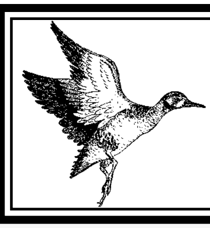

Limnological Characteristics of Waterfowl Production Area Wetlands in St. Croix and Polk Counties, Wisconsin

Technical Bulletin No. 195, 2004
Department of Natural Resources • Madison, Wisconsin 53707

Cover: Photo by Richard A. Lillie, Blue-winged Teal drawing by Jim McEvoy.

ABSTRACT

Although it is well known that waterfowl populations vary on local, regional, and global scales, only recently have we begun to recognize the role that aquatic macroinvertebrates play in affecting these population fluctuations. We now know that many species of waterfowl feed heavily upon wetland invertebrates to obtain essential proteins for the burden of migration and reproduction. Ducklings also depend heavily on invertebrates during their first few weeks. Plants alone do not provide waterfowl sufficient resources to complete their long journeys from over-wintering habitats in the south to breeding grounds in the north.

This study was designed to document the limnological habitat of waterfowl production area (WPA) wetlands in Polk and St. Croix Counties, and to examine the role that macroinvertebrates have in influencing annual variations in local wetland waterfowl production. The intent of this study is to evaluate existing upland habitat management methods with respect to their impact on wetland physical, chemical, and biological attributes to enhance waterfowl production on public lands in Wisconsin.

Limnological measurements and macroinvertebrate and macrophyte studies were done in 20 WPAs wetlands in Wisconsin. Wetlands selected represent a broad range in waterfowl producing capacities. Sixteen wetlands were sampled extensively during the first phase of the study from 1983-86. Two 'long-term' wetlands were sampled for a 10-year span from 1983-92, and four wetlands were sampled extensively from 1989-92 as part of experimental manipulations of fish populations.

Water levels in the study area declined dramatically during the study as the result of a severe drought from 1987-89. However, despite the occurrence of dramatic changes in limnological habitat in many wetlands, waterfowl brood densities, brood sizes and mallard breeding pair densities remained relatively constant.

The stocking of fathead minnows, complex fisheries, or walleye fry into WPA wetlands in three separate experiments did not significantly impact total macroinvertebrate densities. Impacts on macroinvertebrate community structure were inconclusive.

Within individual wetlands, abundance of dragonflies/damselflies, bugs, beetles, and chironomid midges were significantly correlated with plant biomass. Total macroinvertebrate abundance was strongly, positively associated with both plant biomass and stem density within wetlands. Sites with a combination of emergent and submersed vegetation present generally supported more macroinvertebrates than sites with floating-leafed plants or unvegetated sites. Conversely, annual changes in macroinvertebrate abundance within wetlands were not correlated with either plant biomass or plant stem density. Patterns of associations between individual invertebrate abundance and limnological habitat were inconsistent among wetlands.

Changes in limnological habitat had varying impacts on waterfowl breeding pair densities (BPDs), brood densities, and brood size in the two long-term wetlands. Mallard and total waterfowl BPDs were not significantly correlated with total macroinvertebrate abundance in either wetland, while Blue-winged Teal BPDs exhibited a strong positive association with several macroinvertebrate taxa in one wetland but not the other. The response of Mallard brood densities differed according to brood stage and wetland. Blue-winged Teal brood sizes at hatch and rearing stages were strongly correlated with chironomid, total fly, and total macroinvertebrate abundance in one wetland but not in the other. Multiple regression analysis provided a series of 2-, 3-, and 4 variable models for detecting important limnological characteristics. Plant attributes were important factors accounting for much of the variance in Mallard broods, while precipitation patterns and several other physical or chemical variables had strong influence on Blue-winged Teal broods in both long-term study wetlands.

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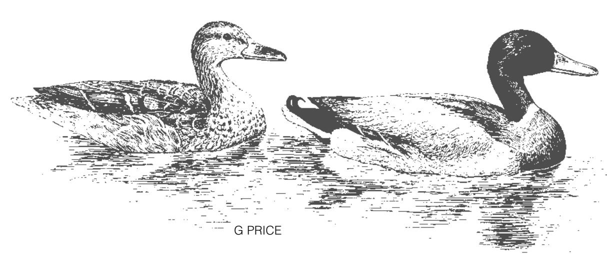


List of Tables

Continued on next page.

LIST OF FIGURES

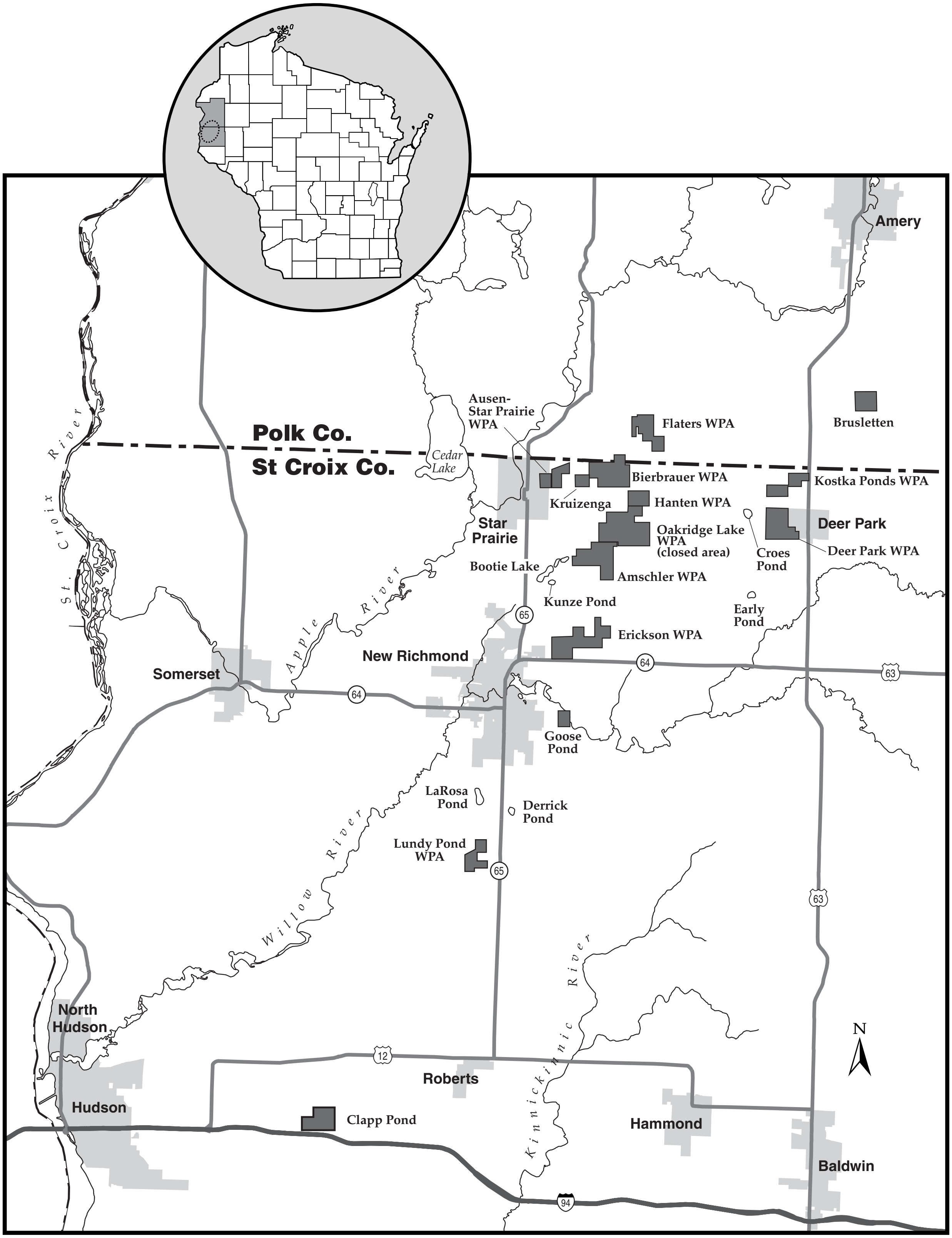
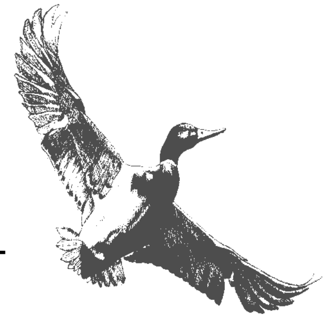


Figure 1. *Outline map of Wisconsin showing location of study area in St. Croix and southern Polk counties and outline map of study area showing the St. Croix, Apple (including the Cedar Lake outlet), Willow, and Kinnickinnic rivers; Bierbrauer, Erickson, Flaters, Kruizenga, and Lundy Pond WPAs; Brusletten, Clapp Pond, Deer Park, Goose Pond, and the Kostka Pond complex. Please note that the wetland boundaries may not be exactly to scale.*



Introduction

This report represents one part of a larger, long-term, multidisciplinary study designed to evaluate existing and potential habitat management methods intended to increase waterfowl and pheasant production on private and public lands in Wisconsin. This federally funded study was conducted from 1983 to 1992 and separated into six categories, each with a distinct set of objectives. The six categories included 1) a management and evaluation program, 2) monitoring waterfowl and pheasant populations, 3) habitat (upland) assessment, 4) hunter bag checks, 5) development and evaluation of predator indices, and 6) limnological assessment of Waterfowl Production Area (WPA) wetlands. The results of the first five categories are presented in Evrard (2002). In this report, I present the results related to category number 6, summarize the significance of these findings to waterfowl management, and provide specific management recommendations that address increased waterfowl production capabilities.

The primary objective of category number 6 was to identify the ecological significance of limnological habitat (as opposed to surrounding upland habitat) in WPA wetlands to waterfowl production. Limnological habitat includes the physical, chemical, and biological attributes of wetland basins. To estimate the relative importance of the various limnological attributes, I compared annual changes in limnological habitat attributes to corresponding annual changes in waterfowl utilization on a selected set of wetland basins located within WPAs. I concentrated on two specific habitat issues that are suspected to be critically important to waterfowl production: fish/invertebrate relationships and aquatic plant/invertebrate relationships since these relationships influence the availability of invertebrate food items to waterfowl.

Study Area

The study area was conducted in an approximately 500 mi^2 region of northern St. Croix County and southern Polk County. This area is termed the "pothole region" of Wisconsin and contains roughly 7,000 acres of federal Waterfowl Production Areas (WPAs), state Extensive Wildlife Habitat Units (EWHUs), and Wildlife Management Areas (WMAs). A more extensive description of the study area is provided in Evrard and Lillie (1996) and Evrard (2002).

Study Phases and Data Applications

Limnological studies were conducted on twenty wetland basins[1] distributed among several WPAs in the study area (Fig. 1). Water levels were also monitored on eight additional wetland basins. The wetland basins selected for monitoring include a broad range of sites subjectively rated by wildlife managers from poor to good on the basis of their waterfowl production. Sampling strategies employed in conducting the limnological assessments were limited by logistical, fiscal, and statistical considerations and further modified in response to unanticipated changes in objectives that occurred during the course of the study. Funding limitations limited the collection of extensive detailed limnological data to only a few selected basins and only permitted a reduced sampling effort on the remainder of the basins (Table 1).

The first phase of the study conducted in 1983-86 included extensive data collection on sixteen basins, including Erickson, Bierbrauer, Lundy Pond (includes 2 basins), Flaters, Kruizenga, Brusletten, Goose Pond, and the Kostka Pond complex (includes 8 basins). Erickson and Bierbrauer (representing large, persistent wetlands) were each sampled three to four times per season during the first phase. Sampling in these two basins included a combination of hydrological, physical, chemical, and

[1] Basin names used throughout this report correspond to the WPA where they were located. The term 'wetland' or 'wetland basin' as used in this report includes both isolated depressional palustrine basins and marginal or lacustrine wetlands associated with larger, more persistent, waterbodies (i.e., lakes). Some basins harbored resident fish communities while other basins were without fish.

biological investigations. Likewise, intensive sampling of the Kostka Pond complex in 1984 and 1986 and the Lundy Pond Main basin in 1985 (representative of smaller, less persistent wetlands) was conducted to document short-term, temporal dynamics in limnological habitat. The comparisons of various limnological attributes and waterfowl production measures among several basins sampled in a narrow time period served as one way to examine relationships between limnological habitat and waterfowl production. The comparisons of correlation between limnological habitat and waterfowl production measured across several years on individual WPA wetland complexes was intended to provide a second way of determining the ecological significance of limnological habitat for waterfowl.

The data collections made at several of the Kostka Ponds (basins #1 East, #1 West, #2a, and #2b) in 1986 were used to measure the impact of fish introductions on WPA wetlands. The stocking and rearing of minnows by commercial bait dealers on federally owned WPAs in Wisconsin and Minnesota generated controversy over a possible detriment to waterfowl production resulting from competitive interactions between fish and waterfowl for the same invertebrate food source. Consequently, two studies were funded to explore possible conflicts in usage (Mauser 1985, McDowell 1989).

The second phase of the study, conducted from 1987-92, began when funding cutbacks in 1987 caused necessary modifications to the study design. All sampling was discontinued on the Kostka Pond complex and sampling was reduced to only one annual sampling date in June that was selected to coincide with the peak of the brood usage period on Erickson, Bierbrauer, and Lundy Pond Main. Two years into the second phase of the study, Wisconsin DNR fish management staff expressed interest in using WPA wetlands as potential walleye brood rearing ponds. This interest resulted in expanding the study in 1989 to include two sets of paired basins [Deer Park (North and South basins) and Clapp Ponds (East and Center basins)]. Two basins were stocked and two basins were non-stocked to serve as controls. The additional funding for this stocking experiment also increased the frequency of sampling on Erickson and Bierbrauer to include two annual sampling periods. In 1989, sampling was discontinued on all other wetland basins with the exception of Flaters. As a result, the Erickson and Bierbrauer basins were sampled at least once annually from 1983-92 and represented regional control wetlands for evaluating the short-term effects of walleye rearing activities, as well as, providing a ten-year record for examining long-term temporal trends in the relationships between the various limnological attributes and selected waterfowl response variables. Data from the Lundy Ponds, Kostka Pond complex, Brusletten, Kruizenga, Goose Pond, Flaters, Clapp Ponds, and Deer Park basins were also utilized for making comparisons among basins within individual sampling periods. The data from the Clapp Ponds and Deer Park basins were additionally used to evaluate the short-term response of the resident invertebrate communities to the stocking of walleye fry.

Table 1. *Limnological sampling periods for the 20 wetlands monitored during this study from 1983-91. Sampling periods are coded as follows: April = 4; May = 5; June = 6; June (early) = 6a; June (late) = 6b; July = 7; August = 8. Please note that NC = no collections made and D = discontinued sampling.*

Wetland	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Bierbrauer	5,6,7	5,6a,6b,7	5,6a,6b,7	5,6a,6b,7	6	6	5,6	5,6	5,6	5,6
Erickson	5,6,7,8	5,6a,6b,7	5,6a,6b,7	5,6a,6b,7	6	6	5,6	5,6	5,6	5,6
Lundy Pond Main	NC	6a	5,6a,6b,7	6a	6	6	D	–	–	–
Lundy Pond South	5,8	6a	D	–	–	–	–	–	–	–
Flaters	5,7	6a	6a	6a	NC	NC	6	D	–	–
Kruizenga	5,7	6a	6a	6a	NC	6	D	–	–	–
Brusletten	6	6a	D	–	–	–	–	–	–	–
Goose Pond	6	6a	D	–	–	–	–	–	–	–
Kostka 1 East	NC	5,6a,6b,7	6a	5,6a,6b,7	D	–	–	–	–	–
Kostka 1 West	NC	5,6a,6b,7	6a	45,6a,6b,7	D	–	–	–	–	–
Kostka 2a	NC	5,6a,6b,7	6a	45,6a,6b,7	D	–	–	–	–	
Kostka 2b	NC	5,6a,6b,7	6a	5,6a,6b,7	D	–	–	–	–	–
Kostka 2c	NC	5,6a,6b,7	D	–	–	–	–	–	–	–
Kostka 3	NC	5,6a,6b,7	6a	6b	D	–	–	–	–	–
Kostka 4	NC	5,6a,6b,7	6a	6b	D	–	–	–	–	–
Kostka 5	NC	5,6a,6b,7	6a	6b	D	–	–	–	–	–
Clapp Pond Center	NC	NC	NC	NC	NC	NC	5,6	5,6	5,6	5,6
Clapp Pond East	NC	NC	NC	NC	NC	NC	5,6	5,6	5,6	5,6
Deer Park South	NC	NC	NC	NC	NC	NC	5,6	5,6	5,6	5,6
Deer Park North	NC	NC	NC	NC	NC	NC	5,6	5,6	5,6	5,6

METHODS

Field Sampling and Laboratory Analysis

Physical Data

Monthly precipitation data were obtained from the U. S. National Oceanic and Atmospheric Administration records for Amery, Wisconsin from 1982-92. The surface acreage, shoreline length, and shoreline development for each wetland basin were obtained from aerial photographs. Surface acreages were computed for maximum and minimum water levels using the computer image analysis software Optimus®. The hydrographic maps for selected wetland basins were prepared from depth soundings taken in the spring 1983. Staff gages, initially installed and surveyed in April 1983, were used to monitor water level fluctuations throughout the study period. The staff gages were installed on new basins in subsequent years when they were added to the study and re-surveyed each spring (except where otherwise noted) to adjust for vertical movement of the gage by ice action or human disturbance. A minimum of two reference benchmarks was established for each staff gage. The water temperatures were measured with an electronic hydrographic thermometer or a pocket thermometer. The collection of water column temperature profiles from the deepest portion of each basin was discontinued after the first year of the study when it was determined that all basins were generally mixed, although short term temporary thermal stratification was occasionally observed. The water transparency was measured using a standard 20 cm black and white Secchi disk.

Water level staff gages were installed in wetlands and resurveyed each spring to adjust for movement due to ice/frost movement. Greg Quinn (deceased) pictured.

Chemical Data

The dissolved oxygen (DO) measurements by azide modification (American Public Health Association 1982) were made on all basins during the first winter and several summers sampling periods. However, because the DO readings were similar among basins and provided little useful information, measurements were later discontinued. The water chemistry data were collected by surface water grabs (i.e., sample bottle submerged below water surface) taken at three to four week intervals from April to August 1983 and on a reduced number of dates during subsequent years. In-field measurements of alkalinity (titration to a fixed end point), pH (color comparison method or meter), and conductivity (potentiometric) were taken within 12 hours of the water sample collection. Additional water samples were collected twice annually from 1983-86 for nutrient analysis (nitrogen and phosphorus), ions (calcium, magnesium, sulfate, and chloride), alkalinity, conductivity, and pH analysis by the State Laboratory of Hygiene in Madison, Wisconsin. The

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Selected field chemistry measurements were done on site; additional samples collected were preserved and taken to the State Lab of Hygiene in Madison, WI to be analyzed.

latter three laboratory measurements also served as a quality control check against field measurements of the same variables. Color (determined using the Heilige Color Comparator) and turbidity (determined using the Hach Model 2100A Turbidimeter) were obtained from darkened, refrigerated samples within 14 days of collection. Because of financial cutbacks in 1986, collection of samples for laboratory analyses at the State Laboratory of Hygiene was discontinued; although one set of samples collected April 1988 in conjunction with an independent research effort (Omernik et al. 1991) were analyzed.

Biological Measurements

Biological sample collections were made through a cooperative, inter-agency effort. The fish surveys were done by the U. S. Fish and Wildlife Service in May and July 1983-84 and in May 1985, 1986, 1988, and 1990, using a combination of AC or DC electroshocking, frame nets, experimental gill nets, and seine nets. The sampling efforts were confined to Erickson and Bierbrauer basins after 1984 and data were reported on a catch-per-unit-effort basis.

During 1983-86 the University of Wisconsin-Steven's Point conducted waterfowl brood surveys and investigations on interactions between fish, waterfowl, and invertebrates. These studies included extensive collections of macrophytes and macroinvertebrates in six WPA basins within the study area. The methods used in these studies are summarized in Mauser (1985), McDowell and Nauman (1986), and Sweitzer (1986).

Wisconsin DNR staff collected paired macroinvertebrate and macrophyte samples from wadeable shoreline littoral sites in each of the 20 wetland basins with a 0.1 m^2 stovepipe column sampler. A total of 170 sets of samples (representing 703 individual samples) were collected during the 10-year study period. Each data set represents a multiple number of samples from a wetland basin on an individual date. Depending upon specific objectives and distribution of available labor, sampling schedules (i.e., frequency of sampling and sampling dates) varied among years and wetlands (Table 1). The location and spacing of paired macroinvertebrate/macrophyte stovepipe sample stations was roughly equidistant along the shoreline perimeter of each basin and was intended to represent the major macrophyte communities present along with the various exposures to prevailing winds and associations with adjacent riparian habitats. The placement of the stovepipe sampler was intended to approximate the middle of the 0-60 cm feeding zone used by dabbling waterfowl (DuBowy 1988). The water depth at each sampling station varied according to bottom slope and was measured after the stovepipe sampler was positioned in the substrate. Actual sampling depth, in this case the depth of water above the top of substrate at each paired macroinvertebrate/macrophyte sampling location, ranged from 10-57 cm between stations. However, sampling depth was generally confined to 20-42 cm (Table 2).

The rooted emergent plants or portions of submerged and floating-leafed plants enclosed within the stovepipe sampler were counted (basal stem density), cut at the water-sediment interface, bagged, labeled, and kept cool and darkened while enroute to the laboratory. At the laboratory, plants were sorted, separated by taxa, examined for the presence of attached macroinvertebrates, bagged, oven-dried at 105°C for a minimum of 60 hours, and subsequently weighed (dry weight reported to the nearest 0.1 g). The dry weights of emergent plants included portions of plants extending above the water. The plants were identified and voucher specimens were prepared. Taxonomy was verified by Theodore S. Cochran and Hugh H. Iltis (both of the University of Wisconsin-Madison Herbarium) or, in the case of pondweeds, by S. G. Smith (University of Wisconsin-Whitewater). Taxonomy employed during the course of this study followed Fassett (1972) and Voss (1972) but was updated to conform to Gleason and Cronquist (1991).

Detailed shoreline vegetation data was collected from Erickson and Bierbrauer basins annually in June 1983-86,

Shoreline seine hauls were made on smaller wetlands as a way to assess resident fish communities. Jim Mulligan (USFWS) and Hannibal Bolton (USFWS) pictured.

PHOTOS: R. LILLIE

After collection, contents of the stovepipe sampler were removed and sieved to separate macroinvertebrates.

1988, and 1990-91 along three or five parallel vegetation transects adjacent to each of the paired macroinvertebrate/macrophyte sampling stations. A similar sampling methodology was conducted in the Kostka Pond complex in both 1984 and 1986 and in the Lundy Ponds in 1985. Vegetation survey transects were spaced approximately 5 m apart and centered on the paired macroinvertebrate/macrophyte stations. The vegetation was sampled within 0.1 m^2 (rectangular 20 by 50 cm) quadrants (Daubenmire 1959) at 150 cm intervals along each transect from shore up to a water depth of 60 or 75 cm. Plant species, stem densities, frequency of occurrence, and percent cover were recorded. Importance values (IVs; the composite average of relative frequency of occurrence, relative stem density, and relative cover) were determined from these surveys and compared with IVs from corresponding stovepipe sample data in order to estimate the representativeness of the data. The vegetative composition of column stovepipe samples was representative of the adjacent flora in the 0-60 cm zone for each wetland where these evaluations were conducted (see Evrard and Lillie 1985, 1987), thus supporting any conclusions about paired macroinvertebrate/macrophyte compositions and interrelationships that are based solely on column data alone. Exceptions included free-floating duckweed that were restricted to shallow waters and other submersed taxa that generally were confined to deeper water (e.g., *Ceratophyllum demersum*).

Vegetation surveys of plants in water > 60 cm were conducted on Erickson and Bierbrauer basins during late June 1984-86, 1988, and 1990-91 using the rake technique (restricted to two rake tosses per site) described in Jessen and Lound (1962). Transects and sample site spacing formed 2500 m^2 grids and resulted in a sample size of 75 quadrants for Erickson and 85 quadrants for Bierbrauer. The vegetation surveys of the deep water

Table 2. *Water depths (cm) at macroinvertebrate/macrophyte sampling stations in 20 WPA wetland basins.*

Wetland Basin	Sample Size	Mean	Standard Deviation	Standard Error	Minimum-Maximum	CV%	Median
Bierbruaer	171	35.3	7.2	0.6	16-57	20	34
Brusletten	10	33.3	4.4	1.4	28-43	13	33
Clapp Pond Center	24	34.2	3.9	0.8	28-42	11	34.5
Clapp Pond East	23	33.9	5.6	1.2	23-48	16	34
Deer Park North	24	32.5	5.0	1.0	21-42	15	32
Deer Park South	24	35.6	5.4	1.1	21-46	15	37
Erickson	156	33.3	7.5	0.6	19-55	21	33
Flaters	18	34.5	7.2	1.7	19-46	21	37
Goose Pond	6	31.8	3.1	1.2	28-37	10	31.5
Kostka 1 East	27	31.3	7.7	1.5	14-49	25	32
Kostka 1 West	30	38.7	6.7	1.2	21-55	17	38.5
Kostka 2A	30	33.8	6.5	1.2	21-45	19	33
Kostka 2B	27	29.5	5.6	1.1	17-40	19	30
Kostka 2C	12	34.1	7.8	2.3	23-47	23	35
Kostka 3	18	35.6	9.6	2.3	14-53	27	35
Kostka 4	18	35.6	4.6	1.1	25-43	13	36
Kostka 5	18	34.0	3.8	0.9	30-43	11	33
Kruizenga	18	32.4	3.5	0.8	23-38	11	33
Lundy Pond South	3	32.3	1.2	0.7	31-33	4	33
Lundy Pond Main	46	24.5	6.2	0.9	10-39	25	24.5

A thirty-gallon oil drum was converted into a stovepipe sampler to collect macroinvertebrates and shoreline vegetation. Bill Fannucchi pictured in Lundy Pond South.

PHOTOS: R. LILLIE

A 'Daubenmire rectangle' (Daubenmire 1959) was used to measure percent cover of aquatic vegetation.

areas of the Kostka Pond complex and Lundy Ponds were conducted during 1984 and 1985 using the same procedure, although spacing between transects was reduced to compensate for the smaller sizes of the ponds.

The 250 ml phytoplankton grab samples were collected from central areas of Erickson, Bierbrauer, Lundy Ponds, Kostka Ponds, Kruizenga, and Flaters Ponds during 1983-84 and were preserved with unbuffered Lugol's solution until analyzed. Taxonomic identifications were made to the genus level using keys described in Prescott (1962). An estimate of dominance was based on scans of several fields using a compound microscope (see Lillie et al. 1993).

To determine chlorophyll *a* concentrations, 1 liter surface grab samples were collected from central basin locations on each field visit. The chlorophyll *a* samples were filtered on 0.45 micron membrane filters and extracted in 90% acetone within 12 hours of collection. The volumes filtered varied depending upon phytoplankton composition and associated suspended particle abundance. Laboratory analysis was completed within one week of collection using a Beckman Spectrophotometer 70 with an 8 nm slit width. Absorbance was corrected to the equivalent of the State Laboratory of Hygiene's Beckman DU-6 (2 nm slit width) based on comparative measurements of U. S. Environmental Protection Agency standard chlorophyll *a* solutions. The data were reported as trichromatic chlorophyll *a*.

Zooplankton were collected with a standard number 10 mesh (158 microns) zooplankton net at the center of each wetland basin. Samples from the deeper basins represented vertical tows taken from a boat. The tows taken from shallow, wadeable basins represented 2 m horizontal tows. The zooplankton samples were preserved in a 4% formalin solution until analysis. Copepod identifications were based on keys to Wisconsin species described in Torke (1975). Cladocera identifications were based on keys presented by Brooks (1957), Smith and Fernando (1978), and Ward and Whipple (1966). Rotifers were keyed using Chengalath et al. (1971).

Sampling of macroinvertebrates consisted of a combination of two collection methods[2]. After rinsing and removing plants from within the 0.1 m^2 stovepipe sampler (described earlier), all loose substrate debris and associated invertebrates were removed with a number 30 mesh (600 mm) hand net. Netting continued until the occurrence of five consecutive empty dips. This was determined by careful visual examination of the net contents. Invertebrates recovered during the processing of plants were added to the corresponding stovepipe column sample. Benthic invertebrates remaining in the bottom substrates of the stovepipe sampler after the netting was completed, were subsampled by removing two cores with a 73 mm diameter polycarbonate coring device (for a total area of 0.0084 m^2) from within the bottom area enclosed by the stovepipe sampler. Coring depth varied with substrate composition (cores always penetrated the root zone of emergent plants) and always exceeded 10 cm. The core samples were processed separately from the column samples. All invertebrate samples from the column and core sampling procedures were sieved (600 mm), placed in separate sample bottles, labeled appropriately, and preserved in 95% ethanol.

In the laboratory, samples were picked, sorted, and enumerated to order, family, or genus level. During the first year of the study entire samples were examined. However, during subsequent years, a random 50%

Core samples from the bottom of the stovepipe sampler were removed and sieved to collect benthic organisms.

PHOTOS: R. LILLIE

Initial separating of macroinvertebrates from organic detritus was done using a ring-light magnifier. Genny Fannucchi pictured.

[2] A third method involving the collection of macroinvertebrates inhabiting deeper water using a standard Ekman dredge was discontinued after the first year of the study when it was discovered that dense submersed macrophytes interfered with the closure of the Ekman dredge.

R. LILLIE

Taxonomic identification of macroinvertebrates was done to the Order, Family, and Genus level using a binocular microscope. Bill Fannucchi pictured.

subsample was processed. The identification of aquatic insects to the order, family, or genus level were based on keys prepared by Hilsenhoff (1981) and Merritt and Cummings (1984). Data were tabulated for 15 community attributes and included tallies for 12 separate groups of macroinvertebrates, all Dipteran (flies) taxa, all non-Dipteran taxa, and total invertebrate taxa. Oligochaetes and zooplankton (present in both the stovepipe and core samples) were excluded from the quantitative macroinvertebrate data after it was discovered that retention of these very small and fragile organisms varied with duration and intensity of sieving (Richard Lillie, Wisconsin DNR, pers. obs.; Engel 1985). Representative voucher specimens of all invertebrate groups were preserved in 70% ethanol.

During this study, a small number of macroinvertebrate samples collected by the Wisconsin DNR were processed under contract by the University of Wisconsin-Steven's Point. A blind split-sampling process (i.e., 50% random subsample) was used as a quality control check on identification consistency and numerical accuracy. The taxa identifications and numerical abundance variability did not differ significantly between the Wisconsin DNR and University of Wisconsin-Steven's Point data.

Macroinvertebrate biomass was not measured in this study because samples were preserved in excess of a year after collection. This long lag time between collection and laboratory processing was due to the large number of samples collected during each sampling season. Differential weight losses or gains are known to occur among preserved organisms and may have produced unreliable data (Howmiller 1972, Donald and Paterson 1977, Wiederholm and Erickson 1977).

Statistical Analysis

Macroinvertebrate column and core data (i.e., raw counts per sample) were transformed using appropriate multiplication factors to compensate for differences in the sizes of the two samplers (i.e., bottom area enclosed) and reported as densities of organisms per m^2. Please note that the metric system is used in reporting macroinvertebrate data because it is the standard way of reporting and comparing macroinvertebrate density data. To visualize or roughly estimate densities on a per square foot basis, divide the reported metric values by 10. Separate reporting and analysis of core and column data were not valid due to the manner of collection. Macroinvertebrates associated with plants (or surface dwellers) were often dislodged while collecting plants within the stovepipe column and subsequently were displaced to the bottom sediments where they would be captured in the core samples. Likewise, many macroinvertebrates inhabiting soft organic sediments were often captured in the process of dip-netting the column samples. Therefore, data from column and core samples were summed and reported as total number of organisms per m^2 of bottom area. The data were reported as densities within an area rather than volumetric densities to compensate for differences in the availability of substrate habitat (dependent upon plant structure and surface area) or water depth between sites.

Quantitative paired macroinvertebrate/macrophyte data were log-transformed ($x + 1$) prior to statistical comparisons; however, sampling depth data were not transformed. Other transformations, including square root (France 1987) and fourth root (Downing 1979) transformations were tested and found to be less efficient than log-transformations in reducing the correlation between mean and variance. Percentage data were transformed using the arc-sine square root transformation prior to analysis.

A combination of statistical methods were used in analyzing the various data sets, including General Linear Model analysis (SAS 1990), *t*-tests, Pearson Product Moment correlation, simple and multiple linear regression analysis, and a series of descriptive statistical techniques. The macroinvertebrate community structure was compared among the 20 wetland basins using the Index of Biotic Similarity (Pinkham and Pearson 1976, Pearson and Pinkham 1992) and BIOSIM1 computer software (Gonzales et al. 1993).

Results and Discussion

Physical Characteristics

The waterbodies included in the study encompassed a range of types from shallow marshes (e.g., Kruizenga) and small kettle-hole potholes (e.g., Kostka Pond complex) to permanent shallow lakes (e.g., Erickson and Bierbrauer). Erickson and Bierbrauer basins were surrounded by lacustrine fringe wetlands around their shoreline perimeters. The waterbodies on WPA wetlands ranged from less than 1 acre to 199 acres in size and from 3 to 10 ft in depth (Table 3). Wetland basins were predominantly classed as type IV (semi-permanent) or V (permanent)(Shaw and Fredine 1956) at the beginning of the study period, but several basins dried up completely during the severe drought that occurred from 1987-89 (Table 4). As a result, the total surface acreage on sampled WPA waterbodies from 1983-88 decreased by 41%. However, despite this decrease in surface acreage during the drought, the amount of wetland basin area available to dabbling waterfowl for feeding (i.e., the area of water less than 60 cm deep) actually increased in some of the larger, deeper waterbodies. In these instances, as water levels dropped, large flat expanses of the basin that had previously been too deep to serve as feeding areas for dabblers suddenly became shallow enough for the waterfowl to utilize. Wetland density has also been reported to have an influence on waterfowl production (Mulhern et al. 1985). Wetland density (i.e., the number of distinct wetland basins with standing water) decreased by nearly 50% in the study area during 1987, corresponding to the first year of the drought (Evrard 2002). However, as the drought continued during 1988-89 wetland density increased, possibly resulting from the division of large, contiguous, wetland basins

R. LILLIE

Table 3. *Physical characteristics of WPA wetland basins sampled for macroinvertebrates. Data were measured in 1983 reflecting the conditions at the beginning of the study.*

Basin	Wetland Type[a]	Basin (acres) Size	Maximum Depth (feet)	Shoreline Length (miles)	Shoreline Development Factor	Brood Use[b]
Erickson	V	58.5[c]	9	2.33	2.36	High
Bierbrauer	V	57.7	9	1.92	1.84	Moderate
Lundy Pond South	IV	0.5	4	0.10	1.01	Low
Lundy Pond Main	V	35.2	5[d]	1.75	2.56	Low
Kostka 1 East	IV	1.1	4	0.16	1.04	Low
Kostka 1 West	IV	1.5	4	0.25	1.61	Low
Kostka 2a	IV	–	4	–	–	Low
Kostka 2b	IV	2.4[e]	3	–	–	Low
Kostka 2c	III-IV	–	2	–	–	Low
Kostka 3	IV	2.2	3	0.39	1.70	Low
Kostka 4	V	1.9	6	0.21	1.30	Low
Kostka 5	IV	0.8	4	0.19	1.53	Low
Kruizenga	IV	4.1	4	0.36	1.25	High
Flaters	IV	2.2	4	0.22	1.03	Low
Brusletten	III-IV	21.7	10	1.55	1.50-1.84	?
Goose Pond	IV	22.0	6	1.21	1.99	?
Clapp Pond Center	V	4.8	?	–	–	?
Clapp Pond East	V	2.7	?	–	–	?
Deer Park North	V	4.7	?	–	–	?
Deer Park South	V	7.6	?	–	–	?

[a] Wetland types taken from Shaw and Fredine (1956).
[b] Based on the experimental management plan of Evrard and Moss (1983).
[c] Includes acreage east of the bridge.
[d] Excludes the southwest basin which was 7.5 ft deep.
[e] Includes basins 2a, 2b, and 2c.

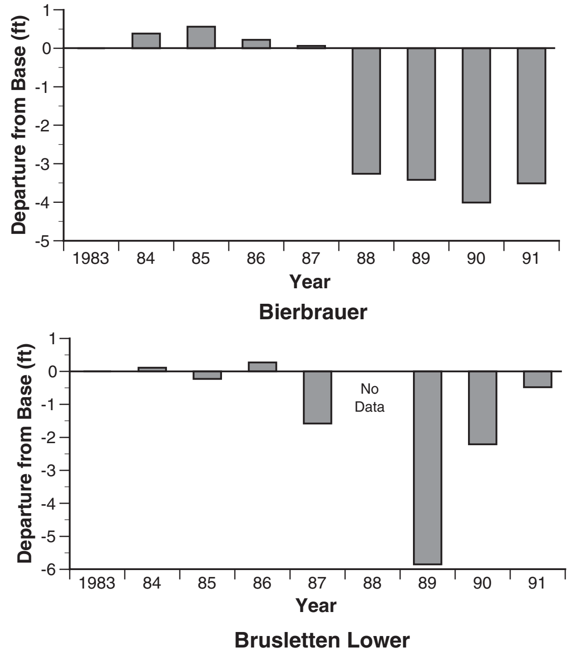
Table 4. *Percent change in total surface area of standing water on selected WPA wetland basins between 1983 and 1988.*

Basins	1983 Acreage	1988 Acreage	Acreage Lost	Percent Change
Erickson	93[a]	53	40	-43.7%
Bierbrauer	58	38	20	-34.5
Oakridge	199	186	13	-6.5
Kruizenga	4.1	0.3	3.8	-93.0
Hanton-Hannes	28	15	13	-44.9
Amschler	40	3	37	-92.5
Flaters (North and South)	72	52	20	-27.3
Star Prairie	25	6	19	-77.5
Lundy Pond basins	46	2	44	-94.8
Deer Park/Hancock	36	15	21	-57.5
Kostka Ponds	15	0	15	-100
Goose Ponds	22	3	19	-86.4

[a] Includes West basin.

into multiple, smaller, shallower, subbasins as the regional water table and wetland water levels declined.

All wetland basins showed thermal mixing during the summer. Water temperatures were extremely variable depending upon weather conditions at the time of sampling and plant densities in the sampling area. Some wetland basins with extensive coverage of floating-leafed or submersed macrophytes exhibited temporary thermal stratification.



Hydrology

Corresponding to regional groundwater conditions, water levels in the study area were near all-time highs during the first several years of the study (Erickson and Cotter 1983, House 1985). The levels in most wetland basins rose or remained relatively high during 1984-86 and then declined rapidly (Fig. 2) in response to the drought of 1987-89 (Fig. 3). Some wetland basins were

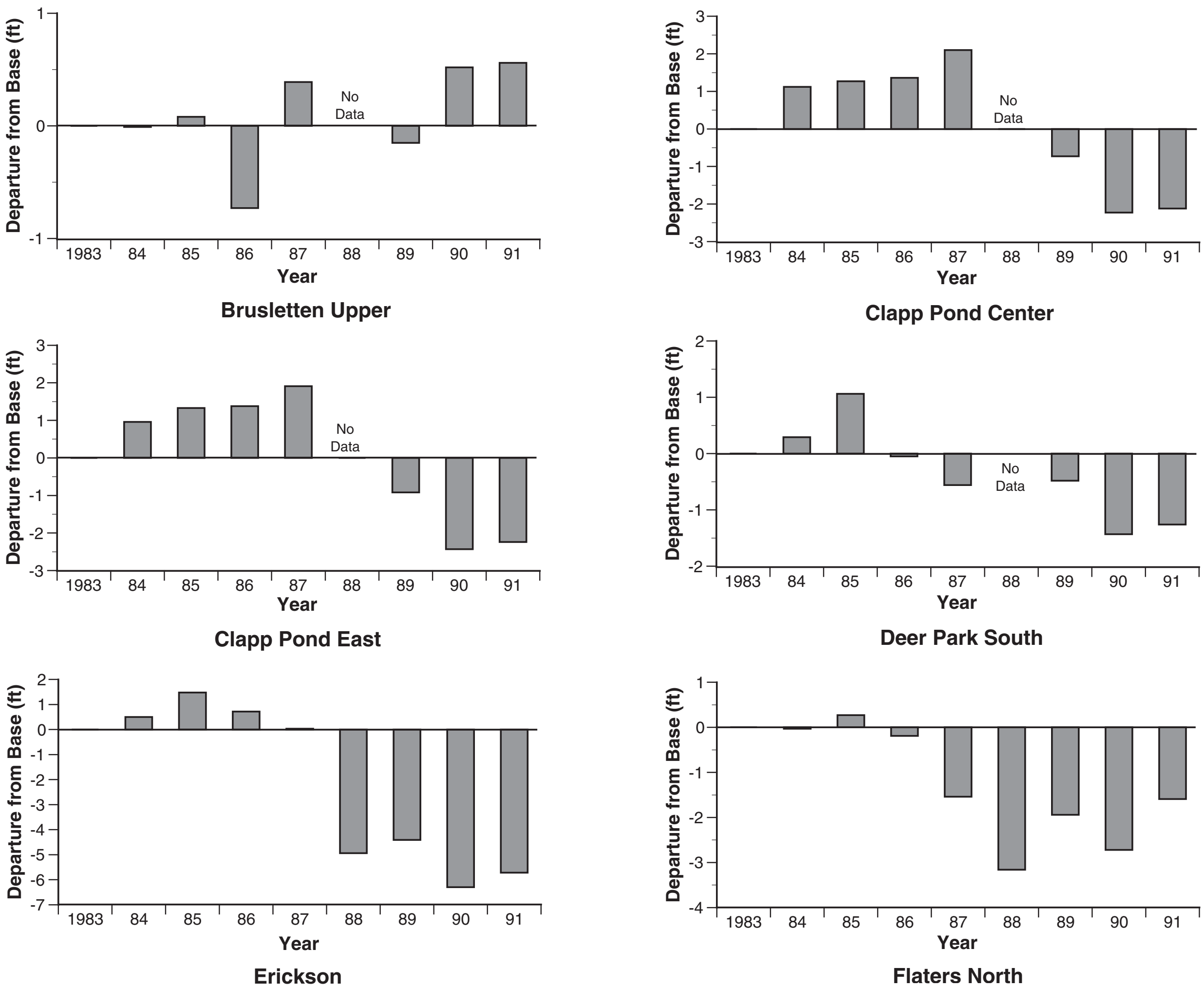


Figure 2. *Water level fluctuations in selected study wetlands (Bierbrauer; Brusletten Upper and Lower; Clapp Pond Center and East; Deer Park South; Erickson; Flaters North and South; Goose Pond; Kostka Pond complex; Kruizenga; Lundy Pond Main, North, and South) from 1983-91. Y-axis represents the departure from base measurements (in ft) recorded in 1983.*

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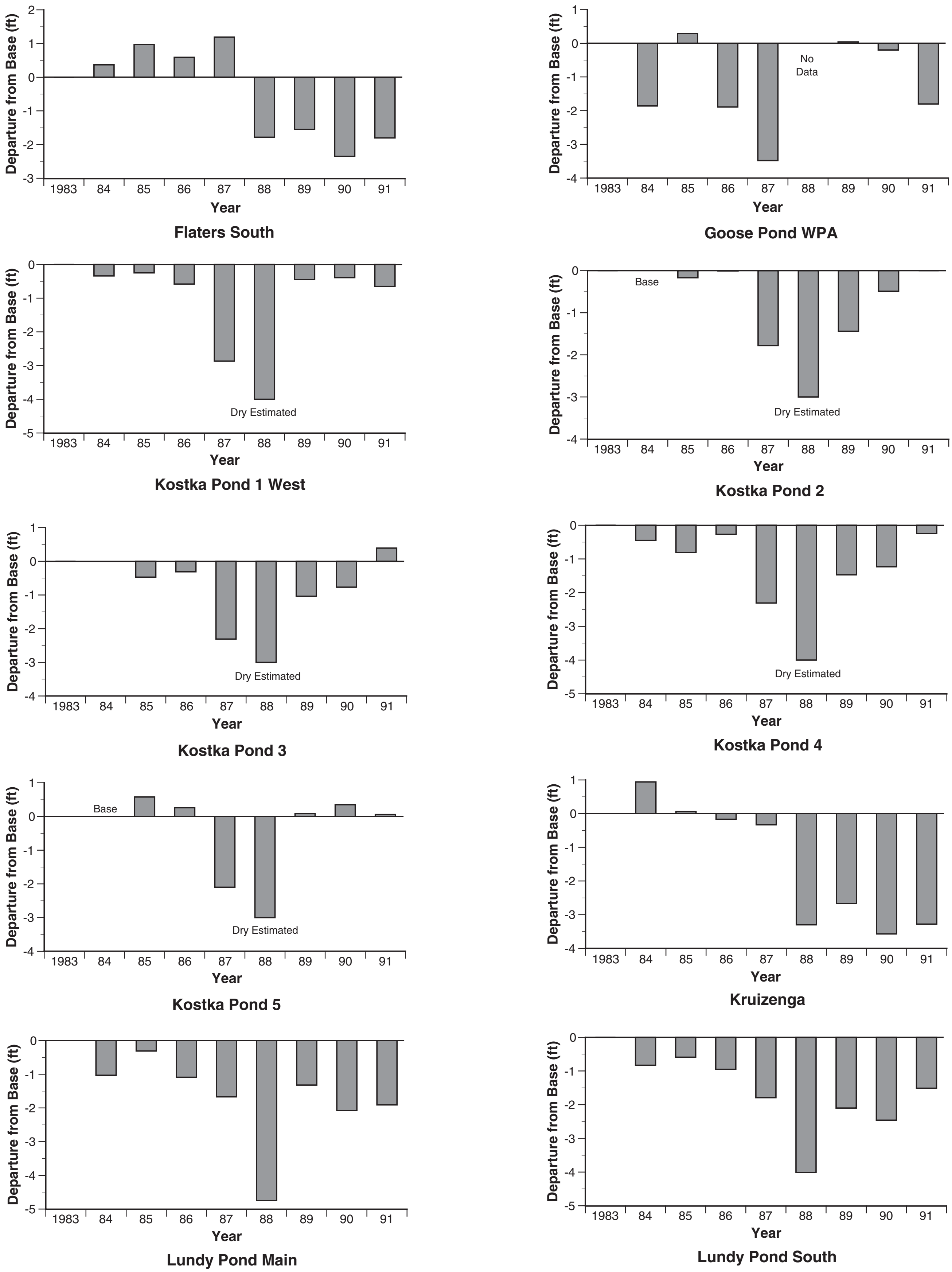
Figure 2. *Continued.*



completely desiccated during the peak of the drought, while others were nearly dry. All basins refilled with the end of the drought in 1990.

Short-term variability in water levels was observed. Seasonal variations were evident, with the highest water levels generally occurring after snow-melt and spring rains in April. Water levels declined through August due to high evaporation and evapotranspiration rates and fluctuations in autumn were highly dependent upon precipitation. Precipitation in the study area was more than 15 inches above normal from 1982-86 (Fig. 3) and during the more restricted period of staff gage measurements from 1983-86 totaled 9.25 inches above normal. Weather patterns during this period were atypical for the region with much above normal precipitation in the colder months and below normal precipitation in the summer months.

Examining the elevation, position, and location of the wetlands relative to the regional groundwater flow pattern (Fig. 4), combined with water level fluctuation records and wetland water chemistry, allows an estimate of the relative proportion of groundwater versus surface water inputs to individual wetlands (Linder and Hubbard 1982, Hubbard and Linder 1986). Wetlands experiencing slow or delayed responses to long-term precipitation changes are most likely groundwater dominated and wetlands which exhibit rapid fluctuations and response in synchronization with current precipitation patterns are generally precipitation dominated. Most wetlands receive varying inputs from both sources that, together with various output components (e.g., evaporation, evapotranspiration, and groundwater outflow), dictate water level fluctuation patterns and water chemistry. The water levels declined in many of the wetland basins from 1985 to 1986 despite the fact that precipitation during the same period was seven inches above normal. These declines most likely resulted from reduced groundwater inputs, corresponding to the temporary dry period in 1984. Likewise, although the drought ended abruptly in 1990, water levels in some wetlands were slow to respond and remained much lower than base levels. These observations suggest the time lag between groundwater recharge and water level response in many WPA wetland basins in the study area is at least one year.

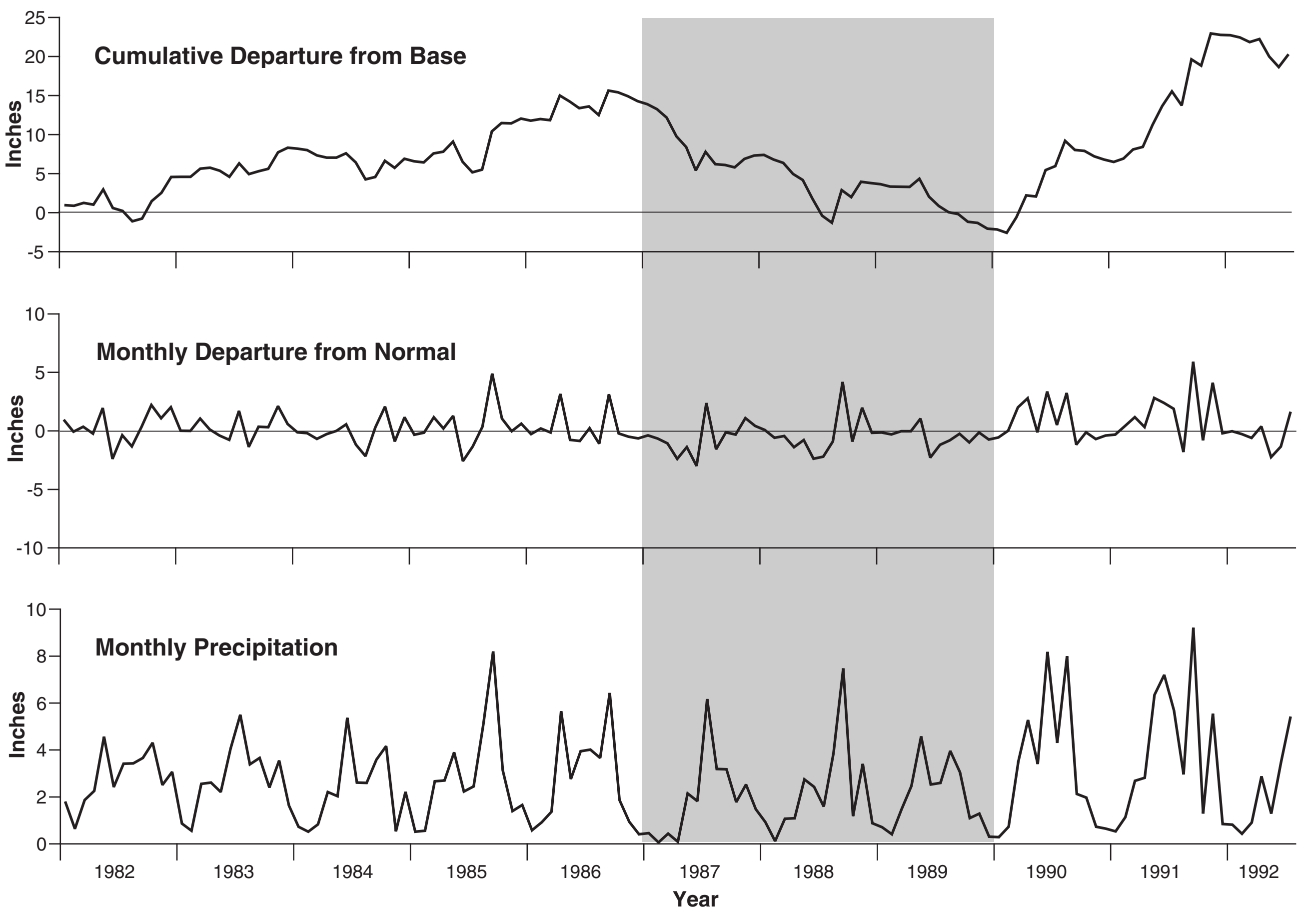


Figure 3. *Precipitation patterns in the study area from 1982-92. Monthly measurement data taken from U.S. NOAA records for Amery, Wisconsin from 1982-92. Shaded area indicates the drought years from 1987-89.*

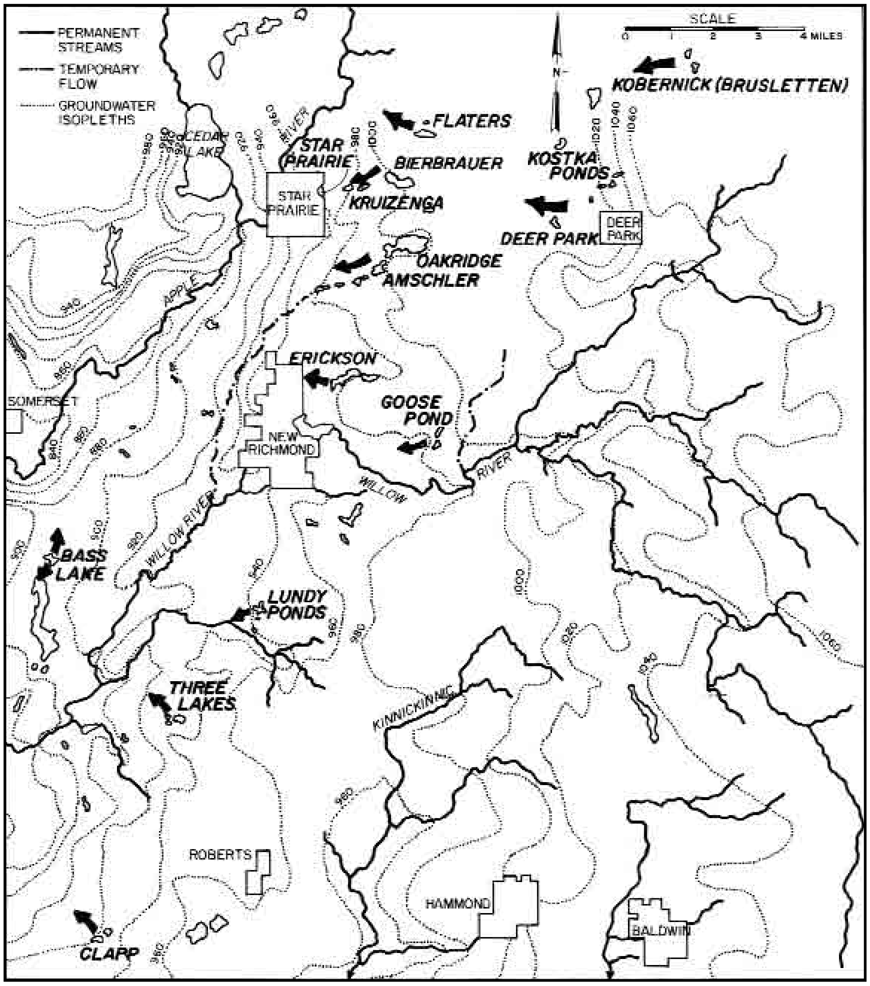


Figure 4. *Groundwater gradient map showing the geographical position of selected study wetlands relative to groundwater flow pattern. Map adapted from Evrard and Lillie (1987).*

Chemistry

The study wetlands exhibited a broad range in water chemistries (Table 5). Wetlands ranged from soft water, precipitation dominated basins (e.g., Kostka Pond complex) with low alkalinity to moderately hard water, groundwater dominated wetlands (e.g., Erickson and Bierbrauer) with high alkalinity.

Conductivity and ionic compositions reflected the basic hydrology of the wetlands. Chloride and sulfate concentrations were highest in wetlands receiving large contributions of surface and groundwater inflows as compared with concentrations in smaller, precipitation dominated ponds. The low pH ranges of the Kostka Pond complex suggest that these pothole wetlands function primarily as groundwater recharge areas.

Nutrient concentrations were influenced by both internal and external factors. The high phosphorus and nitrogen concentrations in Goose and Lundy Pond basins (Table 5) may have reflected nutrient-rich runoff from neighboring livestock operations. The high phosphorus levels in Erickson may reflect the natural rapid recycling of phosphorus within the phytoplankton community or sediment re-suspension. The low nutrient concentrations in the Bierbrauer system may have resulted from the uptake and incorporation of nutrients by the extensive submersed macrophyte community present throughout the basin of this shallow lake during the study period.

The color, turbidity, water clarity, and chlorophyll *a* varied considerably among the wetland basins (Table 5). Dark, stained waters were common in wetlands with substantial amounts of decaying organic matter. The Erickson and Lundy Pond basins lacked stands of deep-water aquatic vegetation. Turbidities were highest in Erickson, Lundy Pond, and Goose basins, and water clarity was lowest in Erickson and Lundy Pond basins. Turbidities were lowest in wetland basins with considerable amounts of vegetation (e.g., Bierbrauer and Kostka Ponds) since rooted aquatic vegetation reduces wave action, inhibits re-suspension of organic and inorganic materials, and depletes the nutrient supply otherwise available to the open-water phytoplankton community. The subsequent reductions in algae blooms also resulted in improved water clarities. Other than Bierbrauer and the Kostka Pond complex, most wetlands in the study area experienced some deterioration in water clarity due to algae blooms (high chlorophyll *a* levels) during the growing season.

Water chemistries, as typified by patterns in alkalinity, remained fairly stable within wetlands (Table 6). Seasonal trends in water chemistries were consistent from one year

Table 5. *Ranges in water chemistry and chlorophyll* a *on selected study wetlands across all years. Data represent different sampling periods. Please see Table 1 for the sampling period on each wetland.*

Wetland	Alkalinity (mg/l)	Conductivity (µS)	Color (Units)	pH (Units)	Turbidity (FTUs)[a]	Chlorophyll *a* (mg/L)	Sulphate (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Chlorine (mg/L)	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)
Erickson	56-143	177-307	7.4-10.8	15-250	2.1-78	2-367	2.9-5.4	20-30	14-17	4.9-7.0	87-360	1.4-4.5
Bierbrauer	90-187	170-370	8.0-10.4	5-60	0.7-6.3	2-44	2.2-4.1	14-25	14-17	5.2-6.0	17-30	0.6-0.9
Lundy Main	10-43	36-147	6.5-9.6	30-250	2.3-40	21-1,569	0.9-6.6	2-5	1-2	1.3-3.6	136-999	1.5-8.5
Kostka Ponds	1-55	9-127	5.2-6.8	20-180	0.6-5.5	3-147	0.9-2.9	0-6	0-3	0.3-1.2	33-450	0.9-2.4
Kruizenga	43-115	133-299	7.0-10.4	10-120	1.7-9.8	8-100	0.9-5.4	18-31	8-12	4.9-8.6	62-420	0.7-2.0
Flaters	14-53	44-168	6.8-9.6	30-320	1.6-20	3-292	0.9-2.4	3-9	3-4	0.7-2.9	95-580	1.0-4.9
Goose Pond	23-45	97-164	6.8-9.6	30-120	2.2-17	27-1,102	1.1-2.9	5-8	3-4	4.0-7.0	540-1,660	2.7-6.2
Brusletten	12-26	37-66	6.0-7.0	40-140	1.0-3.6	7-138	0.9-2.3	3-4	1-2	0.6-1.8	43-154	1.0-1.8
Deer Park North	37-64	111-225	7.0-9.7	70-140	1.2-7.0	7-209	–	–	–	–	–	–
Deer Park South	32-89	110-189	7.3-8.3	20-80	1.3-3.4	6-19	–	–	–	–	–	–
Clapp Pond Center	125-214	215-420	7.2-9.3	10-45	1.5-5.6	3-19	–	–	–	–	–	–
Clapp Pond East	112-146	217-334	7.7-9.0	10-50	1.3-4.2	2-57	–	–	–	–	–	–
Oakridge[b]	109-144	223-291	7.5-8.8	25-35	1.9-16	–	3.6-3.9	18-31	17-18	6.1-6.7	34-695	1.0-1.8

[a] Formazin Turbidity Units
[b] after McDowell 1989

Table 6. *Ranges in alkalinity (minimum - maximum) within selected WPA wetlands from 1983-92. All data are presented in mg/L. Please note that NC = no collections made and D = discontinued sampling.*

Wetland	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Erickson	102-129	109-126	127-133	118-132	130	103-124	56-118	125-143	103-107	138
Bierbrauer	90-129	92-142	94-110	100-153	117-118	103-142	103-159	122-169	95-150	177-187
Lundy Main	11-43	15-32	10-29	10-28	16-42	17-19	D	–	–	–
Kostka Ponds	5-15	4-28	7-15	1-21	dry	dry	25-55	D	–	–
Kruizenga	43-115	91-115	79	92-99	96	82	83-87	D	–	–
Flaters North	14-42	29-40	31	30-36	48	dry	45-53	D	–	–
Goose Pond	32-43	23-45	D	–	–	–	–	–	–	–
Brusletten	14-26	12-17	D	–	–	–	–	–	–	–
Deer Park North	NC	NC	NC	NC	NC	NC	37-47	56-64	51-53	49-51
Deer Park South	NC	NC	NC	NC	NC	NC	40-51	45-47	32-37	76-89
Clapp Pond Center	NC	NC	NC	NC	NC	NC	125-165	158-168	166-183	188-214
Clapp Pond East	NC	NC	NC	NC	NC	NC	145	118-146	112-126	146

Table 7. *Long-term trends of selected limnological characteristics in Erickson and Bierbrauer basins from 1983-92. Data represent means of 1-4 samples per year. Please note that NC = no collections made.*

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Long-Term Mean ± SE (CV%)
Erickson WPA											
Alkalinity (mg/L)	114	118	130	126	130	115	87	134	105	138	120 ± 5 (13%)
Conductivity (µS/cm)	246	272	289	251	218	219	239	274	236	247	249 ± 7 (9%)
Chlorophyll *a* (µg/L)	136	113	159	88	193	363	46	43	7	NC	128 ± 36 (84%)
Turbidity (FTUs)[a]	12	17	26	23	21	77	9	7	3	2	20 ± 7 (111%)
Total Nitrogen (mg/L)	3.05	2.30	3.75	3.00	NC	NC	NC	NC	NC	NC	3.00 ± 0.3
Total Phosphorus (µg/L)	220	210	310	214	NC	90[b]	NC	NC	NC	NC	209 ± 35
Bierbrauer WPA											
Alkalinity (mg/L)	107	120	100	120	118	103	134	143	120	181	125 ± 8 (19%)
Conductivity (µS/cm)	250	263	232	248	200	220	272	285	267	310	255 ± 10 (13%)
Chlorophyll *a* (µg/L)	8	10	8	11	22	16	8	16	6	NC	12 ± 2 (45%)
Turbidity (FTUs)[a]	2	1	2	2	3	4	3	4	2	2	2.5 ± 0.3 (39%)
Total Nitrogen (mg/L)	0.70	0.70	0.75	0.65	NC	NC	NC	NC	NC	NC	0.70 ± 0.1
Total Phosphorus (µg/L)	24	26	24	24	NC	23[b]	NC	NC	NC	NC	24 ± 1

[a] Formazin Turbidity Units
[b] Spring sampling only.

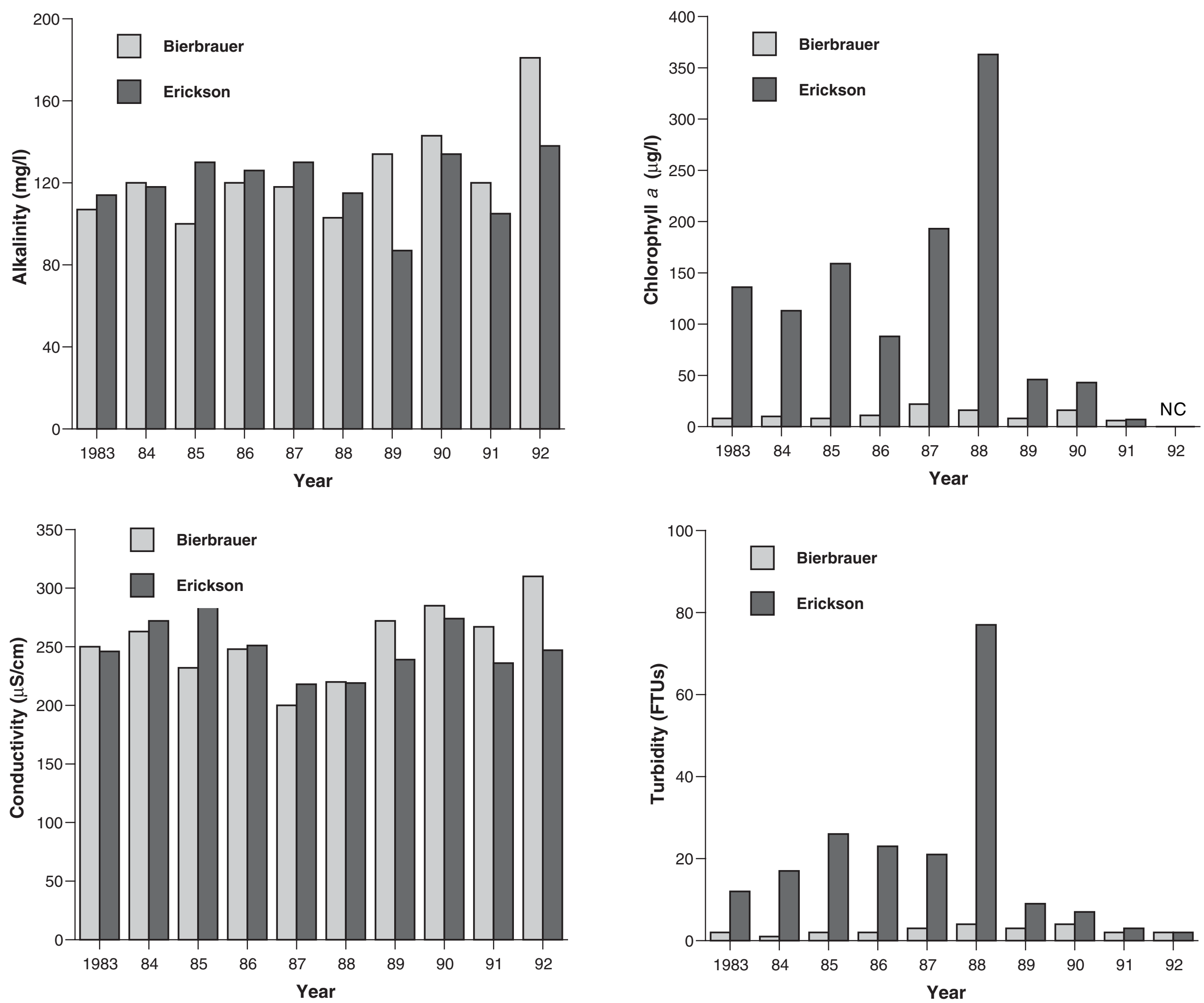


Figure 5. *Long-term trends in alkalinity (mg/l), conductivity (µS/cm), turbidity (FTUs), and chlorophyll* a *(µg/l) in Bierbrauer and Erickson WPAs from 1983-92. Data taken from Table 7.*

to the next, with concentrations generally increasing from spring to summer within individual wetlands. The drought from 1987-89 had minimal impact on alkalinity or conductivity in Erickson and Bierbrauer (Table 7 and Fig. 5). However, in Erickson chlorophyll *a*, color, and turbidity concentrations peaked during 1988 and then declined from 1989-92 (Fig. 5). This water clarity improvement in Erickson may have been related to changes in fish-zooplankton interactions which, unfortunately, were not monitored after 1984. The lowered water levels associated with the drought may have produced a fish kill during the previous winter. A reduction in fish predation on zooplankton may have allowed an increase in large-bodied zooplankton that, in turn, controlled the phytoplankton population resulting in lower chlorophyll *a* concentrations and improved water clarity. Water chemistries in Bierbrauer remained relatively stable during the drought due to a buffering effect by the dense submersed macrophyte community present in the wetland.

In general, the wetlands in this study had lower alkalinity and conductivity than counterpart Wisconsin wetlands or wetlands in most other waterfowl producing regions of North America (Table 8) and ionic concentrations were much lower than most prairie pothole wetlands.

Aquatic Vegetation

The community composition of aquatic vegetation in the study wetlands (see Appendix A) consisted of 86 species and was typical of the vegetation found in northern deep-water marshes and lake littoral zones (Evrard and Lillie 1996). A brief description of the vegetative dominance structure (based on IVs) for each wetland is provided as follows. Emergent plants, including bur-reed (*Sparganium eurycarpum*), sedges (*Carex* spp.), and grasses (Family Gramineae) were the dominant taxa in Erickson. Submersed taxa had lower IVs and appeared to decline slightly during the study period. Dominant submersed taxa included waterweed (*Elodea canadensis*) and coontail.

In Bierbrauer, sedges were among the dominant emergent plants, but submersed taxa, including coontail and northern water-milfoil (*Myriophyllum sibiricum*), were also dominant. Pondweed (*Potamogeton zosteriformis*), water-crowfoot or buttercup (*Ranunculus* spp.), and stonewort (*Chara* spp.) also were periodically found in Bierbrauer.

The main basin of Lundy Pond had large, wind-blown, floating mats of cat-tail (*Typha*

Table 8. *Comparisons of selected limnological attributes between waterfowl producing areas in North America. Data presented are ranges with means listed in parentheses (when available).*

Location	Limnological Attributes							
	Alkalinity (mg/l)	**Conductivity (µS/cm)**	**pH (units)**	**Calcium (mg/l)**	**Chloride (mg/l)**	**Sulphate (mg/l)**	**Total Phosphorus (µg/l)**	**Reference**
Wisconsin								
St Croix and Polk Counties	4-153	11-319	5.2-9.6	0-31	<1-9	1-5	19-1,670	This study
Scattered Wisconsin Wetlands	170-237	381-452	7.6-8.0	32-49	13-17	18-23	100-490	Wheeler and March (1979)
Horicon Marsh	244	768	8.0	–	–	–	–	Wheeler and March (1979)
Grand River Marsh	256	571	7.8	–	–	–	–	Wheeler and March (1979)
Theresa Marsh	318	778	7.9	–	–	–	–	Wheeler and March (1979)
Eldorodo Marsh	257	712	7.5	–	–	–	–	Wheeler and March (1979)
Waunakee Marsh	150-331	312-380	7.2-7.6	30-59	2-10	1-22	20-180	Lee et al. (1975)
Other U.S. Locations								
South Dakota	75-482 (130)	188-747 (333)	–	51-116 (80)	1-4 (3)	12-180 (46)	–	Drewien (1967)
Missouri	24-335 (121)	87-729 (285)	6.8-8.0 (7.5)	9-149 (51)	4-20 (9)	0-65 (22)	61-378 (214)	Hoyer and Reid (1982)
Northern Prairie (Temperate and Seasonal)	50-500 (170)	150-2,800 (570)	7.1-8.9 (8.2)	3-170 (50)	5-115 (17)	2-2,000 (180)	–	Adomaitus et al. (1983)
Northern Prairie (Class IV and V)	90-2,600 (800)	180-60,000 (6,000)	7.2-8.9 (8.7)	1-180 (40)	5-13,500 (370)	5-2,400 (2,300)	–	Adomaitus et al. (1983)
North Dakota	150-1,800	365-70,300	7.4-10.2	1-268	5-13,470	18-87,500	–	Swanson et al. (1988)
Maine	<1-4	18-33	4.5-6.3	<1-2	–	–	2-11	Hunter et al. (1985)
Canada								
Southwestern Manitoba	–	220-12,070 (1,639)	7.9-9.7 (8.7)	27-380 (59)	1-448 (34)	8-9,946 (778)	–	Barcia (1978)
Delta marshes	–	–	7.9	53-68	499-825	170-305	–	Kadlec (1986a, 1986b)

spp.) that interfered with the rooting and establishment of other forms of deep-water vegetation. Consequently, the main basin of Lundy Pond had only a very narrow, marginal mat of emergent plant species consisting primarily of cat-tails, spike-rush (*Eleocharis* spp.), grasses, sedges (*Carex* spp.), and arrowhead (*Sagittaria latifolia*).

Basins in the Kostka Pond complex were diverse and represented a gradation between sedge meadow and deep-water marsh. Although individual basin species richness was quite consistent in this complex (14 to 18 species per basin) considerable variation in species composition existed between the basins (Evrard and Lillie 1985). Forty-two plant taxa (representing 23 families) were collected from the Kostka Pond complex. Grasses and sedges were dominant with *Carex* spp. being the sedge with the highest IV value. Spike-rush and arrowhead were also abundant around the margins of the basins, while yellow water-lily (*Nuphar* spp.), pondweed, and bladderwort (*Utricularia* spp.) were dominant in deep-water habitats.

The plant communities of the Kruizenga and Flaters basins were less extensively surveyed, but are best characterized by narrow marginal bands of emergent vegetation (e.g., cat-tails and reed canary grass) and extensive open water areas.

Even though Patterson (1976) found that standing crops are not necessarily a good indicator of growth rates or production, these data are valuable in interpreting differences and changes in macroinvertebrate populations or associated community structure. In this study, comparison of plant standing crops (i.e., biomass) among or within wetlands (Table 9) was limited by the extremely small sample size, high variability between stations, strong temporal variability, and disparity in weights among the individual plant taxa. Macrophyte standing crops generally increased from May through July or August, suggesting increased availability of substrate area or habitat for macroinvertebrate colonization.

Long-term monitoring on Erickson and Bierbrauer study wetlands revealed temporal changes in their plant communities. Both basins had similar littoral zone communities at the beginning of the study (Tables 10-13) but differed greatly when comparing their deep water vegetation. Bierbrauer had an extensive deep-water submersed community (100% coverage) dominated by pondweed, while Erickson had a sparse (25% coverage) deep-water submersed community (Tables 14 and 15). The drought from 1987-89 had different impacts on the vegetative communities in the two wetlands. As the water levels declined in both wetlands, the areas that were too deep to be accessible to dabbling waterfowl before the drought became available. There was an estimated 50% increase in feeding zone area in Erickson and a 75% increase in Bierbrauer. The Bierbrauer basin showed an increase in total plant biomass during 1987 and 1988 (Fig. 6) as declining water levels stranded massive amounts of plants in the newly formed shallow littoral zone. During the winter of 1989-90, severe winterkill conditions contributed to the death of most aquatic vegetation in

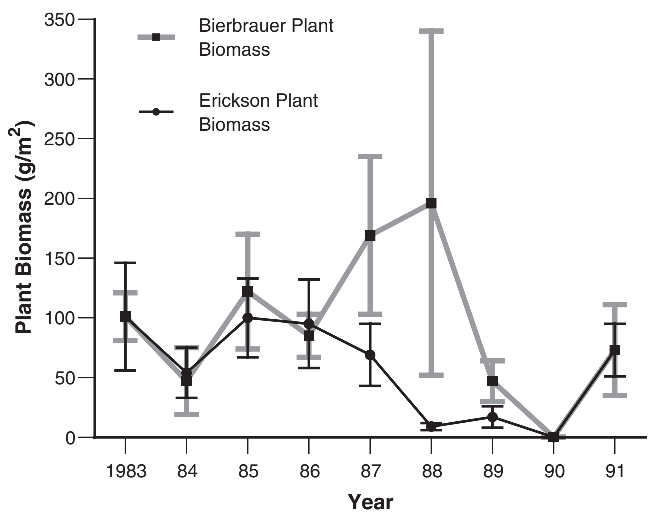


Figure 6. *Long-term trends in plant biomass (g/m^2) for Bierbrauer and Erickson WPAs from 1982-92. Error bars denote Standard Error.*

Table 9. *Total plant biomass (mean ± SE g/m^2)[a] at paired plant/macroinvertebrate stovetop column sampling stations on selected WPA wetlands. Please note that NC = no collections made and D = discontinued sampling.*

Wetland	1983	1984	1985	1986	1987	1988	1989	1990	1991
Erickson	101±45	54±21	100±33	95±37	69±26	9±3	17±9	Trace	73±22
Bierbrauer	101±20	47±28	122±48	85±18	169±66	196±144	47±17	Trace	73±38
Lundy Pond	123±67	40	102±70	68	1	0	Dry	D	
Kostka Ponds	108±29	63±16	106	138±50	Dry	Dry	Dry	D	
Kruizenga	104±6	82	108	246	NC	108±8	NC	D	
Flaters	66±1	85	75	184	NC	Dry	111±75	D	
Clapp Pond Center	NC	NC	NC	NC	NC	NC	176±23	85±49	58±15
Clapp Pond East	NC	NC	NC	NC	NC	NC	274±86	32±16	42±41
Deer Park South	NC	NC	NC	NC	NC	NC	60±25	91±15	170±63
Deer Park-North	NC	NC	NC	NC	NC	NC	9±4	56±22	31±14

[a] Data represent means of means during years that a wetland was surveyed on more than one date (i.e., 4 survey dates for Erickson and Bierbrauer annually from 1983-1986; 4 survey dates for Kostka Ponds in 1984 and 1986; 4 survey dates for Lundy Pond in 1985; and 2 survey dates for Lundy Pond, Kostka Ponds, Kruizenga, and Flaters in 1983). All remaining data represent the mean of 3-9 stations sampled on a single date in June.

Table 10. *Average importance values (IVs)[a] of shallow (≤ 60 cm) littoral zone vegetation across six macroinvertebrate sampling sites in Erickson WPA from 1983-92.*

Plant Taxa	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Emergent Plants										
seedlings	–	–	–	–	–	–	0.57	–	–	–
Carex spp.	0.24	0.49	0.40	0.30	0.07	–	–	–	–	0.17
Grasses	0.11	0.08	0.26	0.18	–	–	0.22	–	–	0.33
Bur-reed	0.30	0.26	0.12	0.20	0.11	–	–	–	0.26	–
Spike rush	0.02	0.02	–	0.07	0.15	–	0.15	–	–	–
Arrow-head	0.13	0.06	0.03	0.24	0.25	–	–	–	0.36	–
Bulrush	–	–	0.01	0.03	–	–	–	–	0.17	–
Floating-leaved Plants										
Smartweed	0.07	0.12	0.11	0.07	–	–	0.13	–	–	0.17
Submergent Plants										
Coon's-tail	0.20	0.06	0.03	0.03	0.23	–	–	–	–	–
Water-milfoil	0.01	–	–	–	–	–	–	0.17	0.16	–
E. canadensis	0.22	0.03	–	0.05	–	–	–	–	–	–
P. crispus	–	–	0.07	0.03	0.30	0.67	–	–	–	–
Other Pondweeds	0.08	–	0.04	–	–	–	–	0.17	0.16	–

[a] Data represent relative importance values of plants found at six water column sample sites. IVs were calculated by averaging the frequency of occurrence, relative stem density, and relative plant biomass for 4 dates from 1983-86 and 1 date for 1987-92. Comparisons of changes in relative IVs among dates within individual years are presented in Evrard and Lillie (1985).

Table 11. *Average importance values (IVs)[a] of shallow (≤ 60 cm) littoral zone vegetation across macroinvertebrate sampling sites in Bierbrauer WPA from 1983-92.*

Plant Taxa	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Emergent Plants										
Carex spp.	0.36	0.43	0.37	0.38	–	–	0.16	–	–	–
Grasses	0.28	0.23	0.08	0.23	–	–	–	–	0.24	0.76
Spike rush	–	0.20	–	0.07	–	–	–	–	0.17	–
Arrow-head	0.09	–	0.05	–	–	–	–	–	0.28	–
Scirpus spp.	–	–	–	–	–	0.17	–	–	0.19	–
Cattail	0.03	–	–	0.03	–	–	–	–	0.15	–
Floating-leaved Plants										
Smartweed	0.04	–	0.03	0.02	0.22	–	–	–	–	0.22
Submergent Plants										
Pondweeds	0.05	0.04	0.16	0.21	–	–	–	–	–	–
P. zosteriformis	0.16	0.11	0.10	0.17	0.43	–	–	–	–	–
P. pectinatus	–	–	–	–	0.24	0.17	0.32	–	–	–
P. gramineus	–	–	–	–	0.07	–	–	–	–	–
Coon's-tail	0.40	0.17	0.33	0.27	–	–	0.08	–	–	–
Water-milfoil	0.20	0.14	0.33	0.33	0.06	0.50	0.73	trace	–	–
Bladderwort	–	0.02	–	–	–	–	–	–	–	0.61
Chara spp.	–	–	0.13	0.12	0.46	0.22	–	–	–	–
Buttercup	–	–	0.15	–	–	–	–	–	–	–
E. canadensis	0.05	–	–	–	–	–	–	–	–	–

[a] Data represent average relative IVs of plants found at 6-9 macroinvertebrate sampling sites. Sampling dates are presented in Table 1.

Table 12. *Littoral zone vegetation importance values (IVs) for Erickson WPA. IVs were calculated from data collected along parallel transects from shore to a water depth of 60 cm. Surveys were not conducted (NC) in 1987 and 1989.*

	Year								
	1983[b]	**1984[b]**	**1985[c]**	**1986[c]**	**1987**	**1988[c]**	**1989**	**1990[d]**	**1991[d]**
Sample Size[a]	**(114)**	**(201)**	**(86)**	**(80)**	**(0)**	**(134)**	**(0)**	**(92)**	**(114)**
Plant Taxa									
Unidentified				0.09	NC	0.04	NC	0.03	Trace
Grasses		0.17	0.22	0.36	NC		NC		0.23
Carex spp.	0.12	0.26	0.24	0.25	NC		NC		Trace
Scirpus spp.		0.01	0.01		NC		NC		0.12
Spike-rush	0.04	0.03	0.02	0.03	NC		NC	0.15	0.34
Arrowhead	0.11	0.06	0.04	0.13	NC		NC	0.01	0.04
Bur-reed	0.32	0.15	0.04	0.12	NC		NC		0.04
Willow				0.01	NC		NC		
Stinging nettle				0.01	NC		NC		
Water-horehound				0.04	NC		NC		
Water-parsnip				0.01	NC		NC		
Boneset				Trace	NC		NC		
Thistle				Trace	NC		NC		
Clover					NC		NC	0.02	0.02
Water-hemlock	0.06	0.01	0.01		NC		NC		
Smartweed		0.04	0.03	0.03	NC	0.01	NC	0.17	
Pondweeds				0.01	NC	0.52	NC	0.03	
P. zosteriformis	0.18	0.01	0.01	0.01	NC		NC		
P. natans				Trace	NC		NC		
P. crispus		0.01	0.03	0.01	NC	0.52	NC		
Bladderwort		0.01	0.01		NC		NC		
Coontail	0.17	0.05	0.04		NC		NC		
Elodea spp.	0.15				NC		NC		

[a] Sample size indicates total number of sample quadrants.
[b] Data from1983 and 1984 represent 30 transects.
[c] Data from1985, 1986 and 1988 represent 18 transects.
[d] Data from 1990 and 1991 represent 12 and 16 transects, respectively.

Table 14. *Percent of sites sampled containing emergent and submersed vegetation in Erickson WPA from 1983-90. Please note that NC = no collections made.*

	Year								
	1983	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Deep-water Sites[a]									
Emergent Plants	NC	6	5	2	NC	0	NC	0	NC
Submersed Plants	NC	28	23	29	NC	30	NC	0	NC
Feeding Zone Sites[b]									
Emergent Plants	70	66	69	76	NC	10	NC	14	62
Submersed Plants	41	15	13	12	NC	59	NC	6	0

[a] Data based on rake samples collected at 75 sites.
[b] Data based on a minimum of 18, 0-60 cm deep parallel transects.

Table 15. *Percent of sites sampled containing emergent and submersed vegetation in Bierbrauer WPA from 1983-90. Please note that NC = no collections made.*

	Year								
	1983	1984	1985	1986	1987	1988	1989	1990	1991
Deep-water Sites[a]									
Emergent Plants	NC	4	0	8	NC	1	NC	0	NC
Submersed Plants	NC	100	100	100	NC	100	NC	0	NC
Feeding Zone Sites[b]									
Emergent Plants	75	75	59	67	NC	6	NC	0	75
Submersed Plants	61	43	88	42	NC	91	NC	Trace	9

[a] Data based on rake samples collected collected at 85 sites.
[b] Data based on a minimum of18, 0-60 cm deep parallel transects.

Table 13. *Littoral zone vegetation importance values (IVs) for Bierbrauer WPA. IVs were calculated from data collected along parallel transects from shore to a water depth of 60 cm. Surveys were not conducted (NC) in 1987 and 1989.*

	Year								
Sample Size[a]	**1983[b] (152)**	**1984[b] (196)**	**1985[c] (92)**	**1986[c] (96)**	**1987 (0)**	**1988[c] (109)**	**1989 (0)**	**1990[e] (0)**	**1991[d] (42)**
Plant Taxa									
Unidentified					NC		NC		0.01
Grasses	0.23	0.28	0.09	0.34	NC		NC		0.38
Carex spp.	0.22	0.20	0.10	0.27	NC		NC		0.26
Arrowhead		0.04	0.03	0.05	NC		NC		0.12
Scirpus spp.				0.02	NC	0.01	NC		0.13
Spike-rush	0.01	0.01	0.01		NC		NC		0.13
Willow		0.01	0.04		NC		NC		
Water-hemlock			Trace	0.01	NC		NC		
Swamp candle				<0.01	NC		NC		
Tear-thumb				<0.01	NC		NC		
Thistle				<0.01	NC		NC		
Water-horehound				0.02	NC		NC		
Cattail			0.01		NC		NC		0.03
Smartweed	0.03	0.05	0.05		NC	0.02	NC		
Ranunculus spp.			0.05		NC		NC		
Pondweeds				0.11	NC	0.21	NC		0.06
P. gramineus		0.01			NC		NC		
P. pectinatus	0.03	0.05	0.07	0.02	NC	0.08	NC		0.04
P. zosteriformis	0.14	0.07	0.18	0.06	NC	0.12	NC		0.01
P. natans				0.01	NC		NC		
P. praelongus	0.04				NC		NC		
P. crispus			0.01		NC		NC		
Najas flexilus			0.15	0.03	NC		NC		0.04
Milfoil	0.22	0.18	0.40	0.18	NC	0.50	NC		
Coontail	0.32	0.07	0.21	0.10	NC		NC		0.01
Chara spp.			0.20		NC	0.33	NC		

[a] Sample size indicates total number of sample quadrants.
[b] Data from 1983 and 1984 represent 30-45 transects.
[c] Data from 1985, 1986 and 1988 represent 18 transects.
[d] Data from 1991 represent 6 transects.
[e] All vegetation was dead during the 1990 survey.

Bierbrauer. Conversely, the drought had a different impact on vegetation in Erickson. The receding water levels during the drought stranded submersed plants but because plant biomass levels were lower in the deeper areas of the basin, possibly due to higher turbidities and shading, biomass levels in the Erickson littoral zone declined as the drought progressed. As will be discussed later, these differences in plant community structure between the two wetlands may have played an important role in waterfowl utilization.

Before the drought, the coverage of emergent littoral zone vegetation was fairly consistent on both Erickson and Bierbrauer showing few changes in littoral vegetation between 1983 and 1986 (Tables 14 and 15). The year to year changes within each wetland reflected real change and may have been caused by fluctuations in water levels or artifacts of attempting to maintain a standardized sampling depth. The extremely high water levels experienced during the early years of the study appeared to have inundated shoreline areas of steeply sloped banks with minimal seedbank potential. Many of the existing emergent plants were in the process of being flooded prior to the drought. During the early phases of the drought, emergent plants (appearing in the column samples) were reduced. But, during 1991-92 as water levels rose, reestablishment of emergent plants in the central flat bottoms of both wetland basins were observed inundating areas that had been mudflats in previous years. The degree of re-establishment may have been influenced by differences in substrate composition and the viability of the seedbank (see Pederson and van der Valk 1984).

The main basin in the Lundy Pond WPA had large areas of open water with little or no vegetation present. Large floating mats of cattails drifted freely, changing position according to wind-direction. A majority of the central basin was covered with broken plant fragments and the bottom appeared too loose and flocculent to support rooted plants. A mixture of spike-rush, sedge, and arrowhead dominated plant community structure in the shallow feeding zone. No submersed species were present (Table 16).

During 1984 and 1986, detailed vegetation surveys were conducted on several of the basins in the Kostka Pond complex. A diverse mixture of plants (> 30 taxa) were represented within the 0-60 cm feeding zone of dabblers (Table 17). Despite the close geographical

Figure 7. *Plant taxa distribution by depth for Bierbrauer, Erickson, and Lundy Pond Main WPAs. Error bars denote Standard Error.*

KEY

ALG = Mixed filamentous algae
ARR = Arrowhead (*Sagittaria spp.*)
BID = Beggar-ticks (*Bidens* spp.)
BLD = Bladderwort (*Utricularia* spp.)
BUL = Bulrush (*Scirpus* spp.)
BUR = Bur-reed (*Sparganium eurycarpum*)
BUT = Buttercup or Crowfoot (*Ranunculus* spp.)
CAR = Sedges (*Carex* spp.)
CAT = Cattail (*Typha* spp.)
CDM = Coon's-tail or Hornwort (*Ceratophyllum demersum*)
CHA = Stonewort or Muskgrass (*Chara* spp.)
CIC = Water-hemlock (*Cicuta bulbifera*)
CRS = Curly pondweed (*Potamogeton crispus*)
DUC = Three-way sedge (*Dulichium arundinaceum*)
GAL = Bedstraw (*Galium* spp.)
GRA = Grasses (Family: Gramineae)
GRM = Variable-leaved pondweed (*Potamogeton gramineus*)
IRI = Blue flag (*Iris versicolor*)
MIL = Water-milfoil (*Myriophyllum sibiricum*)
MLK = Swamp milkweed (*Asclepias incarnata*)
MNT = Mint (*Mentha* spp.)
NAJ = Water-nymph (*Najas flexilis*)
SAG = Sago pondweed (*Potamogeton pectinatus*)
SIU = Water-parsnip (*Sium suave*)
SMT = Smartweed (*Polygonum* spp.)
SPI = Spike-rush (*Eleocharis* spp.)
WAY = Water-horehound or Bugleweed (*Lycopus* spp.)
WIL = Willows (*Salix* spp.)
WTW = Waterwort (*Elatine* spp.)
ZOS = Flat-stemmed pondweed (*Potamogeton zosteriformis*)

Table 16. *Relative importance values (IVs) for vegetation found in the main basin of the Lundy wetland sampled during 1985 based on two methods of monitoring. Stovepipe data represent relative IVs based on frequency of occurrence, relative stem density, and relative dry weight at 6 macroinvertebrate stations. Transect data represent relative IVs based on the average of percent cover, percent relative frequency of occurrence, and percent stem density at 110 sites along 18 transects from shore to a water depth of 60 cm.*

	Stovepipe Sample Date				Transect Sample Date
	May 22	**Jun 12**	**Jun 25**	**Jul 17**	**Jun 25**
Plant Taxa					
Emergent Plants					
Spike-rush	0.68	0.60	0.45	0.72	0.27
Carex spp.	0.18	0.07	0.31	–	0.11
Arrowhead	0.18	0.42	0.37	–	0.13
Cattail	0.38	–	–	–	0.05
Grasses	0.45	0.21	0.27	–	0.12
Waterwort	–	–	0.06	–	0.05
Unidentified	0.06	0.12	–	–	0.01
Three-way Sedge	–	–	–	–	0.02
Bulrushes	–	–	–	–	0.01
Water-parsnip	–	–	–	–	0.02
Bedstraw	–	–	–	–	0.01
Water-horehound	–	–	–	–	0.04
Beggars-ticks	–	–	–	–	0.02
Milkweed	–	–	–	–	0.01
Cottonwood	–	–	–	–	Trace
Floating-leaved Plants					
Liverwort	–	–	–	–	Trace
Smartweed	–	–	–	–	0.01
Duckweed	–	–	–	–	Trace

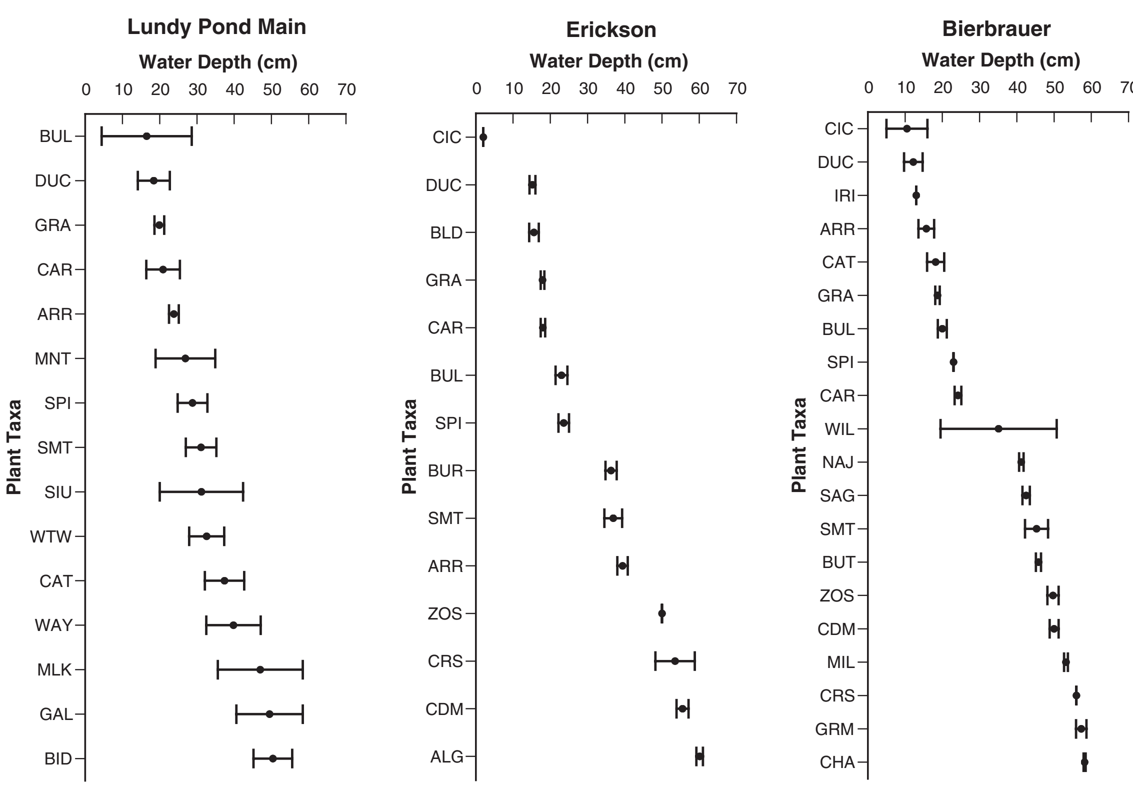


Table 17. *Relative importance values (IVs)[a] for vegetation in the Kostka Pond wetland complex sampled in June 1984 and 1986.*

	Year													
	1984								1986					
Plant Taxa	**1 East**	**1 West**	**2a**	**2b**	**2c**	**3**	**4**	**5**	**1 East**	**1 West**	**2[b]**	**3**	**4**	**5**
Carex spp.	17	6	18	36	60	50	16	11	32	6	29	44	23	14
Grasses	16	26	32	33	19	19	21	33	19	20	27	19	32	24
Spike-rush	15	24	33	14	5	15	48	41	20	18	28	13	53	46
Arrowhead	24	18	22	24	8	8	31	22	33	44	31	19	16	40
Three-way sedge	0	12	6	0	0	8	1	10	0	11	4	3	1	12
Sweet-flag	21	11	0	0	0	0	0	0	21	8	0	0	0	0
Horsetail	0	23	0	0	0	0	0	0	0	26	0	0	0	0
Unidentified	1	1	1	2	1	1	1	4	1	3	Trace	0	2	1
Rushes	8	0	0	0	0	0	0	0	7	3	0	0	0	0
Cattail	3	0	0	0	0	1	0	0	2	0	0	2	0	0
Blue flag	0	5	0	1	0	0	1	3	0	3	Trace	1	0	0
Mint	0	0	0	0	0	0	0	2	0	0	Trace	1	0	0
Water-horehound	2	0	0	1	1	1	1	0	0	0	0	0	0	0
Loosestrife	1	0	0	0	0	0	0	0	2	0	0	0	1	0
Bedstraw	0	0	0	2	1	2	2	3	0	0	3	0	0	0
Skullcap	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Buttercup	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Willows	0	0	2	0	0	3	0	0	0	0	3	1	0	0
Fern	0	0	1	2	0	0	0	0	0	0	0	0	0	0
Stitchwort	0	0	0	Trace	0	0	0	0	0	0	0	0	0	0
Beggar-ticks	0	0	0	0	0	0	0	0	0	0	2	1	5	1
Cyperus spp.	0	0	0	0	0	0	0	0	Trace	0	0	1	0	0
Bur-reed	0	0	0	0	0	0	0	0	0	0	0	Trace	0	0
Water-parsnip	6	8	6	8	8	4	1	0	4	4	16	4	0	1
Water-hemlock	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Milkweed	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Smartweed	7	4	4	6	7	1	0	2	10	0	6	2	0	0
Water-lily	1	12	13	10	0	0	2	0	0	2	3	0	0	0
Water-shield	0	0	0	0	0	0	6	0	0	0	Trace	0	4	0
Bladderwort	0	7	29	12	1	8	11	6	0	Trace	7	4	8	5
Pondweeds	3	4	5	0	1	16	0	3	2	2	2	9	0	2

[a] IVs represent numbers based on averages of relative percent cover, relative stem density, and frequency of occurrence sampled on each wetland along nine transects at 1.5 m intervals 0-60 cm deep.

[b] Data for basins 2a, 2b, and 2c were combined in 1986.

proximity of the wetlands in the Kotska Pond complex, some distinct differences existed among the plant communities. Horsetail (*Equisetum* spp.) only occurred in Kostka #1 West, while rushes and sweet-flag (*Acorus calamus*) had the highest IVs in Kostka #1 East. Bladderwort and yellow water-lily were common on Kostka #2a and #2b, while spike-rushes and arrowheads were important in Kostka #4 and #5 (Table 17).

The individual plant taxa distribution by depth were similar among Erickson, Bierbrauer, and Lundy Pond Main; three wetlands for which extensive data were collected (Fig. 7). Emergent plants dominated at depths less than 40-45 cm, while pondweed and other submersed taxa dominated the 40-60 cm zone. These distributions are consistent with zone patterns arising from differences in water-depth tolerances among plant taxa discussed by Squires and van der Valk (1992) and van der Valk and Welling (1988).

Fish

The fish population surveys focused on the deep Erickson and Bierbrauer basins where there are relatively complex fisheries (Table 18). The fish communities were severely restricted by physical factors, including geographic isolation, basin water depth, and water level fluctuations. Complex fisheries were only found in the deepest basins (i.e., permanent or persistent waterbodies) while many of the smaller, shallower basins only contained fathead minnows (*Pimephales promelas*) and mudminnows (*Umbra limi*). Fathead minnows and mudminnows are able to survive the low dissolved oxygen conditions that prevail in the smaller, shallower WPA wetlands. The relative composition and catch per unit effort varied between wetlands, among years, and among sampling gears[3] and with the severe drought in 1987-89 populations of all species declined precipitously.

[3] Data available from Wisconsin DNR files upon request.

Table 18. *Fish species of selected WPA wetlands.*

Wetland	Composition of Fish Population
Erickson	Yellow perch, White sucker, Golden shiner
Bierbrauer	Yellow perch, Golden shiner, Pumpkinseed, Fathead minnow
Lundy Pond Main	Fathead minnow
Kostka Pond Complex	No Fish[a]
Kruizenga	Stickleback, Fathead minnow, Mudminnow
Flaters	Fathead minnow, Mudminnow
Brusletten	Fathead minnow
Goose Pond	Fathead minnow

[a] A few naturally occurring Fathead minnows were observed in Kostka Pond 4 in 1984. Experiments conducted in 1986 resulted in the stocking and establishment of Fathead minnows in Kostka Pond 2 and a complex fishery in Kostka Pond 1 East.

Table 19. *Phytoplankton communities in selected WPA wetlands.*

Wetland	Phytoplankton Community
Erickson	Green algae, Diatoms, Cryptophytes, Bluegreen algae (primarily *Aphanizomenon* spp., *Microcystis* spp., and *Anabaena* spp.)
Bierbrauer	Green algae, Cryptophytes
Lundy Pond Main	Cryptophytes, Bluegreen algae, Green algae (primarily *Dimorphococcus lunatus*)
Kostka Pond Complex	Green algae, Cryptophytes, Desmids
Kruizenga	Cryptophytes, Green algae, Euglenophytes
Flaters	Cryptophytes, Green algae; Bluegreen algae

Table 20. *Zooplankton communities in selected WPA wetlands.*

Wetland	Zooplankton Community
Erickson	Small cladocerans, *Bosmina* spp., *Chydorus* spp.
Bierbrauer	Small cladocerans, *Chydorus* spp.
Lundy Pond Main	Small copepods, Rotifers
Kostka Pond Complex	Large-bodied zooplankton (primarily *Aglodiaptomus leptomus, Daphnia minnehaha, Holopedium gibberum*, *Polyphemus* spp., and *Chaoborus* spp.)
Kruizenga	Copepods, Rotifers
Flaters	Copepods


R. LILLIE

In Erickson, the population of golden shiners (*Notemigonus crysoleucas*) increased dramatically in 1988, while the population of yellow perch (*Perca flavescens*) remained relatively unchanged from numbers sampled in1983-86. Populations of white suckers (*Catostomus commersoni*) remained fairly stable through 1988 but disappeared in 1990 following the drought.

Fish populations were less consistent in Bierbrauer. Yellow perch and pumpkinseed (*Lepomis gibbosus*) increased initially but decreased prior to the drought. Golden shiner populations were highly variable in the years preceding the drought and declined rapidly as the drought progressed. Small numbers of all four dominant taxa were found during 1990, suggesting that the deeper, western basin of Bierbrauer (with its suspected groundwater springs) served as a refuge for a small, remnant population of native fishes.

Plankton

A mixture of blue-green (Cyanophyta) and green (Chlorophyta) algae dominated the phytoplankton communities (Table 19). Basins with substantial quantities of submersed vegetation had lesser amounts of phytoplankton (i.e., lower chlorophyll *a* concentrations), greater phytoplankton diversities, and better water clarities than counterpart wetlands lacking submersed vegetation. The turbid, nutrient-rich wetlands, such as Erickson, Goose Pond, and Lundy Pond Main, had abundant blooms consisting of blue-green algae (*Aphanizomenon* spp., *Microcystis* spp., and *Anabaena* spp.) and green algae (*Dimorphococcus lunatus*). Green algae and cryptophytes (Cryptophyta) dominated the sparse phytoplankton community of the Kostka Pond complex. Phytoplankton sampling was discontinued on all basins after 1984.

The zooplankton communities were directly dependent on the structure of the existing fish communities (Table 20). Small-bodied forms, including Bosmina spp. and various rotifers, dominated zooplankton communities in basins with resident fish populations. Conversely, fishless basins (e.g., the Kostka wetland complex) had greater zooplankton taxa richness and were dominated by large-bodied forms, such as *Daphnia pulex-pulicaria* (form *D. minnehaha*), *Holopedium gibberum, Aglodiaptomus leptomus*, and the aquatic insect phantom midge larvae (*Chaoborus* sp.). Other than normal seasonal changes, no differences were observed in zooplankton community structure in individual wetlands between years 1983 and 1984.

Some waterfowl feed on zooplankton when they are in abundant supply and zooplankton may be an important food resource in many WPA wetlands, particularly to those species of waterfowl with smaller gill rakers. The contribution of zooplankton to the food resource pool available to waterfowl may be underestimated in this study as most zooplankton were too small to be collected routinely using the stovepipe column and core sampling procedures.

A micro-caddisfly, Orthotrichia spp.*, found in samples.*

Macroinvertebrates

General Composite Analysis

There were approximately 250 invertebrate taxa, including 54 terrestrial taxa and nearly 200 aquatic invertebrate species, collected from WPA wetlands and surrounding uplands from 1983-92. See Evrard and Lillie (1996) for complete taxonomic lists. The majority of aquatic taxa were insects. Taxa were lumped or combined into their respective taxonomic orders: mayflies (Ephemeroptera), dragonflies and damselflies (Odonata), bugs (Heteroptera), caddisflies (Trichoptera), beetles (Coleoptera), and flies (Diptera) for purposes of data analysis. The order Diptera was further separated into the chironomids (non-biting midges or Chironomidae) and biting midges (Ceratapogonidae). Non-insect taxa were reported as scuds (Amphipoda), clams (Pelecypoda), snails (Gastropoda), mites (Hydracarina), and leeches (Hirudinea). In addition, a sum of all non-Diptera taxa and total invertebrate abundance were calculated for each sample. Total invertebrates include other groups such as moths and butterflies (Lepidoptera), spiders (Arenea), and various unidentified terrestrial insects and arthropods.

Table 21. *Summary of macroinvertebrate abundance and frequency of occurrence for all study wetlands and sampling dates combined. Data presented represent means ± standard error (SE), and range of means among all samples (n = 170).*

	Macroinvertebrate Abundance (number of individuals per m^2)		
Variable	**Mean ± SE**	**Range**	**Percent Occurrence**
Mayflies	462 ± 845	0-4,980	82
Odonates	220 ± 268	0-1,440	95
Bugs	378 ± 612	0-4,770	98
Caddisflies	147 ± 369	0-3,890	81
Beetles	214 ± 217	0-1,490	99
Total Diptera	5,750 ± 4,450	212-20,900	100
Chironomids	5,090 ± 4,200	120-20,500	100
Ceratopogonids	366 ± 502	0-2,350	90
Scuds	1,900 ± 2,980	0-17,600	91
Clams	267 ± 622	0-5,140	52
Snails	245 ± 575	0-4,260	79
Mites	50 ± 115	0-983	66
Leeches	227 ± 450	0-4,380	87
Total Non-Diptera	4,240 ± 3,810	83-19,900	100
Total Invertebrates	9,980 ± 6,170	295-29,700	100
Sampling Depth (cm)	33.6 ± 5.0	16.8-45.7	–
Plant Biomass (g/m)	75 ± 71	0-543	86
Plant Stems	184 ± 199	0-1,100	94

Table 22. *Summary of the total macroinvertebrate abundance from pooled samples in each study wetland. Data presented represent number of individuals per* $m^2 \times 10^3$.

Wetland	Number of Samples	Mean	Minimum– Maximum	Median
Bierbrauer	171	12.2	0.3-48.6	9.7
Erickson	156	9.8	Trace-59.5	7.6
Brusletten	10	9.4	2.3-17.3	7.6
Clapp Pond Center	24	12.2	2.6-25.1	11.7
Clapp Pond East	23	9.8	1.6-50.7	7.8
Deer Park North	24	4.8	1.5-11.3	4.2
Deer Park South	24	10.2	3.2-25.3	9.7
Flaters	18	15.2	2.0-37.2	12.5
Goose Pond	6	17.0	12.6-22.6	16.5
Kostka 1 East	27	9.3	2.1-27.8	7.7
Kostka 1 West	30	9.0	2.2-35.4	6.2
Kostka 2a	30	8.5	1.7-23.5	6.5
Kostka 2b	27	7.3	1.6-24.6	5.5
Kostka 2c	12	7.7	1.9-21.0	6.0
Kostka 3	18	7.1	2.8-13.3	7.4
Kostka 4	18	13.5	3.4-37.1	11.6
Kostka 5	18	11.0	3.6-27.4	10.3
Kruizenga	18	6.4	1.0-18.7	5.6
Lundy Pond South	3	5.6	4.6-7.2	5.0
Lundy Pond Main	46	12.6	1.0-66.3	7.7

The composite picture of the typical macroinvertebrate community of a WPA wetland[4] showed that flies were the most common (100% frequency of occurrence) and most abundant (5,750 individuals per m^2) macroinvertebrate with chironomids making up 88.5% of all flies (Table 21). Amphipods represented 19% of all specimens collected with 1,900 individuals per m^2. Chironomid midges and amphipods have been found to be important in the diets of many waterfowl species (Chura 1961, Krapu 1974, Swanson and Meyer 1977, Swanson 1985, Euliss et al. 1991, Jacobsen 1991). Beetles, bugs, dragonflies/damselflies, amphipods, and biting midges were present in more than 90% of the samples collected, while each of the remaining groups represented less than 5% of the total present in a sample. The average total invertebrate abundance for all samples combined was 9,980 individuals per m^2. This number compares favorably to those reported from other Wisconsin

[4] Note: as restricted to the shallow 0-60 cm feeding zone represented by the sampling methods (stovepipe column and cores and 600 micron mesh sieve) used in the study.

Canoes were used in the field to drag equipment across shoreline perimeters in order to gain access to wetlands for sampling.

wetlands and from ponds and wetlands in the prairie pothole region on the Dakotas (see Evrard and Lillie 1987).

Mean total invertebrate abundance (pooled for all dates sampled) in the 20 study wetlands ranged from 4,800 individuals per m^2 to 17,000 individuals per m^2 (Table 22). Individual sample abundance from 703 samples collected ranged from less than 100 individuals per m^2 in Erickson to more than 66,000 individuals per m^2 in Lundy Pond Main. Differences in sampling periods and sample sizes among the wetlands prohibit direct comparisons of the summary data provided in Table 22. However, the data do illustrate the level of the variability in invertebrate abundance that occurred within and among WPA wetlands in Wisconsin.

When looking at abundance, flies (Diptera) were the dominant macroinvertebrate in 80% of the wetlands and scuds (Amphipoda) were the dominant macroinvertebrate in 20% of the wetlands (see Tables 23, 24, and Fig. 8). Chironomids (midges) comprised 21-74% of the total macroinvertebrates sampled. Substantial numbers of mayflies (predominantly of the genus *Caenis*) were found in 30% of the wetlands and clams, bugs, and dragonflies/damselflies were also occasional important contributors to total abundance. Leeches comprised 32% of all invertebrates present in Deer Park North.

When examining frequency of occurrence, flies (chironomid midges in particular) were present in almost every sample (Table 24). Mayflies were found more frequently in larger, more persistent basins and were found infrequently in the smaller Kostka Ponds. Clams were completely absent from three wetlands and were rare in Erickson. Caddisflies were absent from Deer Park North, where leeches were present in every sample.

Mean abundance of flies (Diptera) ranged from a minimum of 1,715 individuals per m^2 in Deer Park North to a maximum of 9,824 individuals per m^2 in Kostka Pond #4 (Table 25). Amphipod (scud) abundance exceeded 10,000 individuals per m^2 in Goose Pond but was rare in Kostka Pond #1 East. Leeches were most abundant in Deer Park North where they reached a maximum of 1,408 individuals per m^2.

Invertebrate community compositions in the Kostka wetland complex were more similar to one another than to the other WPA wetlands (Fig. 9). The Brusletten invertebrate community was also similar to the Kostka complex. Kostka Pond #4 invertebrate community most closely resembled that of Bierbrauer. Since Kostka Pond #4 had the longest water duration among the basins surveyed in the Kostka complex its invertebrate community resembled that of the more persistent Bierbrauer basin. The Flaters and Kruizenga invertebrate communities were similar to one another, as were the two adjacent Clapp Pond invertebrate communities. The Erickson and Lundy Pond Main invertebrate assemblages were closely associated with the more permanent, lacustrine wetlands (e.g., Bierbrauer). With the exception of Kostka Pond #4, most macroinvertebrate associations designated by the cluster analysis (Fig. 9) conformed to the subjective affiliations assigned by the author. A combination of physical, chemical, and biological factors undoubtedly influenced the invertebrate communities through one or more mechanistic pathways relating to their colonization, reproduction, or survival potential. Aside from making paired statistical comparisons, gross community compositions differed among the 20 wetlands in a fashion compatible with one or more of these pathways. Although it is not possible to identify a particular cause-effect relationship, the data presented in this study do show that subtle differences may exist in the macroinvertebrate communities of wetlands that outwardly or subjectively may look very much alike.

The comparisons of total macroinvertebrate abundance among or between wetlands were influenced by variability in the abundance of selected taxa within basins. For example, the occurrence of a large number of a particular taxa in one basin on a given sampling date would often compensate for the decrease in abundance of another taxa on the same date (e.g., higher numbers of pygmy backswimmers in Erickson offset low numbers of amphipods). Additionally, changes in abundance of taxa often were asynchronous; populations of particular taxa may have declined in one wetland basin while increasing in another. To determine the significance that these and other factors had in contributing to the overall variability in macroinvertebrate data, I employed a general linear

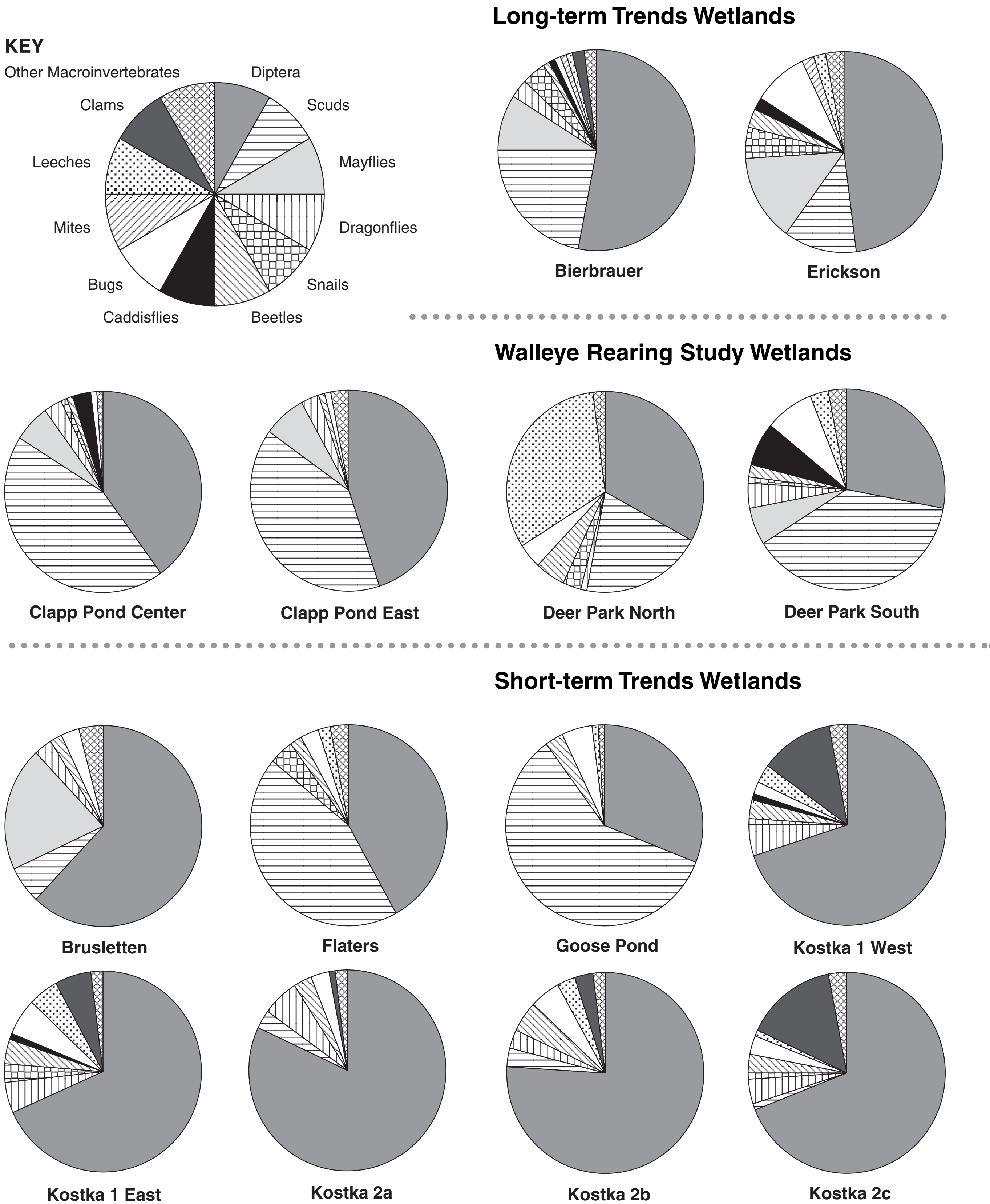
Table 23. *Percent composition of macroinvertebrate abundances on all WPA wetlands for all sampling periods combined. Please note that Trace = less than 0.5 percent.*

Macroinvertebrate Taxa	Bierbrauer	Brusletten	Clapp Pond Center	Clapp Pond East	Deer Park North	Deer Park South	Erickson	Flaters	Goose Pond	Kostka 1 East	Kostka 1 West	Kostka 2a	Kostka 2b	Kostka 2c	Kostka 3	Kostka 4	Kostka 5	Kruizenga	Lundy Pond South	Lundy Pond Main
Number of Samples	171	10	24	23	24	24	156	18	6	27	30	30	27	12	18	18	18	18	3	46
Mayflies	9	20	6	7	1	6	14	Trace	Trace	Trace	Trace	0	0	0	Trace	8	1	1	2	2
Odonates	3	3	3	3	1	4	1	1	Trace	5	5	6	3	4	4	4	5	2	2	Trace
Bugs	2	3	1	1	4	9	9	3	5	6	2	3	5	3	3	2	3	10	13	3
Caddisflies	2	Trace	3	1	0	8	2	Trace	1	1	1	1	1	Trace	1	1	Trace	Trace	1	2
Beetles	2	2	1	1	4	2	3	2	3	4	3	3	4	3	2	1	4	10	3	1
Diptera	53	62	40	46	33	28	48	42	30	69	70	82	76	69	79	74	68	57	37	59
Chironomids	45	56	38	41	26	21	38	41	28	62	62	70	66	62	74	66	61	42	30	50
Ceratapogonids	5	5	1	3	2	4	6	1	1	2	4	5	3	3	1	3	1	2	7	6
Amphipods	22	6	44	40	20	38	12	44	59	0	1	3	3	1	6	8	7	16	7	19
Clams	2	Trace	Trace	Trace	0	0	0	Trace	0	6	12	2	3	15	2	2	9	Trace	Trace	0
Snails	4	1	1	Trace	3	1	4	4	Trace	3	1	Trace	Trace	2	Trace	Trace	Trace	3	1	0
Mites	1	Trace	Trace	Trace	1	1	2	Trace	Trace	0	Trace	0	Trace	0	Trace	Trace	Trace	Trace	Trace	Trace
Leeches	1	1	Trace	Trace	32	3	2	2	1	5	3	1	3	1	1	Trace	Trace	Trace	3	7

Table 24. *Frequency of occurrence of macroinvertebrate taxa on all WPA wetlands for all sampling periods combined. Data represent percentages of samples in which taxa were found to occur.*

Macroinvertebrate Taxa	Bierbrauer	Brusletten	Clapp Pond Center	Clapp Pond East	Deer Park North	Deer Park South	Erickson	Flaters	Goose Pond	Kostka 1 East	Kostka 1 West	Kostka 2a	Kostka 2b	Kostka 2c	Kostka 3	Kostka 4	Kostka 5	Kruizenga	Lundy Pond South	Lundy Pond Main
Number of Samples	171	10	24	23	24	24	156	18	6	27	30	30	27	12	18	18	18	18	3	46
Mayflies	92	90	100	96	54	79	92	50	50	22	33	10	7	8	17	83	72	56	33	61
Odonates	90	80	100	100	42	79	58	83	67	100	100	97	93	92	100	100	100	78	67	41
Bugs	61	80	92	52	87	96	88	89	100	100	83	97	93	92	83	94	100	100	100	78
Caddisflies	71	20	92	65	0	88	60	39	33	56	50	57	41	33	56	83	44	33	67	48
Beetles	65	80	88	83	92	92	90	94	100	100	97	97	100	92	89	94	100	100	100	61
Diptera	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100
Chironomids	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	98
Ceratapogonids	81	80	71	70	46	62	75	44	33	70	83	83	78	75	67	89	72	61	67	72
Amphipods	93	70	100	100	88	92	84	83	100	11	47	73	63	58	67	94	94	89	100	87
Clams	43	20	17	13	0	0	1	11	0	59	83	47	63	83	44	61	83	17	33	7
Snails	75	60	62	39	62	46	69	67	83	93	57	13	33	50	39	11	56	78	67	9
Mites	61	30	50	22	42	54	62	28	67	7	40	3	30	8	28	28	28	28	33	17
Leeches	44	70	37	17	100	88	61	67	100	96	80	63	78	67	44	50	44	28	100	93

Figure 8. *Percent composition of macroinvertebrate taxa in selected WPA study wetlands. Wetlands are presented in 3 groups: Long-term trends wetlands (Erickson and Bierbrauer), short-term trends wetlands (Brusletten, Flaters, Goose Pond, Kostka Pond complex, Kruizenga, and Lundy Pond Main and south), and walleye rearing study wetlands (Deer Park North and South, and Clapp Pond Center and East). Data taken from Table 23.*



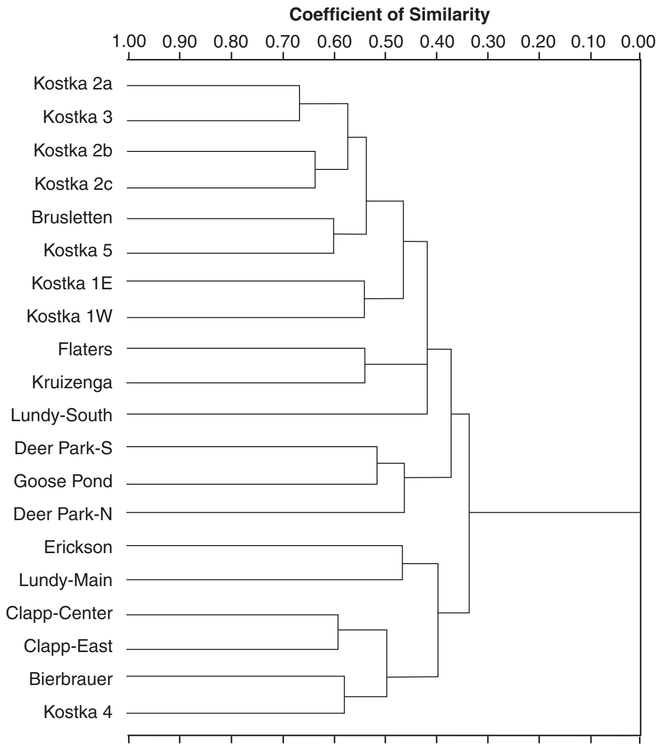


Figure 9. *Coefficient of Similarity comparisons of macroinvertebrate communities in each study wetland based on abundance. Cluster analysis created by BIOSIM1 (Gonzales et al. 1993).*

Short-term Trends Wetlands **Figure 8 continued.**

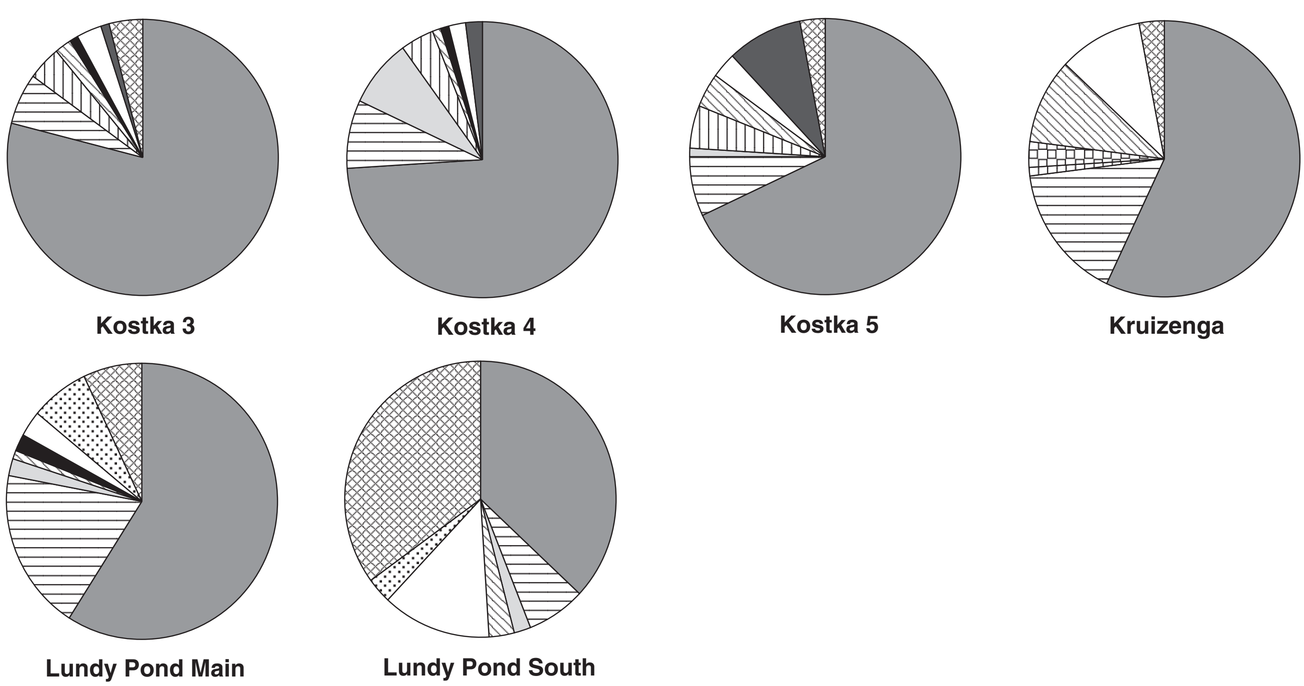


Table 25. *Macroinvertebrate abundances for all WPA wetlands. Data are untransformed means representing the number of individuals per m² ±SE. Sample sizes are the same as those reported in Table 24.*

Wetland	Mayfly	Odonates	Bugs	Caddisfly	Beetle	Diptera	Scuds	Clams	Snails	Mites	Leeches
Bierbrauer	730±10	259±22	171±32	179±25	114±15	6,665±498	2,884±293	369±84	635±94	82±13	64±15
Erickson	1,281±157	78±13	923±155	225±41	232±41	4,414±493	1,495±333	2±1	546±105	156±25	268±36
Brusletten	949±362	174±55	231±58	27±26	265±105	7,015±1,913	629±263	4±3	73±43	19±16	73±33
Clapp Pond Center	805±227	323±62	128±31	311±86	193±54	4,547±628	5,697±897	28±16	74±27	41±20	22±12
Clapp Pond East	547±88	181±30	96±44	39±11	112±26	4,894±1,210	3,826±741	28±19	21±11	14±10	32 +24
Deer Park North	40±13	30±17	190±78	0	179±40	1,715±481	1,066±308	0	87±24	22±6	1,408±314
Deer Park South	498±170	270±92	778±178	710±285	183±40	2,348±374	4,756±1,187	0	94±40	54±19	357±102
Flaters	28±14	102±36	219 +50	41±22	364±155	7,794±2,111	5,443±867	14±13	687±250	18±14	374±139
Goose Pond	23±13	70±41	652±311	173±169	588±143	4,735±1,223	10,477±2,383	0	90±48	25±10	160±42
Kostka 1East	7±3	257±43	599±229	60±19	256±44	6,991±1,224	3±2	546±141	170±32	2±1	248±42
Kostka 1West	49±3	431±157	220±85	63±26	224±47	6,240±899	78±44	1,335±441	93±44	47±30	202±43
Kostka 2a	2±1	366±64	197±34	51±16	235±61	7,297±984	159±43	127±39	11±8	1±1	35±12
Kostka 2b	2±2	148±33	329±66	31±13	340±60	5,897±973	114±30	220±55	16±5	16±10	136±41
Kostka 2c	3±3	180±44	210±60	30±20	268±97	5,692±1,504	93±45	930±252	45±28	2±2	80±37
Kostka 3	6±3	335±148	179±50	49±21	122±39	5,782±731	409±149	151±83	21±13	9±4	43±20
Kostka 4	1,387±522	496±114	157±34	87±29	90±14	9,824±1,573	1,039±308	363±157	2±2	17±8	49±22
Kostka 5	78±24	522±134	240±44	29±14	346±64	7,896±1,206	608±211	1,026±358	28±11	7±3	54±30
Kruizenga	39±18	68±21	498 +134	27±16	486±160	4,017±1,040	932±378	22±20	241±116	20±10	48±30
Lundy Pond South	113±113	117±73	770±279	47±37	130±105	2,120±811	483±336	10±10	47±33	3±3	217±182
Lundy Pond Main	220±67	33±9	208±43	270±107	111±36	8,675±1,930	1,920±461	2±1	2±1	16±9	649±167

model analysis (SAS 1990). An earlier analysis, covering the first four years of the study (Evrard and Lillie 1987), showed that differences between basins were more important than year or sampling period. However, pooling of all wetland data masked differences between specific pairs of wetlands. This point is illustrated by examining data for Erickson and Bierbrauer (Table 26). Year, sampling period, and basin each impacted macroinvertebrate abundance. The interaction affecting invertebrate abundance was confined primarily to Basin X Year, while the Year X Period interaction mainly influenced plant variables. Year alone had the strongest influence on both plant and invertebrate abundance. Most likely the drought of 1987-89 and subsequent recovery in 1990-92 played an important role in creating this effect.

On the two long-term study wetlands, Erickson and Bierbrauer, total macroinvertebrate abundance varied substantially among sampling periods within years (Figs. 10 and 11) and among years (Fig. 12) during similar sampling periods. Macroinvertebrate abundance generally increased between May and July in each year on both wetlands. Prior to the drought, macroinvertebrate abundance on Bierbrauer rose steadily while macroinvertebrate abundance on Erickson was inconsistent to relatively stable. During the drought from 1987-89 macroinvertebrate abundance dropped dramatically in both wetlands (Fig. 12). At the end of the drought (1990-92) the response of macroinvertebrate abundance differed between the two wetlands. In May 1989, macroinvertebrate abundance declined to an extremely low 295 individuals per m² in Erickson. A large resurgence in macroinvertebrates was observed in Erickson during 1991, but abundance declined once again in 1992. In Bierbrauer, macroinvertebrate abundance was lower during 1991-92 when compared with pre-drought abundance.

Other WPA wetlands also experienced seasonal and annual fluctuations in macroinvertebrate abundance (Tables 27 and 28). Within individual sampling periods, large differences in macroinvertebrate abundance were observed among the basins of the Kostka Pond complex (Table 28). The earlier comparisons of macroinvertebrate community

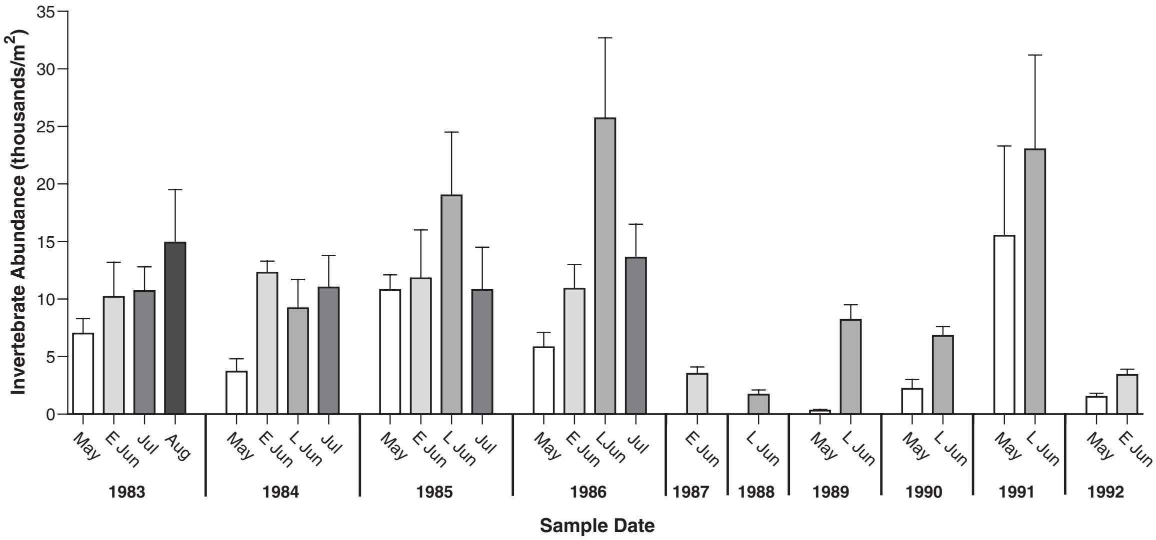


Figure 10. *Trends in macroinvertebrate abundance (thousands/m²) sampled in Erickson WPA from 1983-92. Error bars denote Standard Error. E = Early; L = Late.*

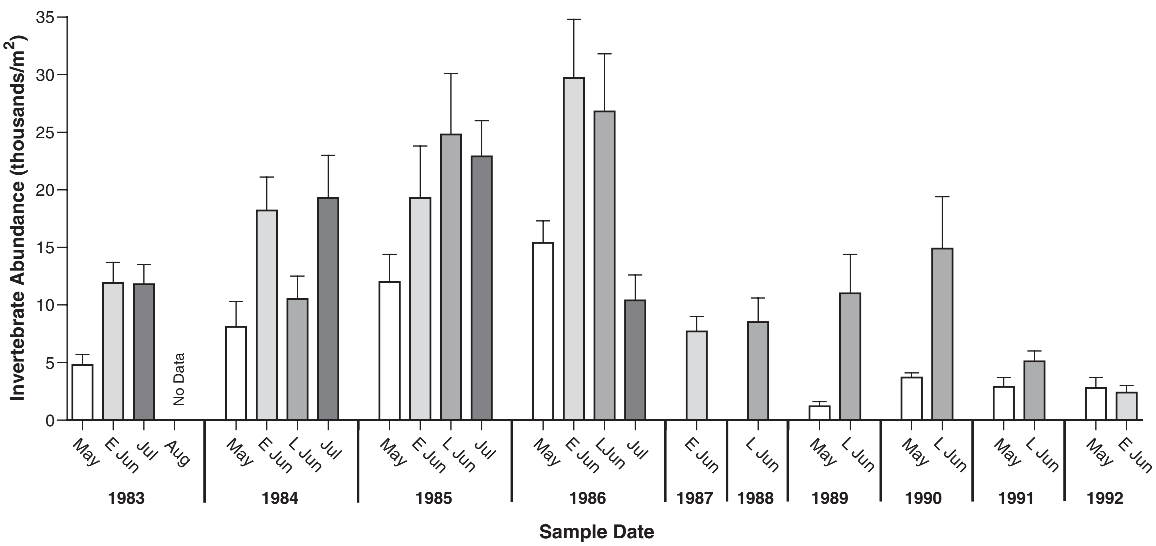


Figure 11. *Trends in macroinvertebrate abundance (thousands/m²) sampled in Bierbrauer WPA from 1983-92. Error bars denote Standard Error. E = Early; L = Late.*

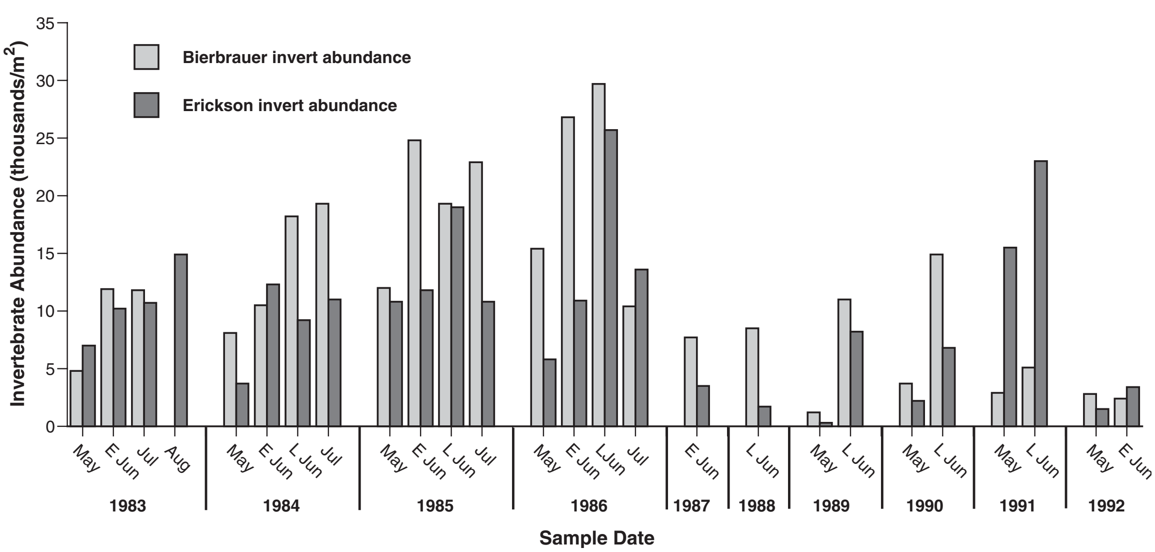


Figure 12. *Comparisons between macroinvertebrate abundance (thousands/m²) sampled in Bierbrauer and Erickson WPAs from 1983-92. E = Early; L = Late.*

Table 26. *Major sources of variability based on General Linear Models analysis (SAS 1990) affecting macroinvertebrate abundance and plant attributes on Erickson and Bierbrauer. Data used in the analysis was for the years 1983-86, and 1989-92[a]. Please note that: n.s. = not significant (p >0.05); * = p < 0.05; ** = p < 0.01; *** = p < 0.001.*

				Interactions		
Variable	**Basin**	**Year**	**Sampling Period**	**Basin X Year**	**Basin X Period**	**Year X Period**
Total Invertebrates	n.s.	***	***	n.s.	n.s.	n.s.
Non-Diptera	n.s.	***	***	n.s.	n.s.	n.s.
Diptera	*	***	*	n.s.	n.s.	n.s.
Mayflies	**	***	*	***	n.s.	n.s.
Odonates	***	**	n.s.	n.s.	n.s.	n.s.
Bugs	***	**	***	**	n.s.	n.s.
Caddisflies	n.s.	***	n.s.	n.s.	n.s.	n.s.
Beetles	***	n.s.	***	n.s.	n.s.	n.s.
Midges	**	**	**	*	n.s.	n.s.
Ceratopogonids	n.s.	***	n.s.	n.s.	n.s.	n.s.
Scuds	***	***	***	***	n.s.	n.s.
Clams	***	**	n.s.	**	n.s.	n.s.
Snails	n.s.	***	***	***	n.s.	*
Mites	n.s.	**	n.s.	n.s.	n.s.	n.s.
Leeches	***	***	***	n.s.	**	n.s.
Depth	n.s.	***	n.s.	n.s.	n.s.	**
Plant Stems	***	***	**	*	*	***
Plant Biomass	***	***	***	n.s.	n.s.	***

[a] 1987 and 1988 data were represented by one set of June samples.

Table 27. *Total macroinvertebrate densities (in thousands of individuals per m^2) organized by sampling period on selected WPA wetlands. Sample size for each sample period is 3 except for Lundy Pond Main where the sample size is 6 per period.*

Wetland	Sampling Period	Mean (±SE)
Brusletten	Early Jun 1983	11.0±2.8
	Early Jun 1984	8.0±2.6
Flaters	May 1983	14.7±3.6
	Jul 1983	10.6±1.0
	Early Jun 1984	15.3±8.9
	Early Jun 1985	21.8±3.1
	Early Jun 1986	7.7±2.8
	Early Jun 1989	21.4±7.9
Goose Pond	Early Jun 1983	18.4±2.6
	Early Jun 1984	15.5±2.2
Kruizenga	Aug 1983	5.5±1.7
	Early Jun 1984	10.9±2.3
	Early Jun 1985	10.5±4.1
	Early Jun 1986	2.4±0.7
	Early Jun 1988	5.8±0.7
Lundy Pond South	May 1983	4.6
	August 1983	7.2
	Early Jun 1984	5.0
Lundy Pond Main	Early Jun 1984	7.9±4.7
	May 1985	17.2±4.7
	Early Jun 1985	10.8±4.7
	Late Jun 1985	16.5±10.0
	July 1985	17.9±3.9
	Early Jun 1986	8.9±3.3
	Early Jun 1987	3.2±1.4
	Early Jun 1989	16.8±8.9

Table 28. *Total macroinvertebrate abundance (in thousands of individuals per m^2) in the Kostka Pond wetland complex from 1984-86. Data represent means ±SE for each sampling period. Please note that NC = no samples collected.*

Sampling Period	1 East	1 West	2a	2b	2c	3	4	5
May 1984	5.4±1.5	10.4±3.8	4.5±0.7	4.0±0.6	5.8±2.2	8.0±2.6	27.6±8.7	15.8±6.1
Early Jun 1984	20.3±3.3	19.4±8.1	11.0±2.3	15.3±5.0	5.8±0.6	5.6±1.9	9.0±2.4	11.5±2.4
Late Jun 1984	8.4±1.2	8.8±3.1	15.1±1.5	7.8±2.0	2.8±0.1	10.8±1.5	17.8±1.4	9.4±2.3
Jul 1984	18.9±5.0	12.7±2.7	19.8±2.6	15.3±1.6	16.3±2.6	7.4±2.0	7.9±2.9	4.9±0.7
Early Jun 1985	7.4±2.6	4.1±0.5	8.9±0.7	5.8±0.9	NC	4.8±1.2	7.1±2.0	10.2±2.2
Apr 1986	NC	2.6±0.2	4.6±0.6	NC	NC	NC	NC	NC
May 1986	3.4±1.2	3.3±0.4	4.1±1.3	5.9±1.7	NC	NC	NC	NC
Early Jun 1986	3.3±0.2	9.7±3.7	4.4±1.0	3.6±1.8	NC	NC	NC	NC
Late Jun 1986	10.8±1.5	13.6±4.9	7.3±1.8	5.0±2.3	NC	6.5 +1.7	12.0 +1.4	14.2±0.5
Jul 1986	5.4±0.5	5.9±0.3	5.5±0.6	3.2±0.5	NC	NC	NC	NC

composition using pooled data may have masked differences among basins (see Fig. 8 and Tables 23-25). For example, when using the pooled data, only macroinvertebrates in the category bugs were statistically more abundant in Erickson than Bierbrauer ($P < 0.001$). However, when making comparisons within sampling dates (Table 29) the differences between these two wetlands became clearer. Erickson supported a higher abundance of mayflies, bugs, beetles, and leeches compared to Bierbrauer on several occasions; Bierbrauer consistently contained a higher abundance of dragonflies/damselflies and clams compared to Erickson. Prior to the drought, Bierbrauer had a higher abundance of amphipods, snails, and chironomids, total non-Diptera, and total invertebrates than Erickson; but after the drought, Erickson contained a higher abundance of amphipods, snails, chironomids, total non-Diptera, and total invertebrates. While macroinvertebrate abundance was adversely affected by the drought in both wetlands, Bierbrauer appears to have been impacted greater than Erickson.

Table 29. *Significant differences*[a] *between Erickson and Bierbrauer basins for abundances of macroinvertebrates, plant biomass, and plant stem density. Only data collected in June from 1983-92 were analyzed. Please note that 'B' = Bierbrauer's numbers are significantly greater than Erickson's; 'E'= Erickson's numbers are significantly greater than Bierbrauer's; '-' = not significant (p ≥ 0.05).*

Year	Date[b]	Total Macroinvertebrates	Non-Diptera	Mayflies	Bugs	Diptera	Chironomids	Scud	Odonates	Caddisflies	Beetles	Clams	Snails	Mites	Leeches	Plant Biomass	Plant Density
1983	3	–	B	E	–	–	–	B	B	B	–	B	B	–	–	–	–
1984	2	–	–	–	E	E	–	–	B	–	–	–	–	–	–	–	–
1984	3	–	–	–	E	B	B	–	B	B	–	B	–	–	–	–	–
1985	2	B	–	–	E	B	B	B	B	B	E	B	B	E	–	–	–
1985	3	–	–	E	E	–	B	–	B	–	E	–	–	–	E	–	–
1986	2	B	B	E	E	–	–	B	B	–	–	B	–	B	–	–	B
1986	3	–	–	E	E	–	–	B	B	–	E	B	–	–	E	–	–
1987	3	B	–	E	–	–	–	B	–	–	–	B	B	–	–	–	–
1988	2	B	B	–	–	B	B	B	–	–	–	–	B	–	–	B	–
1989	2	–	–	–	E	–	–	B	B	–	E	–	–	–	–	–	–
1990	2	–	–	–	–	–	–	E	–	–	–	–	E	–	–	–	–
1991	2	E	E	–	–	–	E	E	–	E	E	–	E	E	E	–	–
1992	3	–	E	–	–	–	–	E	B	–	–	–	–	–	E	–	–

[a] $P < 0.05$; *t*-test (SAS 1990)
[b] Early June date comparisons designated by a "2"; late June dates designated by a "3".

Comparisons among Wetlands by Sampling Period

Table 30 summarizes the results of General Linear Model analysis and Tukey's Honestly Significant Difference comparisons (SAS 1990) of total macroinvertebrate abundance among wetlands sampled during specific periods. The significant differences found in the abundance of individual taxa groups among wetlands are illustrated in Table 30 and described in the following paragraphs. Data are presented according to sampling period.

***May 1983, five basins evaluated*.**

Total macroinvertebrate abundance did not differ significantly among Erickson, Bierbrauer, Lundy Pond-South, Flaters, and Kruizenga. Erickson supported more mites, biting midges, and mayflies than counterpart wetlands, while Flaters supported generally higher numbers of snails, amphipods, and, in some cases, flies than other wetlands. Kruizenga supported the greatest numbers of beetles.

***June 1983, four basins evaluated*.**

During this sampling period, total macroinvertebrate abundance did not differ significantly among Erickson, Bierbrauer, Goose Pond, and Brusletten. However, Erickson supported the greatest numbers of mayflies while Bierbrauer supported greater numbers of caddisflies and snails than other sampled wetlands. Goose Pond and Bierbrauer contained larger populations of amphipods than Erickson or Brusletten.

July 1983, four basins evaluated.

On this date, total macroinvertebrate abundance did not differ significantly among Erickson, Bierbrauer, Flaters, and Kruizenga. Erickson supported larger numbers of leeches and mites than the other three wetlands sampled, while Bierbrauer contained large numbers of dragonflies and damselflies. Erickson and Bierbrauer supported greater numbers of mayflies and flies (including both chironomids and biting midges) than either Flaters or Kruizenga.

May to July 1984, two large basins and eight smaller basins evaluated.

The total macroinvertebrate abundance did not differ significantly among Erickson, Bierbrauer, and the eight Kostka Pond basins. The larger wetlands, Erickson and Bierbrauer, had the highest number of snails, mites, clams, and (except for Kostka Pond #4) mayflies. Additionally, Bierbrauer had the highest numbers of caddisflies, biting midges, and amphipods. Conversely, Bierbrauer had the fewest bugs (Erickson had the highest) and beetles, while Erickson had the lowest numbers of flies and dragonflies/damselflies. Kostka Pond #4, the deepest and most permanent of the basins in the Kostka Pond complex, had the highest abundance of dragonflies/damselflies and mayflies.

June 1984, sixteen basins evaluated.

During this period, total macroinvertebrate abundance did not differ significantly among the sixteen wetlands sampled. Erickson, Bierbrauer, and Kostka Pond #4 supported the largest numbers of mayflies. Bierbrauer contained the fewest bugs and the Kostka Ponds generally supported more dragonflies and damselflies. The abundance of snails was highest in Kruizenga, Flaters, Erickson, and Bierbrauer. The Kostka Ponds also supported good numbers of clams (except for basin #3); Kostka Pond #1 East and Kostka Pond #1 West had the highest numbers of clams but the lowest numbers of amphipods of any wetland sampled.

May to July 1985, three large basins evaluated.

The total macroinvertebrate abundance was significantly higher in Bierbrauer than in Erickson. The total macroinvertebrate abundance in Lundy Pond Main was intermediate between the numbers found in Erickson and Bierbrauer. Despite the higher overall total macroinvertebrate abundance in Bierbrauer, Erickson supported greater numbers of mayflies, bugs, and beetles than either Bierbrauer or Lundy Pond Main. Bierbrauer contained more dragonflies/damselflies, flies (primarily chironomids), snails, clams, and amphipods than either Erickson or Lundy Pond Main.

Early June 1985, twelve basins evaluated.

The total macroinvertebrate abundance was significantly lower in Kostka Pond #1 West than in Flaters or Bierbrauer. Other comparisons of macroinvertebrate abundance among wetlands on this date were not statistically significant. Erickson and Bierbrauer supported more mayflies and mites than the Kostka Pond wetlands. Kostka Pond #1 West had significantly fewer caddisflies and bugs than the other wetlands. Conversely, Kostka Pond #1 East and Kostka Pond #1 West supported the highest abundance of beetles and dragonflies/damselflies. Amphipod abundance was much lower in all Kostka wetlands than other wetlands sampled on this date. Erickson had the lowest number of flies, while Bierbrauer contained the highest number of flies.

May to July 1986, two large basins and four small basins evaluated.

During this period, Bierbrauer and Erickson supported a significantly higher abundance of total macroinvertebrates than did three of the four Kostka Pond basins sampled. Macroinvertebrate abundance in Kostka Pond #1 West was significantly lower than Bierbrauer, but not Erickson. Erickson and Bierbrauer generally supported a greater abundance of mayflies, caddisflies, mites, biting midges, and snails than the Kostka Pond basins. Erickson had low numbers of dragonflies/damselflies and clams compared to the other wetlands sampled, while Bierbrauer contained fewer bugs and beetles. Bierbrauer supported a significantly higher abundance of amphipods than all other wetlands.

Table 30. *Summary of General Linear Model analyses and Tukey Honestly Significant Difference comparisons (SAS 1990) of total macroinvertebrate abundance between wetlands for selected sampling periods during 1983-92. Data were log-transformed prior to analysis. Letters designate when significant differences in abundance occurred between wetlands; where A is more significant than B is more significant than C. Significance was at $P < 0.05$. Multiple letters listed indicates the wetland was not significantly different from the other wetlands in that sampling period.*

	Sampling Periods													
Wetland	**May 1983**	**Jun 1983**	**Jul 1983**	**May/Jul 1984[a]**	**Jun 1984**	**May/Jul 1985[a]**	**Early Jun 1985**	**May/Jul 1986[a]**	**Early Jun 1986**	**Late Jun 1986**	**Jun 1987**	**Jun 1988**	**May/Jun 1989-92[b]**	**May/Jun 1989-92[c]**
Erickson	A	A	A	A	A	B	AB	AB	AB	AB	AB	B	B	C
Bierbrauer	A	A	A	A	A	A	A	A	A	A	A	A	B	C
Lundy Pond Main					A	AB	AB		AB		B	A		
Lundy Pond South	A				A									
Flaters	A		A		A		A		AB					
Kruizenga	A		A		A		AB		B			AB		
Brusletten		A			A									
Goose Pond		A			A									
Kostka 1 East				A	A		AB	C	B	ABC				
Kostka 1 West				A	A		B	BC	AB	ABC				
Kostka 2a				A	A		AB	C	B	BC				
Kostka 2b				A	A		AB	C	B	C				
Kostka 2c				A	A									
Kostka 3				A	A		AB			BC				
Kostka 4				A	A		AB			ABC				
Kostka 5				A	A		AB			ABC				
Clapp Pond East													A	ABC
Clapp Pond Center													A	A
Deer Park North													B	BC
Deer Park South													A	AB

[a] Four sample dates combined for data analysis.
[b] Data analyzed were based on means for each sampling date within the period. Sample size ranged from 24-48.
[c] Data analyzed were based on means for each sampling date within the period. Sample size = 8.

Early June 1986, nine basins evaluated.

On this date, Bierbrauer supported a significantly higher abundance of total macroinvertebrates than Kruizenga and three of the four Kostka Pond basins sampled. Differences in total abundance among the other wetlands were not significant. Erickson and Bierbrauer generally supported a higher abundance of caddisflies, biting midges, snails, and mites compared to the other wetlands. In addition, Bierbrauer was the only wetland with any clams present and also supported the highest numbers of dragonflies/damselflies. Erickson supported significantly higher numbers of mayflies than most other wetlands. The Kostka Pond basins had low numbers of amphipods relative to abundances found elsewhere.

Late June 1986, nine basins evaluated.

The total macroinvertebrate abundance on Bierbrauer was significantly higher than on Kostka Pond #2a, #2b, and #3. Macroinvertebrate abundance on Kostka Pond #2b was significantly lower than in Erickson during this sampling period. Erickson and Bierbrauer supported more mayflies, caddisflies, biting midges, amphipods, snails, and mites than most Kostka Pond basins. Bierbrauer also had the highest abundance of dragonflies/damselflies and chironomid midges of all wetlands sampled on this date.

June 1987 (beginning of 3 year drought), three large basins evaluated.

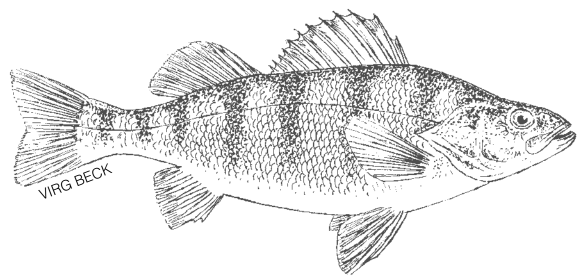
The total macroinvertebrate abundance was significantly higher on Bierbrauer than on Lundy Pond Main on this date. The macroinvertebrate abundance in Erickson was intermediate between Lundy Pond Main and Bierbrauer. Bierbrauer supported the largest numbers of chironomids, amphipods, clams (absent from other wetlands), snails, and mites, while Erickson supported the greatest numbers of mayflies and beetles. Except for leeches and biting midges Lundy Pond Main supported the fewest invertebrates of most taxa groups.

June 1988, four basins evaluated.

The total macroinvertebrate abundance of Bierbrauer and Lundy Pond Main was significantly higher than the abundance in Erickson. The macroinvertebrate abundance in Kruizenga was intermediate between the other 3 wetlands sampled. Bierbrauer had the highest numbers of dragonflies/damselflies and amphipods, while Lundy Pond Main contained the highest numbers of flies (and chironomids) and leeches. Erickson had the lowest number of mayflies (a change from previous sampling periods where Erickson generally had highest numbers of mayflies), and contained no caddisflies, amphipods, or clams on this date. Clams were found only in Bierbrauer.

May and June 1989-92(end of 3 year drought and start of refilling of basins), six basins evaluated.

Two methods of comparisons were made using this data set. The first method represented comparisons using the mean of each sampling site (3-6 sites per wetland) for each individual sampling date (2 dates per year) accounting for a sample size of 24-48. The second set of comparisons was based on the annual means of individual sampling dates (2 dates per year) for a sample size of 8. The total macroinvertebrate abundance in Clapp Pond Center was significantly higher than in Deer Park North, Bierbrauer, and Erickson. The macroinvertebrate abundance in Erickson and Bierbrauer were significantly lower than abundance in Deer Park South. Deer Park North had significantly fewer mayflies, dragonflies/damselflies, caddisflies, and flies than other wetlands sampled, but contained higher numbers of beetles and leeches than counterpart wetlands. Clapp Pond Center supported large numbers of mayflies, dragonflies/damselflies, caddisflies, flies, amphipods, and clams. Deer Park South supported the largest abundance of bugs and mites.



Special Studies Part I.

The Kostka Pond Wetland Complex-Fish Introductions into WPA Wetlands

Sampling on the Kostka Pond wetland complex served multiple purposes. Data provided insight into the range of temporal dynamics occurring within individual wetlands and represented conditions present on small, precipitation-dominated, pothole wetlands that are typical of the region. In addition, the replicated sampling protocol conducted in 1986 supported studies on Kostka Pond basins #1 East, #1 West, #2a, and #2b that addressed the potential impact of fish communities on resident macroinvertebrate populations (see McDowell 1989 for details). Two series of experiments were performed utilizing the previously fishless Kostka Pond complex. In the first experiment, an impenetrable plastic barrier was installed between Kostka Pond #2a and #2b. On May 12, 1986, 32 kg of fathead minnows were stocked in Kostka Pond #2a. Kostka basin #2b was not stocked and served as a fishless control. In the second experiment, 6.8 kg of yellow perch, 9.1 kg of pumpkinseed, 1.5 kg of golden shiners, and 2.3 kg of fathead minnows were stocked in

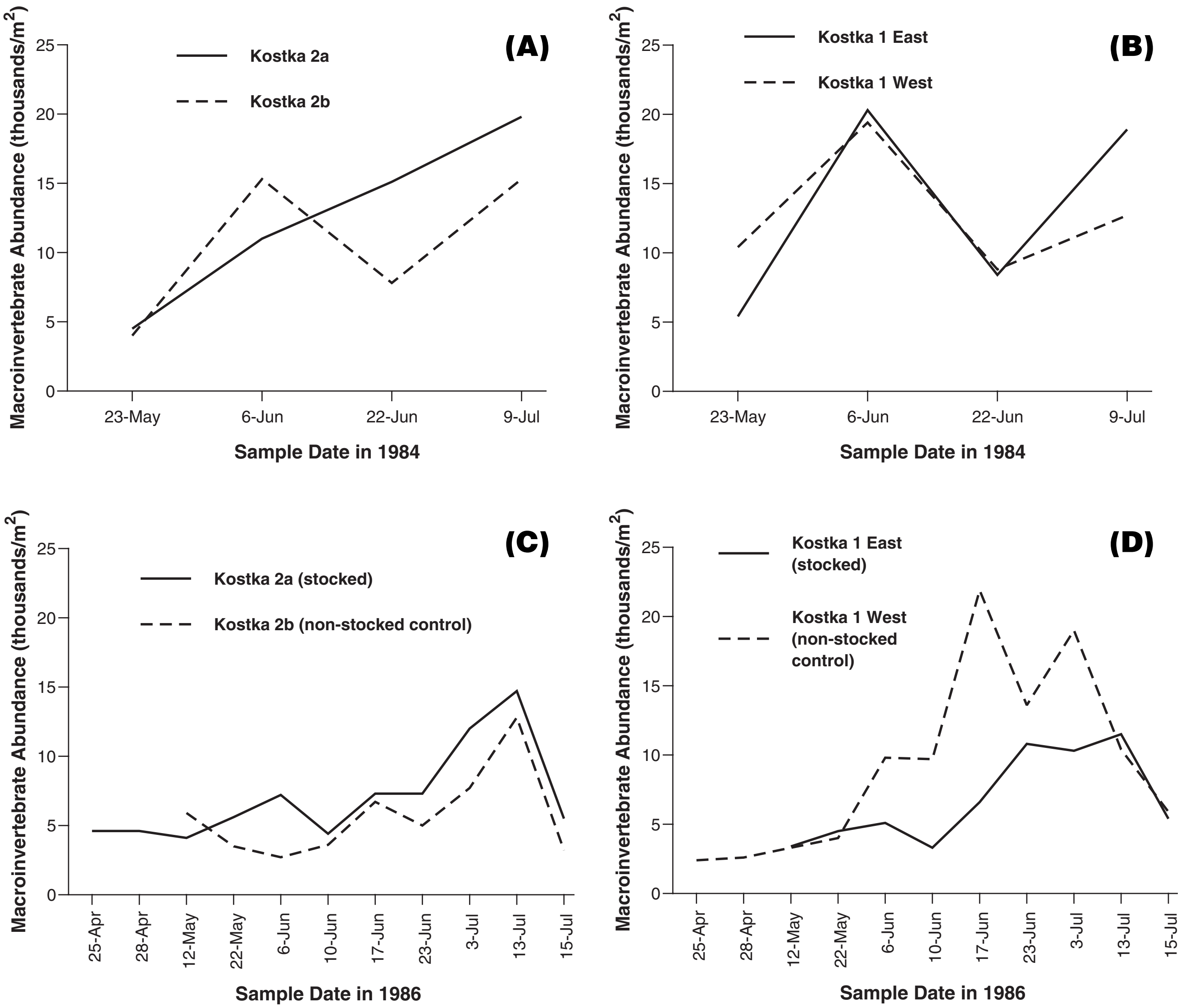


Figure 13. *Total macroinvertebrates (thousands/m^2) in the Kostka Pond complex before and after fish stocking.* **A)** *Comparison of macroinvertebrate abundance in Kostka Ponds 2a and 2b in 1984 before fish were stocked,* **B)** *Comparison of macroinvertebrate abundance in Kostka Ponds 1 East and 1 West in 1984 before fish were stocked,* **C)** *Comparison of macroinvertebrate abundance in Kostka Ponds 2a (stocked) and 2b (non-stocked control) in 1986 after fish stocking,* **D)** *Comparison of macroinvertebrate abundance in Kostka Ponds 1 East (stocked) and 1 West (non-stocked control) in 1986 after fish stocking.*

Kostka Pond #1 East on May 12, 1986. These 4 fish species are native to neighboring WPA pothole lakes. Kostka basin #1 West, immediately adjacent to but not directly connected to Kostka Pond #1 East, was not stocked and served as a fishless control. Two teams of researchers did the macroinvertebrate sampling in 1986. University of Wisconsin- Steven's Point graduate students sampled macroinvertebrates on six dates from April 25th through July 13th, while Wisconsin DNR staff sampled macroinvertebrates on five dates from April 28th through July 15th. These two data sets were combined for analysis in this report. The previous data collected by Wisconsin DNR in 1984 served as a pre-treatment comparison of macroinvertebrate abundance in the stocked and non-stocked basins.

The pre-treatment data collected during 1984 (Figs. 13a and 13b) suggested that both sets of wetland basins contained comparable biotic communities. The mean total macroinvertebrate abundance did not differ between paired wetlands during 1984 (Table 28) averaging 13,200 individuals per m^2 and 12,800 individuals per m^2 on Kostka Ponds #1 East and #1 West, respectively; and 12,600 individuals per m^2 and 10,600 individuals per m^2 on Kostka Pond #2a and #2b, respectively. Kostka Pond #2a contained greater numbers of dragonflies/damselflies than Kostka Pond #2b on both June 1984 sampling dates. In late June, Kostka Pond #2a also contained greater numbers of chironomid midges (and total flies) than Kostka Pond #2b, while Kostka Pond #2b supported greater numbers of snails than Kostka

Pond #2a. In May 1984, Kostka Pond #1 West contained greater numbers of mites than Kostka Pond #1 East, and in late June, Kostka Pond #1 East contained greater numbers of beetles than Kostka Pond #1 West. Please note that these differences within the individual sampling dates are few compared to the number of comparisons made and may have resulted strictly by chance, which may make them relatively meaningless.

The total macroinvertebrate abundance was reduced during the stocking year in all Kostka basins, when macroinvertebrate abundance only reached 37-58% of the abundance observed in 1984 (Table 28). Stocking of fathead minnows had no measurable impact on total macroinvertebrate abundance in Kostka Pond #2a (Fig. 13c), but immediately after stocking, this wetland did exhibit fewer clams and greater numbers of dragonflies/damselflies than the non-stocked basin (Kostka Pond #2b).

In a separate analysis, McDowell (1989) reported finding lower densities of emerging flies in the stocked wetland basin Kostka Pond #2a. McDowell (1989) also reported that during 1986, chironomids were the most important component of fathead minnow diets in a neighboring wetland (Amshler WPA) and concluded that fathead minnows were potentially competing for food items important to waterfowl. However, the basis for McDowell's (1989) conclusions may have been biased by the study design. His dietary findings were based on a series of enclosure studies in which fathead minnows were artificially restrained in deeper, off shore areas where the predominant food item by weight, periphyton, was reduced due to depth and light-limitation. Litvak and Hansell (1990) found that fathead minnows are predominantly benthic feeders, feeding predominantly on algae, plant, and detritus and may only incidentally ingest crustaceans and aquatic insects while grazing. Had McDowell (1989) established his enclosures in near shore areas or allowed the fathead minnows to move freely from deep water to shallow water areas, his conclusions regarding the importance of aquatic insects to their diets may have differed.

The stocking of a complex fish community into a fishless wetland had minimal impact on the resident macroinvertebrate community over the time period in which sampling was conducted for this study. Although total macroinvertebrate abundance declined during June in the stocked Kostka Pond #1 East relative to the abundance in the non-stocked Kostka Pond #1 West (Fig. 13d), the differences were not statistically significant. Similarly, only 3 of 64 paired comparisons of individual taxa group abundance proved statistically significant. In each of these cases the abundance in the stocked basin exceeded that in the non-stocked basin. By the end of the sampling period (mid-July), total macroinvertebrate abundance was nearly identical in the stocked and control basins. The apparent lack of response of the macroinvertebrate community to stocking was not unexpected or unusual based on the myriad of possible direct and indirect effects occurring between fish and macroinvertebrates in wetlands (Batzer et al. 2000).

While it is well recognized that the presence or absence of fish can influence both macroinvertebrate abundance and community structure in wetlands under certain circumstances (Bendell and McNicol 1987, Hanson and Butler 1994, Mallory et al. 1994, Zimmer et al. 2000, Zimmer et al. 2001a), the introduction of fish communities into WPA wetlands had a negligible short-term effect on macroinvertebrate abundance and community structure in this study. Long-term effects were not investigated in this analysis and may be different than that indicated by the short-term response.

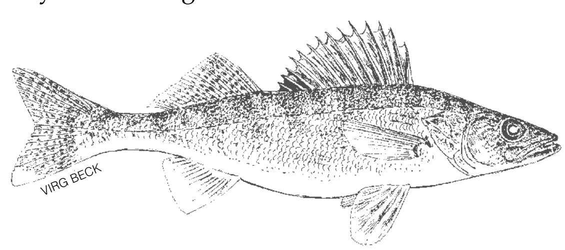
Special Studies Part II.

The Clapp Park and Deer Park Investigations- Impact of Stocking Walleye on Macroinvertebrate Communities of WPA Wetlands.

S. ENGEL

Walleye (*Sander vitreus*) fry were introduced into two WPA wetlands in 1990-92 on an experimental basis to evaluate the potential success of utilizing WPA wetlands as walleye rearing ponds. Successful walleye production was compared against negative impacts on the macroinvertebrate community that is shared with and important to waterfowl production. Because the results of this study were detailed in Lillie (1993), only a condensed summary is presented here.

No adverse impacts on either total macroinvertebrate abundance or on macroinvertebrate community composition were documented. The total macroinvertebrate abundance was not significantly influenced on treatment basins (basins stocked with walleye) relative to non-stocked control basins. Compositional changes in macroinvertebrate communities were indeterminate. Prior to utilizing Wisconsin's WPA wetlands for dual fish/waterfowl production, further evaluations of these pilot introductions are warranted, including examining impacts on the size structure of the macroinvertebrate community and measurement of direct disturbance on breeding waterfowl created by fish stocking and fertilization efforts.



Habitat Associations
(all wetlands combined)

Influence of Sampling Depth

Previous studies have documented a strong inverse relationship between macroinvertebrate abundance and water depth (Cyr and Downing 1988). If this relationship is left unaccounted for in the study design, it may introduce noise into the data and potentially mask important plant/invertebrate/waterfowl associations. Consequently, in order to minimize the amount of variability in the macroinvertebrate data, all macroinvertebrate sampling was restricted to the 0-60 cm feeding zone of dabbling waterfowl (DuBowy 1988) and to the middle of the 0-60 cm zone. A uniform sampling depth was not established because of poor water clarity (i.e., turbid conditions or massive amounts of duckweed present) and the inability to measure water depth until after the stovepipe sampler was in position. Selecting a standard sampling depth may have resulted in disturbance at the sampling site prior to collecting the samples. The height of the stovepipe sampler and the consistency of the bottom substrate determined the maximum sample depth. Consequently, plant-invertebrate sample depth ranged from 10-57 cm (see Methods section and Table 2). The mean sampling depth varied within basins among years but did not differ significantly within basins during any individual year. The mean sample depth also did not differ significantly among basins except for the Lundy Pond Main basin where sampling was conducted at shallow depths to compensate for a dense mat of decaying plant fibers covering the bottom at the standard sampling depth for this wetland. Because differences in plant and macroinvertebrate abundance among wetlands may have resulted from differences in sampling depth among the basins, the associations between sample depth and measured attributes of the plant and macroinvertebrate community were evaluated.

In this study, total macroinvertebrate abundance (log-transformed) in individual samples was not significantly related to sampling depth across the narrow range of depths (n = 703; $P > 0.05$). Conversely, total macroinvertebrate abundance was positively correlated with plant biomass (n = 669, r = +0.337, P = 0.0001) and stem density (n = 700, r = +0.302, P = 0.0001). Neither plant biomass nor stem density was influenced significantly by sampling depth; plots of residuals against independent variables demonstrated that no patterns existed. These findings reduce the possibility that measured statistical differences are an artifact of sampling depth and support the use of the data for making spatial and temporal comparisons among wetland basins.

Pearson correlation tests using sample site means (untransformed data with zeros eliminated) were performed for all wetlands combined. These tests showed that the abundance of the various invertebrate taxa groups (i.e., mayflies, snails, beetles, etc.) were *not* correlated with sampling depth. However, both mean plant biomass and stem density were positively correlated with sampling depth. This relationship of plant biomass and stem density to sample depth appear to be influenced by greater amounts of submersed vegetation in deeper water.

Although sampling depth did not have a *direct* effect on macroinvertebrate abundance, the abundance of several taxa groups were directly related to plant attributes that were influenced by sampling depth. Within the twelve invertebrate taxa groups evaluated, the abundance of four groups (dragonflies/damselflies, bugs, beetles, and chironomids) were significantly (positively) correlated with plant biomass. The abundance of two groups (dragonflies/damselflies and chironomids) were significantly related to plant stem densities. Consequently, plant attributes at a site appear to serve a more important role than water depth alone in structuring the macroinvertebrate community abundance and composition.

Associations among Macroinvertebrates
(all wetlands combined)

R. LILLIE

Amphipods, or Scuds, were common in many WPA wetlands.

Several strong relationships were documented between the various macroinvertebrate taxa groups. Mayflies were positively associated with caddisflies, biting midges, amphipods, and mites. Dragonflies/damselflies were significantly (positively) associated with chironomid midges, clams, and mites, and negatively associated with leeches. Bugs were positively associated with beetles and total flies. Also, caddisflies were associated with amphipods and snails; beetles were associated with clams; and chironomids were associated with beetles, biting midges, and clams. All associations highlighted were significant at $P < 0.01$. The meaning of these associations is not immediately clear, but it appears that several of the associations may be related to the habitat preferences of the macroinvertebrates. This may include physical structural elements related to the plant community (e.g., cover from predators) or the chemical environment produced by the plant community (e.g., harsh conditions due to low dissolved oxygen concentrations within dense plant stands).

Table 31. *Predictive equations relating total macroinvertebrate abundance to plant biomass and plant stem density for Erickson and Bierbrauer from 1983-91. Data were log-transformed prior to analysis. Equations are significant at the P = 0.0001 level.*

	Erickson[a]			Bierbrauer[b]		
Independent Variable	Intercept	+ Slope	r^2	Intercept	+ Slope	r^2
Log of Plant Biomass	2.46	+ 0.28	0.224	2.51	+ 0.29	0.266
Log of Plant Stem Density	2.47	+ 0.21	0.122	2.46	+ 0.26	0.233

[a] N=147
[b] N=162

Table 32. *Community structure/composition of vegetation present at macroinvertebrate sample sites in WPA wetlands. Data are rounded to the nearest whole percent. Habitat type codes: S = Submersed plants, E = Emergent plants, and F = Floating-leaved plants. The order of the letters in mixed communities indicate the general order of dominance within the wetland.*

			Percent of Available Habitat Type								
Wetland	Sample Size	Open Water	S	S/E	S/F	S/E/F	F	E/F/S	E/F	E/S	E
Bierbrauer	171	12	26	5	4	0	2	1	1	19	31
Brusletten	10	0	10	10	0	10	10	0	10	10	40
Clapp Pond Center	24	33	67	0	0	0	0	0	0	0	0
Clapp Pond East	23	39	57	0	0	0	0	0	0	0	4
Deer Park North	24	38	8	0	12	4	4	0	17	0	17
Deer Park South	24	38	17	0	0	12	8	0	0	4	21
Erickson	156	26	5	1	0	1	8	1	4	6	47
Flaters	18	0	11	0	0	0	17	0	6	11	56
Goose Pond	6	0	17	0	0	0	0	0	17	17	50
Kostka 1 East	27	0	0	0	0	0	4	4	15	0	78
Kostka 1 West	30	7	0	0	0	0	0	0	7	7	80
Kostka 2a	30	0	0	0	0	0	0	0	7	7	87
Kostka 2b	27	0	0	0	0	0	0	0	22	4	67
Kostka 2c	12	0	0	0	0	0	0	0	8	0	92
Kostka 3	18	0	11	0	0	0	0	0	0	11	78
Kostka 4	18	0	0	0	0	0	0	0	6	6	83
Kostka 5	18	0	0	0	0	0	0	6	6	0	89
Kruizenga	18	0	0	6	11	0	33	0	33	0	17
Lundy Pond South	3	0	0	0	0	0	0	0	0	0	100
Lundy Pond Main	46	41	0	0	0	0	0	0	0	2	57

Habitat Associations within Erickson and Bierbrauer Basins

Because the broad range of habitats represented by the various wetlands in this study may have masked the study of interrelationships between selected attributes, habitat relationships within the two long-term study basins, Erickson and Bierbrauer, were examined separately from the other wetlands. This approach minimizes the noise in the data and allows an examination of both spatial and temporal effects. Relationships (using General Linear Model Analyses) between sample depth and total macroinvertebrate abundance, plant biomass, or plant stem density were all non-significant ($P > 0.05$). However, total macroinvertebrate abundance was positively associated with plant biomass and plant stem density ($P = 0.0001$) in both wetlands for all sampling periods combined. It should be noted that these same relations using the mean data collected in June ($n = 78$) or using annual means ($n = 9$-10) were non-significant. The fact that the inclusion of data from sampling periods earlier and later in the growing season results in a significant association between plant and macroinvertebrate data suggests that changes in both plants and macroinvertebrates are synchronous and are primarily attributed to seasonal growth and development. The predictive equations relating total macroinvertebrates to plant biomass and plant stem density were very similar for both wetlands (Table 31).

Habitat Associations with Plant Community Type
(all wetlands combined)

Ten different combinations of emergent, floating-leafed, submersed, and open water habitats were available for macroinvertebrate occupation (Table 32). Open water sites (i.e., no vegetation present) averaged 17% overall and ranged from absent to 41% of available habitats within individual wetlands. Sites with only emergent vegetation present were most common, averaging 47% over all wetlands. Sites comprised exclusively of submersed plants represented 13% of all sites sampled. Sites with floating-leafed plants only comprised 5% of all sampled sites. Mixed communities comprised the other 18% of sites.

Table 33. *Macroinvertebrate abundance of selected taxa (individuals per 0.1 m^2) within nine vegetated habitat types and open water habitats on WPA wetlands. Habitat type codes: S = Submersed plants, E = Emergent plants, and F = Floating-leaved plants. The order of the letters in mixed communities, indicate the general order of dominance within the wetland. Data are rounded to nearest whole values*

		Vegetation Habitat Types								
	Open Water	**S**	**S/E**	**S/F**	**S/E/F**	**F**	**E/F/S**	**E/F**	**E/S**	**E**
Macroinvertebrate Taxa										
Mayflies	56	58	34	11	30	97	18	60	87	57
Dragonflies	12	18	20	18	3	7	18	28	28	24
Caddisflies	18	15	15	12	2	18	6	13	17	17
Beetles	9	13	8	16	12	29	11	42	18	24
Total Flies	532	621	671	422	206	514	366	618	539	618
Chironomids	492	562	591	375	181	412	320	540	451	536
Ceratapogonids	26	46	66	36	19	62	22	31	61	45
Scuds	111	292	361	360	730	215	12	129	354	168
Clams	1	23	64	6	<1	10	26	46	39	28
Snails	10	25	86	32	41	33	26	38	66	34
Mites	4	5	7	5	12	4	14	3	11	8
Leeches	24	5	5	50	49	25	17	30	16	25
Total Macroinvertebrates[a]	803	1,100	1,303	1,007	1,261	1,017	558	1,062	1,229	1,068
Other Variables										
Sampling Depth (cm)	32.4	34.1	39.6	32.9	32.4	33.4	36.7	34.1	35.7	33.1
Plant Biomass (g/m^2)	0	76	88	111	93	43	122	94	104	97
Plant Stems (number/m^2)	0	200	298	102	180	47	210	118	216	243
Sample Size (*n*)	116	93	12	11	7	32	6	38	57	331

[a] Includes other miscellaneous taxa.

The strength of associations between macroinvertebrate abundance and plant biomass or stem density varied according to the dominance structure of the plant community at the sampling location. Total macroinvertebrate abundance was reduced at open water sites relative to most vegetated habitats (Table 33). The exception was low total macroinvertebrate abundance at sites characterized by a mixture of emergent, floating, and submersed vegetation (E/F/S). The counterpart mixed community consisting of submersed, emergent, and floating vegetation (S/E/F) had high total macroinvertebrate abundance. The major difference between these two mixed macroinvertebrate communities was the low number of amphipods in the E/F/S habitat. These two communities represented opposite ends of the spectrum in terms of habitat for amphipods. Aside from this anomaly, sites with a combination of emergent and submersed vegetation generally supported more macroinvertebrates than sites with floating-leafed plants. However, despite the lower biomass and stem densities at floating-leafed sites, total macroinvertebrate abundance was higher than would be expected based on the previously mentioned relationship between plant attributes and total macroinvertebrate abundance.

The abundance of other macroinvertebrate taxa also varied according to habitat structure. Bugs were more abundant within floating-leafed and emergent habitats than at sites dominated by submersed taxa. This is not altogether unexpected since most aquatic bugs live on or near the water surface. Total flies (both chironomid midges and biting midges) were less abundant within mixed habitats of either S/E/F or E/F/S. No clear explanation for this disparity can be offered but since plant biomass was highest within E/F/S habitats, environmental conditions (i.e., dissolved oxygen and other chemical attributes) within this heterogeneous habitat may have been unfavorable for larval fly development (Murkin et al. 1991, Murkin et al. 1992). Conversely, these two habitats also contained the highest abundance of mites. Because some water mites are parasitic on chironomids and have caused population declines elsewhere (Smith 1988), the mites in these habitats may be responsible for the reduced chironomid population. Snails were most abundant at sites dominated by a combination of emergent and submersed plants. Again, this is not unexpected since most snails are grazers of epiphytic algae growing on aquatic substrates (plants included). Leeches favored sites with floating-leafed and emergent plants, but were also found at open water sites. It appeared that leeches tended to avoid areas with only submersed plants or mixed submersed and emergent taxa. No clear patterns were observed among the other invertebrate taxa groups.

Long Term Trends and Associations in Erickson and Bierbrauer Basins

Macroinvertebrate Associations with Physical, Chemical, and Plant Attributes

The following comparisons are based on macroinvertebrate abundance and associated limnological habitat conditions monitored in June 1983-92 during the peak of the brood-hatching period. Fluctuations in total macroinvertebrate abundance among years were not significantly correlated with changes in plant biomass or plant stem

Table 34. *Significant associations between physical, chemical, and plant attributes and macroinvertebrate abundance in Erickson and Bierbrauer. Comparisons are based on June means from 1983-92 (n = 10). Levels of significance and direction of significant relationships are indicated by the following symbols: '–' or '+' = negative or positive at P < 0.05; '++' = positive at P < 0.01. A 'period' symbol indicates no significant relationship between the variables.*

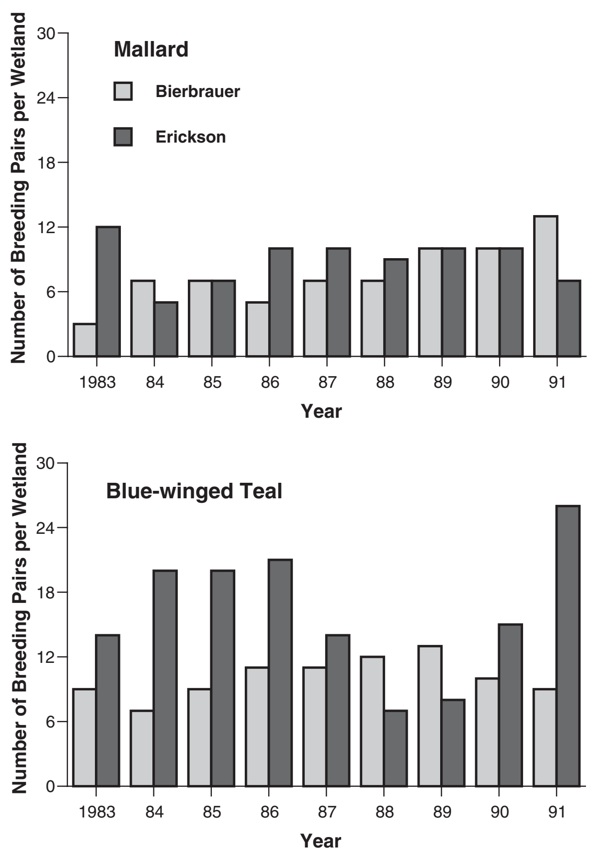
	Bierbrauer									Erickson								
Invertebrate Group	**Sample Depth**	**Plant Biomass**	**Plant Stems**	**Alkalinity**	**Conductivity**	***Chlorophyll a***	**Turbidity**	**Water Level**	**Precipitation**	**Sample Depth**	**Plant Biomass**	**Plant Stems**	**Alkalinity**	**Conductivity**	***Chlorophyll a***	**Turbidity**	**Water Level**	**Precipitation**
Total Flies	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Non-flies	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	++
Amphipods	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	++
Ceratapogonids	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.
Chironomids	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Beetles	–	.	.	.	.	.	.	.	.	.	.	.	–	.	.	.	.	.
Mayflies	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	+	.
Snails	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+
Bugs	.	.	.	.	.	.	.	.	.	.	.	.	.	++	.	.	.	.
Leeches	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mites	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.
Dragonflies	.	.	.	.	.	.	–	++	.	.	.	++	.	.	.	.	.	.
Clams	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Caddisflies	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.

densities in either Erickson or Bierbrauer (Table 34). Among the physical and chemical variables, precipitation had a significant impact on total macroinvertebrate abundance (Erickson only). This appeared largely due to a strong positive association between amphipod abundance (the major component of the non-Diptera) and precipitation. The mechanism for this response is not clear. Patterns of associations between individual macroinvertebrate taxa and physical-chemical variables were inconsistent between the two wetlands. In Bierbrauer, water levels had a strong positive influence on the abundance of amphipods, non-Diptera, mites, caddisflies, and dragonflies/damselflies. In Erickson, plant stem densities were directly correlated with abundance of amphipods, snails, and dragonflies/damselflies and changes in conductivity were positively correlated with changes in the abundance of biting midges, mayflies, mites, and bugs.

Waterfowl Associations with Physical, Chemical, and Plant Attributes

Waterfowl breeding pair densities[5] varied considerably both among years within wetlands and between wetlands within years (Fig. 14). Based on overall waterfowl production, Erickson was consistently more productive than Bierbrauer, however, when production was standardized relative to size of available surface water acreage, Bierbrauer 's production was nearly the same as Erickson (Figs. 15 and16). Blue-winged teal (*Anas discors*) breeding pair densities decreased during 1987-88 in Erickson but increased slightly in Bierbrauer during the same period. Mean Blue-winged Teal breeding pair densities increased each year on all WPAs combined, while

Figure 14. *Mallard and Blue-winged Teal breeding pair densities (number of pairs per wetland) in Bierbrauer and Erickson WPAs from 1983-91.*



[5] Jim Evrard (Wisconsin DNR, retired) provided the waterfowl data presented here.
Definitions of terms and methods used in gathering the waterfowl data are provided in Evrard (2002).

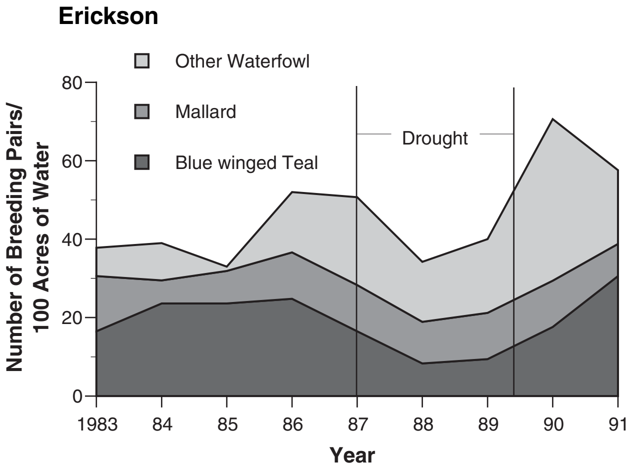


Figure 15. *Number of waterfowl pairs relative to the size of available surface water acreage on Erickson WPA for Mallard, Blue-winged Teal, and other waterfowl from 1983-91.*

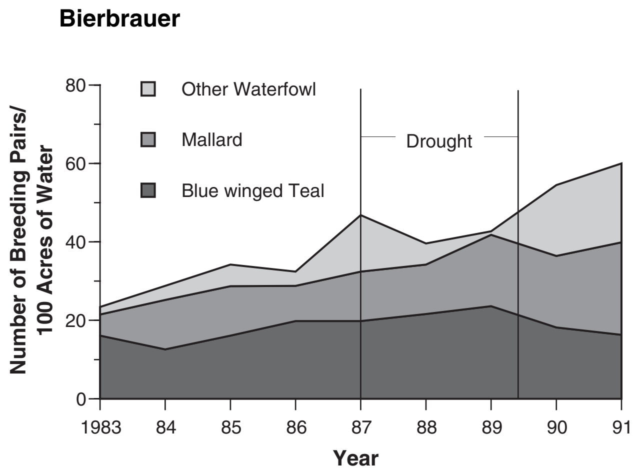


Figure 16. *Number of waterfowl pairs relative to the size of available surface water acreage on Bierbrauer WPA for Mallard, Blue-winged Teal, and other waterfowl from 1983-91.*

they decreased in the whole study area (James Evrard, Wisconsin DNR, pers. comm. 1999). Mallard (*Anas platyrhynchos*) breeding pair densities generally were lower than Blue-winged Teal breeding pair densities on both wetlands. The drought did not have a significant impact on Mallard breeding pair densities in either wetland. Erickson, on average, supported twice the number of other waterfowl species than Bierbrauer.

The number of Mallard and Blue-winged Teal broods varied inconsistently among years and between wetlands (Table 35). The average number of broods observed (combined hatch, rearing, and fledgling stages) was slightly lower in Erickson than in Bierbrauer (1.59 Mallard broods and 1.52 Blue-winged Teal broods in Erickson compared with 1.93 Mallard broods and 1.93 Blue-winged Teal broods in Bierbrauer). These numbers equate to 0.09 broods per ha (3.6 broods per 100 acres) and 0.16 broods per ha (6.7 broods per 100 acres) on Erickson and Bierbrauer, respectively. These values are comparable to the average of 0.21 broods per ha (8.4 broods per 100 acres; all species of waterfowl included) reported for this area in an earlier study (Peterson et al. 1982) suggesting that the drought of 1987-89 did not have a great effect on brood numbers.

The average size (i.e., number of ducklings per brood) of mallard broods was similar in both wetlands, averaging 4 or 5 ducklings across all stages of development (Table 36). The drought had no apparent effect on brood sizes and the differential losses of ducklings between hatch and fledge was steady or inconsistent in the two wetlands. The average size of Blue-winged Teal broods was slightly higher on Bierbrauer than on Erickson. This is in contrast to the generally higher numbers of Blue-winged Teal breeding pair densities on Erickson.

Response of Breeding Pair Densities to Fluctuations in Physical and Chemical Variables

Changes in the physical and chemical environment had different impacts on waterfowl breeding pair densities in the two wetlands (Table 37). Interestingly, high water levels were inversely correlated with mallard (and total waterfowl) breeding pair densities on Bierbrauer. On Erickson, Blue-winged Teal breeding pair densities were positively correlated with annual precipitation, but not with changes in water level. Among the measured chemical variables, turbidity had a significant positive association with Blue-winged Teal breeding pair densities on Bierbrauer.

Response of Breeding Pair Densities to Fluctuations in Plants and Macroinvertebrates

Annual changes in plant biomass and plant stem density within the 0-60 cm feeding zone used by dabbling waterfowl (Fig. 17) had no significant impact on waterfowl breeding pair densities in either wetland (Table 37). Conversely, annual changes in macroinvertebrate abundance among years (Fig. 18) had dramatic, but different, impacts on breeding pair densities in the two extensively studied wetlands (Tables 38 and 39). Blue-winged Teal breeding pair densities responded positively with year-to-year changes in total macroinvertebrates ($P < 0.01$) in Erickson, but not in Bierbrauer (Table 38). Mallard and total waterfowl breeding pair densities were not significantly correlated with total macroinvertebrate abundance in either wetland. Interestingly, Blue-winged Teal breeding pair densities exhibited strong positive associations with several macroinvertebrate taxa (including snails, leeches, dragonflies/damselflies, amphipods, and total non-Diptera) in Erickson. These same associations in Bierbrauer were not significant (Table 39). The biological significance of a strong negative correlation between several macroinvertebrate taxa (i.e., amphipods, mites, and caddisflies) and Mallard breeding pair densities in Bierbrauer is not clear. Associations between total waterfowl breeding pair densities and amphipods, mites, dragonflies/damselflies and total non-Dipteran abundance in Bierbrauer was negative ($p < 0.05$), while in Erickson these same associations were not significant (Table 39).

Table 35 *Estimated numbers of Mallard (MAL) and Blue-winged Teal (BWT) broods at time of hatch (H), during the rearing period (R), and at the fledgling stage (F) on selected WPA wetlands from 1983-91.*

	1983			1984			1985			1986			1987			1988			1989			1990			1991		
	H	R	F	H	R	F	H	R	F	H	R	F	H	R	F	H	R	F	H	R	F	H	R	F	H	R	F
Mallard																											
Bierbrauer	3	3	4	0	0	0	0	0	1	3	3	2	3	2	0	2	4	4	3	3	2	4	3	1	0	0	2
Erickson	2	2	0	3	2	0	2	1	1	0	0	0	1	1	2	0	2	2	6	2	3	2	2	2			5
Flaters	2	3	0	1	1	1						0	2	1	0				1		1	1	0	0	1	2	2
Kruizenga	2	2	2	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0									
Goose Pond	0	1	1	0	1	1	0	0	1	0	0	0	0	1	2	2	0	0	3	3	2	4	2	1	2	2	2
Lundy Pond	0	0	0	3	1	1	0	1	0							1	2	1	0	1	2	0	0	0			
Kostka Ponds	1	1	0	1	0	0																					
Deer Park	0	0	0	0	0	0										1		1									
Blue-winged Teal																											
Bierbrauer	1	1	2	2	2	3	1	1	1	2	2	3	2	1	1	4	1	3	4	3	3	4	1	0	1	1	2
Erickson	1	1	3	2	3	3	1	1	0	1	2	0	1	2	1	0	0	0	3	4	2	2	3	2			3
Flaters	1	0	0	1	1	0						1	0	0	1				0	0	1	1	1	0	0	0	0
Kruizenga	2	2	1	1	2	1	2	1	1	1	2	1	2	2	2	0	0	0									
Goose Pond	0	1	1	0	1	1	1	0	0	2	2	1	0	0	1	0	0	0	2	2	2	2	2	2	1		1
Lundy Pond	0	0	0	0	0	0	1	0	0							0	0	0	0	2	2	1	0	0			
Kostka Ponds	0	1	0	0	1	1																					
Deer Park	0	0	1	0	0	2										0	0	2									

Table 36. *Average brood size (number of ducklings observed) for Mallard (MAL) and Blue-winged Teal (BWT) at time of hatch (H), during the rearing period (R), and at the fledgling stage (F) on selected WPA wetlands from 1983-91. Data includes ducklings from migrant broods.*

	1983			1984			1985			1986			1987			1988			1989			1990			1991		
	H	R	F	H	R	F	H	R	F	H	R	F	H	R	F	H	R	F	H	R	F	H	R	F	H	R	F
Mallard																											
Bierbrauer	9	9	5	0	0	0	0	0	9	7	12	5	7	5	0	9	7	7	8	5	7	8	3	6			7
Erickson	8	4	0	8	3	0	5	6	3	0	0	0	8		6	0	7	7	9		5	9	8	8	0	0	5
Flaters	6	7	0	9	7	0				0	0	0	8	10	8				3		6	1	0	0	10	5	6
Kruizenga	7	6	7	0	0	0	9	0	0	0	0	0	8	0	0	8	0	0									
Goose Pond	0	6	8	0	6	4	0	0	8	0	0	0	0	8	10	8	0	0	8	9	9	7	1	1	9	6	6
Lundy Pond	0	0	0	7	3	0	0	5	0							6		7	0	0	9	0	0	0			
Kostka Ponds	4		0	8	0	0																					
Deer Park	0	0	0	0	0	0										8		4									
Blue-winged Teal																											
Bierbrauer	4	5	8	10	8	7	9	11	11	11	11	9	7	9	6	8		2	5	6	5	8	12	0			3
Erickson	10	9	8	9	6	5	3		0	7	5	0	6	6	4	0	0	0	8	6	7	6	7	8			7
Flaters	1	0	0	7	6	0						7	0	0	4				0	0	4	10	7	0	0	0	0
Kruizenga	11	6	3	12	12	12	8	4	3	9	7	2	7	7	6	0	0	0									
Goose Pond	0	6	5	0	12	12	10	0	0	8	6	3	0	0	11	0	0	0	16	11	6	10	5	6	9		5
Lundy Pond	0	0	0	0	0	0	11	0	0							0	0	0	0	5	7	10	0	0			
Kostka Ponds	0	11	?	0	7	7																					
Deer Park	0	0	8	0	0	9										0	0	7									

Table 37. *Comparisons between waterfowl in Erickson and Bierbrauer WPAs.* r *values are presented showing the relationship of waterfowl breeding pair densities with plant biomass, plant stem densities, and physical/chemical attributes. Relationships that are statistically significant at P = < 0.05 are shown in* ***bold****. BWT = Blue-wing Teal; MAL = Mallard; WFL*

	Bierbrauer			Erickson		
	BWT	MAL	WFL	BWT	MAL	WFL
Plant Biomass	+0.235	-0.476	-0.273	+0.397	+0.119	-0.344
Plant Stem Density	+0.050	-0.425	-0.279	+0.336	-0.190	-0.039
Alkalinity	+0.226	+0.529	+0.521	+0.273	-0.016	+0.299
Conductivity	-0.184	+0.452	+0.213	+0.425	-0.392	+0.035
Chlorophyll *a*	+0.327	-0.131	+0.226	-0.535	+0.068	-0.568
Turbidity	**+0.709**	+0.239	+0.488	-0.488	-0.020	-0.492
Water Level	-0.469	**-0.740**	**-0.730**	+0.272	-0.098	-0.480
Precipitation	-0.397	+0.455	+0.461	**+0.675**	-0.163	+0.540

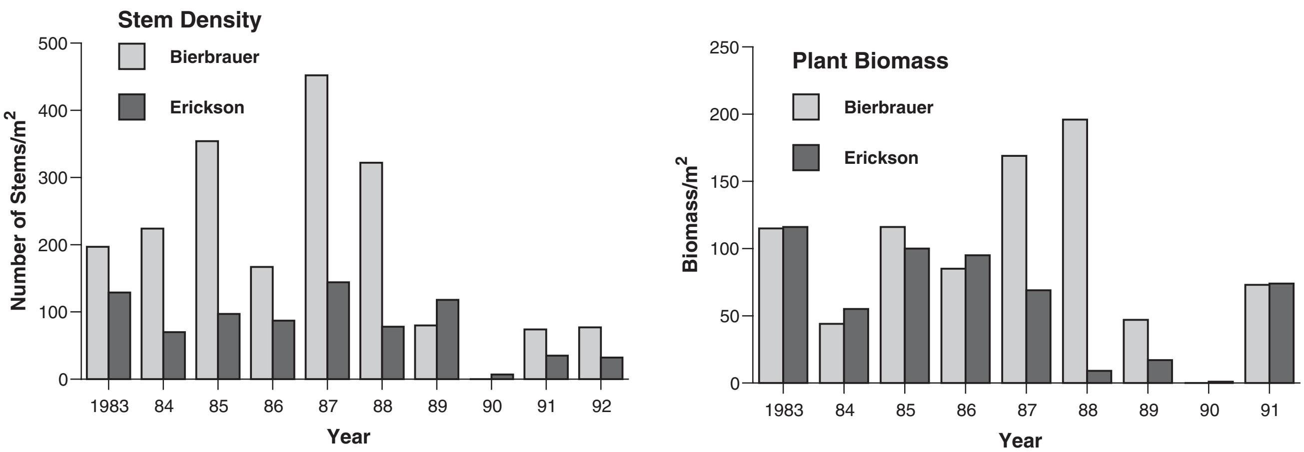


Figure 17. *Comparison of plant stem density (number of stems/m²) and plant biomass in Bierbrauer and Erickson WPAs from 1983-92.*

Table 38. *Summary of response of waterfowl production to changes in macroinvertebrate abundance on Erickson (E) and Bierbrauer (B) basins from 1983-92 as measured by correlation analysis*[a]. *H = at hatch; R = during rearing, and F = at fledgling stage.* r *values are presented in Tables 39 and 40.*

Macroinvertebrate Group	Breeding Pair Densities			Brood Densities						Size of Broods					
	Mallard	Blue-winged Teal	Total Waterfowl	Mallard			Blue-winged Teal			Mallard			Blue-winged Teal		
				H	R	F	H	R	F	H	R	F	H	R	F
Total Inverts		E++			E-						E- -		B+	B+	
Total Flies												E-	B+	B++	
Non-Flies		E++	B-		E-						E-				B+
Scuds	B-	E+	B-			E+									B+
Ceratapogonids															B++
Chironomids													B+	B++	
Beetles															
Mayflies												E-			
Snails		E+			E-							E-			
Bugs					E-										
Leeches		E+													B+
Mites	B-		B-												B+
Dragonflies		E+	B-		E-		B-								B+++
Clams	E-														B+
Caddisflies	B-														B+

[a] Levels of significance and direction of significant relationships are indicated by the following symbols: '**-**' or '**+**' = negative or positive at $P < 0.05$; '**- -**' or '**++**' = negative or positive at $P < 0.01$; and '**- - -**' or '**+++**' = negative or positive at $P < 0.001$.

Table 39. *Significant relationships (P < 0.05) between waterfowl breeding pair densities (BPDs) and the abundance of macroinvertebrates in Erickson and Bierbrauer WPAs from 1983-92 (n = 10).* r *values based on Pearson product moment correlations (SAS 1990) are given in parenthesis.*

Bierbrauer WPA
Mallard BPDs: Amphipods (-0.705), Mites (-0.702), and Caddisflies (-0.795)
Blue-winged Teal BPDs: Relationships with all macroinvertebrate abundances were non significant.
Total Waterfowl BPDs: Amphipods (-0.687), Mites (-0.687), Odonates (-0.703), and Total Non-flies (-0.669)

Erickson WPA
Mallard BPDs: Clams (-0.680)
Blue-winged Teal BPDs: Total Non-flies (+0.862), Amphipods (+0.721), Snails (+0.738), Leeches (+0.779), and Odonates (+0.721)
Total Waterfowl BPDs: Relationships with all macroinvertebrate abundances were non significant.

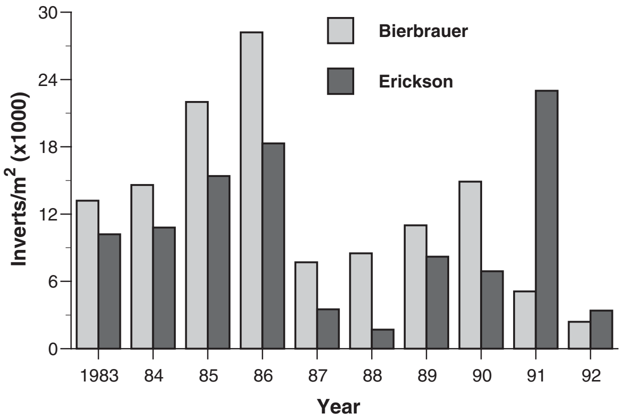


Figure 18. *Comparison of macroinvertebrate abundance (thousands/m^2) in Bierbrauer and Erickson WPAs from 1983-92. Data shown are June collections only.*

Response of Waterfowl Brood Densities

The response of waterfowl, in terms of brood production and wetland utilization, differed according to brood stage and wetland (Tables 38 and 40). The number of Mallard broods at hatch was not correlated with any of the measured physical, chemical, or biological variables in either wetland. In Erickson, the number of Mallard broods during rearing was negatively correlated with the abundance of several invertebrate groups (i.e., dragonflies/damselflies, leeches, snails, total non-Diptera, and total macroinvertebrates). The number of Mallard broods during rearing in Bierbrauer was not associated with any macroinvertebrate abundance, however, there was a strong positive correlation between Mallard brood numbers during rearing and turbidity. The number of Mallard broods at fledgling was not associated with any measured variable in Bierbrauer. In Erickson, the number of Mallard broods at the fledgling stage was positively correlated with amphipod abundance and plant stem densities, and negatively associated with changes in water level.

The number of Blue-winged Teal broods (at any stage) was not significantly correlated with any measured variable in Erickson. The numbers of Blue-winged Teal broods at hatch in Bierbrauer was positively correlated with turbidity and negatively correlated with dragonfly/damselfly abundance. The numbers of Blue-winged Teal broods during rearing and fledgling stages in Bierbrauer were not associated with any of the measured variables.

Response of the Size of Waterfowl Broods

The response of waterfowl production, in terms of the size of broods at the hatch, rearing, and fledgling stage, varied between wetlands (Tables 38 and 40). A significant positive relationship was measured between turbidity and size of Mallard broods at hatch in Bierbrauer but not in Erickson. The sizes of Mallard broods in Bierbrauer during the rearing and fledgling stages were not correlated with any variable. Conversely, the sizes of Mallard broods in Erickson were negatively associated with abundance of snails, total non-Diptera, and total macroinvertebrates during the rearing stage and with abundance of mayflies and flies and with water levels at the fledgling stage. These negative associations do not appear biologically meaningful.

The response in Blue-winged Teal brood sizes was quite different than that exhibited by Mallards. Sizes of Blue-winged Teal broods at hatch and rearing were positively correlated with chironomid, total fly, and total macroinvertebrate abundance in Bierbrauer. No significant associations were detected between macroinvertebrates and Blue-winged Teal brood sizes in Erickson during either stage. The sizes of Blue-winged Teal broods during the fledgling stage in Bierbrauer were strongly positively associated with abundance of amphipods, mites, leeches, biting midges, dragonflies/damselflies, clams, caddisflies, total non-Diptera, and water levels, and negatively associated with turbidity. Conversely, the only significant association with Blue-winged Teal brood sizes in Erickson was a negative association with turbidity during the fledgling stage.

Factors Influencing Waterfowl Production

It is clear from the simple correlation analysis of the waterfowl and limnological attributes that the associations between the two biological assemblages are not simple, but represent complex and apparently contradictory responses depending upon the alternative stable state (i.e., wetlands exhibiting clear water and dense plants versus turbid water and minimal plants) of the basin (Scheffer et al. 1993, Hanson and Butler 1994). Consequently, multiple regression analysis was used to develop models that represent those associations. The following sections present the results of those findings. Tables 41 and 42 show the results of the best 2, 3, and 4 variable models relating year to year changes in Erickson and Bierbrauer.

Factors Affecting Breeding Pair Densities

Factors associated with temporal (year to year) changes in breeding pair densities differed between the two wetlands (Tables 41 and 42). In Erickson, plants, macroinvertebrates, and water chemistry were important factors contributing to or associated with year to year fluctuations in Mallard breeding pair densities, Blue-winged Teal breeding pair densities, and waterfowl breeding pair densities, respectively. In Bierbrauer, turbidity and water clarity were associated with Mallard breeding pair densities; plants, water chemistry, and turbidity were associated with Blue-winged Teal breeding pair densities, and water level and precipitation were associated with total waterfowl breeding pair densities. Among the invertebrate fauna, a simple two-variable model incorporating amphipod and biting midge abundance explained 92% of the variability in Blue-winged Teal breeding pair densities in Erickson.

Table 40. *Significant relationships (i.e.* P < 0.05*) between waterfowl production (measured by brood number or brood size at any particular stage) and macroinvertebrate abundance, plant biomass, stem density, and selected physical and chemical conditions in Erickson and Bierbrauer WPAs from 1983-92 (*n = 10*).* r *values are in parenthesis.*

Bierbrauer WPA

Number of Mallard Broods:
- Hatch: All relationships were non-significant.
- Rearing: Turbidity (+0.702).
- Fledgling: All relationships were non-significant.

Number of Blue-winged Teal Broods:
- Hatch: Turbidity (+0.777) and Odonate abundance (-0.710).
- Rearing: All relationships were non-significant.
- Fledgling: All relationships were non-significant.

Mallard Brood Size:
- Hatch: Turbidity (+0.678)
- Rearing: All relationships were non-significant.
- Fledgling: All relationships were non-significant.

Blue-winged Teal Brood Size:
- Hatch: Total Flies (+0.745), Total Invertebrates (+0.708), and Chironomids (+0.734).
- Rearing: Total Flies (+0.862), Total Invertebrates (+0.711), and Chironomids (+0.859).
- Fledgling: Total Non-flies (+0.766), Amphipods (+0.724), Ceratapogonids (+0.805), Leeches (+0.779), Mites (+0.814), Odonates (+0.947), Clams (+0.738), Caddisflies (+0.749), Water Levels (+0.887), and Turbidity (-0.709).

Erickson WPA

Number of Mallard Broods:
- Hatch: All relationships were non-significant.
- Rearing: Total Non-flies (-0.712), Total Invertebrates (-0.754), Snails (-0.754), Leeches (-0.688), and Odonates (-0.671).
- Fledgling: Amphipods (+0.670), Plant stem densities (+0.688), and Water Levels (-0.753).

Number of Blue-winged Teal Broods:
- Hatch: All relationships were non-significant.
- Rearing: All relationships were non-significant.
- Fledgling: All relationships were non-significant.

Mallard Broods Size:
- Hatch: All relationships were non-significant.
- Rearing: Total Non-flies (-0.698), Total Invertebrates (-0.836), and Snails (-0.767).
- Fledgling: Total Flies (-0.744), Mayflies (-0.753), and Water Level (-0.757).

Blue-winged Teal Brood Size:
- Hatch: All relationships were non-significant.
- Rearing: All relationships were non-significant.
- Fledgling: Turbidity (-0.710).

Factors Affecting Mallard Broods

Plant attributes accounted for 86% of the variability in number of Mallard broods at the fledgling stage in Bierbrauer, while plant stems and water level accounted for 96% of the variability in Mallard broods at the fledgling stage in Erickson (Tables 41 and 42). Dragonflies/damselflies and caddisflies were the most important macroinvertebrate taxa associated with the number of Mallard broods at hatch and during rearing in Bierbrauer, while beetles, leeches, dragonflies/damselflies, and caddisflies were important in Erickson. Additionally, the size of Mallard broods (at all stages) was strongly associated with total macroinvertebrate abundance in Erickson, while plant stems, turbidity, and chlorophyll *a* concentrations were important in Bierbrauer. The abundance of amphipods, leeches, bugs, and mites were strongly related to brood sizes in Erickson, while dragonflies/damselflies, leeches, and caddisflies were important in Bierbrauer.

Factors Affecting Blue-winged Teal Broods

In both wetlands, the number of Blue-winged Teal broods at all stages of development was strongly associated with precipitation and several other physical or chemical variables, including chlorophyll *a* concentration (Tables 41 and 42). Among the macroinvertebrate taxa, bugs were of primary importance to the number of Blue-winged Teal broods in both wetlands, and chironomid midges were important in Bierbrauer. Chlorophyll *a* concentrations and total macroinvertebrate abundance were strongly associated with the size of Blue-winged Teal broods on Bierbrauer, while in Erickson, turbidity and either plant stems or precipitation and water levels were strongly associated with Blue-winged Teal brood sizes. In Bierbrauer, the importance of various macroinvertebrate groups to Blue-winged Teal brood size shifted from smaller bodied forms (i.e., chironomids, bugs, and mites) to larger bodied forms (i.e., caddisflies, amphipods, and dragonflies/damselflies) as the broods aged. A similar picture was seen in Erickson where the important macroinvertebrate taxa shifted from mayflies, beetles, and snails during the early stages to amphipods, chironomids, and snails at the fledgling stage.

Table 41. *Best 2-, 3-, and 4 models showing significant relationships when comparing plant, physical, chemical , and macroinvertebrate variables to waterfowl breeding pair densities, brood densities, and brood size in Erickson WPA from 1983-92 for Mallards (MAL), Blue-wing Teal (BWT) and total waterfowl (WFL). Data shown are* r^2 *values based on regression analyses (SAS 1990).*

	Combined Plant, Physical, and Chemical Variables[a]			Combined Macroinvertebrates Only[a]		
	Best 2	**Best 3**	**Best 4**	**Best 2**	**Best 3**	**Best 4**
Breeding Pair Density						
MAL	Stm, Cnd (0.327)	Stm, Cnd, Tbd (0.454)	Bio, Stm, Cnd, Chl (0.565)	Amp, Clm (0.844)	May, Snl, Clm (0.984)	Bet, May, Snl, Clm (0.993)
BWT	Tot, Alk (0.884)	Tot, Alk, Tbd (0.895)	Bio, Stm, Wtr, Pcp (0.908)	Amp, Cer (0.920)	May, Odo, Cad (0.949)	Amp, Cer, Snl, Cad (0.991)
WFL	Alk, Chl (0.515)	Alk, Chl, Wtr (0.863)	Cnd, Alk, Chl, Wtr (0.983)	Lch, Mit (0.363)	Amp, Snl, Cad (0.859)	May, Snl, Mit, Clm (0.995)
Brood Number						
MAL						
H[b]	Chl, Pcp (0.580)	Tot, Cnd, Alk (0.800)	Tot, Cnd, Alk, Tbd (0.915)	Bet, Lch (0.767)	Bet, Bug, Lch (0.985)	Bet, May, Bug, Lch (0.993)
R	Tot, Cnd (0.703)	Tot, Cnd, Alk (0.895)	Tot, Cnd, Alk, Pcp (0.918)	Odo, Cad (0.941)	Bug, Odo, Cad (0.966)	Bet, Bug, Odo, Cad (0.997)
F	Stm, Wtr (0.962)	Stm, Cnd, Wtr (0.974)	Tot, Stm, Cnd, Wtr (0.991)	Snl, Lch (0.935)	May, Bug, Odo (0.977)	Bet, May, Snl, Lch (0.999)
BWT						
H	Chl, Pcp (0.746)	Stm, Chl, Pcp (0.903)	Stm, Chl, Wtr, Pcp (0.990)	May, Bug (0.854)	Chi, May, Bug (0.920)	Bet, Bug, Lch, Cad (0.981)
R	Chl, Pcp (0.781)	Stm, Chl, Pcp (0.930)	Bio, Stm, Chl, Pcp (0.990)	May, Bug (0.735)	May, Bug, Cad (0.881)	Bet, Bug, Lch, Cad (0.948)
F	Alk, Tbd (0.539)	Alk, Chl, Tbd (0.602)	Tot, Bio, Stm, Cnd (0.815)	Bug, Odo (0.688)	Cer, May, Mit (0.866)	Cer, Bet, May, Mit (0.985)
Brood Size						
MAL						
H	Tot, Tbd (0.846)	Tot, Cnd, Tbd (0.934)	Tot, Cnd, Tbd, Pcp (0.961)	Bug, Lch (0.687)	Snl, Bug, Odo (0.806)	Snl, Bug, Odo, Clm (0.932)
R	Tot, Cnd (0.776)	Tot, Stm, Cnd (0.883)	Tot, Stm, Cnd, Wtr (0.928)	Lch, Mit (0.976)	Amp, Lch, Cad (0.989)	May, Lch, Mit, Clm (0.999)
F	Tot, Wtr (0.698)	Alk, Wtr, Pcp (0.788)	Tot, Bio, Stm, Pcp (0.927)	Amp, Mit (0.935)	Amp, Bet, Mit (0.963)	Chi, Bet, Lch, Odo (0.996)
BWT						
H	Tbd, Pcp (0.629)	Bio, Cnd, Pcp (0.864)	Bio, Stm, Chl, Pcp (0.999)	May, Snl (0.661)	Bet, May, Snl (0.863)	Bet, May, Lch, Cad (0.950)
R	Stm, Tbd (0.649)	Stm, Cnd, Tbd (0.891)	Stm, Cnd, Tbd, Wtr (0.983)	May, Snl (0.541)	Amp, Chi, Snl (0.705)	Amp, Chi, Snl, Cad (0.870)
F	Tbd, Wtr (0.697)	Chl, Tbd, Wtr (0.874)	Tot, Alk, Tbd, Pcp (0.937)	Cer, Bug (0.547)	Amp, Chi, Snl (0.945)	Amp, Chi, Snl, Cad (0.977)

[a] Abbreviations for individual variables are. Alk = alkalinity; Amp = scuds; Bio = plant biomass; Bug = bugs; Bet = beetles; Cad = caddisflies; Cer = ceratapogonid midges; Chi = chironomid midges; Chl = chlorophyll *a*; Clm = clams; Cnd = conductivity; Fly = total flies; Lch = leeches; May = mayflies; Mit = mite; Non = total non-flies; Odo = dragonflies and damselflies; Pcp = precipitation; Snl = snails; Stm = plant stem densities; Tbd = turbidity; Tot = total macroinvertebrates; and Wtr = water levels.

[b] H = at hatch, R = at rearing stage, F = at fledgling stage.

Table 42. *Best 2-, 3-, and 4 models showing significant relationships when comparing plant, physical, chemical , and macroinvertebrate variables to waterfowl breeding pair densities, brood densities, and brood size in Bierbrauer WPA from 1983-92 for Mallards (MAL), Blue-wing Teal (BWT) and total waterfowl (WFL). Data shown are r^2 values based on regression analyses (SAS 1990).*

	Combined Plant, Physical, and Chemical Variables[a]			Combined Macroinvertebrates Only[a]		
	Best 2	**Best 3**	**Best 4**	**Best 2**	**Best 3**	**Best 4**
Breeding Pair Density						
MAL	Tbd, Wtr (0.675)	Stm, Tbd, Wtr (0.760)	Stm, Alk, Tbd, Wtr (0.934)	Clm, Cad (0.694)	Crt, May, Mit (0.825)	Cer, Lch, Clm, Cad (0.877)
BWT	Tbd, Pcp (0.602)	Bio, Alk, Chl (0.804)	Bio, Alk, Chl, Tbd (0.907)	Bet, Odo (0.592)	Cer, Chi, Bet (0.881)	Chi, May, Bug, Clm (0.965)
WFL	Wtr, Pcp (0.593)	Chl, Wtr, Pcp (0.734)	Bio, Cnd, Wtr, Pcp (0.947)	May, Cad (0.716)	Cer, May, Mit (0.884)	Cer, Bet, May, Mit (0.958)
Brood Number						
MAL						
H[b]	Bio, Alk (0.524)	Stm, Tbd, Wtr (0.847)	Stm, Cnd, Tbd, Wtr (0.898)	Odo, Cad (0.844)	May, Odo, Cad (0.887)	Cer, Chi, Snl, Cad (0.970)
R	Tbd, Pcp (0.567)	Stm, Tbd, Wtr (0.685)	Bio, Stm, Tbd, Wtr (0.877)	Odo, Cad (0.630)	Cer, Chi, Mit (0.752)	Cer, Chi, Mit, Clm (0.851)
F	Bio, Stm (0.863)	Bio, Stm, Cnd (0.936)	Bio, Stm, Cnd, Pcp (0.961)	Cer, Lch (0.551)	Cer, Mit, Clm (0.773)	Cer, Lch, Mit, Cad (0.861)
BWT						
H	Wtr, Pcp (0.800)	Tot, Wtr, Pcp (0.930)	Tot, Chl, Wtr, Pcp (0.963)	Chi, Odo (0.745)	Chi, Bug, Odo (0.837)	Chi, Bug, Odo, Clm (0.937)
R	Cnd, Pcp (0.680)	Alk, Chl, Pcp (0.898)	Bio, Alk, Chl, Pcp (0.924)	Chi, Bug (0.274)	Chi, Bug, Clm (0.606)	Cer, Chi, Bet, May (0.864)
F	Chl, Pcp (0.495)	Tbd, Pcp, Wtr (0.549)	Bio, Cnd, Tbd, Pcp (0.719)	Bet, Bug (0.560)	Snl, Bug, Clm (0.865)	Chi, Snl, Bug, Clm (0.942)
Brood Size						
MAL						
H	Tbd, Pcp (0.556)	Stm, Tbd, Wtr (0.721)	Bio, Stm, Tbd, Wtr (0.880)	Odo, Cad (0.736)	Odo, Clm, Cad (0.780)	Bet, May, Odo, Cad (0.833)
R	Stm, Cnd (0.340)	Tot, Stm, Cnd (0.897)	Tot, Stm, Cnd, Pcp (0.949)	Cer, Cad (0.787)	Cer, Chi, Mit (0.832)	Cer, Chi, Bug, Mit (0.888)
F	Chl, Tbd (0.770)	Stm, Chl, Tbd (0.898)	Stm, Chl, Tbd, Pcp (0.960)	Lch, Odo (0.455)	May, Lch, Cad (0.696)	Chi, May, Lch, Cad (0.841)
BWT						
H	Tot, Chl (0.763)	Tot, Chl, Pcp (0.836)	Tot, Cnd, Chl, Pcp (0.846)	Chi, Bug (0.616)	May, Lch, Mit (0.816)	Chi, May, Lch, Mit (0.973)
R	Tot, Chl (0.816)	Tot, Bio, Chl (0.883)	Tot, Stm, Cnd, Chl (0.958)	Chi, Cad (0.768)	Amp, Chi, Cad (0.847)	Cer, Bug, Lch, Cad (0.940)
F	Chl, Wtr (0.900)	Chl, Tbd, Wtr (0.943)	Stm, Chl, Tbd, Wtr (0.957)	Bet, Odo (0.915)	Amp, Odo, Cad (0.962)	Amp, Cer, Odo, Cad (0.990)

[a] Abbreviations for individual variables are. Alk = alkalinity; Amp = scuds; Bio = plant biomass; Bug = bugs; Bet = beetles; Cad = caddisflies; Cer = ceratapogonid midges; Chi = chironomid midges; Chl = chlorophyll *a*; Clm = clams; Cnd = conductivity; Fly = total flies; Lch = leeches; May = mayflies; Mit = mite; Non = total non-flies; Odo = dragonflies and damselflies; Pcp = precipitation; Snl = snails; Stm = plant stem densities; Tbd = turbidity; Tot = total macroinvertebrates; and Wtr = water levels.

[b] H = at hatch, R = at rearing stage, F = at fledgling stage

Summary

Significance of Limnological Habitat to Waterfowl

Physical characteristics of wetlands, including numerical density, depth, size, morphology, shoreline configuration, shoreline length, and magnitude and direction of water level fluctuation are all significant factors in waterfowl production. Duebbert and Frank (1984) reported that duck broods preferred seasonal and semi-permanent wetlands. In addition, the numbers of basins or wetland distribution patterns have been shown to be significant (Mulhern et al. 1985). Strong relationships between water acreage and breeding pair densities (due to behavioral spacing mechanisms) and overall waterfowl use have also been documented (Evans 1951, Patterson 1976, Godin and Joyner 1981, Hobaugh and Teer 1981, Ringelman and Longcore 1982). Wetland size and volume have been found to be important factors affecting relationships between waterfowl and wetland acidity (DesGranges and Darveau 1985) and fish composition (Pehrsson 1984). Water depth directly influences the plant habitat and availability of the associated macroinvertebrate community (Robel 1961, Boyer and Psujek 1977, van der Valk and Davis 1978), and water level fluctuations (i.e., through either drawdowns, stabilization, or natural events) may be beneficial or detrimental to waterfowl production depending on direction, timing, and magnitude of change (Johnsgard 1956, Kadlec 1962, Robel 1962, Harris and Marshall 1963, Dirschl 1969, Swanson and Meyer 1977, Baldassarre and Nauman 1981, Sjoberg and Danell 1981, Briggs and Maher 1985, Crome 1986, Murkin and Kadlec 1986b, Murkin et al. 1991, Batzer and Resh 1992, Batzer et al. 1993). Hydrologic conditions appear to be the driving force behind waterfowl production with both long-term climatic trends and short-term aberrations having considerable influence (Danell 1981, Danell and Sjoberg 1982a, 1982b, Hill 1984, Jackson et al. 1985).

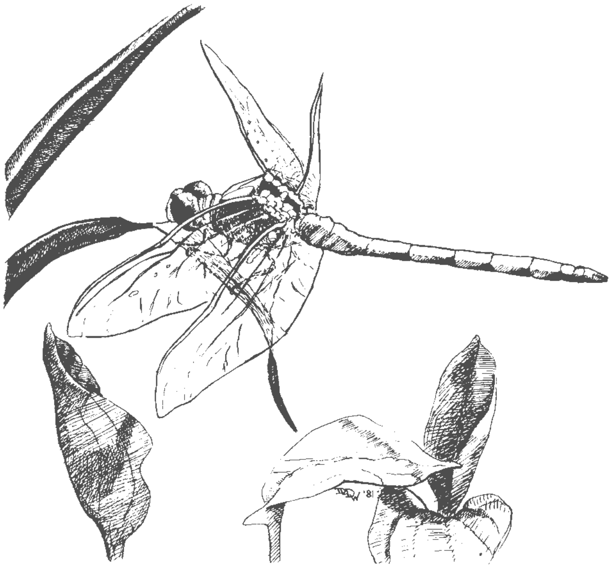
The water chemistries of the wetlands examined in this study differ distinctly from wetlands in the western prairie pothole region of North America. Wisconsin wetlands are generally fresher (i.e., less alkaline) than the saline, hard water wetlands of the western states. This basic difference accounts for much of the compositional differences in vegetation between the regions. Low alkalinity and associated high acidity (low pHs) in some Wisconsin wetlands may also directly influence the fish and macroinvertebrate communities, and therefore may influence waterfowl use (DesGranges and Darveau 1985, Hunter et al. 1985, DesGranges 1989, Bendell and McNicol 1987, McNicol et al. 1987). The impact of water quality in wetland selection and use by waterfowl is difficult to determine because of the complexity of the interrelationships and masking by other external, overriding factors (Walker and Wehrhahn 1971, Briggs et al. 1985). It is clear that the vegetative compositions of wetlands are directly dependent on their respective water chemistries. However, this impact is primarily concerned with differences in taxa since the vegetative structure and biomass are similar between the regions. Nutrients, particularly nitrogen and phosphorus, can control vegetative conditions and influence waterfowl use (Baldassarre and Nauman 1981, Briggs et al. 1985). Street (1977) has demonstrated the beneficial impact of fertilization of relatively infertile ponds on waterfowl production.

One important aspect of the chemical environment that this study did not address is the application of insecticides and herbicides. Using these chemicals within the WPA watersheds may have pronounced impacts on pond biota and waterfowl (Brown and Hunter 1985, Gibbs et al. 1984, Hunter et al. 1984, Lawrenz 1985, Dewey 1986, Huckins et al. 1986).

While physical and chemical attributes of wetlands may ultimately control waterfowl production, the relationships between wetland biota and waterfowl are stronger and more direct. This may be because both biota and waterfowl are responding to a similar set of environmental conditions (i.e., an incidental relationship) or because the waterfowl are dependent on the wetland biota (i.e., a cause-effect relationship). Composition, distribution, and quantity of vegetation are critical to waterfowl (see Kantrud 1986). Vegetative interspersion, cover-water ratio, semi-marsh conditions, diversity, and structure are all important characteristics that, based on behavioral studies of movements and habitat selection, are directly evaluated by waterfowl (Keith 1961, Weller and Fredrickson 1974, Kaminski and Prince 1981, Murkin et al. 1982, Nelson and Kadlec 1984). In addition to providing nesting, escape cover, and offshore loafing sites,

R. LILLIE

Waterfowl broods were often encountered when sampling the wetlands.



aquatic vegetation is a major item in the diet of most waterfowl. Also, plant community composition and physical structure indirectly influence waterfowl productivity through their impacts on invertebrate production. Many studies have documented a strong correlation between vegetative structure and macroinvertebrate abundance, diversity, and composition (Krecker 1939, Krull 1970, Moyle 1961, Schroeder 1972, Voights 1976, Hohman 1977, Street 1977, Pardue and Webb 1985, McCrady et al. 1986). The aforementioned physical factors affect the quality of a wetland's vegetation as well as interrelationships between the wetland biota. Carp (*Cyprinus carpio*) and muskrats (*Ondatra zibethicus*) may play important functions in destroying native vegetation and lowering the value of a particular wetland for waterfowl (Murkin and Batt 1987, Huener and Kadlec 1992). Conversely, muskrats can also create habitat openings in dense plant beds, thus contributing to an increase in available edge structure. Such interactions may be managed to the overall benefit of waterfowl.

The structure of aquatic vegetation in the wetlands examined during this study was not entirely conducive to good waterfowl production. At the beginning of this study, most of the larger basins had only narrow, marginal bands of littoral vegetation and large expanses of open water. These conditions resulted from the extremely high water levels present in the region. In undisturbed, natural ecosystems, waterfowl might be expected to benefit from extended periods of high precipitation, high groundwater tables, and high water levels due to the expected increase in availability of habitat; both in terms of increased numbers of basins and increased surface acreage. Submersion and subsequent death of large quantities of emergent vegetation should provide habitat for a host of microbes and invertebrate detritivores that subsequently increase the rate of nutrient recycling and availability of nutrients to other organisms in the food web (Danell and Sjoberg 1979, Crome 1986, Murkin et al. 1991, Campeau et al. 1994, Nelson et al. 1990). Unfortunately this was not true for most of the wetlands in this study. Humans have interceded by draining and farming lowlands adjacent to wetlands during periods of drought. Consequently, as the climate becomes wetter, the rise in the water table inundates wetland soils that have been severely disturbed. These areas may have relatively low seedbank potential and minimal amounts of organic detritus. Hence, the quality of waterfowl habitat in the permanent waterbodies decline as central basin emergent vegetation is killed and slowly replaced by smaller areas of shallow, lowlying disturbed wetlands. This chain of events emphasizes the need to maintain an adequate buffer around all WPA wetlands.

On Erickson and Bierbrauer, the impact of the drought was not fully realized in respect to waterfowl response for a number of reasons. First, and perhaps most importantly, the drought ended almost as quickly as it began. When the drawdown exposed large areas of bottom mud in Erickson and Bierbrauer and vegetative seedlings began to reestablish themselves over much of the area, the rapid return to wet conditions appeared to drown out most stands of emergent vegetation. Consequently, the wetlands returned to an open, marsh condition before the vegetation could become fully reestablished. However, other than the decrease in Blue-winged Teal use of Erickson during the drought, there appeared to be little influence on other waterfowl species.

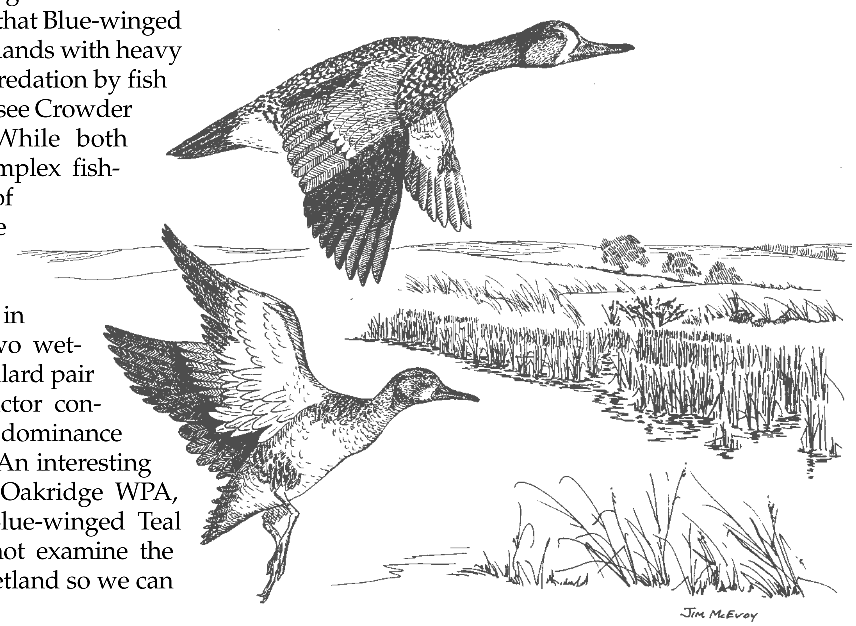
Macroinvertebrates are extremely important items in the diets of waterfowl (Schroeder 1973). Breeding hens require large sources of proteins for egg-laying and ducklings depend heavily on invertebrates as a source of protein during their first few weeks of life (Chura 1961, Perret 1962, Bartonek and Hickey 1969, Krapu 1974, Reinecke 1977, Pehrsson 1979, Swanson 1985). Other times, most waterfowl species appear to be opportunistic feeders and may rely heavily on vegetative food items. During most sampling periods, food resources in the form of macroinvertebrate densities on the studied wetlands appeared adequate to support waterfowl. Mauser (1985) reached a similar conclusion regarding the adequacy of macroinvertebrate food items on an earlier study of several wetlands in the study area. Wheeler and March (1979) also drew similar conclusions regarding the influence of water chemistries and invertebrate densities on scattered southeastern Wisconsin wetlands.

Chironomid densities in the study area were comparable to or exceeded densities reported for many well-known waterfowl producing areas in North America and on most sampling dates were equal to or exceeded densities that were attractive to broods in North Dakota wetland basins. Talent et al. (1982) reported that chironomid densities in North Dakota basins with sedentary broods ranged from 684 to 10,092 individuals per m^2. He found that mobile broods moved from basins with densities of 205 and 68 chironomids m^2 to basins with densities of 7,047 and 1,950 chironomids m^2, respectively. In this study, chironomid densities may have reached critically low levels during the drought in both Erickson and Bierbrauer but the response of waterfowl production to fluctuations in macroinvertebrate abundance differed between the two wetlands. Blue-winged Teal breeding pair densities were positively associated with total macroinvertebrate abundance in Erickson, while no response in Blue-winged Teal breeding pair densities was observed in Bierbrauer. However, Blue-winged Teal brood sizes were strongly associated with chironomids at hatch and during the rearing stage, and with several macroinvertebrate taxa (including dragonflies and damselflies and biting midges) at fledgling stage. Blue-winged Teal broods in Erickson did not respond significantly to changes in macroinvertebrates. Mallards did not respond to changes in macroinvertebrate abundance in either wetland. The lack of response in breeding pair densities in Bierbrauer suggested that macroinvertebrates were not limiting waterfowl production and upland factors (e.g., predation) may have had a greater impact (see Evrard 2002). Alternatively, the large standing crop of macroinvertebrates simply may not have been readily available to waterfowl. The differences in vegetative cover, water depth, and water clarity can affect macroinvertebrate composition, size structure, behavioral activity, nutritive value to wildlife, and general accessibility to waterfowl. These factors may interfere in determining the significance of macroinvertebrate abundance to waterfowl production (Reinecke 1977, Tozer et al. 1981, Corkum 1984).

Nudds and Bowlby (1984) documented that prey size selection occurs among some co-existing dabbling duck species. Bill morphology, specifically the number of lamellae per cm of bill length, was negatively correlated with mean prey size. Comparisons between environmental prey size distribution and dietary prey size structure were used to classify ducks along a gradient from generalists to specialists. Despite both Mallards and Blue-winged Teal being classed as generalists (DuBowy 1985) and some overlap in diets, significant differences in prey-size-energy distributions between the two species have been noted (Hepp 1985) with Blue-winged Teal depending heavily on smaller sizes of prey. Assuming all others variables are held constant, we might expect that Blue-winged Teal would outcompete Mallards on wetlands with heavy fish predation (assuming size selective predation by fish would result in smaller mean prey sizes; see Crowder and Cooper 1982, Pehrsson 1984). While both Erickson and Bierbrauer supported complex fisheries in this study, the small amount of vegetative cover in Erickson may have contributed to higher fish predation on the available macroinvertebrates. This may account for the observed difference in breeding pair densities between the two wetlands (e.g., high Blue-winged Teal to Mallard pair ratios in Erickson) and may be one factor contributing to the pattern in waterfowl dominance structure among the regional wetlands. An interesting situation presents itself in the case of Oakridge WPA, where Mallard use was higher than Blue-winged Teal (Evrard 2002). Unfortunately, we did not examine the macroinvertebrate community of this wetland so we can not make necessary comparisons.

Another important issue concerns the availability and use of macroinvertebrates by waterfowl. No food habit or behavioral studies of waterfowl were conducted in this study. Even though large numbers of macroinvertebrates were usually present, they may not have been readily available to waterfowl. Many macroinvertebrates have evolved elaborate behavioral adaptations to escape detection and avoid predation. The timing of insect emergence is primarily controlled by temperature and day length. There is some evidence to suggest that the waterfowl breeding period has evolved in order to assure synchronization of duckling hatch with insect emergence, or at least that waterfowl nesting and insect densities are responding to similar environmental cues (Danell and Sjoberg 1977, McCrady 1982, Sjoberg and Danell 1982, Hill 1984, Maher and Carpenter 1984). Briggs (1985) suggests possible relationships between food availability and patterns of egg-laying and additional evidence supporting the importance of macroinvertebrates include the synchronization of brood behavior with the diel activity patterns of macroinvertebrates (Swanson and Sargeant 1972, Ball 1973, Sjoberg and Danell 1982). Even though the standing crop of macroinvertebrates in the studied wetlands were high, climatic variations may have delayed insect emergence and impacted duckling survival either through direct starvation or reduced fitness (Sjoberg and Danell 1981, Danell and Sjoberg 1982b).

Substrate differences can directly influence the abundance or composition of various macroinvertebrate populations (Berg 1949, Rosine 1955, Hargrave 1970, Voights 1976, Gerrish and Bristow 1979, Dvorak and Best 1982, Kangasniemi and Oliver 1983, Sarkka 1983, Maher 1984, Scheffer et al. 1984, Rabe and Gibson 1984, Mauser 1985) and their importance to waterfowl (Krull 1970, Voights 1976, Maher and Carpenter 1984, Mauser 1985). Substrate additions, including hay infusion or enrichment, have succeeded in increasing available habitat for macroinvertebrate colonization (Pardue 1973, Street and Titmus



1979, Anderson and Danell 1982, Danell and Andersson 1982, Rasmussen 1985). Plant decomposition provides nutrients for epiphytic microflora and fauna (e.g., bacteria, protozoa, fungi, and periphyton) that further accelerate the decomposition process and provide food for larger invertebrate shredders and grazers (Kadlec 1962, Danell and Sjoberg 1979). This process has been offered as an explanation for the dramatic increase in productivity during the first several years following impoundment (Whitman 1974, Kadlec 1986a, 1986b) and during water level fluctuations (Crome 1986, Murkin and Kadlec 1986a, 1986b).

Fish have long been suspected of competing with waterfowl for similar food items (Swanson and Nelson 1970, Erickson 1983, Pehrsson 1984, Hunter et al. 1985). Many studies have identified predation mechanisms and relationships within the invertebrate and plankton communities (Ball and Hayne 1952, Crowder and Cooper 1982, Savino and Stein 1982, Mittelbach 1984, Paszkowski 1985, Hanson and Butler 1994, Batzer et al. 2000, Zimmer et al. 2001a, 2001b) and recent studies have examined the degree of dietary overlap between fish and waterfowl (Erickson 1979, Carmichael 1983). McDowell (1989) documented that fathead minnows could potentially compete with waterfowl for midge larvae, however, food resources can be sufficient for both fish and waterfowl to co-exist.

While fish undoubtedly exerted considerable influence on the composition of the macroinvertebrate communities in the studied wetlands, macroinvertebrate densities (in particular, midge densities) appeared to be more than adequate to support waterfowl. However, the fact that the dominant waterfowl in the studied wetlands were generalist feeders (i.e., Mallards and Blue-winged Teal) suggests that strong inter-specific competition may be occurring as the result of limited food reserves (for alternative explanations see Poysa 1984). While structural differences between macroinvertebrate communities (taxa and size composition) may have an impact on waterfowl species compositions, their impact on total waterfowl utilization is unknown. Waterfowl dietary studies may be necessary to examine if causative relationships exist. While the macroinvertebrate compositions and densities in wetland basins with fish appear adequate for waterfowl broods in the study wetlands, there remains the possibility that selected manipulations of the fish community may trigger responses that would be detrimental to waterfowl.

Recommendations and Management Implications

It is imperative that future efforts to preserve or reestablish wetland habitat for waterfowl provide a complex of habitat types. Natural wetland ecosystems include a mosaic of temporary and semi-permanent waterbodies that provide a diversity of habitats for exploitation by wildlife. Small, fishless, waterbodies adjacent to larger wetlands with resident fisheries expand the biodiversity of a region, harboring distinct floral and faunal communities. In the past, many of these basin depressions have been severely disturbed by human activities (e.g., filling and plowing). Temporary wetlands are among the most vulnerable wetland habitat and every effort must be taken to protect them. When constructing or designing artificial wetlands, basin slopes should be varied to maximize the area of feeding zones for dabblers while providing for normal water level fluctuations. Contour furrowing of bottom substrates should be considered as a practical management application on managed impoundments for improving vegetation and macroinvertebrate production (see Huener and Kadlec 1992).

Water chemistry had little influence on waterfowl use in this study. If anything, wetlands receiving nutrient inputs (e.g., Goose Pond and Lundy Pond Main) were "visited" by waterfowl more intensively than less productive wetlands. In general, future wetland acquisition should be directed at providing a diversity of wetland types, including wetlands described as low alkalinity, groundwater recharge wetlands, and high alkalinity groundwater discharge wetlands.

Waterfowl use and production are related to habitat availability and associated biodiversity. When ignoring biological interactions, the abundance of macroinvertebrate food resources is largely dependent upon substrate and climatic variations. In the case of wetlands, it is important to recognize that stability is not desirable. Rather, managers need to manage for change and accept the fact that the natural hydrologic cycle controls wetland habitat. The boom and bust cycle, the rise and fall of water levels, and the degenerating and regenerating phases of marshes are desirable. If managed properly, alternative habitats in neighboring areas can serve as refuge for inoculation of habitats that may be lost during periods of drought. This can be accomplished by encouraging the purchase or reestablishment of a complex of wetland habitats and providing corridors between adjoining wetlands. Buffer strips of low-lying wetlands or moist soils should be established around the perimeter of WPA basins. Best management practices should be implemented on all WPA wetland watersheds to minimize runoff and perpetuate the flood-mud-crud syndrome. Herbicide and pesticide applications should be disallowed within a given distance around all WPA wetlands. A continued emphasis should be given to educating the public on the benefits of wetlands and the possible consequences that loss of wetlands and waterfowl will have to humans.

APPENDIX A.

Common and scientific names of plants found in WPA wetlands during this study.

Common Name	Scientific Name
Emergent Plants	
Arrowhead	*Sagittaria* spp.
Bedstraw	*Galium* spp.
Beggar-ticks	*Bidens* spp.
Blue flag	*Iris versicolor*
Bulrush	*Scirpus* spp.
Bur-reed	*Sparganium eurycarpum*
Cattail	*Typha* spp.
Cyperus sedges	*Cyperus* spp.
Grasses	Family: Gramineae
Horsetail	*Equisetum* spp.
Loosestrife	*Lysimachia* spp.
Mint	*Mentha* spp.
Reed canary grass	*Phalaris arundinacea*
Rushes	*Juncus* spp.
Sedges	*Carex* spp.
Skullcap	*Scutellaria lateriflora*
Spike-rush	*Eleocharis* spp.
Stichwort	*Stellaria longifolia*
Stinging nettle	*Urtica* spp.
Swamp milkweed	*Asclepias incarnata*
Sweet-flag	*Acorus calamus*
Three-way sedge	*Dulichium arundinaceum*
Water-hemlock	*Cicuta bulbifera*
Water-horehound or Bugleweed	*Lycopus* spp.
Water-parsnip	*Sium suave*
Willows	*Salix* spp.
Wool-grass	*Scirpus cyperinus*
Submersed Plants	
Bladderwort	*Utricularia* spp.
Buttercup or Crowfoot	*Ranunculus* spp.
Coon's-tail or Hornwort	*Ceratophyllum demersum*
Curly pondweed	*Potamogeton crispus*
Flat-stemmed pondweed	*Potamogeton zosteriformis*
Floating pondweed	*Potamogeton natans*
Pondweeds	*Potamogeton* spp.
Sago pondweed	*Potamogeton pectinatus*[1]
Stonewort or Muskgrass	*Chara* spp.
Variable-leaved pondweed	*Potamogeton gramineus*
Water-milfoil	*Myriophyllum sibiricum*
Water-nymph	*Najas flexilis*
Waterweed	*Elodea canadensis*
Waterwort	*Elatine* spp.
White-stemmed pondweed	*Potamogeton praelongus*
Floating-leaved Plants	
Giant duckweed	*Spirodela polyrrhiza*
Liverwort	*Riccia fluitans*
Small duckweed	*Lemna minor*
Smartweed	*Polygonum* spp.
Star duckweed	*Lemna trisulca*
Water-meal	*Wolffia* spp.
Water-shield	*Brasenia schreberi*
Yellow water-lily	*Nuphar* spp.

[1] Now *Stuckenia pectinata* (L.) Börner (Crow and Hellquist 2000).

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