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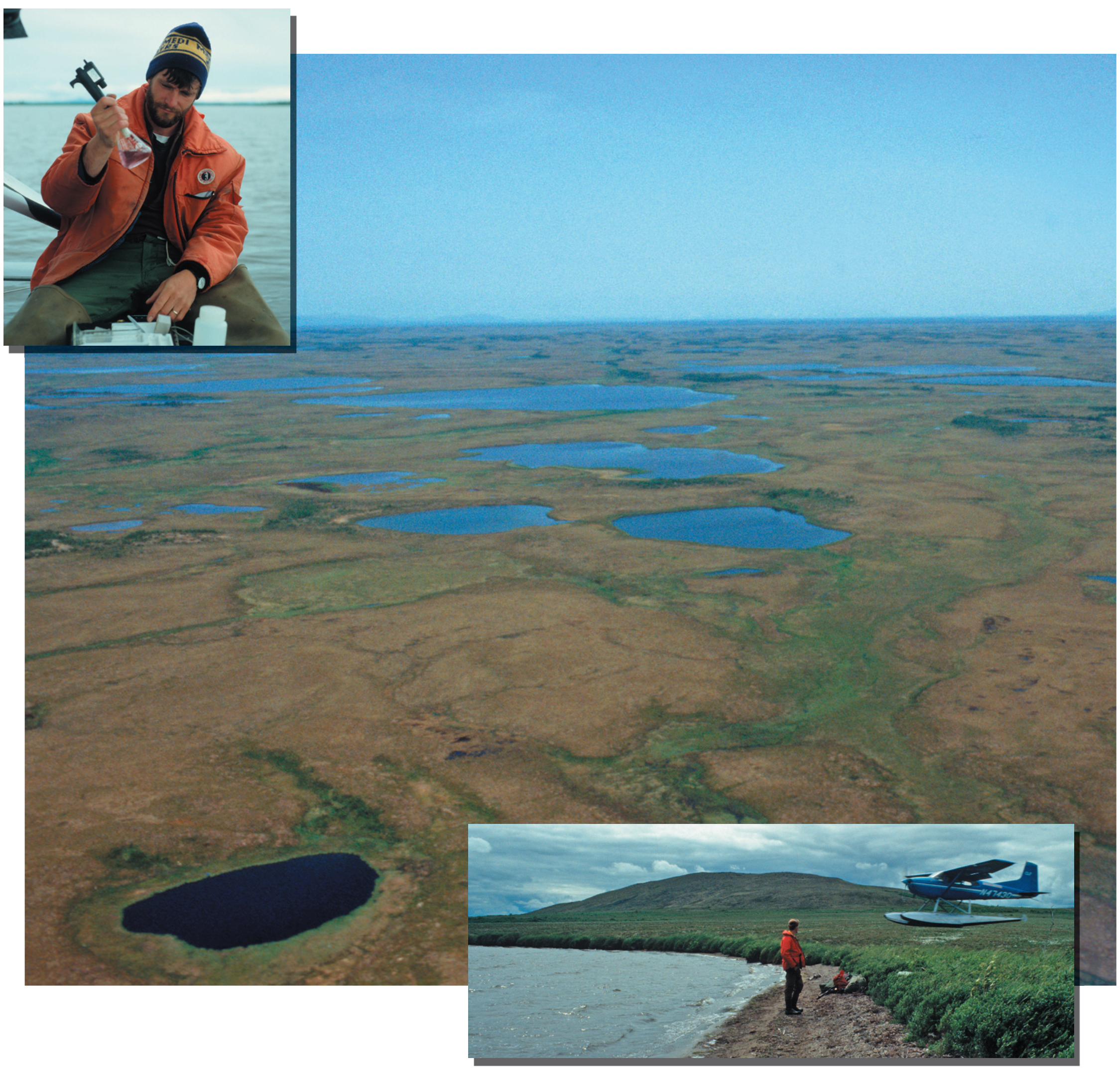
Waterfowl Use of Wetlands in Relation to Limnological Variables in the Kvichak River Area, Alaska

A final report of the 1992 and 1993 waterfowl habitat evaluation effort in the Kvichak and Alagnak block of the Anchorage Field Office

Bruce E. Seppi



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Mission Statement

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Authors

Bruce E. Seppi is a wildlife biologist with the Anchorage Field Office, Anchorage, Alaska.

Cover

BACKGROUND PHOTO: Aerial view of the study area between the west shores of Lake Iliamna and Alagnak River. TOP LEFT: the author conducts alkalinity testing on wetlands in the study area. LOWER RIGHT: a floatplane lands at a small lake to collect researchers. Wetlands too small for floatplane access required helicopters for transporting researchers and their equipment.

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Alaska State Office
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Anchorage AK 99513

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Abstract

The relationship between 20 habitat variables and use by duck broods and adult waterbirds of all species was investigated in 1992 and 1993 on 156 wetlands in the Kvichak River area, Alaska. The study examined whether wetland size and shape, water chemistry characteristics, primary productivity and aquatic invertebrate biomass affected the density of waterfowl on wetlands. Biases in the visibility and detectability of birds, especially duck broods, were recognized.

Results suggest brood use by all species of ducks was influenced by wetland cation concentrations, particularly sodium. Use by adult ducks and all species of waterbirds was related to total alkalinity and shoreline length. Limnological variables associated with swan use of wetlands were inconclusive, but general trends indicate productivity and salinity may be factors. On a density basis (birds/m shoreline), sodium, chlorophyll a, pH and total alkalinity most strongly influenced use by duck broods, adults and all species of waterbirds. These results suggest that large, relatively productive wetlands with low to moderate salinity were used most by waterfowl.

Introduction

Waterfowl populations in North America have declined to historically low levels due to increasing losses of breeding, wintering and migration habitat (N. Am. Waterfowl Management Plan 1986). These declines are primarily a result of the continued conversion of wetland habitat to agricultural use in the mid-continent prairie-parkland breeding areas (Tiner 1984, Sanderson 1980), as well as in the Central Valley of California (Graziano and Cross 1993). Industrial and urban land development has also contributed to loss of wetlands nationwide (Dahl and Johnson 1991). Although legislation exists that attempts to slow or reverse these trends (Section 404-1B of the Clean Water Act), habitat loss remains a substantial threat to waterfowl production. The production potential of pristine high latitude areas is therefore increasingly important, as these areas now contain substantial portions of breeding populations of species of significant management interest (e.g. northern pintail) (Derksen and Eldridge 1980, Smith 1970, Hansen and McKnight 1964).

Alaska contains millions of acres of wetland habitat representing a significant production area for many species of waterfowl. While much of this habitat is managed by the U.S. Fish and Wildlife Service, important breeding areas exist on Bureau of Land Management (BLM) lands. Some of these lands may be more important as waterfowl breeding habitat than others, however the Kvichak and Alagnak block within the Anchorage Field Office contains substantial wetland habitat, representing significant waterfowl production potential. Aerial breeding pair surveys in 1992 and 1993 revealed breeding waterfowl densities of 35.9 and 29.3 ducks per square mile in stratum 8 (Bristol Bay) in 1992 and 1993 respectively (Conant and Groves 1992, 1993). While these densities are low relative to other BLM lands in Alaska, it is crucial to understand habitat features important to breeding, nesting and brooding waterfowl using the Kvichak area so comparisons of its waterfowl production potential can be made with other areas.

Related Research

BLM has funded a similar investigation of waterfowl and wetland habitat quality relationships in the Iditarod George block of the Anchorage Field Office. The relationship between 20 habitat variables and use by waterfowl broods was investigated in the Lower Innoko River area, Alaska. In that area, brood use was most strongly associated with shoreline length, potassium, and aquatic invertebrates, or temperature, color, chlorophyll <u>a</u> and shoreline length, depending on an analysis using separated or combined cations and anions (Seppi 1993). When limnological variables were compared with overall duckling density (broods/m shoreline length), stepwise regression linked chlorophyll <u>a</u>, temperature, color and total phosphorous concentrations with higher brood densities (Seppi 1993).

Other research has assessed waterfowl use patterns and hydrochemical characteristics of Interior Alaska wetlands. Murphy et al. (1984) showed phosphate and nitrate concentrations in the water column to be correlated with duck use. High concentrations of these nutrients where linked to both high duck density and species richness. Hydrological connection to flowing water was also associated with higher densities of ducks when compared to isolated waterbodies, because of higher nutrient levels associated with the inflow of water (Kessel et al. 1980, Murphy et al. 1984, Heglund 1988, 1992). Breeding densities of waterbirds (ducks, geese, swans, loons, grebes) were found to be positively correlated to total phosphorous concentrations by Nilsson and Nilsson (1978) as well.

Inorganic nutrients, particularly phosphorous and nitrogen, are considered limiting factors in the productivity of wetlands (Richardson et al. 1978). Growth of aquatic plants is often limited by nitrogen and phosphorous availability, therefore the rates at which these nutrients are supplied, cycled and removed from the wetland environment are critical to plant growth (Kadlec 1979). Ducks in turn may use nitrogen and phosphorous rich lakes in a response to higher productivity levels. On Interior Alaska wetlands, Heglund (1988) reported a positive correlation between waterbird density (ducks, geese, swans, loons, grebes) and total phosphorous and nitrogen concentration, cation salinity (calcium, sodium and potassium concentration) and shoreline length. Large, productive, slightly brackish lakes supported the highest densities of waterbirds. Further work in boreal forest wetlands by Heglund (1992) suggests brackish water and wet-meadow wetlands with sedge and grass vegetation, which provided cover and abundant invertebrate and plant foods were preferred by some species of waterfowl and grebes. Differences in visibility of broods among wetland types may have influenced these results, which are therefore offered with caution.

Habitat requirements for duck broods depend both on the amount of surface water available and wetland fertility. Patterson (1976) found the highest density of duck broods on fertile, hard water ponds with abundant submerged macrophytes because these ponds provided both escape cover and food. Courcelles and Bedard (1979) found that broods, as well as adult birds, selected habitats of open cattail (Typha augustifolia) with open areas dominated by submerged hydrophytes (Lemna, Myriophylum, Ceratophylum and Utricularia species).

Submerged aquatic plants and their associated invertebrates are important factors in waterfowl use of ponds. Duck use of wetlands is positively correlated with invertebrate numbers (Joyner 1980), although invertebrate numbers depend largely on the species and abundance of submerged aquatic plants (Krull 1970). Aquatic vegetation alone can be an important waterfowl food, however even those plants of low food value are indirectly important to waterfowl production as they provide habitat for macroinvertebrates which are an important source of animal protein for ducks (Krull 1970, Serie and Swanson 1976). Dabbling ducks concentrate their foraging in areas with the highest abundance and biomass of invertebrates and often seek out areas inhabited by prey items of high nutritive quality (Kaminski and Prince 1981). High invertebrate populations often coincide with peak hatching of waterfowl (Bergman et al. 1977) and constitute a major portion of the diet for many species of ducklings (Sudgen 1973).

Wetland salinity may also be a factor in use by waterfowl broods. Brood use of saline lakes is determined principally by salt concentration, the availability of freshwater, and aquatic foods, although ducklings cannot tolerate high concentrations of sodium chloride (Swanson et al. 1984). In addition, high concentrations of sodium chloride can cause changes in the species structure of invertebrates and plants attractive to ducks, thus affecting their use of saline wetlands (Swanson et al. 1984).

The physical, chemical and biological characteristics of wetlands directly and indirectly affect use patterns by waterfowl. These characteristics can therefore be used as indicators in evaluating wetlands as potential habitat for waterfowl. Before management to increase or maintain waterfowl production is undertaken, it is essential that the relationship between habitat factors and brood production be understood. Limited data exist that relate characteristics of Alaskan wetlands to their use by waterfowl broods (Murphy et al. 1984, Heglund 1988, 1992). The Lower Innoko/Iditarod George study is the only data that exists for BLM lands in Alaska (Seppi 1993). The purpose of this study is therefore to examine if any relationships exist between wetland characteristics and waterfowl use on BLM lands in the Kvichak area. These results can in turn be compared to other waterfowl habitat on public lands under BLM management and used to recognize those areas most important to waterfowl production.

Objectives

The overall objective of this project was to evaluate the Kvichak area for its waterfowl production potential. To do this, the project attempted to determine if a correlation exists between a wetlands water chemistry, morphological measurements and selected biological factors and its use by waterfowl broods, adult birds, (ducks, geese and swans) and other water-loving birds (loons, grebes). This involved identifying those wetlands most used by waterbirds and used to produce waterfowl broods and surveying and describing their: basic morphometric characteristics; water chemistry; aquatic vegetation and associated macroinvertebrate fauna. These parameters were then statistically compared to waterfowl production and waterbird use within each wetland to identify possible habitat\use relationships.

Study Area Description

The study area is located at the base of the Alaska Peninsula near King Salmon, Alaska, approximately 465 km (290 miles) southwest of Anchorage. The lands are BLM-administered public lands, however large portions are in the process of conveyance to the State of Alaska. The area (59^{o} 00'N, 156^{o} 30'W), covers approximately 8,300 square kilometers and extends east to the western shore of Lake Iliamna, west to the Nushagak River, north to 59^{o} 45'N latitude, and south to the village of King Salmon (Figure 1). At present, 490 square kilometers of BLM-administered lands are interspersed with private and state-owned lands (ADNR December 1992).

The major drainages for the area are the Nushagak, Alagnak and Kvichak Rivers. The villages of Levelock and New Stuyahok lay within or on the boundaries of the study area. Several private hunting and fishing guide/outfitters operate within or near the region. The area is roadless, with the exception of a road between King Salmon and Naknek, a small coastal community largely influenced by the Bristol Bay salmon fishery.

The area lies on a glacial outwash of shallow sandy/gravel soils with discontinuous and isolated masses of permafrost (Selkregg 1976). The dominant vegetation is a transition between the forest/tundra plant communities found farther north and the treeless grass/sedge/dwarf shrub/lichen tundra typical of the Alaska Peninsula. Most of the area is rolling dwarf shrub tundra with numerous small pothole lakes and larger, more shallow wetlands. A band of spruce forest (Picea spp.) extends in a narrow strip across the center of the area, approximately along the path of the Alagnak and Kvichak Rivers.

Aerial view of the study area between the west shores of Lake Iliamna and the Alagnak River.

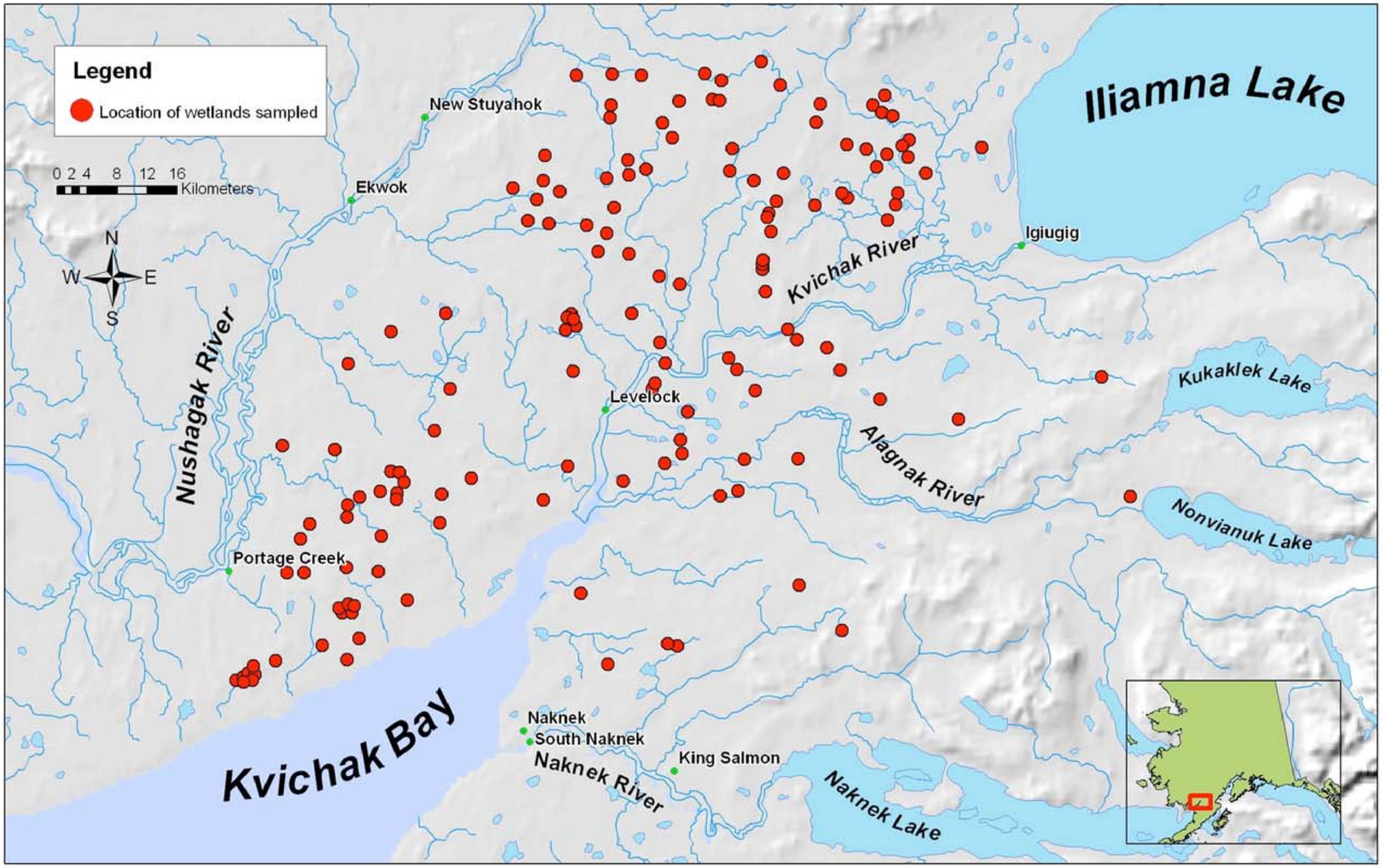


Figure 1. Kvichak study area showing the location of villages and wetlands surveyed.

A unique band of wetlands exists along a glacial moraine in the northeast portion of the study area. This band of wetlands is situated west of Lake Iliamna and extends for 72 kilometers (45 miles) in an arc which begins northwest of the lake and ends southwest of the lake. These wetlands are of variable size and shoreline development, yet all are deep, clear and virtually void of sediment and aquatic vegetation. These pools typically have a deep emerald green color that is apparent from the air and when using a Secchi disk to measure transparency. They have deep, bowl-shaped basins with rock, gravel or sand bottoms that drop off quickly in depth with minimal shallow areas along the shoreline. Those moraine lakes surveyed averaged 4.4 m in overall depth and 8.2 m maximum depth, including one wetland with a maximum depth which exceeded 14 meters (waterbody 1002, appendix 2). These wetlands have closed hydrological regimes with snowmelt, rain and ground water as their only source of water replenishment. Such wetlands obtain their nutrient flux mainly from rain and ground water, depending on the substrate (Gosselink and Turner 1978), thus have a low nutrient flux and may be less desirable to waterfowl (Murphy et al. 1984).

Larger wetlands in the other parts of the study area had larger surface areas, were shallower, more turbid and have more aquatic plant life than the moraine lakes. These non-moraine wetlands had both closed and open hydrological regimes, however even those with closed hydrologies were relatively more productive because of their shallow depth (< 1 m) which provides favorable conditions for aquatic plant growth. The higher surface area, shallow depths and subsequent higher productivity may make these wetlands more desirable to breeding waterfowl (Heglund 1988, 1992, Seppi 1993).

Geology and Topography

The geology of the area is dominated by glacial moraine and drift, or glacialfluvial outwash deposits bordering older moraines, or alluvial flood plain deposits associated with rivers and streams (Selkregg 1984).

Soils

Soils are well drained, shallow and gravelly, and are formed in well drained course volcanic ash deposits in the inland areas to poorly drained, fiberous peat soils over a shallow, discontinuous permafrost table near Lake Iliamna and the coast (Selkregg 1984).

Climate

Climate in the Kvichak area is considered transitional between the Interior's continental climate and the maritime climate of the southern coastline of the Aleutian Islands (Selkregg 1984). Average maximum temperatures range from 63 ^{0}F (17 ^{0}C) to 38 ^{0}F (3 ^{0}C) in July and 29 ^{0}F (-2 ^{0}C) to 4 ^{0}F (-16^{0}C) in January. Extremes of -42 ^{0}F (-41^{0}C) and 88^{0}F (31^{0}C) have been recorded at King Salmon. Mean annual precipitation is 20 in (51 cm), which includes 45 in (114 cm) of snowfall (Selkregg 1984). Winds average 9.6 knots (17.8 kph), with an extreme of 115 kph. Average freeze up of the Nushagak River is November 20th, the river is ice free by May 5th. An average growing season of 97 days is estimated for Dillingham (Selkregg 1984).

Methods

Selection of Wetlands

Wetlands were selected using 1:63,360 topographical maps and 1:21,120 black and white aerial photographs. Wetland habitats were stratified according to the following criteria: connected wetlands (wetlands that were hydrologically connected to flowing water); closed wetlands (wetlands that were not connected to flowing water); moraine wetlands (the deep green pools along the glacial moraine described earlier); rivers (the major river channels of the Alagnak and Kvichak Rivers). To select individual wetlands for brood and waterfowl use and limnological analysis, each 1 mi^2 section marked on the topographical maps was assigned a number. After single sections within the study area were selected with the use of a random numbers table, a second random number was used to pick a wetland from that section. If sections without wetlands were chosen, they were rejected and a new section chosen. This was done repeatedly until 200 individual wetlands had been selected.

Thirty-two connected wetlands, 61 closed wetlands, 5 moraine wetlands and 3 rivers were surveyed in 1992; 35, 58, 14, and 1 of these respective wetlands were surveyed in 1993, resulting in samples from 156 different wetlands in the 2 years (Table 1). No wetlands were repeatedly surveyed within each year, however I returned to 53 ponds in 1993. Forty-eight wetlands were sampled in 1992 only and 55 in 1993 only (Table 1).

Table 1. Number of wetlands surveyed in each habitat stratum in the Kvichak study area 1992 and 1993.

	YEAR SURVEYED				
Wetland Type	**1992**	**1993**	**1992 only**	**1993 only**	**Both years**
Connected	32	35	15	18	17
Closed	61	58	28	25	33
Moraine	5	14	2	11	3
River	3	1	3	1	0
Total	101	108	48	55	53

Total different wetlands surveyed in 2 years = 156

Brood Surveys

Use of individual wetlands by waterfowl was estimated by aerial and ground surveys. Larger, deeper wetlands were accessed by float plane. Smaller, shallower ponds were accessed by helicopter. Complexes of wetlands of various sizes were also accessed by float plane by landing on the largest lake and walking to the nearby, smaller ponds. All wetlands accessed by helicopter were surveyed for broods from the air as they were first approached. The shoreline perimeter of each selected wetland was flown at low altitude (<50 feet) and broods recorded as they flushed. Larger wetlands accessed by floatplane were surveyed from the ground. A collapsible pack canoe was also used on wetlands accessed by floatplane. For ground surveys, two people walked, or when possible canoed in opposite directions along the shoreline of each wetland and recorded the species, age class (Gollop and Marshall 1954) and number of all waterfowl broods observed. Adult, non-breeding waterbirds without young of all species were also recorded on the wetlands surveyed for broods.

Ideally, brood surveys were to be timed as to occur midway between the peak hatch and occurrence of dabbler and diver broods in the area. I did not feel this was accomplished. Brood surveys were initiated on 25 June and 19 June in 1992 and 1993 respectively. The brood survey continued until 17 July in 1992 and 5 July in 1993. Only one survey was conducted for each wetland. The estimated peak hatch of broods for the Kvichak/Alagnak river drainage area is between 7-15 to 7-21 (Hodges and Conant 1990), therefore the survey may be an underestimation of broods as it was too early in both years and did not account for those broods hatching in July, particularly diving broods.

Limnology

Limnological analysis of wetlands was carried out on the same day wetlands were surveyed for waterfowl use. Water samples were collected at the surface of each wetland in plastic containers for total nitrogen, total phosphorous, major cations (sodium, calcium, potassium, magnesium) and major anions other that carbonates (chloride, sulfate). Water samples for chlorophyll a were collected and filtered and preserved on site for subsequent laboratory analysis. Physical characteristics (transparency, surface temperature, average depth) and those chemical characteristics that could be determined on site (conductivity, total alkalinity, water color, pH) were also measured at each water body. I estimated shoreline length and surface area for all wetlands by digitizing 1:21,120 black and white aerial photographs using Arc/Info (1991). A shoreline development index, which compares shoreline irregularity, was calculated from the ratio of shoreline length to the circumference of a circle that has the same area as the lake (Wetzel 1983). Water transparency was measured using a Secchi disk attached to a graduated cord and depth was recorded to the nearest 0.25 meter. Conductivity (recorded in μS/cm) and pH were measured using a Corning Check-Mate 90 handheld meter with detachable conductivity and pH sensors. Water temperature was measured at the surface with a digital thermometer built into each detachable sensor. Filtered water samples were visually compared with a Hach color comparitor kit to estimate water color and recorded in platinum cobalt units. Bicarbonate alkalinity was determined by titration with sulfuric acid using a Hach digital titrator. Phenolphthalein and bromcresol green-methyl red were used as titration endpoint indicators and total alkalinity recorded as mg/L $CaCO_3$.

Chlorophyll a samples were collected using a hand operated vacuum pump to filter up to 1 liter of surface water through a 0.45µm Gelman A/E glass fiber filter. The glass filters were then wrapped in paper filters and placed in airtight, darkened containers filled with desiccant for preservation by drying. Chlorophyll a concentrations were later determined flourometrically (Knowlton 1984) using acetone extraction (APHA 1985) and recorded in mg/L. I used laboratory facilities in the Department of Biology and Wildlife at the University of Alaska, Fairbanks to determine chlorophyll a concentrations from field samples.

Water samples collected to determine concentrations of total nitrogen, total phosphorous, major cations and major anions were sent to the University of Missouri at Columbia for analysis. Samples for total phosphorous and total nitrogen were collected in 500 ml plastic bottles and subsamples of 10 ml each were pipetted into clean acid washed test tubes at the end of each day. Total nitrogen samples were preserved with one drop of concentrated sulfuric acid. Total phosphorous samples were kept in a cool place and preserved by refrigeration upon return from the field. A single filtered sample of 50 ml was collected for calcium, magnesium, potassium and sodium and preserved with one drop of concentrated sulfuric acid. A single water sample of 125 ml was collected for sulfate and chloride analysis and also reserved by refrigeration.

Invertebrate Sampling

Aquatic invertebrate samples were collected only in 1993 on a limited number of wetlands within each stratum in conjunction with limnological sampling. At each wetland, aquatic invertebrate abundance in the benthos and water column was measured using a sampling device made of a graduated Plexiglass tube (Pederson and Pederson 1983) with a 500 micron screen that could be inserted into a slot at the bottom. Samples where collected by quickly lowering the tube through the water column and 3 cm into the benthos. The water column and benthos enclosed by the sampler was then agitated to suspend benthic organisms. The screen was then slid into place to collect a combined sample of organisms from the sediments and water column. Water was allowed to drain from the sampler, and material on the screen was then washed into plastic jars with 95% ethanol and saved for later sorting. Samples were taken at 3 random sites around the perimeter of the wetland in water no deeper than 40 cm. In the laboratory, the 3 samples from each wetland were combined, then sorted and identified to family when possible using Pennak (1978), and Thorp and Covich (1991). After weighing the samples wet, I dried them for 24 hrs at $100^{o}C$ and reweighed them to determine total dry biomass (g/cm^2) of invertebrates per sample. The mass of invertebrates was determined on the basis of area and not volume as the sampling device used was probably biased toward benthic invertebrates and did not capture many of the more mobile organisms in the water column.

Vegetation Sampling

I sampled aquatic vegetation in each wetland and collected field notes on terrestrial vegetation to enhance the descriptions of wetland habitat characteristics, but I did not directly compare vegetation data with use by waterfowl. Aquatic vegetation types were recorded once for all wetlands during limnological sampling. Two transects across each wetland were used to determine the species of aquatic plants present. On each wetland, transect lines were established across the center of the wetland in east-west and north-south directions perpendicular to the shoreline. Using the canoe and a compass bearing, each transect line was followed from shoreline to shoreline. At approximately 10 m intervals, all aquatic plant species encountered were recorded. Those species that could not be identified on site were collected and placed in a plant press for later identification using Welsh (1974) and Hulten (1968).

Depth measurements were also taken along transect lines used to sample aquatic vegetation. Depth was determined using a weighed measuring line with 0.25 m graduations. Soundings were taken at approximately 10 m intervals for transects >50 m and every 5 m for shorter transects. Depth measures from both transects combined were used to calculate mean depth (m) for each wetland.

Statistical Analysis

Waterfowl use of wetlands was divided into 4 categories for statistical analysis: ducklings of all species (total ducklings), including dabbling ducklings (tribe Anatini) and diving ducklings (tribes Aythyini, Mergini); adult dabbling and diving ducks; all waterfowl/waterbirds, including adults and juveniles of ducks, geese and swans (tribes Anatini, Aythyini, Mergini, and Anserini) and loons (genus Gavia); and swans only (trumpeter swans (Cygnus buccinator) and/or tundra swans (Cygnus columbianus). Six species of duck broods (Table 2), 12 species of adult ducks, 2 species of loons and 2 species of swans (Table 3), occurred in surveys and were used in the analysis.

Table 2. Number and species of duck broods observed in the Kvichak study area in 1992 and 1993[a].

Species	1992 # Broods	1992 # Ducklings	1993 # Broods	1993 #Ducklings
Scaup[1]	1(5)[3]	1(2)[4]	1(17)[3]	9(30)[4]
Black Scoter	1(5)	2(3)	0(0)	0(0)
White-winged Scoter	0(0)	0(0)	0(0)	0(0)
Mallard	3(15)	11(17)	2(33)	11(37)
Goldeneye[2]	0(0)	0(0)	0(0)	0(0)
Pintail	2(10)	5(8)	1(17)	2(7)
Oldsquaw	0(0)	0(0)	0(0)	0(0)
Green-winged Teal	2(10)	10(16)	0(0)	0(0)
Wigeon	4(20)	12(19)	0(0)	0(0)
Hooded Merganser	0(0)	0(0)	0(0)	0(0)
Bufflehead	0(0)	0(0)	0(0)	0(0)
Unidentified	7(35)	22(35)	2(33)	8(27)
Total	20(100)	63(100)	6(100)	30(100)

[a] adult birds were seen of all species listed
[1] includes both greater and lesser scaup
[2] includes both common and barrow's goldeneye
[3] percent of total broods in parenthesis
[4] percent of total ducklings in parenthesis

Table 3. Number and species of waterbirds observed on wetlands surveyed in the Kvichak study area in 1992 and 1993.

Species	1992	1993	Total
Swans[1]	54(11)[a]	69(9)[b]	123(10)[c]
Scaup[2]	208(42)	202(27)	410(33)
Black Scoter	129(26)	361(48)	490(39)
White-winged Scoter	16(3)	4(0.5)	20(2)
Red Breasted Merganser	1(0.2)	4(0.5)	5(0.3)
Common Loon	7(1)	15(2)	22(2)
Arctic Loon	21(4)	8(1)	29(2)
Mallard	10(2)	5(0.7)	15(1)
Goldeneye[3]	6(1)	2(0.3)	8(0.6)
Pintail	9(2)	2(0.3)	11(0.9)
Oldsquaw	1(0.2)	4(0.5)	5(0.4)
Green-winged Teal	11(2)	3(0.4)	14(1)
Wigeon	5(1)	1(0.1)	6(0.5)
Hooded Merganser	6(1)	0(0)	6(0.5)
Bufflehead	3(0.6)	0(0)	3(0.2)
Unidentified	11(2)	77(10)	88(7)
Total	498(100)	757(100)	1255(100)

[1] includes tundra swans adult and cygnets
[2] includes both greater and lesser scaup
[3] includes both common and barrow's goldeneye
[a] percent of total for 1992
[b] percent of total for 1993
[c] percent of total for both years

To reduce dimensionality of wetland variables I calculated scores for each wetland along the first 3 principal components derived from wetland variables. Transparency and aquatic invertebrates where excluded from all multivariate analysis. Transparency exceeded wetland depth in most wetlands, and aquatic invertebrates were collected on a limited number of wetlands in only 1993, resulting in too few data points for each variable. Factor score coefficients were based on the correlation matrix of the original variables (Johnson and Wichern 1988). To more easily recognize the relationship between wetland characteristics and brood use of wetlands, 95% confidence ellipses of the first 2 principal component scores for wetlands used by duck broods of all species, adult ducks, all species of waterbirds and swans were plotted separately for the first 2 principal components. The confidence ellipses of the first 3 principal components are also included in appendix 3 for a 3 dimensional comparison.

Stepwise multiple regression was used to determine which wetland habitat variables were most strongly related to waterfowl use (Draper and Smith 1980). All species of duck broods combined, adult ducks, total waterbirds and swans were used as the dependent variables in 4 separate analysis. Before regression analysis, variables were tested for multicollinearity by examining a correlation matrix of all variables and eliminating 1 variable from each with a correlation ≥0.70 (Bowyer et al. 1988, table 6). The final regression model was tested for aptness by plotting residuals against fitted dependent variables (Neter et al. 1985). Finally, the Durbin-Watson test for autocorrelation was performed on the final model to ensure that no correlation existed among error terms (Neter et al. 1985). This allowed me to determine if any important variables were not included in the final model or mistakenly eliminated because of autocorrelation with other variables. All statistical analysis were performed using StatSoft Statistica software packages (StatSoft 1994).

The conductivity of natural waters is closely related to concentrations of the major ions present (Wetzel 1983). Conductivity of wetlands ranged from 5 to 468 μS/cm, with lowest average conductivity in moraine wetlands and highest conductivity in rivers and connected wetlands (Table 5). Salinity concentrations from 6 major ions reflect similar patterns as conductivity measures in the 4 strata; lowest average concentrations in moraine wetlands and higher in rivers and closed and connected wetlands (Table 5).

Results

Limnological Variables

Wetlands ranged in surface area from <0.5 to 668 ha (Table 4). Connected wetlands had the largest sampled average surface area (60 ha), followed in order by rivers, moraine and closed wetlands (Table 5). Wetlands averaged 1.32 m deep overall (Table 4). Moraine wetlands had the highest mean depth (3.97 m), while mean depths of closed wetlands were 1.0 m (Table 5). No depth measurements were taken on the rivers because of swift currents, but estimated depths probably did not exceed 2 m (personal observation). Shoreline length, which was measured from aerial photos taken in mid summer, ranged from 187 to 12,425 m (Table 4), and was greatest in rivers and lowest in closed wetlands (Table 5). Shoreline development indices ranged from 1.02 (nearly circular closed wetlands) to 3.57 (very long irregular shorelines of the rivers, Tables 4,5).

Wetland surface water color ranged from zero (very clear, unmeasurable color) to 275 PtU (heavily stained), with a mean value of 47 PtU (Table 4). Color varied somewhat across strata; rivers and moraine wetlands were clear while connected and closed tundra ponds were more highly stained (Table 4).

Secchi disk transparencies exceeded wetland depth in 78% of the wetlands in 1992 and 68% in 1993 (Appendix 2). Even heavily stained wetlands were often too shallow to measure transparency. In those wetlands were it could be measured, Secchi transparency averaged 2.0 m across all strata (Tables 4, 5).

Surface water temperature averaged 16 ^{o}C across all wetlands (Table 4), rivers were coolest while moraine wetlands were most warm (Table 5). Wetland pH was near neutral in each stratum and averaged 7.12 overall (Tables 4,5).

Total alkalinity ranged from 0.0 (unmeasurable with field kits) to 47 mg/L $CaCO_3$ (Table 4), with highest alkalinities in rivers and connected wetlands and lowest alkalinities in moraine wetlands (Table 5).

Total phosphorous and total nitrogen levels ranged from 4.0 to 409 µg/L and 0.03 to 1.55 mg/L respectively (Table 4). River strata had higher average total phosphorous concentrations and moraine wetlands lower average phosphorous concentrations than other strata (Table 5). Connected wetlands averaged higher in total nitrogen while rivers averaged lowest (Table 5), although wetlands in all strata were relatively close to the 0.37 mg/L average overall (Table 4).

Table 4. Descriptive statistics of 20 variables measured within the Kvichak study area in 1992 and 1993.

Variable[a]	N	Mean	S.E.	Minimum	Maximum
Invert	31	0.140	0.071	0.004	2.223
Trans	60	2.02	0.34	0.25	11.0
Temp	204	5.58	0.21	9.1	26.16
pH	192	7.12	0.04	5.5	9.45
Cond	208	29.50	2.46	4.65	467.5
T. Alk	206	8.18	0.53	0.0	46.5
Color	204	47.28	3.27	0.0	275.0
TP	174	36.09	3.39	4.0	409.0
TN	174	0.37	0.02	0.03	1.55
Ca	174	1.04	0.08	0.03	7.68
Mg	174	0.67	0.04	0.06	3.54
K	174	0.64	0.15	0.08	25.0
Na	174	2.72	0.15	0.76	14.1
Cl	174	2.19	0.68	0.20	119.5
SO_4	173	0.42	0.04	0.05	3.3
Chloroa	208	4.58	0.44	0.052	63.52
Surface	209	51.70	6.24	0.32	667.9
SLL	209	2531.6	142.8	187.2	12425.4
SLD	209	1.30	0.03	1.02	3.57
Ave Depth	183	1.32	0.11	0.10	8.61

[a] Explanation of variable abbreviations in Appendix 1.

Table 5. Mean and standard error of wetland characteristics within each habitat stratum in the Kvichak study area in 1992 and 1993.

	WETLAND TYPE			
Variable[a]	**Connected Wetland**	**Closed Wetland**	**Moraine**	**River**
Invert	0.3074±(0.4073)	0.0676±(0.0372)	0.0193±(0.0116)	-
Trans	0.82±(0.24)	1.34±(0.57)	6.20±(1079)	-
Temp	15.36±(0.70)	15.57±(0.55)	16.52±(1.37)	14.51±(2.14)
pH	7.20±(0.12)	7.06±(0.12)	7.25±(0.23)	7.11±(0.22)
Cond	31.94±(4.07)	30.31±(7.73)	13.40±(5.24)	44.62±(5.10)
T. Alk	9.97±(1.86)	7.98±(1.33)	2.23±(1.68)	13.80±(1.87)
Color	56.5±(11.5)	46.3±(7.9)	20.8±(15.1)	13.3±(15.8)
TP	39.29±(6.34)	38.78±(10.56)	9.64±(2.30)	48.67±(74.42)
TN	0.4014±(0.0418)	0.3949±(0.0462)	0.1748±(0.0356)	0.1107±(0.0215)
Ca	1.29±(0.24)	0.91±(0.15)	0.73±(0.79)	2.64±(0.09)
Mg	0.82±(0.13)	0.66±(0.12)	0.25±(0.12)	0.93±(0.36)
K	0.53±(0.07)	0.76±(0.49)	0.36±(0.07)	0.47±(0.15)
Na	3.06±(0.41)	2.78±(0.44)	1.43±(0.25)	2.19±(0.33)
Cl	1.55±(0.31)	2.77±(2.30)	1.29±(0.23)	0.73±(0.13)
SO_4	0.45±(0.12)	0.42±(0.10)	0.29±(0.13)	1.07±(0.44)
Chloroa	5.28±(1.17)	4.83±(1.32)	1.11±(0.34)	1.03±(0.55)
Surface	60.46±(12.70)	46.39±(17.89)	53.1±(49.32)	56.15±(67.68)
SLL	3039.3±(417.9)	2061.5±(301.4)	3273.3±(1578.8)	4488.1±(2007.4)
SLD	1.27±(0.06)	1.22±(0.04)	1.73±(0.32)	2.24±(0.46)
Ave Depth	2.72±(3.28)	1.02±(0.20)	3.97±(0.90)	-

[a] Explanation of variable abbreviations in Appendix 1.

Biological Variables

Chlorophyll a concentrations averaged higher in connected wetlands (5.28 mg/L) than the other strata (Table 5).

Seven classes, 5 orders, 5 suborders, and 20 families of aquatic invertebrates from 8 phyla occurred in sampled wetlands (Appendix 4). No aquatic invertebrate samples were taken in the river strata. Moraine wetlands had fewer invertebrate taxa (Appendix 4), and lower biomass than the other strata, while connected wetlands had the highest biomass of invertebrates (Table 5). Predacious diving beetle larva (dytiscidae), mosquito larva (culicidae), black fly larva (simuliidae), hydra (hydridae), lymnaeid snails, nemtodes and gordian worms (gordiidae) were found only in closed wetlands (Appendix 4). Midge larva (ceratopogonidae) and leptophlebiid may flies were found only in connected wetlands while caddis flies (leptoceridae) were found only in moraine wetlands (Appendix 4). Aquatic earth worms (oligochaeta), chrimomid midge larva, limnephilid caddis flies, planorbid snails and fingernail clams (sphaeriidae) were found in all strata (Appendix 4).

Thirty species of aquatic emergent, submergent and upland plants where recorded in wetlands or near shorelines (Appendix 5). The river and moraine wetland strata were devoid of aquatic vegetation. No truly aquatic plant species were found in the river stratum; the main species recorded where willows along the riverbank. Most moraine wetlands had no aquatic plants, although bureed, water shield, and pond lily occurred in some moraine wetlands that had shallower areas. Most aquatic plant species occurred in both connected and closed wetlands with the exception of manna grass, cotton grass, labrador tea, marsh fivefinger, lingonberry, sweet gale, spike rush, water hemlock and pondweed (Potomogeton natans) found only in and around hydrologically closed wetlands (Appendix 5). A fern species (probably Thelypteris phegopteris) occurred only in the elevated upland areas around moraine wetlands.

Brood Use/Overall Waterbird Use

Duck broods of 6 species were recorded within the study area. American wigeon (Anas americana), green-winged teal (Anas crecca), mallard (Anas platyrhynchos) and northern pintail (Anas acuta) were the most abundant species of broods in both years (Table 2). Even though 6% more wetlands were surveyed in 1993 than in 1992, 52% fewer ducklings were recorded in 1993 compared to 1992 (Table 2). In 1992 and 1993, 100% and 93%, respectively, of all ducklings observed were seen on connected or closed wetlands (Tables 6, 7). No broods were recorded on the river strata in either year (Tables 6, 7). Scaup broods (Aythya spp.) were seen only on closed wetlands in both years while green-winged teal (Anas crecca), were seen only on connected wetlands.

Table 6. Number of ducklings of each species observed within each habitat type in the Kvichak study area in 1992.

	WETLAND TYPE				
Species	Connected Wetlands	Closed Wetlands	Moraine Wetlands	River	Total
Scaup[a]	0(0)[b]	1(6)	0(0)	0(0)	1(2)
Black Scoter	0(0)	0(0)	0(0)	0(0)	0(0)
Mallard	0(0)	2(12)	0(0)	0(0)	2(3)
Pintail	0(0)	2(12)	0(0)	0(0)	2(3)
Green-winged Teal	10(24)	0(0)	0(0)	0(0)	10(17)
Wigeon	5(12)	7(41)	0(0)	0(0)	12(21)
Unidentified	26(64)	5(29)	0(0)	0(0)	31(54)
Total	41(100)	17(100)	0(0)	0(0)	58(100)

[a] includes both greater and lesser scaup
[b] number in parenthesis equal percent of total ducklings within each stratum

Table 7. Number of ducklings of each species observed within each habitat type in the Kvichak study area in 1993.

	WETLAND TYPE				
Species	Connected Wetlands	Closed Wetlands	Moraine Wetlands	River	Total
Scaup[a]	0(0)[b]	9(53)	0(0)	0(0)	9(30)
Black Scoter	0(0)	0(0)	0(0)	0(0)	0(0)
Mallard	7(64)	4(24)	0(0)	0(0)	11(37)
Pintail	0(0)	0(0)	2(100)	0(0)	2(7)
Green-winged Teal	0(0)	0(0)	0(0)	0(0)	0(0)
Wigeon	0(0)	0(0)	0(0)	0(0)	0(0)
Unidentified	4(36)	4(23)	0(0)	0(0)	8(26)
Total	11(100)	17(100)	2(100)	0(0)	30(100)

[a] includes both greater and lesser scaup
[b] number in parenthesis equal percent of total ducklings within each stratum

Fifteen species of adult waterbirds were also seen on the study area. Swans (Cygnus buccinator, C. columbianus), scaup (Aythya spp.) and black scoter (Melanitta nigra) were the most abundant species seen in both years (Table 3). Twenty percent more waterbird species were seen in 1993 than in 1992 (Table 3). In both 1992 and 1993, 99% of all waterbirds seen were observed on connected and closed wetlands (Tables 8,9). Connected wetlands were most used overall with 65% of the total birds observed in both years (Tables 8,9). No waterbirds were recorded on the river stratum in either year.

Statistical Analysis

All habitat variables were originally included in principal component analysis and multiple stepwise regression. The results from these analysis indicated shoreline length, sodium and magnesium were the dominant factors associated with brood use of wetlands. It appeared that sodium and magnesium were an overall measure of cation concentration. At the same time, shoreline length was highly correlated with adult ducks and total waterbirds, but the analysis did not account for the density of birds using wetlands. Therefore, to allow other variables to enter the analysis, salinity variables were combined in a second analysis that used major cations and anions other than carbonates in place of each ion separately. A third analysis also used density (ducklings or adult ducks or waterbirds/shoreline length) as the dependent variable in multiple stepwise regression. The results of all 3 analysis are reported.

Table 8. Number of adult waterbirds of each species observed within each habitat type in the Kvichak study area in 1992.

	WETLAND TYPE				
Species	Connected Wetlands	Closed Wetlands	Moraine Wetlands	River	Total
Swans[a]	33(11)[b]	21(13)	0(0)	0(0)	54(54)
Scaup[c]	159(52)	46(29)	0(0)	0(0)	205(43)
Black Scoter	64(21)	61(38)	3(50)	0(0)	128(27)
White-winged Scoter	10(3)	6(4)	0(0)	0(0)	16(3)
Red-breasted Merganser	0(0)	1(4)	0(0)	0(0)	1(<1)
Common Loon	0(0)	5(3)	2(33)	0(0)	7(1)
Arctic Loon	17(6)	3(2)	1(17)	0(0)	21(4)
Mallard	3(4)	4(3)	0(0)	0(0)	7(1)
Goldeneye[d]	2(4)	4(3)	0(0)	0(0)	6(1)
Pintail	2(<1)	5(3)	0(0)	0(0)	1(<1)
Oldsquaw	0(0)	1(<1)	0(0)	0(0)	1(<1)
Green-winged Teal	7(2)	2(1)	0(0)	0(0)	9(2)
Wigeon	1(<1)	0(0)	0(0)	0(0)	1(<1)
Hooded Merganser	6(2)	0(0)	0(0)	0(0)	6(1)
Bufflehead	3(1)	0(0)	0(0)	0(0)	3(1)
Unidentified	0(0)	0(0)	0(0)	0(0)	0(0)
Total	307(100)	159(100)	6(100)	0(0)	472(100)

[a] tundra swans
[b] number in parenthesis equals percent of each species in each stratum
[c] includes both greater and lesser scaup
[d] includes both common and barrow's goldeneye

Table 9. Number of adult waterbirds of each species observed within each habitat type in the Kvichak study area in 1993.

Species	WETLAND TYPE Connected Wetlands	Closed Wetlands	Moraine Wetlands	River	Total
Swans[a]	37(8)[b]	32(13)	0(0)	0(0)	69(9)
Scaup[c]	140(29)	55(22)	1(10)	0(0)	195(26)
Black Scoter	237(49)	124(50)	0(0)	0(0)	361(48)
White-winged Scoter	2(<1)	2(<1)	0(0)	0(0)	4(<1)
Red-breasted Merganser	0(0)	0(0)	4(40)	0(0)	4(<1)
Common Loon	2(4)	8(3)	5(50)	0(0)	15(2)
Arctic Loon	0(0)	8(3)	0(0)	0(0)	8(1)
Mallard	0(0)	3(1)	0(0)	0(0)	3(<1)
Goldeneye[d]	1(<1)	1(<1)	0(0)	0(0)	2(<1)
Pintail	0(0)	1(<1)	0(0)	0(0)	1(<1)
Oldsquaw	1(<1)	3(1)	0(0)	0(0)	4(1)
Green-winged Teal	3(<1)	0(0)	0(0)	0(0)	3(<1)
Wigeon	0(0)	1(<1)	0(0)	0(0)	1(<1)
Hooded Merganser	0(0)	0(0)	0(0)	0(0)	0(0)
Bufflehead	0(0)	0(0)	0(0)	0(0)	0(0)
Unidentified	64(13)	12(5)	0(0)	0(0)	76(11)
Total	487(100)	250(100)	10(100)	0(0)	746(100)

[a] tundra swans
[b] number in parenthesis equals percent of each species in each stratum
[c] includes both greater and lesser scaup
[d] includes both common and barrow's goldeneye

Principal Component Analysis

Three biologically interpretable principal components (PC) were developed from the data set of 18 variables. The first 3 principal components accounted for 51% of the variance in the original data (Table 10). Magnesium, sodium, total nitrogen, total alkalinity, conductivity, chlorophyll a, total phosphorous, color and calcium loaded positively on the first principal component while temperature and shoreline development loaded negatively (Table 10). PC2 described a gradient of variables where shoreline length, surface area, and shoreline development varied inversely with temperature, pH, total phosphorous and chlorophyll a. On PC3, chlorophyll a, total nitrogen and total phosphorous load positively, and chloride and conductivity load negatively.

Table 10. Factor loadings for each variable along principal component axes 1, 2 and 3.

Habitat Variable	PC1	PC2	PC3
Total Nitrogen	0.738	-0.056	0.331
Total Phosphorous	0.590	-0.204	0.325
Chloride	0.482	-0.063	-0.778
Sulfate	0.478	-0.118	-0.466
Calcium	0.550	0.164	0.082
Magnesium	0.824	0.007	-0.178
Sodium	0.804	-0.116	-0.194
Potassium	0.129	-0.051	-0.246
Average Depth	0.070	0.041	0.025
Surface Area	0.184	0.738	0.106
Shoreline Length	0.159	0.920	0.045
Shoreline Development	-0.132	0.511	-0.124
Temperature	-0.316	-0.466	-0.013
pH	0.387	-0.294	0.236
Conductivity	0.697	-0.012	-0.665
Total Alkalinity	0.712	0.059	0.203
Color	0.581	0.091	0.089
Chlorophyll a	0.691	-0.112	0.386
Cumulative variance accounted for		50.7%	

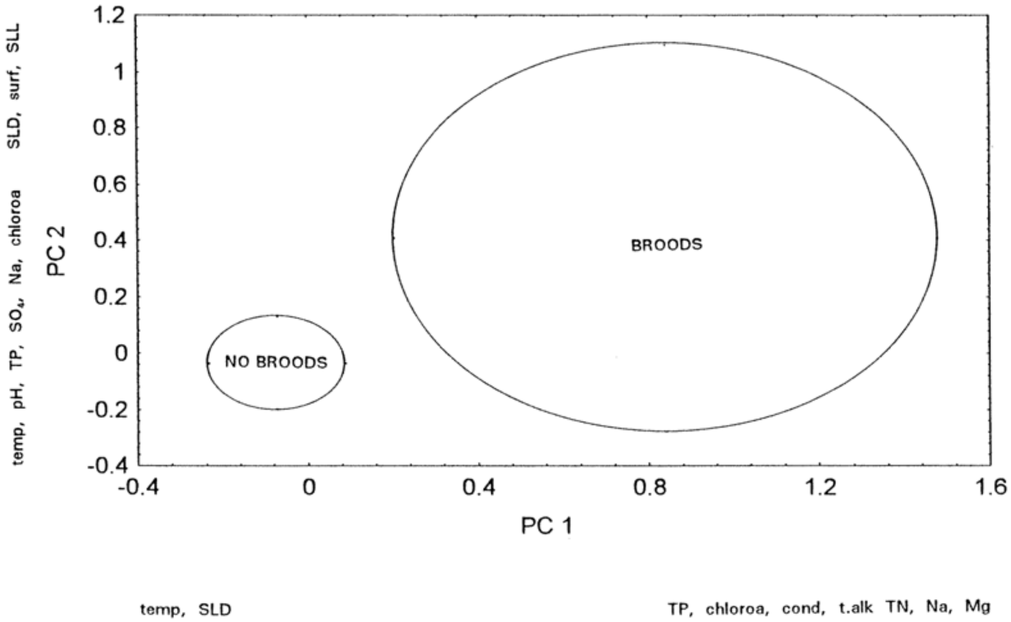
When cations and anions other than carbonates where each combined, the first three principal components accounted for 55% of the variance in the original data (Table 11). Total nitrogen, chlorophyll a, cations, total alkalinity, conductivity, total phosphorous and color loaded positively on PC1, while temperature and shoreline development loaded negatively (Table 11). On PC2, shoreline length, surface area and shoreline development loaded positively as temperature, pH, and total phosphorous were negative. On PC3, chlorophyll a, total phosphorous and total nitrogen were positive while anions and conductivity where negative (Table 11).

Table 11. Factor loadings for each variable along principal component axes 1, 2 and 3 with cations and anions each combined.

Habitat Variable	PC1	PC2	PC3
Total Nitrogen	0.779	-0.073	0.290
Total Phosphorous	0.628	-0.242	0.302
Total Anions	0.469	0.009	-0.816
Total Cations	0.750	-0.088	-0.117
Average Depth	0.071	0.025	0.001
Surface Area	0.224	0.731	0.154
Shoreline Length	0.178	0.905	0.112
Shoreline Development	-0.143	0.511	-0.065
Temperature	-0.373	-0.492	-0.05
pH	0.407	-0.311	0.183
Conductivity	0.636	0.021	-0.748
Total Alkalinity	0.660	-0.028	0.080
Color	0.620	0.116	0.076
Chlorophyll a	0.764	-0.140	0.355
Cumulative variance accounted for		54.9%	

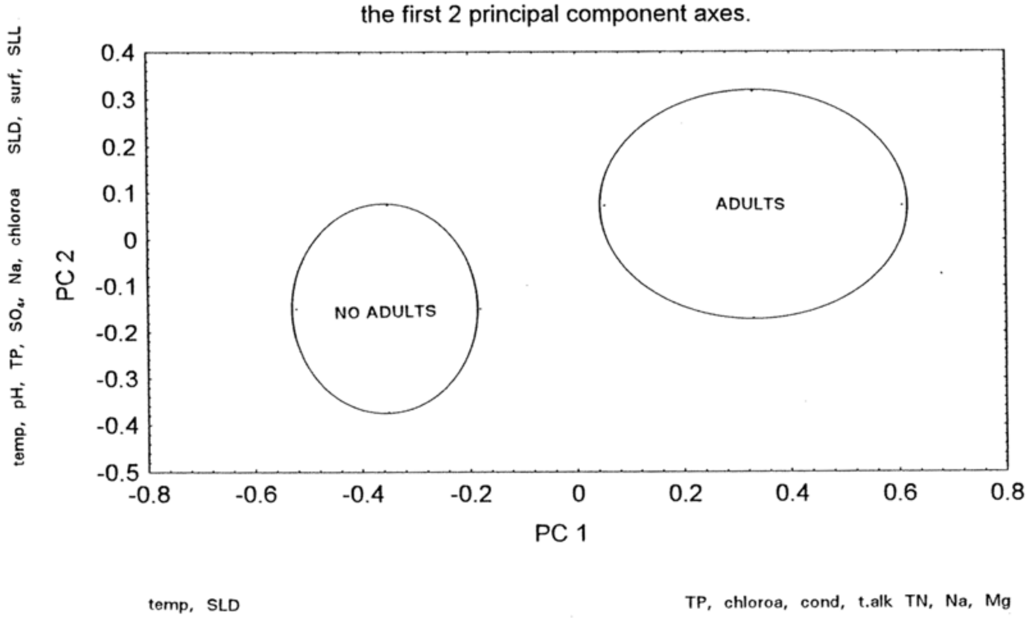
Wetlands with ducklings of all species had significantly higher PC scores along PC1 (t_{137}=-2.99) than wetlands with no page ducklings (Figure 2). Wetlands with adult ducks of all species had significantly higher PC scores along PC1 (t_{137}=-3.79, Figure 3). Wetlands with waterbirds of any species (t_{137}=-3.46) as well as wetlands with swans (t_{137}=-3.11) also had significantly higher PC scores along PC1 (Figures 4,5).

Figure 2. The 95% confidence ellipses of wetlands with at least one brood and wetlands with no broods along the first 2 principal component axes.



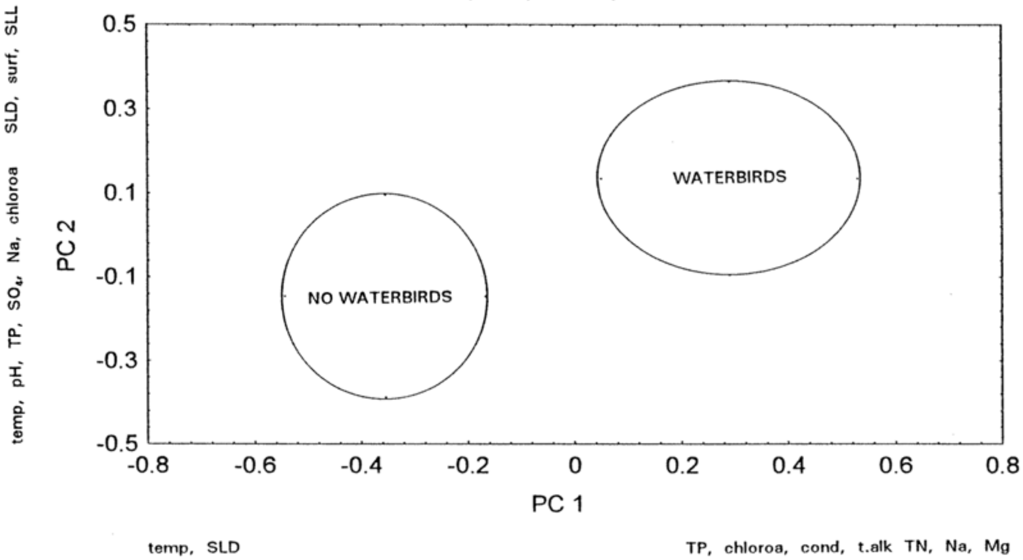
Explanation of variable abbreviations in Appendix 1.

Figure 3. The 95% confidence ellipses of wetlands with at least 1 species of adult duck and wetlands with no ducks along the first 2 principal component axes.



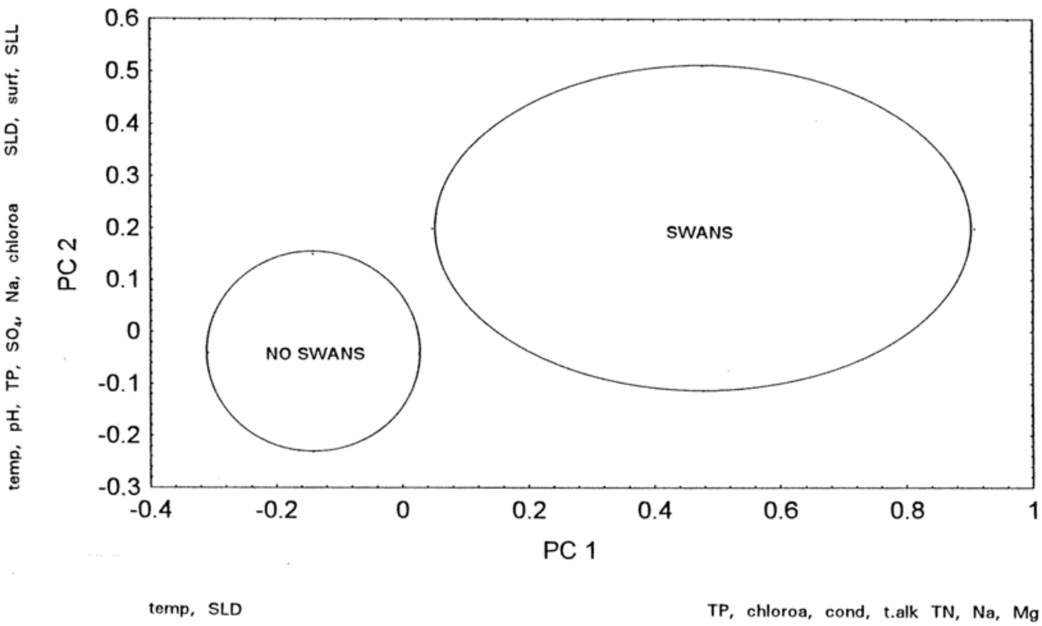
Explanation of variable abbreviations in Appendix 1.

Figure 4. The 95% confidence ellipses of wetlands with at least 1 species of waterbirds and wetlands with no waterbirds along the first 2 principal component axes.



Explanation of variable abbreviations in Appendix 1.

Figure 5. The 95% confidence ellipses of wetlands with at least 1 swan and wetlands with no swans along the first 2 principal component axes.



Explanation of variable abbreviations in Appendix 1.

Regression Models

In all regression models where cations and anions where analyzed separately, aquatic invertebrates, transparency, magnesium, chloride and total nitrogen were removed from the analysis because of high correlations with other variables (Table 12). When salinity variables where combined, and when the density (birds/meter of shoreline) was used as the dependent variable, aquatic invertebrates, transparency and total nitrogen were excluded.

Table 12. Correlation Matrix for 20 habitat variables[a]

	TN	TP	CL	SO_4	Ca	Mg	Na	K	AD	Surf	SLL	SLD	Trans	Temp	pH	Cond	T. Alk	Color	Chlor	Invert
TN	1.00	.53	.17	.26	.24	.47	.66	.05	.01	.16	.12	-.20	-.51	-.18	.27	.29	.48	.48	.74	.04
TP	.53	1.00	.10	.23	.26	.42	.44	.06	-.02	.01	-.00	-.12	-.47	-.09	.18	.23	.44	.31	.65	.12
CL	.17	.10	1.00	.47	.05	.39	.23	.18	-.02	.02	.00	-.01	-.11	-.13	.05	.88	.06	.22	.18	.19
SO_4	.26	.23	.47	1.00	.14	.33	.24	.05	.01	-.04	.00	.04	-.25	-.12	.12	.49	.09	.31	.24	.23
Ca	.24	.26	.05	.14	1.00	.66	.40	.04	.07	.10	.22	.16	-.12	-.04	.14	.35	.63	.13	.21	.46
Mg	.47	.42	.39	.33	.66	1.00	.65	.12	.04	.11	.13	-.06	-.43	-.13	.22	.71	.75	.36	.37	.25
Na	.66	.44	.23	.24	.40	.65	1.00	.09	.05	.06	.04	-.11	-.49	-.18	.36	.44	.54	.53	.58	.35
K	.05	.06	.18	.05	.04	.12	.09	1.00	.03	-.02	-.02	.03	.02	-.05	.08	.18	.05	.05	.07	.16
AD	.01	-.02	-.02	.01	.07	.04	.05	.03	1.00	.00	.03	.02	.87	-.02	.01	.04	.12	.03	.04	-.19
Surf	.16	.01	.02	-.04	.10	.11	.06	-.02	.00	1.00	.68	.05	-.18	-.24	-.04	.08	.13	.13	.09	.24
SLL	.12	-.00	.00	.00	.22	.13	.04	-.02	.03	.68	1.00	.51	.06	-.23	-.09	.08	.16	.08	.08	.41
SLD	-.20	-.12	-.01	.04	.16	-.06	-.11	.03	.02	.05	.51	1.00	.48	.00	.00	-.03	-.05	-.10	-.09	.18
Trans	-.51	-.47	-.11	-.25	-.12	-.43	-.49	.02	.87	-.18	.06	.48	1.00	.44	-.06	-.22	-.43	-.57	-.35	-.11
Temp	-.18	-.09	-.13	-.12	-.04	-.13	-.18	-.05	-.02	-.24	-.23	.00	.44	1.00	-.04	-.12	-.02	-.25	-.14	-.24
pH	.27	.18	.05	.12	.14	.22	.36	.08	.01	-.04	-.09	.00	-.06	-.04	1.00	.12	.18	.09	.35	.02
Cond	.29	.23	.88	.49	.35	.71	.44	.18	.04	.08	.08	-.03	-.22	-.12	.12	1.00	.43	.27	.23	.44
T. Alk	.48	.44	.06	.09	.63	.75	.54	.05	.12	.13	.16	-.05	-.43	-.02	.18	.43	1.00	.22	.37	-.07
Color	.48	.31	.22	.31	.13	.36	.53	.05	.03	.13	.08	-.10	-.57	-.25	.09	.27	.22	1.00	.48	.08
Chlor	.74	.65	.18	.24	.21	.37	.58	.07	.04	.09	.08	-.09	-.35	-.14	.35	.23	.37	.48	1.00	.12
Invert	.04	.12	.19	.23	.46	.25	.35	.16	-.19	.24	.41	.18	-.11	-.24	.02	.44	-.07	.08	.12	1.00

[a] Explanation of variable abbreviations in appendix 1.

I conducted stepwise multiple regression for all species of adult ducks combined, for all species of ducklings combined, for all waterbird species, and for swans. Using 15 variables, stepwise regression models identified 6 habitat variables that most strongly influence use of wetlands by ducklings, adult ducks or all waterbirds. For all species of duck broods with ions separated, sodium was the only significant variable that contributed to the variation in habitat use (R^2=0.11, Table 13). When ions were combined, total cations explained 8% of the variation in use (Table 13). When density of ducklings was used, sodium (R^2=0.07), chlorophyll a (R^2=0.03) and pH (R^2=0.03) accounted for 15% of the variation in use by all species of ducklings (Table 13).

Table 13. Stepwise multiple regression equations showing the relationship between all species of duck broods and 15 habitat variables on wetlands within the Kvichak study area.

WITH IONS SEPARATED

TOTAL # DUCKLINGS = -0.423 + 0.325 (sodium)
R^2=0.11 p=0.0001

WITH IONS COMBINED

TOTAL # DUCKLINGS = -0.312 + 0.289 (Total Cations)
R^2=0.08 p=0.0006

AS DUCKLINGS/SHORELINE LENGTH

TOTAL # DUCKLINGS = -0.002 + 0.323 (sodium) - 0.25 (chlorophyll a) + 0.204 (pH)
R^2=0.13 p=0.0002

For adult ducks analyzed with ions separated and with ions combined, total alkalinity (R^2=0.12) and shoreline length (R^2=0.03) explained 15% of duck use (Table 14). When analyzed by density, chlorophyll a explained 19% of the adult duck use of wetlands (Table 14).

Table 14. Stepwise multiple regression equations showing the relationship between all species of adult ducks and 15 habitat variables on wetlands within the Kvichak study area.

WITH IONS SEPARATED

TOTAL # DUCKS = -0.997 + 0.319 (total alkalinity) + 0.176 (shoreline length)
R^2=0.15 p=0.00011

WITH IONS COMBINED

TOTAL # DUCKS = -0.997 + 0.319 (total alkaklinity) + 0.176 (shoreline length)
R^2=0.15 p=0.00002

AS DUCKS/SHORELINE LENGTH

TOTAL # DUCKS = 0.0009 + 0.438 (chlorophyll a)
R^2=0.19 p=0.00000

For waterbirds of all species, total alkalinity (R^2=0.14) and shoreline length (R^2=0.03) explained 17% of the waterbird use when cations and anions where either separated or combined (Table 15). Chlorophyll a (R^2=0.18) and total alkalinity (R^2=0.03) accounted for 21% of the variation in use when the density of waterbirds was used as the dependent variable (Table 15).

When stepwise regression analysis was run for swans, no variables were significant, suggesting that there was no relationship between the 15 habitat variables and use of wetlands by swans.

Table 15. Stepwise multiple regression equations showing the relationship between all species of waterbirds and 15 habitat variables on wetlands within the Kvichak study area.

WITH IONS SEPARATED

TOTAL # WATERBIRDS = -0.905 + 0.346 (total alkalinity) + 0.189 (shoreline length)
R^2=0.18 p=0.00002

WITH IONS COMBINED

TOTAL # WATERBIRDS = -0.905 + 0.346 (total alkalinity) + 0.189 (shoreline length)
R^2=0.18 p=0.000002

AS WATERBIRDS/SHORELINE LENGTH

TOTAL # WATERBIRDS = 0.0007 + 0.353 (chlorophyll a) + 0.199 (total alkalinity)
R^2=0.21 p=0.00000

Discussion

Hydrology

Murphy et al. (1984) suggested that hydrologic connection to flowing water is an important factor in the nutrient dynamics of Interior Alaska wetlands and is reflected in the patterns of habitat use by ducks. In the Iditarod George block of the Lower Innoko River area, morphological variables and some chemical and biological variables were significantly different between hydrologically closed and connected wetlands suggesting hydrology affected the chemical composition of the wetlands there (Seppi 1993). In the Kvichak area, I found no significant difference in limnological characteristics between closed and connected wetlands when all variables were compared with a multivariate T-test (Hotelling's T^2=27.42, p<0.1788). However T-tests for 4 individual variables were significant (calcium p= 0.0027, magnesium p=0.0159, shoreline length p=0.0029, total alkalinity p=0.0086) suggesting hydrology may influence the chemical composition of wetlands in the study area.

The wetlands in the Kvichak area were not as hydrologically distinct as those in Lower Innoko River area. In fact, the hydrology of many wetlands was apparent only from aerial photos, and was often difficult to determine. Some wetlands were connected to ephemeral drainages and were difficult to classify as hydrologically connected or closed. Hydrology is important in controlling the chemical and biological characteristics of aquatic systems (Gosselink and Turner 1978), and the results of this study indicate that wetland hydrology does influence the nutrient and cation concentrations in ponds. Connected wetlands were higher in total nitrogen, total phosphorous, calcium, magnesium, sodium, sulfate and chlorophyll a than closed wetlands (Table 5). More broods were found in connected wetlands in 1992 (Table 6), and 37% of connected wetlands were used by broods in 1993 (Table 7). Waterbirds of all species were most likely to be found on connected wetlands than on closed wetlands, although a substantial number were seen on closed tundra ponds in both years (Tables 8,9).

Brood use data should be interpreted cautiously as it is likely that many of the broods present were missed because they were difficult to see when they took cover in surrounding vegetation, particularly on large wetlands where the float plane was used for access.

Additional evidence of a correlation between water chemistry and use by adult ducks, broods and waterbirds in general is that multiple stepwise regression showed that birds were associated with large, shallow, more productive wetlands with higher cation (sodium) and chlorophyll a concentrations, higher alkalinity and longer shorelines (Tables 13,14,15). The combination of these characteristics was typical of all hydrologically connected and some closed tundra ponds in the study area.

Limnology/Wetland Traits

Cation concentration contributes to salinity and is positively correlated with conductivity (Wetzel 1983, Heglund 1988, 1992, Seppi 1993). Data from this project shows a high correlation between sodium and chloride and conductivity, suggesting that NaCl is the predominant source of ions (Table 12), and probably is influenced by the marine environment, especially in wetlands close to the coast. Conductivity and individual cations loaded positively on PC1 (especially magnesium and sodium, Table 10), as did combined cations (Table 11). PC1 scores imply conductivity and salinity from cation concentrations had a substantial influence on use of wetlands by duck broods and waterbirds of all species (Figures 2,3,4,5). The importance of salinity to duck broods is also suggested by the results from multiple stepwise regression, as sodium emerges as 1 of 2 variables with a major influence on duck brood use when ions are analyzed separately and on a density basis (Table 13).

Swanson et al. (1984) has shown that highly saline water can be toxic to ducklings. Moderate salinity levels have been related to the density of waterfowl broods in boreal forest wetlands (Heglund 1988, 1992, Seppi 1993), and on the prairies (Swanson et al. 1988, Swanson and Duebbert 1989). Moderately saline wetlands have also been associated with adult waterbirds (Heglund 1992). Levels of salinity in the Lower Innoko River area are less than 500 µS/cm and considered fresh (mean=67.5 µS/cm, Seppi 1993), as are salinity levels in the Kvichak area (mean=29.5 µS/cm, Table 4), and both are far lower than average salinities on prairie wetlands (Stewart and Kantrud 1971). The positive correlation between brood use in the Innoko River area and duck brood/waterbird use I found in the Kvichak area seems to apply to slightly or moderately saline wetlands (Seppi 1993), but becomes lethal to duck broods at very high levels (Swanson et al. 1984).

Total alkalinity is a measure of the buffering capacity of water resulting from the alkaline contributions of the negative ions of salts of weak acids (APHA 1985). Alkalinity was measured in this study as mg/L as $CaCO_3$. Total alkalinity loaded strongly on PC1 (Tables 10,11), and comparisons of wetlands with and without use by broods, adult ducks, waterbirds and swans with principal component axes 1 and 2 imply that all categories of birds were using wetlands with higher total alkalinities than wetlands were no birds were found (Figures 2,3,4,5). In addition, stepwise multiple regression implies a correlation with total alkalinity and adult duck use with ions separated (R^2=0.12, p=0.00011) and combined R^2=0.12, p=0.00002, Table 14), as well as with use by all waterbirds (ions separated and combined R^2=0.14, p=0.00002), and by density of waterbirds (R^2=0.03, p=0.00000, Table 15). Total alkalinity may indirectly influence waterfowl use by providing a higher buffering capacity and thereby providing more favorable conditions to plants and animals that are attractive to waterfowl. This scenario was suggested for the Innoko River area where wetlands with little or no brood use had very low alkalinity and low aquatic invertebrate biomass (Seppi 1993). This relationship between alkalinity and waterfowl use was also found in the Kvichak area, as the majority of duck brood and waterfowl use was on wetlands with the higher alkalinities (Tables 5,6,7,8,9). There are probably other factors involved in this relationship, however, as very little waterfowl use was seen on rivers in the Kvichak area, yet total alkalinity was highest in rivers compared to other strata (Table 5,6,7,8,9).

pH was included in the multiple stepwise regression for ducklings/shoreline length, although the relationship was weak (R^2=0.03, p=0.0002, Table 14). pH loaded moderately on PC1 (Tables 10,11), and factor scores for wetlands with no waterfowl were low, suggesting waterfowl use increased on wetlands with higher pH (Figure 2,3,4,5). Low pH (<6.0) has a negative affect on aquatic invertebrates (Eilers et al. 1984, Bell 1971), including benthic organisms (Haines 1981), although some species are more sensitive than others. McAuley and Longcore (1988) found diets of ring-necked ducklings from high pH wetlands in maine (>6.0) to be more diverse than those from low pH wetlands (<6.0), and suggested retarded growth and lower survival rates could result if ducklings were forced to feed on less nutritious and more mobile species when invertebrate diversity was low. Low pH may therefore indirectly affects wetland use by reducing abundance of invertebrate species important to broods, as well as adult birds. Heglund (1992), found broods of all species of ducklings used wetlands higher in pH, with the exception of deep water divers (ring-necked duck <u>Aythya</u> <u>collaris</u>, barrow's <u>bucephala</u> <u>islandica</u> and common goldeneye <u>Bucephala</u> <u>clangula</u>, bufflehead, <u>Bucephala</u> <u>albeola</u>) which were found in slightly more acidic water. On the Yukon Flats, Alaska, most species of adult waterbirds used wetlands with moderate to high pH, although deep water divers and loons tended to use wetlands with pH ≤7.0 (Heglund 1992). In the Kvichak area, all strata had pH values very near 7.0 (Table 5). The relationship between pH and waterfowl use of wetlands I found is weak, but this may be attributed to the narrow range of pH of wetlands in the Kvichak area (5.5 to 9.5, Table 4). In addition many species adult waterfowl may be habitat generalists, especially post-breeding males and unmated pairs, making relationships with any habitat variable hard to detect.

Temperature loaded negatively on PC1 (Tables 10,11), and PC1 scores for wetlands used by waterfowl suggest birds preferred cooler wetlands (Figures 2,3,4,5). This variable is hard to interpret, because surface water temperature may vary depending on weather conditions. Therefore the relationship may actually be artificial and related to other habitat variables, since temperature is not highly negative on PC1 (-0.316 Table 10, -0.373 Table 11). Moraine wetlands tended to be slightly warmer than other strata, yet they did not have any of the characteristics desirable to waterfowl (i.e. shallow depth, cover, plant and invertebrate foods). Therefore I think birds were not actually using wetlands that were cooler, but were using cooler wetlands that provided them with the food and cover which the warmer, moraine wetlands did not provide.

Shoreline development also loaded negatively on PC1 (Tables 10,11), and PC1 scores for wetlands used by waterfowl suggest birds use wetlands with more round, less convoluted shorelines (Figures 2,3,4,5). At the same time, shoreline length emerged as an important factor for use by adult ducks and all species of waterbirds (Table 14,15). Multiple stepwise regressions imply birds occur every 1700 to 1800 meters of shore length on average (Tables 13,14,15). Longer shorelines provide more shallow areas, emergent vegetation and escape cover important to broods and molting waterfowl. Surface area and shoreline irregularity of man-made ponds in Quebec influenced broods use; however those same ponds had abundant emergent vegetation and high densities of aquatic invertebrates which provided broods with adequate cover and food (Belanger and Couture 1988). Small stock ponds in Montana were likely ignored by broods because of the lack of escape cover and food, not because of their small size (Hudson 1983). Shoreline length was also associated with dabbler brood use in South Dakota stock ponds, but wetlands with long shorelines provided more shallow water and emergent shoreline vegetation than wetlands with smaller shore lengths (Mack and Flake 1980). Results from Heglund (1992) again imply a strong relationship between shoreline length and use of wetlands by 6 species of dabbling ducks, 11 species of diving ducks and 6 other species of waterbirds. Shoreline length and shoreline development have both been related to waterbird use in this study, although the two variables are correlated (0.51, Table 12). I believe the relationship with wetland shore length and shape in this study is also a result of birds using wetlands that provide them with the most food and cover, and not of them using wetlands because of there morphological characteristics. Many of the wetlands in the Kvichak area are tundra ponds, which tend to be more circular than the convoluted shorelines of moraine wetlands which lay between the small hills and valleys created by the moraine itself. Large tundra ponds provide waterfowl with shallow depths, and relatively more cover and plant and invertebrate foods than moraine wetlands with long, convoluted shorelines (see shoreline development, Table 5). I believe birds are using the connected and closed tundra ponds more because they have more food and cover yet are more round, not because they have a lower shoreline development than moraine wetlands, which provide lesser amounts of aquatic invertebrate food and cover (Table 5).

Phosphorous and nitrogen are the two most important nutrients governing wetland primary productivity (Kadlec 1979, Wetzel 1983), although phosphorous is more often limiting in aquatic systems and far more important to wetland productivity in comparison to nitrogen (Schindler 1974). Phosphorous concentrations have also been related to annual rates of primary productivity of algae in many lakes world wide (Vollenweider 1979, in Wetzel 1983). Total phosphorous and total nitrogen loaded strongly positively on PC1 (Tables 10,11). The plotted factor scores of wetlands with brood, waterfowl and general waterbird use suggests birds used wetlands higher in total nitrogen and total phosphorous concentrations (Figures 2,3,4,5).

Eutrophication status (level of primary productivity) has been related to concentrations of total phosphorous (Vollenweider 1968); lakes are considered eutrophic if total phosphorous concentrations exceed 20 μg/L. Across all wetlands, total phosphorous concentrations averaged 36 μg/L (Table 4), and wetlands in all habitat strata were above 20 μg/L, except for moraine wetlands (9.64 μg/L, Table 5). This would indicate that all wetlands could be considered in or near a eutrophic state, with the exception of Moraine wetlands. Total phosphorous concentrations were positively correlated with dabbling and diving duck use of oligotrophic lakes in Sweden (Nilsson and Nilsson 1978). This association between phosphorous and waterfowl use was related to higher levels of productivity in more eutrophic lakes. Increases in total phosphorous levels due to pollution also caused higher productivity, but did not lead to higher waterbird species richness in formerly oligotrophic lakes. Similarly, Nilsson (1978) reported breeding waterfowl used naturally more eutrophic lakes more often. However when oligotrophic lakes where polluted with phosphorous, diving species disappeared, and dabbling species first increased then declined with increasing eutrophication (Nilsson 1978). Duck density was directly related to natural levels of phosphate and nitrite in boreal forest wetlands in Alaska (Murphy et al. 1984). Heglund (1988) showed waterbird density, including adult dabbling and diving ducks, to be related to total phosphorous and total nitrogen. Heglund (1992) found associations between omnivorous dabbling broods and total phosphorous concentrations.

A positive relationship between annual average chlorophyll a concentrations and total phosphorous has been found for many lakes (Vollenweider 1979, cited in Wetzel 1983). I found that as chlorophyll a concentrations increased, duck brood density decreased (Table 13), while adult duck and waterbird density increased (Tables 14,15). In addition, total phosphorous and chlorophyll a loaded strongly positively on PC1, and the plotted factor scores of wetlands with duck broods, adult ducks, swans and waterbirds of all species shows a relationship between bird use and wetlands with higher levels of total phosphorous and chlorophyll a (Figures 2,3,4,5), suggesting productive wetlands with higher nutrient levels are attractive to waterbirds. This relationship was apparent in moraine wetlands where total phosphorous and chlorophyll a levels were low, and waterfowl use was low (Tables 5, 6,7,8,9). The negative correlation between chlorophyll a and broods may not be real but a result of an inadequate count of the broods that were actually present. Many large, productive wetlands were used by broods but were not seen during surveys, and suggests a relationship that is probably false.

Aquatic Invertebrates

Aquatic invertebrates are an important source of food for ducklings (Chura 1960, Bartonek and Hickey 1969, Bengston 1971, Sudgen 1973, Krapu and Swanson 1977, Street 1978, Eriksson 1978, Joyner 1980, Talent et al. 1982, Hohman 1985, Jarvis and Noyes 1986). In the prairie pothole region fresh (<500 µS/cm) to slightly brackish (500-2000 µS/cm) wetlands (as defined by Stewart and Kantrud 1971) support the greatest abundance and diversity of aquatic invertebrates (LaBaugh and Swanson 1988, Kantrud et al. 1989a). Submerged aquatic plants play a crucial role in providing habitat for macroinvertebrates (Krull 1970) and are therefore also a major factor in determining their abundance and availability. Aquatic plant communities are themselves important for broods as they provide escape cover (Patterson 1976) and food for some species, particularly in the later stages of development before fledging (Sudgen 1973, Swanson and Duebbert 1989). In the prairie pothole region, Stewart and Kantrud

(1972) found that plant community composition was related to wetland salinity, and that many plant species were intolerant of highly saline conditions. In general, species diversity of aquatic vegetation decreases with increasing salinity (Kantrud et al. 1989b), which in turn reduces potential habitats for aquatic invertebrates. Therefore salinity indirectly influences brood use of wetlands by affecting the potential of wetlands to support the species composition and abundance of aquatic plants and invertebrates that are attractive to waterfowl (Joyner 1980, Swanson et al. 1988, Heglund 1992). Results of this study show waterfowl use was highest on closed and connected wetlands (Tables 6,7,8,9). These wetlands had higher cation and anion concentrations and the highest invertebrate biomass (Table 5), which apparently provided a richer food source for birds. The aquatic invertebrate data is limited, however (31 wetlands in 1993, Appendix 2), and for this reason was not included in the multivariate statistical analysis. Simple linear regression with aquatic invertebrates as the independent variable reveals a correlation with all waterbirds (r^2=0.26, p=0.003) and adult ducks (r^2=0.26, p=0.003).

Brood Use

The use of wetlands by waterfowl and other waterbirds was most strongly associated with sodium, total alkalinity, and shoreline length or total cations, total alkalinity and shoreline length, depending on the separation or combination of cations and anions (Tables 13,14,15). These results suggest that sodium is a measure of overall ionic concentration, which is a logical result from an area that is in close proximity to a marine environment. When the density of waterfowl (birds/m of shoreline) is compared with limnological variables, stepwise regression equations imply and association of sodium, chlorophyll a and total alkalinity and use by ducklings, adult ducks, and waterbirds (Tables 13,14,15).

No waterfowl were seen on river strata during surveys or at any other time, although the two rivers (Kvichak and Alagnak) were surveyed for chemistry and waterfowl only 4 times over the two years. Both rivers were extremely clear with swift currents and had no visible aquatic vegetation and were probably not attractive to broods, but use was undoubtedly underestimated because of small sample sizes in the river stratum.

The greatest total number of waterfowl of all species and the highest biomass of aquatic invertebrates were found on connected wetlands (Tables 5,6,7,8,9). This suggests that birds were using connected wetlands to feed where invertebrates were more abundant. Connected wetlands provided conditions of higher total alkalinity and higher water color. Darker water color was associated with brood use in the Innoko River area (Seppi 1993), but wetlands were very clear in the Kvichak and there was no apparent relationship with waterfowl use and water color.

Connected and some closed wetlands provided large areas of shallow water and long shorelines lined with emergent vegetation which were important to broods for cover and food. I found an association between shoreline length and use by broods and all types of waterbirds (Tables 13,14,15). I did not relate use directly with the amount of shoreline cover, nor did I relate waterfowl use to individual species of plants. Shoreline length may be an indirect method of evaluating plant cover and the extent of shallow areas of a wetland. Many other studies have reported relationships between shoreline cover and brood use (Mack and Flake 1980, Hudson 1883, Belanger and Couture 1988, Heglund 1992) and indirect associations were found for broods in the Lower Innoko River area (Seppi 1993), and on the Kvichak area for all waterbirds.

Nitrogen and phosphorous have been recognized as limiting factors in productivity in boreal forest wetlands in Alaska (Alexander and Barsdate 1971, 1974, Barsdate and Alexander 1971). Moraine wetlands had lower chlorophyll a concentrations and lower aquatic invertebrate biomass associated with lower phosphorous levels, making them less attractive to waterfowl. In the Kvichak area, I believe broods used wetlands that provided them with maximum cover and food, which was found on ponds with increased biotic activity resulting from higher nutrient levels. The river strata had the highest total phosphorous concentrations, but no waterfowl use. Some species of waterfowl do use rivers for brooding (i.e. common and red-breasted merganser, harlequin), although most species of dabbler and diver prefer ponds and are not able to take advantage of deep or swift current rivers.

All habitat variables notwithstanding, I believe the ability of field crews to spot and identify broods and differences in the visibility of broods among wetland types may have influenced the results. Small, deep moraine wetlands and small closed or connected tundra ponds were easy to survey for broods and there was no doubt all birds were accounted for. However, larger wetlands with long, convoluted shorelines and thick shoreline cover were very difficult to survey and often held higher densities of broods and waterfowl, which were momentarily visible on approach by plane. But after landing and canoeing or walking the shorelines, most birds particularly broods, could not be flushed to be counted, resulting in vast underestimations of use. This is apparent in the low total numbers of broods seen in each year and in the large percentage of birds that were classified as unidentified. More substantial statistical associations could be determined for adult ducks and other waterbirds. This is probably a result of the greater visibility of these birds as well as the probability that they are habitat generalists and do not require abundant food and cover in specific wetlands when compared to broods. Adult birds are mobile and may have been seen on wetlands that provided them with loafing sites but not food gathering habitat. It is possible that I never observed pre-breeding and non-breeding adult birds in the habitats that are important to them for food (i.e. coastal marine environments).

In conclusion, wetland use by broods and waterfowl is related to several limnological and biological factors. Productive lentic wetlands with hydrologic connection to flowing water, moderate salinities and relatively high alkalinities are used most by duck broods, adult ducks, swans and other waterbirds. As with all biological systems, these factors do not function independently of one another, and may be indirect determinants of the physical and biological habitat variables that actually attract waterfowl.

Management Implications

The vast size and remote location of BLM lands in Alaska creates unique management problems requiring decisions that must account for pending land selection procedures, subsistence use of wildlife resources, public use of federal lands and use of other natural resources, as well as long-term wildlife management goals. Therefore, to be cost effective and appropriate, management decisions on important wetlands and waterfowl habitat require an understanding of the ecology and habitat requirements of nesting, breeding and migrating waterfowl.

The Kvichak area is a mosaic of private, federal, state and Native corporation lands, a situation common to other important waterfowl habitat on BLM lands in Alaska. There are increasing economic incentives to develop natural resources (i.e. minerals development) in the Bristol Bay river drainages. At the same time, sport hunting, sport and commercial fishing and subsistence hunting remain an important way of life for the region. These lifestyles and the desire to maintain them may persuade Native and hunting and fishing groups, and the general public, to protect these lands and allow this largely pristine ecosystem to remain intact, and thereby protect vital wetlands important to staging and breeding waterfowl.

Due to its geographic location and size, management to improve or create waterfowl habitat in the Kvichak area is impractical. The production of waterfowl in the area is lower than other areas of the state (Hodges and Conant 1990) with the exception of swans (Groves et al. 1990, Groves and Conant 1991). Yet, the Kvichak area may be an important staging ground for waterfowl bound for the Yukon Kuskokwim Delta and the North Slope, particularly in the spring before breeding ground ponds are ice free. Protection of the area is the best management practice by insuring that needed migration and breeding habitat for waterfowl, as well as many other species of wildlife that depend on the Kvichak and Alagnak river drainages, will remain for future production.

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Appendix 1. Explanation of variable abbreviations.

Invert = aquatic invertebrates (mg/cm^2)

Trans = transparency (m)

Temp = temperature (^oC)

pH = pH (no units)

Cond = conductivity (µS/cm)

T. Alk = total alkalinity (mg/L)

Color = water color (platinum cobalt units)

TP = total phosphorous (µg/L)

TN = total nitrogen (mg/L)

Ca = calcium (mg/L)

Mg = magnesium (mg/L)

K = potassium (mg/L)

Na = sodium (mg/L)

Cl = chloride (mg/L)

SO_4 = sulfate (mg/L)

Chloroa = chlorophyll a (mg/L)

Surface = surface area (hectares)

SLL = shoreline length (m)

SLD = shoreline development index (no units)

Ave Depth = average depth (m)

Appendix 2. Raw data of 20 habitat variables for each wetland.

Date	WB	TN	TP	Cl	SO4	Tot-An	Ca	Mg	Na	K	Tot-Cat	Ave-Depth
6-25-92	299	0.293	20.3	5.00	0.15	5.15	1.10	0.95	2.81	0.64	5.50	0.41
6-25-92	301	0.360	22.7	1.70	1.40	3.10	1.53	1.07	2.29	0.54	5.43	0.67
6-25-92	302	0.236	21.0	.020	0.15	0.35	0.24	0.24	1.15	0.30	1.93	0.38
6-25-92	303	0.220	19.7	0.40	0.15	0.55	0.52	0.53	1.69	0.23	2.97	1.20
6-26-92	298											0.64
6-26-92	304			0.40	0.15	0.55	0.12	0.17	1.08	0.26	1.63	1.45
6-26-92	305											0.25
6-28-92	274											0.25
6-28-92	276	0.400	32.0	1.40	0.50	1.90	0.52	0.32	2.00	0.33	3.17	0.25
6-28-92	277											0.38
6-28-92	300											0.47
6-28-92	290	0.266	20.3	1.30	0.60	1.90	1.69	1.02	2.99	0.46	6.16	
6-28-92	295	0.116	7.00	.080	0.154	0.95	0.16	0.15	0.77	0.31	1.39	4.31
6-28-92	296	0.143	6.00	1.40	0.15	1.55	0.12	0.17	0.87	0.29	1.45	3.41
6-28-92	297											1.99
6-29-92	280	0.246	10.0	0.90	0.15	1.05	0.76	0.31	1.65	0.27	2.99	3.98
6-29-92	281											1.24
6-29-92	284	0.216	12.0	0.50	0.15	0.65	1.16	0.54	2.27	0.32	4.29	0.25
6-29-92	285											0.50
6-29-92	288											0.38
6-29-92	289											0.45
6-29-92	291											0.75
6-29-92	294											1.38
6-30-92	149											1.88
6-30-92	150	0.343	70.0	2.90	0.15	3.05	2.04	1.54	14.1	0.63	18.31	0.42
6-30-92	153	0.263	15.0	0.60	0.15	0.75	0.68	0.34	1.39	0.29	2.70	0.50
6-30-92	156											0.42
6-30-92	158	0.310	13.7	0.50	0.15	0.65	0.92	0.62	2.12	0.34	4.00	1.84
6-30-92	160											5.33
6-30-92	161	0.353	22.3	0.60	0.15	0.75	0.22	0.20	1.00	0.13	1.55	0.50
7-1-92	164											1.00
7-1-92	207	0.266	8.70	0.40	0.15	0.55	0.18	0.24	1.24	0.56	2.22	2.77
7-1-92	208	0.296	8.70	0.60	0.15	0.75	0.58	0.29	1.57	0.23	2.67	
7-1-92	209											
7-1-92	214	0.290	18.3	0.30	0.15	0.45	0.53	0.51	1.66	0.38	3.08	0.38
7-1-92	216	0.490	54.7	0.70	0.40	1.10	1.10	1.04	2.73	0.35	5.22	0.94
7-1-92	218											0.50
7-1-92	222											0.46
7-1-92	223	0.413	29.0	0.30	0.15	0.45	1.03	.095	1.86	0.38	4.22	0.71
7-2-92	254											1.09
7-2-92	255	0.323	27.0	0.30	0.30	0.60	0.30	0.28	1.57	0.24	2.39	0.44
7-2-92	257											2.45
7-2-92	258											0.46
7-2-92	259	0.253	20.3	0.80	0.15	0.95	2.60	1.49	3.56	0.79	8.44	1.35
7-2-92	140											0.63
7-2-92	143	0.376	33.7	2.90	.015	3.05	1.34	1.52	3.92	0.78	7.56	0.57
7-2-92	145	0.220	20.3	1.50	0.40	1.90	0.36	0.44	2.17	0.24	3.21	0.46
7-2-92	146											0.63
7-3-92	8B											0.69
7-3-92	8C	0.326	30.0	0.60	0.15	0.75	1.13	1.33	3.66	0.46	6.58	1.22
7-3-92	8D											0.25
7-3-92	145A	0.340	38.3	1.00	0.30	1.30	0.44	0.36	2.06	0.17	3.03	0.25
7-3-92	145E	0.340	19.0	1.20	0.15	1.35	3.67	2.59	3.60	0.56	10.42	0.38
7-3-92	183											0.56
7-3-92	136	0.246	10.7	0.40	0.15	0.55	0.22	0.14	1.09	0.16	1.61	0.25
7-3-92	137											1.28
7-4-92	183	0.133	10.0	0.80	0.70	1.50	2.68	1.08	2.27	0.38	6.41	
7-4-92	188	0.223	7.30	1.80	0.30	2.10	7.68	0.29	1.46	0.40	9.83	3.63
7-4-92	191	0.443	11.7	.040	0.15	0.55	0.20	0.21	1.19	0.82	2.42	0.63
7-4-92	198	0.320	19.0	0.50	0.15	0.65	0.24	0.26	1.37	0.43	2.30	0.39

Date	WB	TN	TP	Cl	SO4	Tot-An	Ca	Mg	Na	K	Tot-Cat	Ave-Depth
7-7-92	4E											
7-7-92	22	0.300	25.70	0.70	0.15	0.85	0.95	0.17	1.23	0.15	2.50	0.50
7-7-92	23	0.406	84.70	0.60	0.15	0.75	1.28	1.10	2.43	0.48	5.29	0.82
7-7-92	30	0.686	56.00	1.70	0.15	1.85	1.24	1.00	3.42	0.50	6.16	0.70
7-7-92	32											0.77
7-7-92	4C	0.386	51.30	1.00	0.15	1.15	2.07	1.32	2.37	0.39	6.15	1.35
7-8-92	96A	0.146	6.7	1.2	0.15	1.35	0.15	0.15	0.95	0.15	1.40	
7-8-92	90A	0.156	11.0	0.7	0.15	0.85	0.70	0.51	1.65	0.25	3.11	
7-8-92	100C	0.446	41.30	2.80	0.90	3.70	2.58	1.32	4.62	0.60	9.12	2.31
7-9-92	86											0.83
7-9-92	88	0.433	41.00	1.60	0.15	1.75	1.35	0.85	2.02	0.39	4.61	0.52
7-9-92	94	0.363	38.70	0.40	1.10	1.50	4.11	1.62	2.65	0.58	8.96	0.82
7-10-92	15	0.110	93.00	0.30	0.15	0.45	0.22	0.19	1.12	0.15	1.68	1.89
7-10-92	41	0.166	7.300	0.80	0.15	0.95	0.86	0.50	1.66	0.38	3.40	7.06
7-10-92	61	0.276	15.50	0.60	0.15	0.75	0.33	0.28	1.11	0.17	1.89	0.42
7-10-92	81	0.373	30.00	1.20	0.15	1.35	1.85	1.44	2.87	0.48	6.64	1.25
7-11-92	186	0.490	31.7	0.70	0.15	0.85	2.03	1.38	2.42	0.51	6.34	0.25
7-11-92	183	0.096	127.0	0.60	1.00	1.60	2.69	1.16	2.44	0.40	6.69	
7-11-92	kvic											
7-11-92	39	0.366	23.30	1.10	0.15	1.25	2.18	1.65	2.20	0.31	6.34	0.75
7-11-92	68	0.380	36.30	0.80	0.10	0.90	0.51	0.55	3.00	0.37	4.43	0.50
7-13-92	12	0.466	27.30	0.70	2.50	3.20	0.83	0.70	1.79	0.30	3.62	1.40
7-13-92	14	0.356	28.00	1.20	0.15	1.35	1.69	1.17	2.55	0.44	5.85	3.84
7-13-92	54	0.330	25.70	1.30	0.15	1.45	1.59	1.21	2.27	0.39	5.46	0.44
7-14-92	6	0.426	42.00	1.10	0.15	1.25	0.87	0.65	2.04	0.31	3.87	0.75
7-14-92	310	0.803	85.0	0.60	0.15	0.75	2.42	1.74	2.84	0.82	7.82	
7-14-92	312	1.196	138.0	1.50	0.15	1.65	2.71	2.41	14.1	2.22	21.44	0.28
7-14-92	20	0.380	61.00	0.40	0.15	0.55	0.45	0.28	1.95	0.24	2.92	0.25
7-14-92	21	0.256	24.30	0.40	0.15	0.55	0.38	0.20	1.40	0.16	2.14	0.25
7-14-92	47	0.343	72.00	2.60	0.15	2.75	1.21	0.86	5.06	0.54	7.67	0.85
7-15-92	2	0.293	16.70	0.50	.015	0.65	0.49	0.16	1.15	0.19	1.99	0.25
7-15-92	66	0.123	18.00	0.50	1.10	1.60	4.27	2.36	2.95	0.89	10.47	3.19
7-15-92	67	0.653	42.70	1.70	0.60	2.30	2.91	2.70	9.60	1.05	16.26	0.42
7-15-92	70	0.380	22.70	0.70	0.15	0.85	1.10	0.70	2.09	0.30	4.20	0.75
7-16-92	8	0.566	118.3	2.70	0.15	2.85	4.38	1.57	6.10	1.24	13.29	0.80
7-16-92	73											0.33
7-16-92	79	0.233	14.00	0.40	0.15	0.55	0.48	0.20	1.07	0.80	1.83	1.08
7-16-92	84	0.333	26.70	1.50	0.15	1.65	0.75	0.64	2.10	0.55	4.04	0.25
7-17-92	69	0.370	39.70	1.10	0.30	1.40	0.34	0.30	1.43	0.19	2.26	0.50
7-17-92	71											0.65
7-17-92	85	0.413	35.00	0.70	0.40	1.10	1.30	0.81	2.95	0.32	5.38	0.63
6-19-93	302	0.310	28.00	1.20	0.70	1.90	0.16	0.14	1.78	0.28	2.36	0.67
6-19-93	303	0.353	16.00	1.02	0.30	1.50	0.43	0.34	1.85	0.26	2.85	1.23
6-19-93	305	0.347	30.00	1.60	1.70	3.30	0.88	0.60	3.11	0.71	5.30	0.30
6-19-93	299	0.540	85.00	1.20	0.60	1.80	0.76	0.40	2.56	0.44	4.16	0.88
6-19-93	301	0.373	35.00	1.60	0.20	1.80	1.52	0.79	2.81	0.61	5.73	0.5
6-20-93	276	0.276	32.00	1.60	0.80	2.40	0.30	0.20	2.16	0.47	3.13	0.33
6-20-93	277	0.210	14.00	0.80	0.05	0.85	0.18	0.12	1.20	0.48	1.99	0.34
6-20-93	274	0.207	12.00	1.20	0.05	1.25	0.16	0.10	1.15	0.49	1.90	0.38
6-20-93	304	0.103	12.00	1.60	0.05	1.65	0.10	0.10	0.79	0.62	1.61	
6-20-93	296	0.030	6.00	0.80	0.05	0.85	0.11	0.11	1.09	0.26	1.57	3.28
6-20-93	295	0.053	12.00	0.800	0.200	1.00	0.28	0.06	0.93	0.32	1.59	5.18
6-20-93	298	0.167	11.00	0.80	0.10	0.90	0.36	0.24	1.27	0.16	2.03	0.89
6-20-93	297	0.373	49.00	1.20	0.30	1.50	1.50	1.22	2.38	0.57	5.67	1.49
6-20-93	300	0.630	8.00	0.80	0.05	0.85	0.03	0.07	0.76	0.17	1.03	0.71
6-21-93	294	0.103	10.00	0.80	0.05	0.85	0.06	0.08	0.90	0.18	1.22	1.22
6-21-93	290	0.230	17.00	2.10	0.10	2.20	0.90	0.45	2.40	0.28	4.03	1.04
6-21-93	291	0.277	28.00	0.80	1.30	2.10	1.14	0.54	1.86	0.34	3.88	0.83
6-21-93	288	0.293	33.00	2.30	0.30	2.60	1.80	0.89	3.41	0.85	6.95	0.66
6-21-93	281	0.430	29.00	0.80	0.10	0.90	1.12	0.82	2.54	0.38	4.86	1.58
6-21-93	280	0.300	13.00	2.00	0.80	2.80	0.48	0.25	1.81	0.30	2.84	6.69
6-21-93	285	0.190	19.00	0.80	0.30	1.10	0.15	0.18	2.09	0.37	2.79	1.33

Date	WB	TN	TP	Cl	SO4	Tot-An	Ca	Mg	Na	K	Tot-Cat	Ave-Depth
6-21-93	289	0.330	47.00	0.80	0.70	1.50	1.22	0.88	3.30	0.67	6.07	
6-22-93	161	0.427	29.00	0.80	0.50	1.30	0.17	0.11	1.14	0.18	1.60	0.33
6-22-93	164	0.623	245.00	0.80	0.40	1.20	1.12	0.65	2.10	0.42	4.29	1.00
6-22-93	158	0.253	17.00	1.20	0.10	1.30	1.04	0.43	1.82	.036	3.65	2.96
6-22-93	156	0.267	13.00	0.80	0.05	0.85	1.56	0.14	1.23	0.26	3.19	0.63
6-22-93	284	0.260	13.00	1.20	0.05	1.25	0.84	0.32	2.52	0.42	4.10	0.81
6-22-93	150	1.440	211.0	4.60	0.80	5.40	2.04	1.15	12.00	1.33	16.52	0.68
6-22-93	149	0.177	11.00	1.20	0.30	1.50	0.18	0.17	1.67	0.30	2.32	3.95
6-22-93	153	0.400	18.00	0.80	0.05	0.85	0.34	0.14	1.40	0.28	2.16	0.50
6-23-93	223	0.493	44.00	0.80	1.30	2.10	0.70	0.59	2.16	0.47	3.92	1.50
6-23-93	207	0.317	10.00	2.00	0.05	2.05	0.47	0.14	1.49	0.58	2.68	3.11
6-23-93	208	0.273	14.00	1.20	0.40	1.60	1.34	0.26	1.64	0.38	3.62	
6-23-93	214	0.407	35.00	1.20	1.40	2.60	0.66	0.26	2.57	0.44	3.93	
6-23-93	209	0.377	15.00	3.00	0.20	3.20	0.96	0.64	4.86	0.52	9.68	0.38
6-23-93	222	0.370	30.00	1.20	1.10	2.30	0.68	0.48	2.46	.034	3.96	0.58
6-23-93	216	0.657	88.00	1.20	1.00	2.20	0.83	0.76	2.68	0.63	4.90	1.31
6-23-93	218	0.490	409.00	1.60	1.30	2.90	2.43	1.78	3.52	1.06	8.79	0.53
6-24-93	1010	0.143	4.00	0.80	0.40	1.20	0.23	0.09	0.95	0.36	1.63	3.00
6-24-93	1011	0.133	6.00	1.02	0.05	1.25	0.32	0.18	1.82	0.26	2.58	3.31
6-24-93	1012	0.110	7.00	1.20	0.30	1.50	0.18	0.18	1.23	0.30	1.89	4.90
6-24-93	1013	0.293	24.00	2.00	0.10	2.10	0.40	0.30	1.84	0.42	2.96	1.98
6-24-93	1014	0.103	9.00	0.80	1.50	2.30	2.54	0.56	1.86	0.62	5.58	
6-24-93	1000	0.153	9.00	0.80	0.20	1.00	0.09	0.11	0.96	0.22	1.38	4.96
6-24-93	1001	0.233	8.00	1.70	0.30	2.00	0.14	0.12	1.02	0.40	1.68	6.65
6-24-93	1002	0.140	5.00	1.60	0.05	1.65	0.14	0.14	1.01	0.29	1.58	8.61
6-24-93	1003	0.247	9.00	1.20	0.40	1.60	0.25	0.16	1.48	0.36	2.25	5.40
6-24-93	1004	0.323	19.00	1.20	1.20	2.40	0.35	0.34	1.91	0.31	2.90	0.90
6-27-93	259	0.337	43.00	3.10	0.40	3.50	1.58	0.82	2.88	0.44	5.75	
6-27-93	257	0.280	8.00	2.50	0.30	2.80	0.52	0.34	1.82	0.46	3.14	
6-27-93	258	0.317	55.00	3.60	0.40	4.00	0.36	0.20	2.35	0.29	3.20	
6-27-93	140	1.007	193.00	5.10	0.70	5.80	1.35	2.24	4.68	2.21	13.48	
6-27-93	143	0.500	60.00	3.00	1.80	4.80	1.18	1.10	3.98	0.520	6.78	
6-28-93	105A	0.540	31.00	1.70	0.30	2.00	1.45	0.95	2.94	0.74	6.08	2.56
6-28-93	100A	0.553	41.00	1.60	0.60	2.20	1.51	0.55	1.04	0.94	7.37	0.97
6-28-93	100B	0.657	43.00	2.00	0.20	2.20	1.53	0.78	3.08	0.74	6.13	0.72
6-28-93	96	0.620	28.00	1.60	0.10	1.70	1.66	0.89	3.38	0.58	6.51	1.00
6-28-93	105A	0.303	20.00	2.50	0.05	2.55	1.14	0.92	2.17	0.53	4.76	4.84
6-28-93	100	0.570	45.00	2.00	1.00	3.00	3.14	1.57	5.18	1.02	10.91	1.04
6-28-93	96A	0.577	38.00	1.20	0.10	1.30	1.81	0.96	3.50	0.64	6.91	
6-29-93	1014	0.527	49.00	2.60	0.10	2.70	3.03	0.56	4.99	1.02	9.60	4.79
6-29-93	105B	0.310	27.00	1.20	0.10	1.30	1.82	0.74	3.80	0.64	7.01	2.33
6-29-93	111B	0.177	23.00	1.20	0.05	1.25	0.76	0.39	1.74	0.32	3.21	1.60
6-29-93	100C	0.330	44.00	3.10	0.80	3.90	1.94	1.02	4.74	0.77	8.47	
6-29-93	111B	0.207	14.00	1.60	0.05	1.65	1.45	0.56	2.00	0.28	4.29	1.54
6-29-93	105B	0.733	38.00	3.00	0.40	3.40	1.02	0.50	4.12	0.52	6.16	0.69
6-29-93	100C	0.157	19.00	0.80	0.10	0.90	0.97	0.64	2.48	0.18	4.27	
6-30-93	95A	0.210	17.00	1.20	0.20	1.40	0.58	0.24	1.50	0.32	2.64	0.78
6-30-93	88	0.653	35.00	1.60	0.05	1.65	1.13	0.54	2.12	0.43	4.22	1.00
6-30-93	12	0.297	32.00	1.20	0.40	1.60	0.70	0.56	1.71	0.39	3.60	
6-30-93	15	0.120	13.00	1.60	0.05	1.65	0.24	0.80	1.14	0.20	1.66	1.38
6-30-93	90A	0.260	19.00	1.20	0.05	1.25	0.24	0.10	1.40	0.22	1.96	0.68
6-30-93	90	0.403	37.00	0.80	0.40	1.20	1.37	0.94	2.47	0.80	5.58	0.38
7-1-93	311A	0.463	44.00	0.80	0.20	1.00	1.21	0.94	1.72	0.76	4.63	0.95
7-1-93	311B	0.763	79.00	0.80	1.00	1.80	1.36	1.30	3.31	0.55	6.52	0.79
7-1-93	311C	0.183	14.00	1.20	0.05	1.25	0.37	0.26	1.26	25.00	26.89	2.19
7-1-93	4B	0.397	20.00	1.20	0.50	1.70	0.28	0.14	1.80	0.25	2.47	0.75
7-1-93	311	0.560	44.00	0.88	0.60	1.40	1.92	1.20	5.01	1.32	9.45	0.938
7-1-93	4	0.377	90.00	1.60	0.60	2.20	0.43	0.28	2.40	0.34	3.45	0.58
7-1-93	6	0.350	51.00	7.00	0.80	7.80	0.49	0.30	3.20	0.54	4.55	0.58
7-1-93	310	0.940	133.00	0.80	0.30	1.10	1.58	1.44	4.85	1.09	8.96	0.88
7-2-93	4A	0.423	33.00	2.00	0.20	2.20	0.29	0.26	2.97	0.25	3.77	1.00
7-2-93	4C	0.395	17.00	1.20	0.40	1.60	0.40	0.44	2.71	0.28	3.83	0.69

Date	WB	TN	TP	Cl	SO4	Tot-An	Ca	Mg	Na	K	Tot-Cat	Ave-Depth
7-2-93	4E	0.340	34.00	0.80	0.60	1.40	0.43	0.35	2.12	0.33	3.23	0.79
7-2-93	32	0.567	37.00	1.20	0.50	1.70	0.92	0.69	4.33	0.39	6.33	0.88
7-2-93	30	1.550	77.00	1.60	0.80	2.40	0.86	0.71	5.73	0.49	7.79	0.58
7-2-93	44A	0.587	37.00	1.20	1.20	2.40	0.74	0.54	3.30	0.52	5.10	0.58
7-2-93	44	0.430	27.00	1.60	0.10	1.70	0.20	0.21	3.21	0.26	3.88	0.75
7-3-93	270A	0.730	85.00	119.5	3.30	122.8	1.56	3.54	7.22	5.17	17.49	0.75
7-3-93	1020	0.180	14.00	2.70	0.20	2.90	0.19	0.27	2.72	0.29	3.47	0.81
7-3-93	85	0.375	41.00	3.30	0.40	3.70	0.68	0.60	2.58	0.26	4.12	0.75
7-3-93	85A	0.365	21.00	4.00	0.20	4.20	0.38	0.42	2.74	0.60	4.14	0.75
7-3-93	81	0.350	33.00	1.20	0.70	1.90	1.60	1.30	4.46	0.60	7.96	0.81
7-3-93	84	0.307	23.00	1.20	0.40	1.60	0.56	0.55	3.42	0.49	5.02	0.56
7-3-93	8A	0.460	49.00	2.50	1.10	3.60	0.34	0.28	2.76	0.30	3.68	0.50
7-3-93	8B	0.340	19.00	3.60	0.40	4.00	0.26	0.41	2.96	0.16	3.97	0.75
7-3-93	8C	0.180	11.00	3.00	0.80	3.80						0.50
7-3-93	8E	0.297	21.00	3.00	0.80	3.80	0.25	0.40	3.34	0.39	4.38	0.46
7-3-93	8D	0.263	23.00				0.29	0.24	2.22	0.44	3.19	0.46
7-5-93	137B	0.350	15.00	0.80	1.20	2.00	0.28	0.22	2.80	1.70	3.47	0.58
7-5-93	137A	0.467	18.00	1.60	0.10	1.70	1.12	0.86	2.78	0.23	4.99	0.58
7-5-93	1023	0.283	12.00	1.20	0.80	2.00	1.54	1.22	2.38	0.94	6.08	2.25
7-5-93	66	0.303	8.00	2.00	0.30	2.30	1.92	1.40	2.88	0.94	7.14	4.50
7-5-93	145A	0.530	42.00	4.00	0.50	4.50	1.20	1.46	7.84	0.97	11.47	
7-5-93	145B	0.403	16.00	3.90	0.50	4.40	0.24	0.39	2.40	0.29	3.32	
7-5-93	145C	0.723	25.00	5.00	1.70	6.70	0.74	0.84	4052	0.62	6.72	0.25
7-5-93	145D	0.517	16.00	4.00	1.50	5.50	0.47	0.70	5.01	0.14	6.32	0.96
7-5-93	145E	0.680	22.00	8.20	0.30	8.50	0.54	0.82	4.91	0.66	6.93	0.10

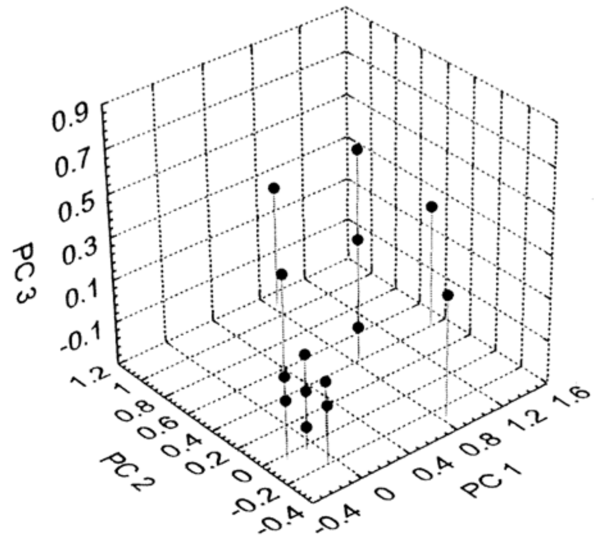
Date	WB	Surface	SLL	SLD	Trans	Temp	pH	Cond	Alk	Color	Chloro	Invert
6-25-92	299	32.30	2453.40	1.22		15.83	7.18	28.23	8.10	20	2.502	
6-28-92	300	4.80	862.20	1.11		9.10		57.90	0.80	0	0.958	
6-25-92	301	2.80	604.80	1.02		14.33	6.90	34.00	10.80	20	2.857	
6-25-92	302	11.10	1446.50	1.22		16.25	7.80	8.97	5.00	25	1.006	
6-25-92	303	4.60	899.10	1.18		15.66	7.38	15.04	3.00	20	1.602	
6-26-92	304	0.97	356.60	1.02		10.96		8.12	1.90	10	0.525	
6-26-92	305	1.80	684.20	1.44		12.06		30.10	8.50	160	5.769	
6-26-92	298	9.30	1479.40	1.37		11.70	7.80	14.16	6.50	5	0.970	
6-28-92	295	1.40	461.30	1.10		12.46		9.79	0.80	0	0.587	
6-28-92	296	3.30	921.30	1.43		11.30		8.88	1.10	0	0.548	
6-28-92	297	3.50	736.00	1.11	0.75	12.36	7.00	48.00	15.20	40	16.458	
6-28-92	290	6.90	980.70	1.05		12.66	7.67	37.40	12.30	5	3.035	
6-28-92	274	0.37	222.20	1.03		13.50	7.90	20.86		50	9.632	
6-28-92	276	6.70	1286.90	1.40		9.80	7.74	18.25	2.50	53	2.568	
6-28-92	277	3.10	711.30	1.14		11.15	8.01	16.74	1.40	5	1.00	
6-29-92	291	17.10	1598.00	1.09		16.73		38.50	6.80	8	2.763	
6-29-92	294	25.30	2267.20	1.27			7.31	18.25	1.90	0	0.649	
6-29-92	280	2.30	551.90	1.03			6.98	24.30	3.80	0	1.414	
6-29-92	281	11.20	1877.60	1.58			7.19	31.36	10.60	25	6.822	
6-29-92	284	6.20	1156.90	1.31		14.33		36.30	4.00	25	1.347	
6-29-92	285	4.70	1023.40	1.33		14.50		10.64	9.50	30	1.413	
6-29-92	288	8.50	1078.90	1.04		14.40	7.53	63.16	17.20	25	4.895	
6-29-92	289	11.90	1345.40	1.10			7.29	61.83	5.20	43	8.462	
6-30-92	149	9.70	1626.50	1.47		15.73	7.83	13.47	4.90	2	1.457	
6-30-92	150	1.20	443.30	1.14		13.26	7.57	83.26	20.00	70	5.068	
6-30-92	153	18.10	1762.40	1.17		13.55		12.87	7.00	5	2.647	
6-30-92	156	7.80	1122.10	1.13		16.36		9.75	0.50	10	0.613	
6-30-92	158	6.70	1084.60	1.18		15.16		20.83	6.60	15	2.037	
6-30-92	160	11.80	1861.20	1.53	2.00	14.63		38.56	17.50	30	4.511	
6-30-92	161	3.10	730.60	1.17		16.46	7.80	11.67	2.30	25	2.539	

Date	WB	Surface	SLL	SLD	Trans	Temp	pH	Cond	Alk	Color	Chloro	Invert
7-1-92	164	16.90	2070.60	1.42	0.75	15.63	7.27	35.00	18.50	37	12.284	
7-1-92	207	2.30	692.90	1.29		26.16	7.84	12.33	8.50	10	0.686	
7-1-92	208	0.86	341.60	1.04		19.10	6.75	14.61	8.60	10	1.150	
7-1-92	209	3.50	714.10	1.08		20.03	7.00	45.16	10.90	45	1.447	
7-1-92	214	17.40	1717.40	1.16		19.26	6.50	15.19	3.00	65	1.174	
7-1-92	216	6.80	1181.70	1.28	0.50	18.73	7.54	14.80	11.60	80	9.981	
7-1-92	218	6.10	921.40	1.05		23.80	6.83	69.06	26.60	72	8.821	
7-1-92	222	0.83	348.50	1.08		16.80	6.50	20.43	4.70	80	1.954	
7-1-92	223	8.90	1104.60	1.04		13.66	6.75	20.90	9.60	70	3.854	
7-2-92	254	7.30	1371.10	1.43		14.93		17.79	8.00	10	0.699	
7-2-92	255	3.20	810.20	1.28		15.40	7.75	34.36	1.90	40	1.472	
7-2-92	257	10.70	1384.20	1.19		14.80	6.25	23.56	5.10	10	1.041	
7-2-92	258	14.70	1585.50	1.17	1.25	15.36	6.25	14.13	1.80	50	1.756	
7-2-92	259	12.10	1307.60	1.06		15.80	7.00	40.10	12.60	70	5.861	
7-2-92	140	22.20	1836.20	1.10		15.22	6.25	72.70	28.90	100	3.321	
7-2-92	143	4.40	760.50	1.02		14.76	6.25	41.80		125	2.735	
7-2-92	145	6.90	1438.80	1.55		15.50		11.41	2.40	45	0.962	
7-2-92	146	5.90	1063.20	1.23		14.00		27.63	3.60	80	1.118	
7-3-92	8B	1.90	589.40	1.21		17.10	6.25	26.03	7.00	200	2.437	
7-3-92	8C	4.90	2150.00	2.74		17.60	6.50	37.45	15.00	40	5.110	
7-3-92	8D	1.00	382.60	1.08		20.70	5.50	15.10	5.90	75	1.460	
7-3-92	145A	7.40	1060.10	1.10		18.13	5.50	20.90	2.50	42	2.845	
7-3-92	145E	49.00	2978.80	1.20		15.30	7.25	64.85	23.70	50	2.632	
7-3-92	183	22.90	2413.50	1.42		16.25	6.00	11.39	3.50	45	2.013	
7-3-92	136	15.00	1440.10	1.05		13.76	6.00	9.62	6.30	2	0.660	
7-3-92	137	6.20	1132.90	1.28	1.50	14.86	6.50	23.76	7.80	58	1.756	
7-4-92	188	34.90	6030.40	2.89	7.00	17.40	6.50	11.65	3.90	3	0.596	
7-4-92	191	1.60	570.90	1.27		18.53	6.50	16.31	2.30	10	0.512	
7-4-92	198	0.46	264.80	1.10		20.30	6.50	13.26	8.20	5	2.091	
7-4-92	183	8.90	2701.30	2.55		12.63	7.00	42.66	12.20	5	1.588	
7-7-92	4E	58.60	3501.4	1.29		15.93	7.00	28.26	7.20	35	4.237	
7-7-92	22	62.30	3097.60	1.11		15.27	6.25	7.36	1.70	20	2.377	
7-7-92	23	64.40	3058.10	1.07	0.50	15.67	7.00	46.25	9.10	150	9.623	
7-7-92	30	372.30	7997.20	1.17	0.25	15.36	7.00	29.90	17.20	40	7.123	
7-7-92	32	104.40	3903.90	1.08		16.80	7.00	28.26	11.20	10	3.020	
7-7-92	4C	64.60	3792.60	1.33	0.50	13.67	7.25	38.35	13.50	30	12.778	
7-8-92	96A	90.80	3795.5	1.12		16.10	6.00	14.27	5.00	5	0.266	
7-8-92	90A	52.10	2738.40	1.07		13.90		21.20	4.40	15	1.028	
7-8-92	100C	115.50	6045.80	1.59	1.25	15.82	8.00	55.95	18.50	20	8.406	
7-9-92	86	62.40	3043.00	1.09		16.90	6.00	10.43	5.20	20	1.546	
7-9-92	88	194.50	7505.40	1.52		16.33	7.25	25.43	11.20	55	11.805	
7-9-92	94	45.50	2773.10	1.16	0.75	15.63	7.50	60.70	20.80	45	4.818	
7-10-92	15	181.90	5458.90	1.14		15.63	6.25	13.51	5.00	1	0.562	
7-10-92	41	58.50	5510.30	2.03	5.00	15.60	7.00	25.93	4.30	5	732	
7-10-92	61	59.60	3129.70	1.14		14.93	6.25	11.74	9.50	12	3.501	
7-10-92	81	124.20	4529.60	1.15	1.00	16.52	7.50	38.30	18.50	20	4.317	
7-11-92	39	41.30	2531.60	1.11		19.03	6.75	41.10	19.90	10	2.617	
7-11-92	186	18.20	1857.10	1.23		17.70	8.00	35.56	11.20	55	1.627	
7-11-92	183	8.90	2701.30	2.55		14.37	7.00	49.92	15.60	30	0.906	
7-11-92	kvic	159.50	6834.10	1.53								
7-11-92	68	57.60	3076.10	1.14		19.73	6.50	23.30	9.80	40	2.945	
7-13-92	12	97.30	5133.80	1.47		17.23	6.25	38.76	6.60	40	0.632	
7-13-92	14	33.00	3295.30	1.62	1.25	17.13	7.50	49.11	13.10	35	6.275	
7-13-92	54	173.50	5428.20	1.16		20.16	7.00	41.70	9.10	40	1.353	
7-14-92	20	52.90	2689.50	1.04	0.25	16.23	6.50	14.00	2.80	50	3.154	
7-14-92	21	34.50	2498.70	1.20		15.60	6.25	11.63	3.00	20	0.722	
7-14-92	310	76.20	3397.20	1.10		15.70	7.50	47.54	46.50	55	4.563	
7-14-92	312	76.50	3438.20	1.11		16.45	9.00	98.63	44.70	150	12.917	
7-14-92	6	164.90	6187.80	1.36	0.37	15.16	6.50	18.73	8.20	50	2.065	
7-14-92	47	78.00	3348.70	1.07	0.50	15.80	7.00	39.34	13.10	150	3.980	
7-15-92	2	60.20	2967.40	1.08		16.10	6.25	11.52	1.80	1	0.498	
7-15-92	66	67.60	4656.90	1.60	2.50	14.92	7.50	68.12	27.20	5	1.493	

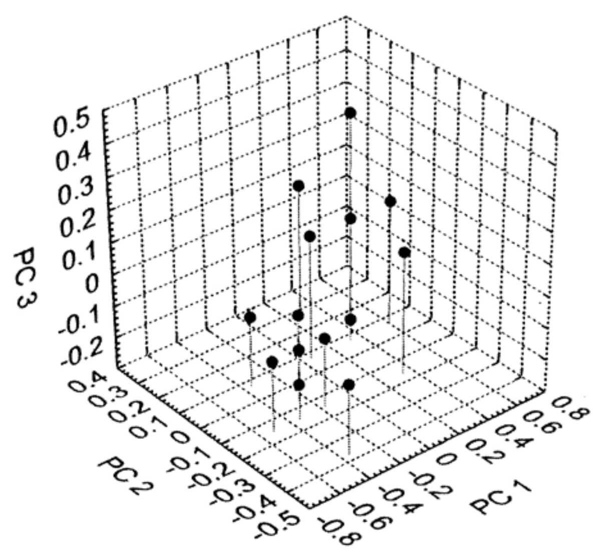
Date	WB	Surface	SLL	SLD	Trans	Temp	pH	Cond	Alk	Color	Chloro	Invert
7-15-92	67	76.10	3635.30	1.18	0.25	17.32	8.50	82.24	3.90	125	9.188	
7-15-92	70	69.70	5706.50	1.93		18.13	6.80	22.33	12.50	5	1.443	
7-16-92	8	43.80	2439.80	1.04	0.50	18.13	7.25	45.93	15.30	95	9.653	
7-16-92	73	25.40	2076.40	1.16		18.26	7.50	29.10	8.60	125	15.628	
7-16-92	79	42.40	2796.30	1.21		17.43	6.00	8.11	1.90	20	0.642	
7-16-92	84	42.70	3209.70	1.39		16.90	6.40	21.73	9.30	45	0.733	
7-17-92	69	113.80	4327.00	1.14		14.20	6.25	11.39	3.00	5	2.958	
7-17-92	71	73.80	4537.70	1.50	0.50	14.86	6.70	37.53	20.80	35	8.344	
7-17-92	85	69.40	3772.40	1.28		14.26	6.70	25.10	10.00	60	3.608	
6-19-93	299	32.30	2453.40	1.22		21.00	7.93	40.00	2.70	30	16.775	0.226
6-19-93	301	2.80	604.80	1.02		19.53	7.71	41.20	13.40	10	4.805	0.167
6-19-93	302	11.10	1446.50	1.22		21.51	7.67	13.41	0.00	11	0.906	
6-19-93	303	4.60	899.10	1.18		19.26	7.49	22.05	5.20	10	0.509	
6-19-93	305	1.80	684.20	1.44		22.40	7.58	28.00	14.10	15	0.990	
6-20-93	296	3.30	921.30	1.43		16.83	8.18	6.55	1.00	5	0.052	
6-20-93	295	1.40	461.30	1.10	8.50	17.07	7.77	7.02	1.50	15	0.530	
6-20-93	298	9.30	1479.40	1.37		20.01	6.99	12.68	2.10	15	0.972	0.004
6-20-93	297	3.50	736.00	1.11		20.70	6.79	39.10	13.80	30	2.978	
6-20-93	300	4.80	862.20	1.11		20.05	6.42	4.65	0.70	10	.0615	
6-20-93	276	6.70	1286.90	1.40		19.75	6.98	13.57	0.60	5	2.319	0.034
6-20-93	277	3.10	711.30	1.14		31.60	6.99	12.21	7.40	5	0.646	
6-20-93	274	0.37	222.20	1.03		23.30	6.91	8.45	1.90	5	1.210	
6-20-93	304	0.97	356.60	1.02		19.50	6.94	8.06	0.50	5	0.643	0.007
6-21-93	294	25.30	2267.20	1.27		17.70	7.04	9.48	1.00	5	0.911	0.009
6-21-93	290	6.90	980.70	1.05		19.10	6.93	30.60	9.50	5	2.123	0.044
6-21-93	291	17.10	1598.00	1.09		20.55	6.92	26.73	4.90	10	1.409	
6-21-93	288	8.50	1078.90	1.04		20.70	6.88	45.30	5.00	40	4.398	0.021
6-22-93	28	46.20	1156.90	1.31		17.67	8.08	23.43	6.00	100	1.950	
6-22-93	150	1.20	443.30	1.14	0.25	17.53	9.45	5.55	24.20	175	63.515	
6-22-93	149	9.70	1626.50	1.47	3.50	18.33	8.45	9.70	0.80	50	1.805	
6-22-93	153	18.10	1762.40	1.17		19.00	7.72	12.33	3.70	10	3.805	
6-22-93	161	3.10	730.60	1.17		13.90	6.98	8.34	0.00	15	2.212	0.005
6-22-93	164	16.90	2070.60	1.42		15.70	6.92	31.70	17.30	30	20.186	
6-22-93	158	6.70	1084.60	1.18	2.00	17.60	7.03	20.05	0.80	10	2.662	0.006
6-22-93	156	7.80	1122.10			18.40	6.99	8.39	2.50	10	0.749	
6-23-93	207	2.30	692.90	1.29	5.00	16.93	7.63	10.93	1.00	30	2.038	0.010
6-23-93	208	0.86	341.60	1.04		17.47	7.26	15.58	3.10	30	1.194	
6-23-93	214	17.40	1717.40	1.16	0.50	17.90	7.02	16.35	3.80	70	4.070	0.191
6-23-93	209	3.50	714.10	1.08	0.50	19.75	6.97	40.60	11.60	50	1.577	
6-23-93	223	8.90	1104.60	1.04	1.50	13.76	8.67	17.20	8.10	15	9.536	
6-23-93	222	0.84	348.50	1.08		14.90	7.88	20.40	3.80	30	2.398	
6-23-93	216	6.80	1181.70	1.28	1.00	15.75	8.63	22.40	5.20	25	22.727	
6-23-93	218	6.10	921.40	1.05		15.98	7.34	56.80	20.00	25	13.623	
6-24-93	1010	5.10	871.70	1.09		16.80	7.11	5.30	0.00	5	0.386	0.021
6-24-93	1011	23.30	3940.40	2.30		17.20	7.08	7.95	0.00	5	2.661	0.008
6-24-93	1012	69.30	12425.40	3.57	7.00	18.80	7.09	9.27	0.90	15	0.621	
6-24-93	1013	6.60	1676.80	1.84	2.75	19.00	7.31	14.64	1.50	20	1.688	0.029
6-24-93	1014	47.30	5715.50	2034		16.53	7.34	41.27	13.60	5	0.610	
6-24-93	1000	106.40	11471.40	3.14	9.50	16.40	7.10	7.90	0.50	1	0.592	
6-24-93	1001	1.50	474.90	1.09	8.00	17.50	7.00	8.90	0.20	5	0.906	
6-24-93	1002	4.90	1198.30	1.53	11.00	18.50	7.00	9.10	0.00	5	0.587	
6-24-93	1003	3.50	896.40	1.35	5.50	18.90	7.00	11.00	1.80	10	0.929	
6-24-93	1004	9.20	1777.80	1.65		23.60	7.00	15.60	1.90	100	1.723	
6-27-93	259	12.10	1307.60	1.19		12.70	7.02	33.00	11.50	75	7.415	0.121
6-27-93	257	10.70	1384.20	1.19		13.80	7.00	20.50	4.70	10	1.487	0.040
6-27-93	258	14.60	1585.50	1.17		11.40	7.00	14.40	1.30	100	8.199	
6-27-93	140	22.20	1836.20	1.10		11.40	6.97	68.30	25.20	125	26.427	0.103
6-27-93	143	4.40	760.50	1.02		11.30	6.97	39.40	9.30	125	10.718	
6-28-93	105A	480.00	6547.80	1.20	1.25	15.30	7.30	42.40	15.80	50	11.743	
6-28-93	100A	85.10	4945.70	1.51	0.75	14.50	7.30	50.90	19.50	75	6.192	
6-28-93	100B	78.90	2578.30	1.17		13.90	7.30	32.90	10.80	75	10.289	0.075
6-28-93	96	144.60	4591.60	1.08	0.50	14.80	7.09	36.90	10.40	50	5.320	

Date	WB	Surface	SLL	SLD	Trans	Temp	pH	Cond	Alk	Color	Chloro	Invert
6-28-93	105A	73.80	3718.90	1.22		15.70	7.12	37.40	13.10	15	3.414	
6-28-93	100	95.60	3606.50	1.04	0.75	14.40	7.11	76.10	22.50	100	10.702	
6-28-93	96A	51.90	2716.00	1.06	0.50	14.60	7.11	43.60	14.00	75	9.536	
6-29-93	100C	115.50	6045.80	1.59	2.00	11.80	7.10	55.40	1.20	50	5.961	2.223
6-29-93	111B	577.30	8927.20	1.50	2.50	11.90	7.10	28.40	0.60	50	1.267	0.338
6-29-93	105B	114.50	5377.50	2.03	0.25	11.90	7.06	30.10	5.80	150	13.631	
6-29-93	100C	59.70	2914.20	1.52		14.10	7.00	29.30	9.50	5	2.601	0.016
6-29-93	1014	97.90	3958.10	1.13	2.00	12.70	7.21	62.60	26.00	50	5.984	
6-29-93	105B	118.40	5532.30	1.43		13.00	7.27	42.90	15.60	35	1.727	
6-29-93	111B	667.90	3397.60	1.16		13.60	7.44	19.40	8.80	50	0.681	
6-30-93	95A	56.30	3237.90	1.23		12.30	7.20	11.20	6.20		2.114	0.028
6-30-93	88	194.50	7505.40	1.52		12.50	7.18	31.50	13.40	25	7.761	0.122
6-30-93	12	97.90	5313.60	1.47		13.30	6.80	19.10	6.30	30	0.872	0.020
6-30-93	15	181.90	5458.90	1.14		13.60	7.20	6.90	0.60	5	1.144	
6-30-93	90A	57.30	2898.30	1.08		13.20	7.05	10.37	1.50	15	1.649	
6-30-93	90	125.70	4844.70	1.22		13.10	7.00	49.60	18.20	75	1.661	
7-1-93	311A	28.70	2034.90	1.07		13.60	6.90	26.90	9.50	125	2.359	0.080
7-1-93	311B	36.30	2284.10	1.07		14.40	7.14	33.00	11.80	100	6.207	
7-1-93	311C	10.50	1810.40	1.58	3.50	14.60	7.30	11.50	0.80	20	1.711	
7-1-93	4B	69.30	4517.80	1.53	0.50	10.70	7.10	9.40	0.10	75	3.062	
7-1-93	311	54.70	2759.00	1.05		14.00	7.03	56.40	20.90	100	10.847	
7-1-93	4	165.20	5386.80	1.18		12.30	7.01	12.72	1.90	275	13.725	
7-1-93	6	164.90	6187.80	1.36		11.70	7.00	15.99	1.60	225	24.775	
7-1-93	310	76.20	3397.20	1.10		13.20	7.02	46.40	18.80	60	20.328	0.174
7-2-93	4A	40.50	3279.90	1.45	0.50	10.60	7.48	8.96	1.50	80	4.921	
7-2-93	4C	10.30	1276.00	1.12		11.40	8.20	13.50	4.20	75	3.203	0.044
7-2-93	4E	49.20	2811.40	1.13	0.50	12.20	7.90	13.40	4.90	75	4.697	
7-2-93	32	104.40	3903.90	1.08		12.10	7.03	27.60	7.20	25	6.635	
7-2-93	30	372.30	7997.20	1.17	0.25	11.90	6.98	24.60	6.30	25	18.630	
7-2-93	44A	64.50	3201.40	1.12		11.90	7.03	24.50	4.20	100	7.599	
7-2-93	44	34.60	2208.80	1.06		12.60	7.04	12.31	1.00	50	4.487	
7-3-93	270A	76.50	2783.50	1.28	0.25	11.50	7.40	467.50	14.00	150	16.551	
7-3-93	1020	142.50	3239.30	1.09		11.20	6.76	12.50	0.20	25	2.037	
7-3-93	85	69.40	3772.40	1.28		11.00	7.00	22.00	4.70	25	5.746	
7-3-93	85A	12.50	2333.50	1.86		11.50	8.34	21.50	3.50	50	2.806	
7-3-93	81	124.20	4529.60	1.15	0.75	11.50	7.17	41.90	15.60	50	4.793	
7-3-93	84	42.70	3209.70	1.39		11.40	7.10	18.70	3.90	100	4.988	
7-3-93	8A	51.30	4285.10	1.69	0.25	10.50	7.03	14.27	6.50	125	7.268	
7-3-93	8B	2.10	550.50	1.07		11.20	7.05	16.71	1.30	100	1.721	0.011
7-3-93	8C	0.85	338.90	1.04		14.40	7.05	24.07	2.60		1.342	
7-3-93	8E	2.10	525.40	1.02		13.65	7.05	19.14	0.60		1.762	
7-3-93	8D	35.80	2398.50	1.13	0.33	12.27	7.02	15.22	0.10		1.818	
7-5-93	137B	47.60	3658.30	1.50	0.50	11.10	6.90	16.10	3.30	125	5.230	
7-5-93	137A	44.40	4239.40	1.79		11.60	7.00	50.60	16.00	75	3.869	
7-5-93	1023	487.40	6661.90	1.22	0.50	11.30	7.10	59.40	17.00	125	2.604	
7-5-93	66	67.60	4656.90	1.60		14.60	7.30	84.30	24.00	50	2.840	
7-5-93	145A	73.80	2628.70	1.23		11.35	7.03	4.68	11.90	70	8.187	
7-5-93	145B	5.30	670.30	1.17	0.50	13.15	7.10	18.97	3.20	70	1.196	0.128
7-5-93	145C	67.50	3195.20	1.57		15.43	7.03	38.63	3.00	150	5.073	0.044
7-5-93	145D	23.70	1449.40	1.34		15.85	7.01	25.57	1.20	100	1.770	
7-5-93	145E	0.32	187.20	1.20		17.25	7.01	40.07	1.80	60	3.813	

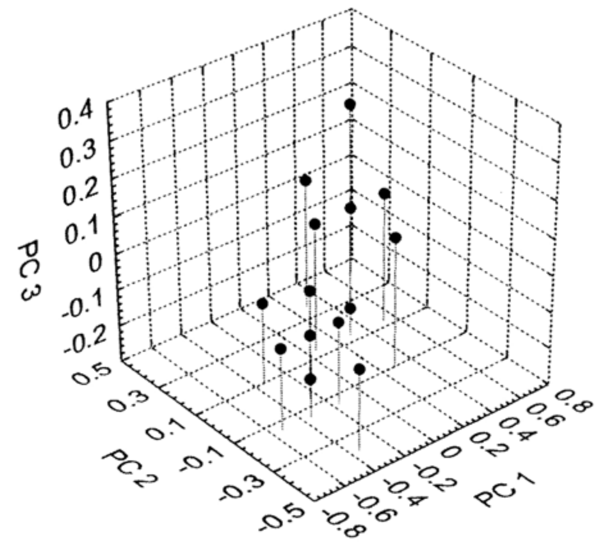
Appendix 3a. A 3-D scatterplot of the 95% confidence ellipses of wetlands with at least 1 brood and wetlands with no broods along the first 3 principal component axes.



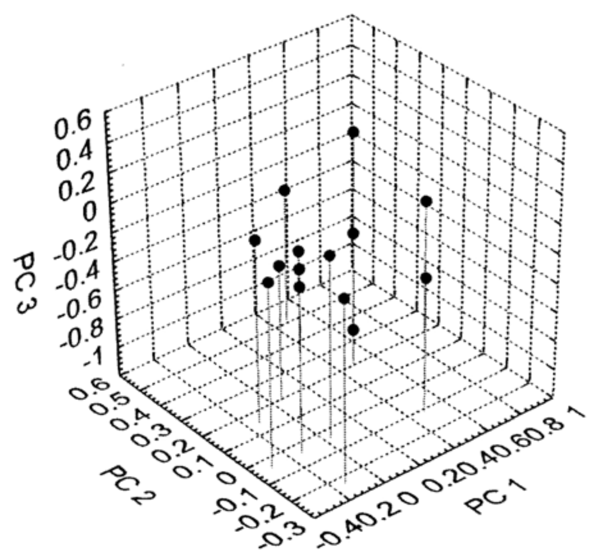
Appendix 3b. A 3-D scatterplot of the 95% confidence ellipses of wetlands with at least 1 species of adult duck and wetlands with no ducks along the first 3 principal component axes.



Appendix 3c. A 3-D scatterplot of the 95% confidence ellipses of wetlands with at least 1 species of waterbirds and wetlands with no waterbirds along the first 3 principal component axes.



Appendix 3d. A 3-D scatterplot of the 95% confidence ellipses of wetlands with at least 1 swan and wetlands with no swans along the first 3 principal component axes.



Appendix 4. Occurrence of all invertebrate organisms found in 3 wetland habitat strata within the Kvichak study area.

	Connected	Closed	Moraine
Annelida			
Oligochaeta	X	X	X
Hirudinea			
Glossiphoniidae	X	X	
Arthropoda			
Insecta			
Coleoptera			
Dytiscidae		X	
Gyrinidae		X	X
Diptera			
Ceratopogonidae	X		
Chironomidae	X	X	X
Culicidae		X	
Simuliidae		X	
Ephemeroptera			
Leptophlebiidae	X		
Hemiptera			
Corixidae	X	X	
Trichoptera			
Leptoceridae			X
Limnephilidae	X	X	X
Phryganeidae	X		
Cnidaria			
Hydrozoa			
Hydridae		X	
Crustacea			
Amphipoda			
Gammaridae	X	X	
Cladocera			
Chydoridae	X	X	
Daphnidae	X	X	
Copepoda			
Cyclopoida	X	X	
Arachnida			
Hydracarina	X	X	

Mollusca			
Gastropoda			
Lymnaeidae		X	
Planorbidae	X	X	X
Pelecypoda			
Sphaeriidae	X	X	X
Nemetoda		X	
Nemetomorpha			
Gordiodea			
Gordiidae		X	

Appendix 5. List of aquatic and upland plant species recorded from wetlands surveyed in the Kvichak study area in 1992 and 1993.

	Connected Wetland	Closed Wetland	Moraine Wetland	River
UPLAND/SHORELINE				
Bluejoint Grass (*Calamagrostis canadensis)*	X	X		
Manna Grass (*Glyceria borealis)*		X		
Sedge (*Carex aquatilus)*	X	X		
(*Carex rostrata)*	X	X	X	
Horsetail (*Equisetum spp*.)		X		
Cotton Grass (*Eriophorum augustifolium)*	X	X		
Labrador Tea (*Ledum palustre)*		X	X	
Cassandra (*Cham*aedaphne calyculata)		X		
Dwarf Birch (*Betula nana)*	X	X		
Shrub Birch (*Betula glandulosa)*	X	X		
Willow (*Salix spp.)*	X	X		X
Marsh Fivefinger (*Potentilla palustris)*		X		
Lingonberry (*Vaccinium vitis-idaea)*		X		
Sweet Gale (*Myrica gale)*		X		
Alder (*Alnus crispa)*	X	X	X	
Black Spruce (*Picea marianna)*	X	X		
White Spruce (*Picea glauca)*	X	X		
Moss (*Sphagnum spp.)*	X	X		
Fern (*Thelypteris phegopteris?)*			X	
EMERGENTS				
Mares Tail (*Hippuris vulgaris)*	X	X		
Spike Rush (*Eleocharis acicularis)*		X		
Water Hemlock (*Cicuta mackenzieana)*		X		
Buckbean (*Menyanthes trifoliata)*	X	X		
SUBMERGENTS				
Pondweed (*Potomogeton praelongus)*	X	X		
(Potomogeton natans)		X		
Water Milfoil (Myriophyllum spicatum)	X	X		
Bureed (*Sparganium augustifolium)*	X	X	X	
Water Shield (*Brasenia schreberi)*		X	X	
Pond Lilly (*Nuphar polysepalum)*	X	X	X	
Hornwort (*Ceratophyllum demersum)*	X	X		