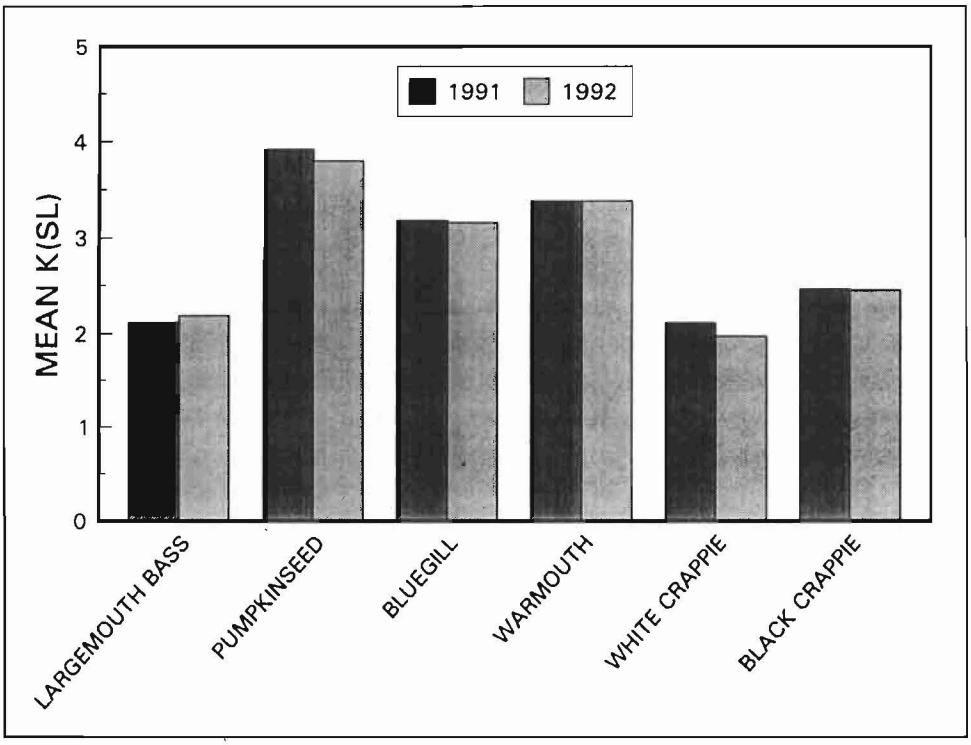


Figure 29. Condition factors [K(SL)] of Kirk Pond centrarchids during 1991 and 1992

shallow, with mild temperatures and an abundance of submersed macrophytes) are conducive to the success of many of these species (Carlander 1977).

Bluegills were collected in relatively large numbers during both years, although significantly fewer were taken in 1992. Bluegills are highly prolific and prefer conditions found in Kirk Pond, and the species was expected to be dominant in the pond's fish assemblage, in part because the pond supported a high density of submersed macrophytes. Although samples were not taken, vegetation generally provides food and cover for invertebrates, the principal diet of bluegills (Pflieger 1975). Additionally, bluegills are reported to feed directly on vegetation when invertebrates are scarce. Condition factors and regression coefficients indicated that bluegills were healthy during both years,

**Table 13**
**Mean Condition Factors (K) Calculated from Standard Lengths (SL) of Selected Centrarchid Species, with K(SL) Ranges[1]**

| Species | Kirk Pond 1991 K(SL) | Kirk Pond 1992 K(SL) | K(SL) Range (Carlander 1977) |
|---|---|---|---|
| *Micropterus salmoides* | 2.12 | 2.2 | 1.90-3.06 |
| *Lepomis macrochirus* | 3.18 | 3.16 | 1.83-5.65 |
| *Lepomis gibbosus* | 3.92 | 3.80 | 3.09-5.01 |
| *Lepomis gulosus* | 3.38 | 3.38 | 2.45-5.04 |
| *Poxomis annularis* | 2.11 | 1.97 | 1.48-3.88 |
| *Poxomis nigromaculatus* | 2.46 | 2.45 | 2.31-4.05 |

[1] Compiled by Carlander (1977).

**Table 14**
**Mean Standard Lengths (SL) and Weights of Species Collected from Kirk Pond in 1991 and 1992**

| | Mean SL, mm | | Mean Weight, g | |
|---|---|---|---|---|
| Species | 1991 | 1992 | 1991 | 1992 |
| *Salmo clarki* | 191.0 | ---- | 198.9 | ----- |
| *Carassius auratus* | ---- | 200.0 | ---- | 276.8 |
| *Cyprinus carpio* | 271.0 | 323.1 | 558.4 | 750.4 |
| *Catostomus macrocheilus* | 83.0 | 275.0 | 10.6 | 654.0 |
| *Ictalurus natalis* | 143.0 | ---- | 72.2 | ----- |
| *Lepomis gibbosus* | 92.8 | 109.0 | 31.6 | 49.2 |
| *Lepomis gulosus* | 61.2 | 94.2 | 10.4 | 30.6 |
| *Lepomis macrochirus* | 78.8 | 69.9 | 24.0 | 15.3 |
| *Micropterus salmoides* | 97.3 | 85.0 | 73.7 | 15.4 |
| *Poxomis annularis* | 82.1 | 74.6 | 12.5 | 10.0 |
| *Poxomis nigromaculatus* | 105.9 | 117.3 | 33.0 | 39.7 |

comparing well with ranges reported in the literature for average fish (Carlander 1977). Size classes were evenly distributed in 1991, with no dominance by any class, another indicator of a healthy population (Anderson 1973). The shift in bluegill numbers to smaller size classes in 1992 was not significant, but may indicate a trend toward overcrowding. The presence of

**Table 15**
**One-Way ANOVA of Commonest Species Frequency by Sample Site and Zone in 1991**

| Species | Source | df | SS | MS | F |
|---|---|---|---|---|---|
| *Micropterus salmoides* | Treatments | 2 | 6.22 | 3.11 | 1.87 |
| | Within Trtmnts | 6 | 10.00 | 1.67 | |
| | Total | 8 | 16.22 | | Pr>0.23 |
| *Lepomis macrochirus* | Treatments | 2 | 200.67 | 100.33 | 3.09 |
| | Within Trtmnts | 6 | 32.89 | | |
| | Total | 8 | 233.56 | | Pr>0.12 |
| *Poxomis annularis* | Treatments | 2 | 1866.67 | 933.33 | 3.30 |
| | Within Trtmnts | 6 | 1697.33 | 282.89 | |
| | Total | 8 | 3564.00 | | Pr>0.11 |

**Table 16**
**One-Way ANOVA of Commonest Species Frequency by Sample Site and Zone in 1992**

| Species | Source | df | SS | MS | F |
|---|---|---|---|---|---|
| *Micropterus salmoides* | Treatments | 2 | 2.88 | 1.44 | 1.08 |
| | Within Trtmnts | 6 | 8.00 | 1.33 | |
| | Total | 8 | 10.88 | | Pr>0.389 |
| *Lepomis macrochirus* | Treatments | 2 | 139.56 | 69.78 | 16.10 |
| | Within Trtmnts | 6 | 26.00 | 4.33 | |
| | Total | 8 | 165.56 | | Pr>0.003 |
| *Poxomis annularis* | Treatments | 2 | 5722.89 | 2861.44 | 5.28 |
| | Within Trtmnts | 6 | 3249.33 | 541.56 | |
| | Total | 8 | 8972.22 | | Pr>0.047 |

small bluegills (<50 mm total length) during both years indicates recruitment by reproduction had occurred in the pond, although fewer small individuals collected in 1992 may indicate a reduction in reproductive success. Lower total numbers collected during the second year coupled with smaller average size of individuals may have been a result of excessive competition for a limited food supply. Since bluegills often compete directly with other sunfish for food and space, the large increase in white crappie numbers between 1991 and 1992 may have negatively influenced the bluegill population size. Also, significantly more bluegills were collected from Zone 3, while white crappie

were collected more frequently from Zone 1. Although overlap between zones did occur, it appears that the two species were segregated in the second year, possibly due to competitive interactions. The smaller average size of bluegills in the second year also suggests selective mortality of larger fish, probably due to fishing pressure. Anglers were observed during both collecting periods, and informal creel surveys showed only larger size class bluegills and white crappie were being taken.

Low numbers of pumpkinseeds (*Lepomis gibbosus*) collected during both years may have been due to competition with other sunfish in the pond, especially bluegills. Pumpkinseed food and nesting site requirements are similar to those of bluegill, and when both species occur together pumpkinseeds generally exhibit poor success (Carlander 1977). Although habitat provided by Kirk Pond was adequate to support larger numbers of pumpkinseeds, a total of only five individuals were taken during both years. These fish exhibited above average K factors, probably because they were preparing to spawn. As fish approach spawning condition, weight increases faster than length due to increased gonadal development, and length-weight relationships are altered considerably. Food is required for any type of fish growth, and the relatively large size of the pumpkinseeds collected in the pond may have enabled them to utilize a food source not available to most other centrarchids. Only a single size class was collected each year, indicating limited recruitment through reproduction in the pond. The population's survival may be dependent upon immigration from the reservoir and/or outlet creek.

Warmouths (*Lepomis gulosus*) were relatively common in the pond, comprising 5 percent and 3 percent of the fish assemblage during 1991 and 1992, respectively. Length-weight relationships were only slightly below average for the species, size classes were evenly represented and no significant changes were seen in the population from 1991 to 1992. The presence of smaller size classes may indicate reproductive success in the pond. Although the warmouth population was stable during the study period, the fish may have played an important role in changes observed for several other species. Warmouths compete directly with other lepomids for macroinvertebrates, potentially increasing competition for food among sunfishes in Kirk Pond. Warmouths also exhibit piscivory as they increase in size, where they begin to compete with other predator species for food (Larimore 1957). In Kirk Pond, adult warmouths would compete directly with largemouth bass and adult crappie.

White crappie were collected in numbers equal to that of bluegills in 1991, when both species shared dominance in the pond. In 1992, white crappie became the dominant species, with the number collected nearly doubling, indicating recruitment had occurred between 1991 and 1992. Average total length of white crappie was slightly less in 1992, although not by a significant amount. K factors and slopes calculated for white crappie were below average when compared with the literature during both years, and 1992 K factors were significantly lower than those in 1991. Size class distribution was strongly dominated by an intermediate size class in 1991 and by the smallest size class

in 1992. Size class dominance coupled with changes in the white crappie population from one year to the next (greater numbers, smaller average size, and poorer condition) indicate overcrowding of white crappie, most likely due to a poor food supply. Since smaller-sized crappie feed primarily upon macroinvertebrates, overcrowding was probably aggravated by competition with bluegills and other sunfish for the same food supply. Also, although habitat preference of white crappie is similar to that of bluegills, the former usually prefers deeper, more turbid waters (Pflieger 1975). A combination of limited food availability and habitat preference may explain the apparent segregation of white crappie and bluegills observed in 1992.

Black crappie (*Poxomis nigromaculatus*) are less tolerant of turbidity than most centrarchids, which may account for low numbers collected during both years, although the species is usually found at relatively low densities (Pflieger 1975). Black crappie were collected only in deeper, barren rocky flats. K factors were below average even though the fish were sexually mature and near spawning condition. Competition for food with other centrarchids probably contributed to the population's poor condition and low numbers. Although size classes assigned were well-distributed, no small size classes were collected, indicating a failure to reproduce successfully in the pond.

Largemouth bass, the dominant predator found in Kirk Pond, were the third most abundant centrarchid collected during both years, comprising about 6 percent of the assemblage both years. The species is found in a wide variety of habitats, particularly those with an adequate supply of smaller forage fish (Carlander 1977). K factors and regression slopes rated below average for all size classes when compared with the literature, suggesting inadequate food supplies for the bass. Size class distributions were uneven both years, with the smallest size class strongly dominating the population. This may indicate excessive fishing pressure on larger individuals, a problem common to many small impoundments (Gerking 1978). The presence of small bass does indicate some reproductive success in the pond.

Common carp, an introduced Asian species, are omnivorous, with plants comprising a significant portion of their diet (Moen 1953). Conditions in the pond were favorable to support a carp population, and although individuals collected were not large for the species, this trait is not uncommon in northern waters (Pflieger 1975). Failure to collect juvenile fish may indicate that recruitment occurred only through immigration. Dominance of the fish biomass by this species is typical in densely vegetated ponds, since the fish generally access food sources not used by other fish species, and are capable of growing rapidly to a large size. Increases in number and size of carp collected from 1991 to 1992 suggest that the Eurasian watermilfoil population is preferred by the fish, and individuals entering the pond (either through the inlet pipe or outlet weir) are remaining.

Wild goldfish, another Asian species, are similar to common carp in habits and habitat requirements, and natural hybrids between the two species have been reported (Pflieger 1975). ODFW personnel reported electrofishing small

numbers of goldfish from Fern Ridge Reservoir during early April 1992, and it is probable that the reservoir was the source of the individual collected in the pond.

Largescale suckers are creek fish endemic to the Columbia River system[1]. Their presence in Kirk Pond may have been incidental. Both specimens were taken near the outlet weir in Zone 2, where the fish were possibly moving to or from Coyote Creek.

Yellow bullheads were taken in low numbers in 1991, which may have been due to the fact that catfish are more difficult to take by electrofishing than many other species. However, since the species is usually found at lower densities than most ictalurids (Pflieger 1975) and prefers flowing water, it is probable that the species is uncommon in Kirk Pond. Both individuals taken were in the vicinity of the inlet-to-weir current through Zones 1 and 2, an indication that the fish may have been restricted to lotic conditions in the pond. An adult and juvenile were collected, perhaps indicating some reproductive success in the pond.

Mosquitofish were not taken during electrofishing, but were collected in seine nets. This species, widely stocked throughout the U.S. for mosquito control, is common in static, heavily vegetated water bodies, and is generally found occupying very shallow waters near shorelines (Barnickol 1941). Mosquitofish represented the smallest species found in Kirk Pond, and by observation was common, but its use as forage by predator species was probably limited due to its shallow water preference.

Cutthroat trout specimens were taken only in 1991, and these individuals were concluded to belong to the stock introduced by the ODFW the previous month. The success of the trout as a self-sustaining species in Kirk Pond is very doubtful due to the dense vegetation and warmwater conditions. However, since the population is maintained as a "put-and-take" fishery the species will likely continue to be part of the assemblage in the pond.

Relative numbers of forage and predator species in Kirk Pond were reasonable during both years. However, the small size of the majority of largemouth bass and other predators and relative size of most forage species present are indicative of a predator/prey relationship that is out of balance (Weatherley 1972). Most largemouth bass collected were too small to consume the smallest bluegills or white crappie size classes that occurred in the pond. Failure of predator species to control numbers of forage species frequently leads to overcrowding of the forage species, a condition that appears to have developed in Kirk Pond. Overcrowding is characterized by relatively high numbers of forage fish which exhibit poor growth and/or condition (Weatherley 1972). Reproductively prolific species such as bluegill and crappie commonly develop overcrowded populations in small impoundments (Anderson 1973). Although

[1] ODFW biologists, personal communication.

no species were collected in unusually high numbers from Kirk Pond, several species, most notably largemouth bass and white crappie, exhibited poor condition and growth (size), and relative numbers of white crappie were high and increasing compared with other species. Poor growth and length-weight relationships under overcrowded conditions can usually be attributed to low food availability relative to the number of fish in a particular habitat (Swingle 1950). Fish density in Kirk Pond was not especially high, but a limited amount of food available per fish may have resulted in their poor condition, and may have also limited their numbers.

When forage fish are overcrowded, reproduction and thus production of smaller, food-sized fish for smaller size classes of predators are inhibited, sustaining the imbalance. Overcrowded forage species can also limit growth and survival of smaller sized predator species due to interspecific competition: small bass compete directly with bluegills and crappie for macroinvertebrates. The second year data suggest the average size of bass is decreasing, probably due to a poor food supply for smaller bass and selective removal of larger individuals by anglers, both of which throw the predator/prey relationship further out of balance. In a balanced population, larger fish lost to mortality and angling are replaced by growth of smaller individuals, which are replaced by reproductive recruitment. When larger fish are removed from Kirk Pond, smaller fish do not have enough food available to achieve growth rates necessary for replacement, and reproductive recruitment has been reduced due to removal of mature fishes.

Submersed aquatic vegetation has been implicated as a negative factor in growth, behavior, and reproduction of some fish species, especially largemouth bass and bluegill (Savino and Stein 1982, Barwick and Holcomb 1976, Buck and Thoits 1970). Extensive forage cover reduces hunting success of predator species, limiting growth rates and decreasing length/weight condition values. This can lead to an increase in numbers of forage species, which increases competition for food by the foraging species and ultimately leads to an overcrowded condition. Vegetation also serves as cover for macroinvertebrates, and forage species ability to find food may be decreased, intensifying intraspecific and interspecific competition for food. Abundant cover may also allow forage species to harass nesting predators, reducing spawning successes necessary to offset predator mortality rates. Additionally, water quality influenced by dense macrophyte or algae stands often affects fish growth and reproductive success, especially where photosynthesis causes pH shifts above 10. Largemouth bass, for example, become lethargic at high pH, and will not feed or spawn (Buck and Thoits 1970).

Dense vegetation in Kirk Pond provides cover for smaller forage species, which have become overcrowded due to reduced predation. This overcrowded condition of forage species is inhibiting growth of smaller predators, and when larger predators are removed by angling, emigration, or natural mortality, few fish available are able to replace them. The result is an abundance of small, overcrowded fish and a decline in the number of harvestable fish over time.

Population sizes of fish in Kirk Pond cannot be accurately assessed by the techniques employed. However, conversations with ODFW personnel indicate that the densities were relatively low for the common sport species (< 1,000 per hectare), especially considering the overall small size of the fish. It is difficult to ascertain a reason for this, but a combination of excessive vegetation, relative ease of immigration or emigration, low food availability, and fishing pressure are all possible contributors to the low densities seen. Dense vegetation may have reduced the efficiency of the collecting technique applied, resulting in apparent low densities of fish. However, densities were similar during both years, indicating that the collection technique was efficient.

Examination of stomach contents revealed that most centrarchids collected during both years had not fed recently, which accounts for the relatively poor condition and small numbers of fish in the pond. The invertebrate population was not sampled, but it appears that their numbers and/or availability were not adequate to sustain large numbers of fish. Whether the cool temperatures precluded hatching of aquatic larvae, dense vegetation provided too much cover, or vegetation present was incompatible with larger invertebrate populations is unknown. Larger size class bluegills were feeding primarily upon Eurasian watermilfoil buds, an indicator of limited macroinvertebrate availability. Smaller bluegill and white crappie stomachs contained small quantities of microcrustaceans and chironomid larvae or were empty. Smaller size class largemouth bass stomachs were empty, and larger bass stomachs contained only adult odonates: these fish were evidently leaping from the water to capture food. One adult largemouth bass collected in 1991 had eaten a juvenile cutthroat trout stocked by the ODFW and was the only fish examined that had exhibited piscivory.

## Conclusions

The fish assemblage of Kirk Pond is typical for a warmwater fishery, with the exception of cutthroat trout periodically stocked by the ODFW. In 1991, the fishery exhibited marginally healthy individuals and a reasonably desirable diversity at low densities, but samples collected in 1992 suggest a declining fishery in terms of decreases in fish size and condition, increases in size class dominance in forage species, and decreases in numbers of harvestable individuals. The probable causes of this decline include: (1) the increase in submersed aquatic macrophytes reported in recent years and (2) excessive fishing pressure. Dense plant growth has disrupted the balance of predator and prey species by providing too much cover for forage species and their food, reducing food availability for most fish species in the pond. Excessive vegetation may have also decreased spawning successes of desirable species by altering water quality and providing cover for nest predation. At the same time less desirable species, such as common carp, flourish. The problem is compounded when larger predator species (largemouth bass, adult crappie, etc.) are removed

by anglers: less control of forage species through predation sustains competition between smaller fish, limiting growth and interfering with reproductive recruitment.

Selective removal of aquatic macrophytes and stocking additional predator species (largemouth bass) in Kirk Pond should improve the fishery. Smaller forage species would have less cover to protect them from bass and other piscivorous species, decreasing forage fish numbers and increasing the growth and condition of both predators and prey. Spawning success in the pond should also improve, providing replacement individuals for forage species taken by predators and for larger fish taken by angling. Aquatic plant management from a recreational view would also make more of the pond accessible to anglers, increasing the use of the facility by the public. The probability of increased fishing pressure accompanying the management of plants should be addressed by an aggressive stocking program and/or limitations on fish taken by species and size.

Failure to implement some type of management practice in the pond will probably result in further decline of the fishery. Although periods of recovery may occur naturally, long-term health of the fishery is dependent upon both vegetation control and continued direct fishery manipulations.

# 5 *Mycoleptodiscus Terrestris* Survey

## Introduction

Management technique selections for controlling *M. spicatum* in Kirk Pond have been restricted to biological control methods because of restrictions on the use of pesticides by federal agencies in the Willamette River valley. Biological control methods for *M. spicatum* have proven very difficult and have been slow to develop because (1) there appear to be few natural enemies of the plant; and (2) biologicals which have shown some success in controlling the plant have not been host specific. In 1983, Gunner demonstrated that a fungus isolated from *M. spicatum* in Massachusetts and identified as *Mycoleptodiscus terrestris* (Gerdemann) Ostazeski had potential as a microbial biocontrol agent. This fungus has been developed as a mycoherbicide, Aqua-Fyte™, by EcoScience Corporation, Worcester, MA. The product has been demonstrated to be successful in controlling *M. spicatum* in greenhouse and small-scale enclosure trials (Gunner et al. 1990; Stack 1990; Winfield 1990).

The objective of this portion of the baseline study was to survey the *M. spicatum* population at Kirk Pond for the presence of the plant pathogenic fungus, *M. terrestris*. The microorganism is known to occur naturally in Alabama, Delaware, Florida, Illinois, Kentucky, Maryland, Massachusetts, Michigan, Minnesota, New York, Tennessee, Texas, and Virginia on a variety of plants, including *M. spicatum*. Finding the fungus as an endemic in Oregon was of primary importance because (1) it would facilitate the granting of a permit to transport the formulated organism into Oregon and (2) the concern over introducing a new pathogen into an area where it was not known to occur would be alleviated. Since *M. terrestris* commonly occurs on *M. spicatum*, it was reasonable to assume that the fungus would be found throughout the range of the host, including Oregon.

*Mycoleptodiscus terrestris* is a Hyphomycete in the form-class Deuteromycotina. When the pathogen comes in contact with the host, it is believed that a recognition mechanism results in the development of an appressorium and attachment to the plant. Production of enzymes believed to be cellulases and pectinases enable the fungus to penetrate directly into the cell walls of the

host. Once the fungus invades and ramifies throughout the host tissue, necrotic lesions develop and decomposition of plant tissues ensues (EcoScience 1992). Once established on host tissue, the fungus forms a sporodochium of dark walled conidiogenous cells one layer thick. From within these cells, asexual spores (phialoconidia) develop and are exuded from an apical aperture (Sutton 1973). The thin-walled hyaline conidia are falcate with a median septum, measuring 20-35 by 4.5-7 µ. Arising from each end of the conidium is a lateral cellular appendage measuring 9-12 µ. Once dispersed, the spores are capable of initiating secondary cycles of plant decomposition. The fungus is also capable of forming thick-walled masses of hyphal tissue called sclerotia. These dark walled reproductive structures measuring 230-5,000 by 100-600 µ serve as survival units during adverse conditions. The sexual stage of the fungus has not been ascertained.

For commercial development of Aqua-Fyte™, the fungus is grown in large-scale fermentation equipment and formulated into a 20 percent granule in a biodegradable medium of calcium alginate. Following the current baseline assessments of Kirk Pond, a field test of the mycoherbicide is proposed for the east end of the pond.

## Materials and Methods

Plant samples were collected at Kirk Pond on 21 May and 10 September 1991. At each sampling date, 20 bulk samples of *M. spicatum* were collected with a rake from sites located peripherally around the pond (Figure 30). The samples were placed in sterile plastic bags and kept in an ice-cooled chest for transport to the laboratory. Each sample was thoroughly washed in tap water and stored at 4 °C until processed.

Two methods were used to isolate fungi from the *M. spicatum* plants. One method involved direct examination of plant tissue for fungal lesions. Fifteen plants were pulled from each bulk sample and carefully scanned under a dissecting scope for damage which could have been of fungal origin. A 1-cm segment of damaged tissue from each stem was cut, surface sterilized in a 0.5 percent sodium hypochlorite solution for 30 sec, and rinsed in sterile distilled water. A maximum of three stem pieces per plate were placed in slits cut in Martin's agar, a medium which supports growth of *M. terrestris*. The plates were incubated in the dark at 28 °C for 4 days or until good fungal growth was evident around the stem pieces. The plates were first visually examined for the distinctive colony growth of *M. terrestris*. Then, any fungus growing out from a stem segment was carefully picked by cutting out a small triangular piece of agar containing hyphal tips and placing it on a PDA agar slant.

The slants were incubated at room temperature for 10 days. The actively growing fungal colonies on the PDA slants were sorted based on colony morphology, and the numbers of different growth forms representing

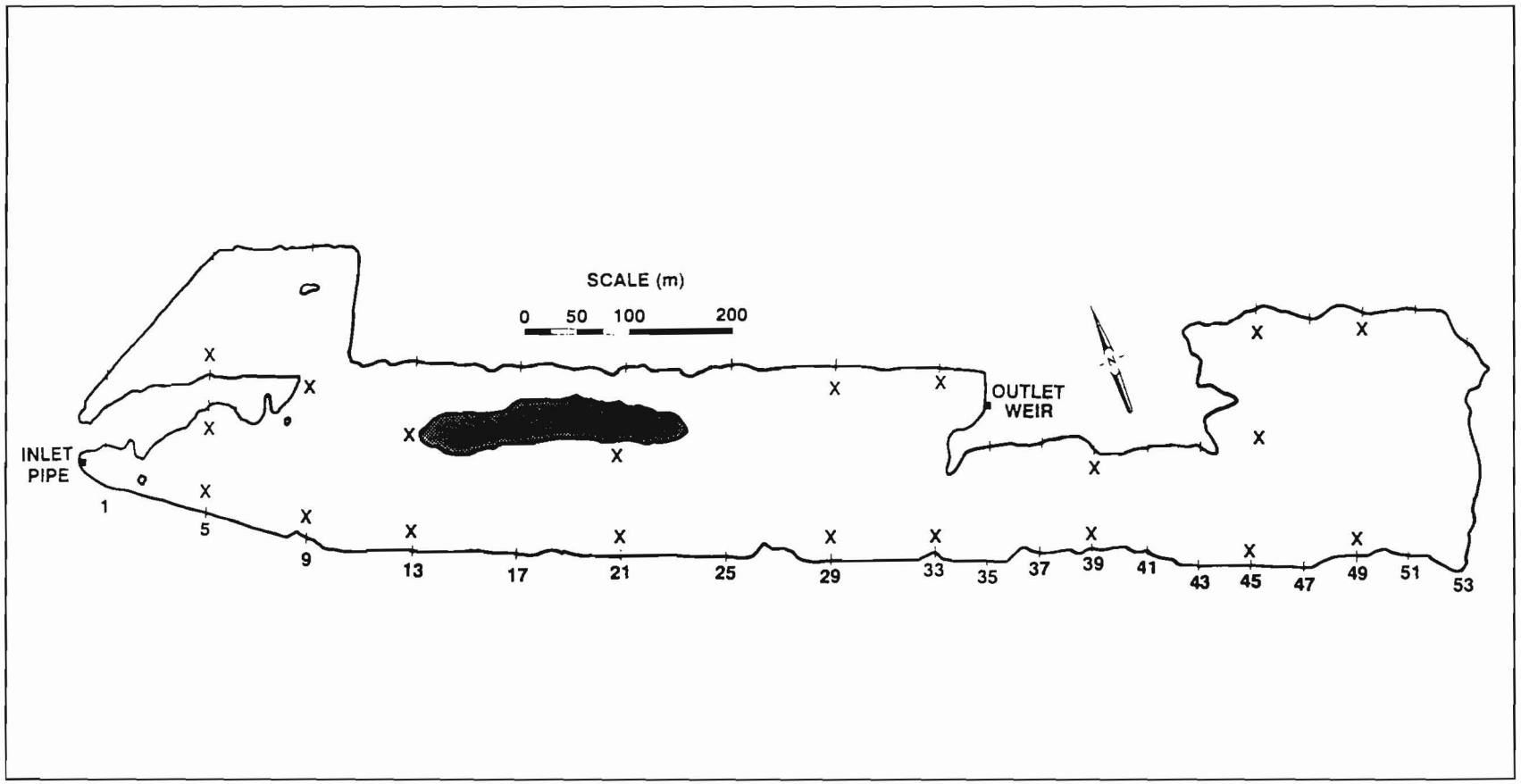


Figure 30. Map of Kirk Pond indicating sample locations for a survey of fungal associates of *Myriophyllum spicatum*

potentially different fungal species were recorded. The slants were kept at 4 °C until the fungal isolates could be plated on standard media and identified.

The second method of fungal isolation was nonselective in that direct examination of plant tissue was not used. Twenty-five grams of plant stem and leaf tissue were surface-sterilized in a 0.5 percent hypochlorite solution and rinsed in sterile distilled water. They were placed in a blender with 250 ml of sterile distilled water and homogenized for 30 sec. The homogenate was serially diluted and $10^{-3}$ and $10^{-4}$ dilutions were plated in 1-ml aliquots onto plates of PDA amended with streptomycin sulfate to inhibit bacterial growth. The plates were incubated in the dark at room temperature for 4 days. Fungal colonies were picked and processed as described above.

For identification purposes each isolate was inoculated onto a plate each of PDA and cornmeal agar (Difco Laboratories). The plates were incubated at room temperature and fungal genera and/or species were identified if sporulating structures developed.

## Results and Discussion

*Myriophyllum spicatum* plants collected from Kirk Pond appeared healthy, and showed little evidence of disease. Because disease symptoms were absent, pathogenic fungi were not expected among the isolates obtained during the study. A total of 64 morphologically different fungal units were isolated from the stem and leaf tissue. In many cases, positive identification was not possible because the isolate either did not sporulate on standard media or did not produce growth patterns characteristic of non-spore producers in laboratory culture.

No colonies of *M. terrestris* were noted upon direct examination of Martin's agar plates nor was *M. terrestris* identified from among the isolates transferred to PDA and cornmeal agar plates at either collection period. The fungus has not been documented as occurring in western U.S. and may not be an endemic in that region. Since most fungi are reported to be cosmopolitan in their distribution, more extensive collecting within the state on known host species will be necessary to verify the presence or absence of *M. terrestris* in Oregon.

The principal species (i.e. those isolated with the greatest frequency from *M. spicatum* stem and leaf tissue) are listed in Table 17. Of these, none have been documented as pathogens on *M. spicatum.* A species of *Acremonium*, *Acremonium curvulum* W. Gams, has been reported to attack *M. spicatum* (Andrews, Hecht, and Bashirian 1982), but it was not among the species complex of *Acremoniums* that was isolated from plant material collected at Kirk Pond. A single isolate of *Fusarium sporotrichoides*, another reported pathogen on *M. spicatum* (Andrews and Hecht 1981), was also isolated during the study. Some members of the genera *Cladosporium*, *Cylindrocarpon*, *Phoma*, and

**Table 17**
**Fungi Occurring with the Greatest Frequency on Stem and Leaf Tissue of *M. spicatum* Collected at Kirk Pond, May and September 1991**

| Species | Number of Isolates |
|---|---|
| *Cylindrocarpon heteronema* (Berk. & Br.) Wollenw. | 36 |
| *Sigmoidea* sp. | 30 |
| *Plectosphaerella cucumeris* (Lindf.) W. Gams | 14 |
| *Cylindrocarpon destructans* (Zinssmeister) Scholten | 10 |
| *Acremonium* spp. | 10 |
| *Phoma* spp. | 9 |
| *Papulaspora* sp. | 5 |
| *Cladosporium cladosporoides* (Fresen.) G.S. De Vries | 3 |
| *Penicillium verruculosum* Peyronel | 3 |
| *Geotrichum candidum* Link | 3 |
| *Tetracladium setigerum* (Grove) Ingold | 2 |
| *Cylindrocarpon lucidum* Booth | 2 |

*Acremonium* have been reported to be pathogenic or weakly pathogenic on plant species other than *M. spicatum.*

Most of the fungi isolated from *M. spicatum* tissues during this study would be classified as decomposers and commonly occur as saprophytes on a wide variety of organic substrates. No potentially significant plant pathogenic species were noted among the isolates obtained from the *M. spicatum* samples collected at Kirk Pond.

## Recommendation for Testing

The easternmost end of Kirk Pond provides the best location for a bioherbicide test area. Not only does *M. spicatum* biomass reach its maximum (488 g $m^{-2}$) there, but the area is removed from the flow-through system of discharge from Fern Ridge Reservoir into Coyote Creek, minimizing the possibility of spore transmission downstream (Figure 31). Furthermore, the lack of easy access and public improvements to the easternmost area has resulted in far less public use than the more-developed westernmost section of the pond. During the test period, an area approximately 250 m by 250 m would be cordoned off and flagged to restrict public use (Figure 31).

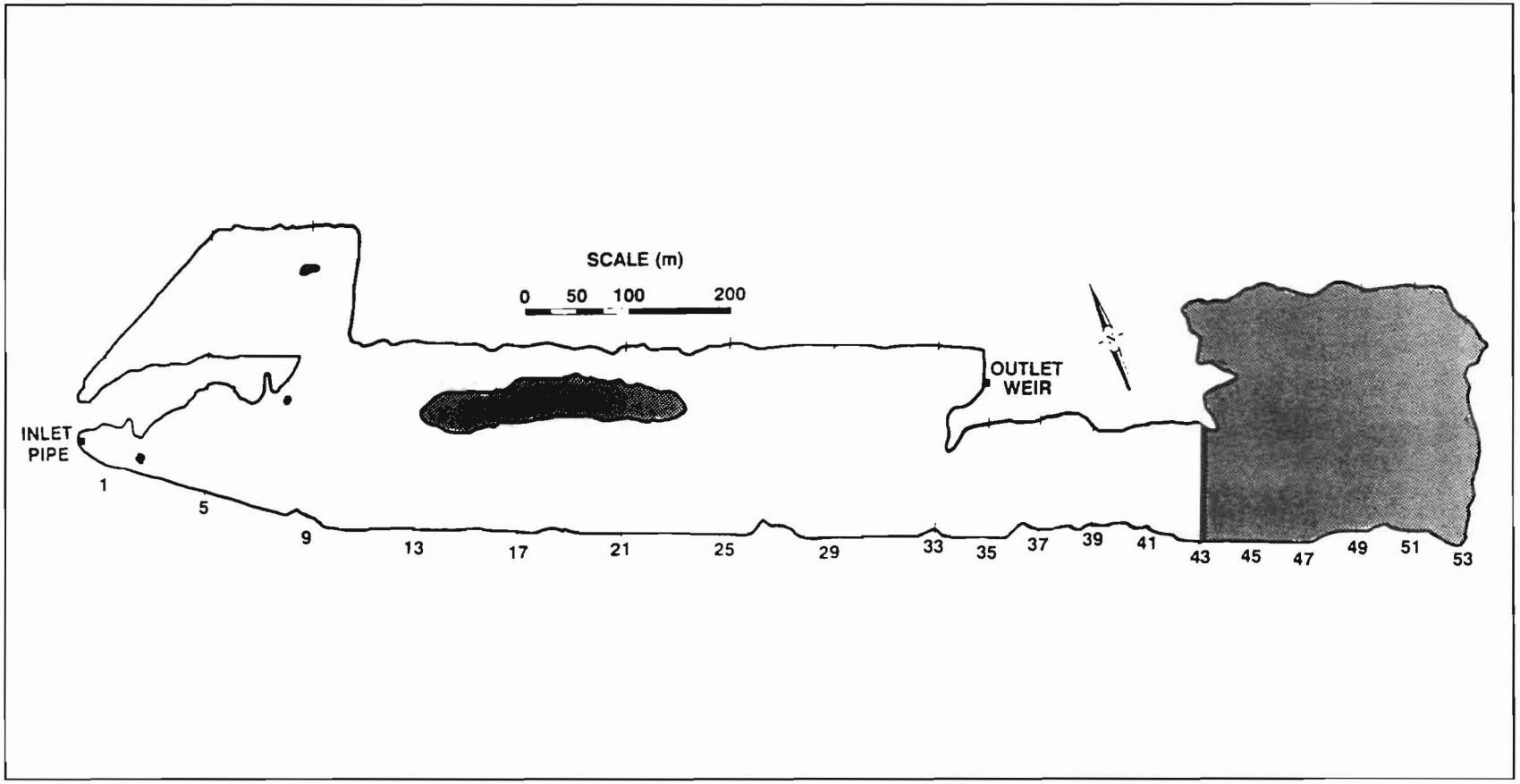


Figure 31. Map of Kirk Pond indicating the location for the test with the bioherbicide, Aqua-Fyte™

# 6 Summary and Conclusions

## Physical Parameters of Kirk Pond

Kirk Pond has an average depth of 1.6 m and maximum depth of 4.4 m, with an irregular bottom resulting from "borrow" activities. Sediment was composed primarily of sand (36 percent), followed by organic matter (30 percent), gravel (16 percent), silt (14 percent), and clay (5 percent). Light extinction was high in the western end of the pond, preventing plant growth in the deeper "holes." Light penetration was greater in the eastern end where plants grew to the deepest point.

## Water Quality

Two distinct pools of water were in evidence in Kirk Pond, with little interchange between them. The western and central portions of the pond were flow-dominated with reservoir outlet water passing through the pond and into Coyote Creek. The water remains cool and turbid. In the eastern portion, a small pool of clearer and warmer water remains separate from this flow-through system.

## Vegetation

All but 15 percent of the pond was covered by vegetation, and 69 percent of the total pond area was comprised of a near-monoculture of *Myriophyllum spicatum*. The growth form of *M. spicatum* caused a thick surface mat over much of the pond during the summer months. Other common species included *Ceratophyllum demersum* (25 percent) and *Elodea canadensis* (9 percent), but only coontail formed significant stands. Eleven additional species were observed, but covered less than 5 percent of the pond. Native species, including *C. demersum* and *E. canadensis*, rarely reached the surface and did not develop a surface mat. Species diversity was low, with less than 1.5 species found per sample interval.

Biomass sampling at six sites dominated by *Myriophyllum spicatum* indicated that this species comprised 94 percent of the total biomass, 100 percent in the eastern portion. Biomass in the eastern portion (488 g $m^{-2}$) was twice as high as that found in the central (211 g $m^{-2}$) and western portions (238 g $m^{-2}$). Nutrient analyses indicated that whereas nutrient acquisition might have limited plant growth in the eastern portion of the pond, nutrients were not limiting plant growth in the western and central portions of the pond. Growth limitation in the western and central portions of the pond was possibly due to light reduction in the turbid water. Turbidity was also a major factor restricting the distribution of plants in these areas of the pond.

## Fisheries

Kirk Pond supported a typical warmwater fishery, dominated by centrarchids as both the primary forage and predatory fish species. However, the relatively small size and low numbers of fish of all species may have indicated a fishery in decline. The high density and widespread cover of aquatic vegetation may have contributed to the population problems of the fish community.

## *Mycoleptodiscus terrestris* Survey

*Mycoleptodiscus terrestris* was not observed on *M. spicatum* in Kirk Pond. However, more extensive surveys on all known hosts would have to be performed before its presence in Oregon is ruled out. Other species of aquatic fungi were found on *M. spicatum*, none of which are reported to have pathogenic properties.

The eastern end of the pond should be utilized for the demonstration test of the bioherbicide Aqua-Fyte™ (*Mycoleptodiscus terrestris*). This area has the highest biomass of *M. spicatum*, minimal hydraulic mixing with the water of the main pond and outlet, and can have restricted access during the test period without significantly interfering with public use of the pond.

## Management Techniques

Aquatic plant management should be implemented to both provide access for recreation and to improve the fishery. Reducing the density and distribution of plants in Kirk Pond to an intermediate level would provide less cover for smaller forage species, allowing an increase in the vigor of game fishes, and increase spawning success. No single aquatic plant management approach is superior to all others under all circumstances, or even given the same set of conditions. Particular management approaches (biological, chemical, mechanical, or physical) should be chosen depending on the objectives of the overall

management plan. Many management approaches can be used in tandem to meet multiple objectives or increase the efficiency of an aquatic plant management plan. In this section, we present several management approaches that may be appropriate for Kirk Pond. We will divide these approaches into their respective technology areas: biological, chemical, mechanical, and physical. The specific applicability of each of these control measures to Kirk Pond is summarized in Table 18.

**Table 18**
**Potential Management Tactics for Use in the Management of *M. spicatum* in Kirk Pond**

| Management Tactic | Selectivity | Probability of Control | Length of Control | Notes on Applicability |
|---|---|---|---|---|
| Grass carp | Low | Medium | Multiseason | Questionable control potential |
| Pathogenic fungi *Mycoleptodiscus terrestris* (AquaFyte™) | High | Unknown | Unknown | Experimental |
| Fluridone (Sonar™) | Medium | High | Multiseason | Long residence time |
| Triclopyr (Garlon 3A™) | Medium-High | High | Multiseason | Short residence time EUP Required |
| Rotovating | Low | Medium | Multiseason | May result in multiseason control |
| Harvesting | Low | Low | Single season (Repeated harvests needed) | Maintenance only |
| Drawdown | Medium | High | Multiseason | Engineering required, but low additional costs |

The purpose of these aquatic plant management recommendations is to indicate that many potential solutions exist to the aquatic plant problems of Kirk Pond, and all of these solutions have potential costs and drawbacks, as well as strengths and positive attributes. If one solution cannot be pursued, other possibilities to solve the aquatic plant problems are available.

## Biological control

Only two biological control technologies are available for controlling *M. spicatum*: Grass carp and the fungal pathogen *Mycoleptodiscus terrestris* (Mt).

**Grass carp**. Sterile hybrid grass carp are used in many of the United States for aquatic plant control, including the Pacific Northwest in several lakes in Washington State. However, grass carp would be an undesirable solution for Kirk Pond for several reasons. First, *M. spicatum* is one of the least preferred foods of grass carp; therefore, other desirable native plants would probably be consumed before *M. spicatum*. Stocking of sufficient grass carp to control *M. spicatum* would result in a pond largely barren of vegetation and susceptible to high turbidity from resuspension of sediment. In addition, it would be difficult to prevent the spread of grass carp, especially downstream. Even barriers over the outlet would not be totally effective in preventing fish escape.

***Mycoleptodiscus terrestris***. Although Mt has shown promise under experimental conditions in both laboratory and small field studies, this technology is not fully developed and as yet has not been demonstrated effective for controlling *M. spicatum* in a large-scale field experiment. The use of Mt in Kirk Pond would be the first such experimental use and, as such, is of great interest.

Some concern has been expressed by regulatory agencies over the spread of spores downstream. Although this possibility is far from likely, both in terms of the limited water exchange within the pond and the low probability of spores distributing themselves in water any great distance, no one can be certain that spores will not escape the pond without some preventive effort. One potential solution to this dilemma is to use a polyethylene sleeve or other device, such as the Aqua Control Sleeve™ (Darryl Dockery, Inventor) to direct water from the inlet to the outlet without mixing with the water in Kirk Pond (Leslie and Van Dyke 1991). This would ensure the continued flow of water through Coyote Creek, without allowing downstream release of Mt-treated water from the pond. The Aqua Control Sleeve has been successfully used in the Vortex Springs, Ponce de Leon, FL (Leslie and Van Dyke 1991). This device could also be used in conjunction with other management tactics.

## Chemical control

Current restrictions prevent the use of herbicides in Kirk Pond. However, changes in policy or the development of an acceptable plan may allow the use of herbicides in the future. For instance, the mixture of treated water with outlet water could be prevented. This could be achieved by using the polyethylene sleeve discussed above. Once the water exchange problem is addressed, many options for herbicide treatments are possible. Compared to other control techniques, chemical techniques are currently the most likely to be effective and, when used properly, do not pose adverse environmental impacts relative to other management techniques.

**Fluridone**. Fluridone (Sonar™ from DowElanco) is widely used for the management of *M. spicatum* and is highly effective. Fluridone requires long contact times to be effective, but can be used at rates substantially below the maximum allowed label rate. Although *M. spicatum* is more susceptible than

other species, fluridone can control most aquatic plant species if used during the peak of the growing season. However, a long treatment will be effective in removing *M. spicatum*, after which natural revegetation or active transplanting efforts would restore a native plant community. A recent fluridone treatment in Long Lake near Tacoma, WA, was effective in removing over 99 percent of *M. spicatum* in one season's treatment (Getsinger, in press).

**Triclopyr**. A new herbicide for the aquatic market is triclopyr (Garlon 3A™). Currently, it can only be used under an experimental-use permit, on a site-by-site basis. However, field experimental use to date has shown it to be very effective in managing *M. spicatum*. In addition, it requires hours rather than days of contact time, and is selective, affecting only broad-leaf (e.g., predominately dicotyledonous) plants. Therefore, most of the native pondweeds and elodea would not be affected by a triclopyr application. A recent experimental application of triclopyr in the Pend Oreille River in Washington State was effective in managing *M. spicatum*, while not affecting most native plant species (Getsinger, Turner, and Madsen 1992).

## Mechanical control

Two mechanical techniques that would be applicable to managing vegetation in Kirk Pond are rotovating (rototilling) and harvesting.

**Rotovating**. Rotovating is currently used in both Washington State and in British Columbia, Canada, for managing *M. spicatum*. Rotovating typically provides two seasons of vegetation management, but is a slow and expensive process (Newroth 1985; Maxnuk 1985). In addition, some of the gravel and clay lenses in Kirk Pond may not be amenable to rotovation and rotovation would resuspend sediments, increasing turbidity. In spite of these drawbacks, it is a technique that should be considered.

**Harvesting**. Traditional harvesting, with removal of plant material, is also a widely used management practice. In some instances, repeated harvesting within a given season has resulted in the control of *M. spicatum* for more than one season after application, but in general this practice is largely performed to maintain open water, and has little long-term management benefit. A typical scenario would be the repeated harvesting of the entire pond throughout the growing season. In addition, this tactic has many unresolved environmental issues, such as disposal of large amounts of harvested plant material, the impact of harvesting on young-of-the-year fish and forage fish species entrapped in vegetation, and nonselectivity of control.

## Physical control

**Drawdown**. The only feasible physical management tactic for Kirk Pond would be drawdown. If inlet water could be diverted or directed through a pipe to the outlet, a drawdown might be feasible.

**Engineering corrections**. In addition, the outlet structure would have to be reengineered to provide drainage down to 3 m below present levels. However, if these engineering corrections are made, a midwinter drawdown would be effective in dewatering 90 percent of *M. spicatum*. In addition, this technique could be used at low cost, once an initial investment in engineering is made, whenever additional management of vegetation is needed without additional operational costs. Additional environmental considerations include maintaining an adequate area to overwinter fish and the impact of creating two isolated pools of water in the eastern and western basins of the pond.

# References


Allen, S. E., Grimshaw, H. M., Parkinson, J. A., and Quarmby, C. (1974). *Chemical analysis of ecological materials.* Wiley, New York.

American Public Health Association, American Water Works Association, and Water Pollution Control Federation. (1989). *Standard methods for the examination of water and wastewater.* 17th ed., American Public Health Association, Washington, DC.

Anderson, R. O. (1973). "Application of theory and research to management of warmwater fish populations." *Transactions of the American Fisheries Society* 102, 164-117.

Andrews, J. H., and Hecht, E. P. (1981). "Evidence of pathogenicity of *Fusarium sporotrichoides* to Eurasian milfoil *Myriophyllum spicatum*," *Canadian Journal of Botany* 59, 1069-77.

Andrews, J. H., Hecht, E. P., and Bashirian, S. (1982). "Association between the fungus *Acremonium curvulum* and Eurasian milfoil *Myriophyllum spicatum*," *Canadian Journal of Botany* 60, 1216-21.

Barnickol, P. G. (1941). "Food habits of *Gambusia affinis* from Reelfoot Lake, Tennessee, with special reference to malarial control," Report of the Reelfoot Lake Biological Station 5, 5-13.

Barwick, D. H., and Holcomb, D. E. (1976). "Relation of largemouth bass reproduction to crowded sunfish populations in Florida ponds." *Transactions of the American Fisheries Society* 105, 244-6.

Bremner, J. M. (1965). "Inorganic forms of nitrogen." *Methods of soil analysis, Part 2: Chemical and microbiological properties.* Black, ed., American Society of Agronomy, Madison, WI, 1179-1237.

Buck, D. H., and Thoits, C. F., III. (1970). "Dynamics of one-species populations of fishes in ponds subjected to cropping and additional stocking," *Illinois Natural History Survey Bulletin* 30, 1-67.

Carlander, K. D. (1977). *Handbook of freshwater fishery biology.* Vol. 2, Iowa State University Press, Ames, 431 pp.

Colman, J. A., Sorsa, K., Hoffman, J. P., Smith, C. S., and Andrews, J. H. (1987). "Yield- and photosynthesis-derived critical concentrations of tissue phosphorus and their significance for growth of Eurasian water milfoil, *Myriophyllum spicatum* L.," *Aquatic Botany* 29, 111-122.

Day, P. R. (1956). "Report of the committee on physical analyses," *Soil Science Society of America Proceedings* 20, 167-9.

EcoScience Corporation. (1992). *Draft Environmental Assessment: Small scale field release of Aqua-Fyte™, A 20 percent Mycoleptodiscus terrestris formulation against Eurasian milfoil (Myriophyllum spicatum)*, Worcester, MA.

Foth, H. D. (1978). *Fundamentals of soil science.* 6th ed., John Wiley & Sons, New York, 436 pp.

Gerking, S. D. (1978). *Ecology of freshwater fish production.* Halstead Press, New York, 520 pp.

Gerloff, G. C., and Krombholz, P. H. (1966). "Tissue analysis as a measure of nutrient availability for the growth of angiosperm aquatic plants," *Limnology and Oceanography* 11, 529-37.

Getsinger, K. D. (1993). "Long Lake project: Chemical control technology transfer. Proceedings, 27th Annual Meeting, Aquatic Plant Control Research Program," Miscellaneous Paper A-93-2. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. In press.

Getsinger, K. D., Turner, E. G., and Madsen, J. D. (1992). "Field evaluation of the herbicide triclopyr for managing Eurasian watermilfoil," Aquatic Plant Control Research Program Information Exchange Bulletin Vol. A-92-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Gunner, H. B. (1983). "Microbiological control of Eurasian watermilfoil," Technical Report A-83-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Gunner, H. B., Limpa-amara, Y., Bouchard, B. S., Weilerstein, P. J., and Taylor, M. E. (1990). "Microbiological control of Eurasian watermilfoil," Technical Report A-90-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Hile, R. (1936). "Age and growth of the cisco, *Leucichthys artedi* (Lesueur), in lakes of the northeastern highlands, Wisconsin," United States Bureau of Fisheries Bulletin 48, 211-317.

Larimore, R. W. (1957). "Ecological life history of the warmouth (Centrarchidae)," Illinois Natural History Survey Bulletin 27, 1-83.

Lee, D. S., Gilbert, C. R., Hocutt, C. H., Jenkins, R. E., McAllister, D. E., and Stauffer, J. R. (1980). *Atlas of North American freshwater fishes.* North Carolina State Museum of Natural History, 534 pp.

Leslie, A. J., and Van Dyke, J. M. (1991). "Success in flowing water with the 'Aqua Control Sleeve'," *Aquatics* 13(3), 18-20.

Madsen, J. D. (1991). "Bibliography of critical tissue nutrient concentrations in submersed aquatic macrophytes and tissue nutrient concentrations in sago pondweed (*Potamogeton pectinatus* L.)," Rensselaer Freshwater Institute Report 91-1, Rensselaer Polytechnic Institute, Troy, NY, 10 pp.

Madsen, J. D., Hartleb, C. F., and Boylen, C. W. (1991a). "Photosynthetic characteristics of *Myriophyllum spicatum* and six aquatic macrophyte species native to Lake George, New York," *Freshwater Biology* 26, 233-40.

Madsen, J. D., Sutherland, J. W., Bloomfield, J. A., Eichler, L. W., and Boylen, C. W. (1991b). "The decline of native vegetation under dense Eurasian watermilfoil canopies," *Journal of Aquatic Plant Management* 29, 94-9.

Maxnuk, M. D. (1985). "Bottom tillage treatments for Eurasian water milfoil control." *1st International Symposium on watermilfoil (Myriophyllum spicatum) and related Haloragaceae species. 23-24 July 1985, Vancouver, British Columbia.* Aquatic Plant Management Society, Vicksburg, MS, 163-72.

Moen, T. (1953). "Food habits of the carp in northwest Iowa lakes," *Iowa Academy of Science* 60, 665-86.

Newroth, P. R. (1985). "A review of Eurasian water milfoil impacts and management in British Columbia." *1st International Symposium on watermilfoil* (Myriophyllum spicatum) *and related* Haloragaceae *species. 23-24 July 1985, Vancouver, British Columbia.* Aquatic Plant Management Society, Vicksburg, MS. 139-53.

Pflieger, W.L. (1975). *The fishes of Missouri.* Missouri Dept. of Conservation, 343 pp.

SAS Institute. (1988). *SAS statistical software Release 6.03.* Cary, NC.

Savino, J. F., and Stein, R. A. (1982). "Predator-prey interaction between largemouth bass and bluegill as influenced by simulated, submersed vegetation," *Transactions of the American Fisheries Society* 111, 255-66.

Smart, R. M. (1990). "Effects of water chemistry on submersed aquatic plants: a synthesis," Miscellaneous Paper A-90-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stack, J. P. (1990). "Development of the fungal agent *Mycoleptodiscus terrestris* for the biological control of Eurasian watermilfoil (*Myriophyllum spicatum* L.)." *Proceedings, 24th Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-90-3. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Sutton, B. C. (1973). "*Pucciniopsis*, *Mycoleptodiscus*, and *Amerodiscosiella*." *Transactions of the British Mycological Society*. 60, 525-36.

Swingle, H. S. (1950). "Relationships and dynamics of balanced and unbalanced fish populations," Auburn University Agricultural Experiment Station Bulletin 274, Auburn, AL.

Titus, J. E. (1977). "The comparative physiological ecology of three submersed macrophytes," Ph.D. diss., University of Wisconsin-Madison, 195 pp.

Weatherley, A.H. (1972). *Growth and ecology of fish populations*. Academic Press, London, 293 pp.

Wetzel, R. G. (1960). "Marl encrustation on hydrophytes in several Michigan lakes," *Oikos* 11, 223-36.

Winfield, L. E. (1990). "Biological control of Eurasian watermilfoil." *Proceedings, 24th Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-90-3. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

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**13. ABSTRACT** *(Maximum 200 words)*

Kirk Pond is a 29-ha man-made pond adjacent to Fern Ridge Reservoir, OR. It is the central feature of Kirk Park, a multiple day-use park at the project. Kirk Pond supports a naturally reproducing warmwater fishery and a put-and-take trout fishery. For many years, the pond has been impacted by dense growths of Eurasian watermilfoil (*Myriophyllum spicatum* L.), which has greatly restricted recreational use of the pond and threatens both the native plants and vigor of the fishery.

The primary purpose of this study was to provide an ecological assessment of the pond in preparation for an experimental application of the potential biological control agent *Mycoleptodiscus terrestris* (Mt), marketed as the mycoherbicide Aqua-Fyte™. The primary goals of the assessment were to (1) determine the role of environmental factors, such as water depth, sediment and water chemistry, and light availability in affecting the present and future distribution and abundance of submersed aquatic plants (particularly *M. spicatum*) in Kirk Pond; (2) assess the condition of the Kirk Pond ecosystem, including water quality

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as well as the distribution, abundance, and species diversity of fish populations; and (3) document the existence of any endemic populations of the pathogenic fungus *Mycoleptodiscus terrestris*.

Intensive studies indicated that Kirk Pond is divided into two separate bodies or pools: an eastern basin that is relatively clear, has low turbidity, and is higher in dissolved cations. Plants grow throughout the basin, with light penetrating to the bottom in all areas. Although *M. spicatum* dominates most of this area, significant beds of coontail also occur in the deeper areas. Biomass of *M. spicatum* is significantly higher in the eastern portion, and its growth appears to be limited by available nitrogen. In the western and central portions of the pond, the water chemistry is heavily influenced by reservoir inflow water, which flows from the inflow at the westernmost end to the outlet in the middle of the pond. This area of the pond is significantly more turbid, with sufficient light to grow plants penetrating only one meter or less. Therefore, a large proportion of this pond portion is bare, and the rest is dominated by *M. spicatum*. The growth of *M. spicatum* appears to be limited by light availability rather than available nutrients. Although still growing to nuisance proportions, the biomass is significantly less than that observed in the eastern end of the pond.

Species diversity is low, with few native species observed. Additional species observed included coontail (*Ceratophyllum demersum*), elodea (*Elodea canadensis*), and another Eurasian introduction, curly-leaf pondweed (*Potamogeton crispus*). The fish community composition reflected that of a typical warmwater pond in Oregon, but fish were small and with low densities, possibly indicating a fishery in decline. No *Mycoleptodiscus terrestris* was observed on *M. spicatum* in the pond.

14. Subject Terms

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