Fairbanks Fishery Resources Project Report Number FY-86/7

# PROGESS REPORT
# LAKE FISHERY HABITAT SURVEY AND CLASSIFICATION ON INTERIOR ALASKA NATIONAL WILDLIFE REFUGES, 1984 AND 1985

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ABSTRACT

During 1984 and 1985 a total of 69 lakes located on six Interior Alaska National Wildlife Refuges were surveyed. The primary objective of these surveys is to provide a means for characterizing lake fisheries habitat by using topographic maps. This will enable a general method of qualifying fisheries habitat for the thousands of lakes found on Interior Alaska National Wildlife Refuges.

Lakes were stratified into map classification groups including lake type (lowland, oxbow, foothill), river/no river connections and flood probability. Data stratified by refuge location was used to evaluate regional differences. Field parameters were then tested for significant differences in mean values within each of the map classification groups. Preliminary map parameter classification for characterizing fish habitat, species abundance, growth and lake productivity were prepared by integrating significant relationships between field data and one or more of the map classification groups.

Regional variation was the primary factor affecting differences among edaphic variables. Highest values for four chemical parameters were found for the Yukon Flats NWR lakes, moderate values were found for Nowitna, Koyukuk, Kanuti and Tetlin refuges and lowest values were found for lakes on Innoko NWR.

Morphometric parameters relating to lake productivity were most effectively classified by lake type or the combination of lake type and flood probability. Morphometric parameters for lowland lakes were indicative of higher productivity levels than for oxbow and foothill lakes.

The presence of fish populations in the study lakes is primarily influenced by connections to rivers. All lakes having river connections had fish present. Other factors affecting the fish use of these lakes include susceptibility to flooding and lake depth, suitable to provide overwintering habitat.

Total gillnet catch-per-unit-effort (CPUE) was greatest for lowland lakes with high flood probability and lowest for lowland lakes with low flood probability. Oxbow lakes and foothill lakes had CPUE values moderating between the later. Northern pike, broad whitefish, least cisco and humpback whitefish were the most commonly occurring species.

Early age growth of northern pike showed significant differences when lakes were grouped by lake type and the combination of lake type and flood probability, showing similar relationships as for the map parameter classification of morphometric parameters.

A comprehensive final report will be completed during FY-1986, following the 1986 field season data collection.

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# INTRODUCTION

There are thousands of lakes located on Interior National Wildlife Refuges. An abundance of wildlife and fishery resources are associated with this habitat. At present, very little information is available on the use of this habitat by fish and wildlife resources, the quality of the habitat to support these resources, and the quantity of habitat. Limited fishery survey work has been reported in Dingell-Johnson Federal Aid Reports. U.S. Fish and Wildlife Service (FWS) biologists have actively surveyed waterfowl use for several years and have accomplished some limnological surveys relating to waterfowl production.

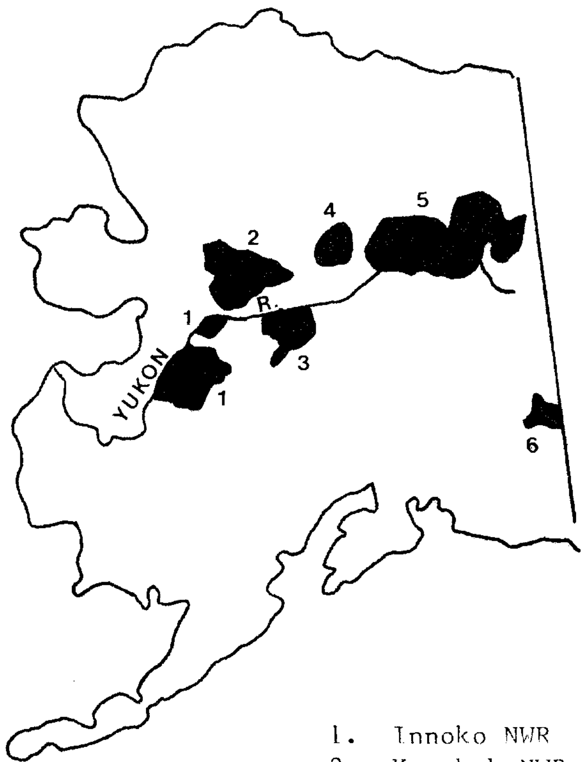
The Alaska National Interest Lands Conservation Act (ANILCA) requires the survey of fish habitat and populations on all Alaska National Wildlife Refuges. Refuge Comprehensive Plans and fishery management plans will require a more detailed assessment of the existing aquatic resources than is now available. In order to accomplish this, a method of habitat classification that allows extrapolation of results to unsurveyed waters is required.

The benefits of habitat classification include the following:

- Catalogue of fishery habitat of value to resource user groups.
- Determination of restoration and enhancement opportunities.
- Use in resource management where comparisons of resource values are required, such as in land exchanges and aquisition and in determining mitigation for losses from environmental perturbations.
- Use in environmental assessment for planning alternatives.
- Use in directing and developing management recommendations for protection, restoration and enhancement.

The objectives of this study are to develop models for characterization of general productivity, fish use and abundance for lakes on Interior Alaska National Wildlife Refuges (Figure 1). The hypothesis is; that field parameter measurements, representing productivity and fish use, may be significantly related to parameters taken from topographic maps, which then would form the basis for the model.

Many studies have linked field parameters with lake productivity, with the ultimate purpose of determining how an overwhelming number of relationships can be narrowed down into a less cumbersome method of predicting productivity. A literature review on northern lake modeling is provided by Fox et al. (1979). Very little literature is available on relating lake




1. Innoko NWR
2. Koyukuk NWR
3. Nowitna NWR
4. Kanuti NWR
5. Yukon Flats NWR
6. Tetlin NWR

Figure 1. General locations of Interior Alaska National Wildlife Refuges.

productivity to models that allow extrapolation to unsurveyed waters. Most of what is available relates productivity to regional differences, by latitude and growing season, and has little importance to localized studies. In regard to stream habitat, there is much literature available relating fish habitat quality and productivity to geomorphic parameters that allow extrapolation (Thompson and Hunt 1930, Slack 1955, Ziemer 1973, Burton and Wesche 1974, Swanston et al. 1977, Hughes and Omernik 1981, Lotspeich and Platts 1981, and Parsons et al. 1981).

# METHODS

Because of the numerous lakes located on Interior Alaska National Wildlife Refuges, generalization is required to provide information that is meaningful to decision makers and the public. Assessing all lake habitat is impractical. However, variation in the lakes, with regard to their surrounding topography, proximity and connections to rivers, regional distribution and characteristics relating to their formation, justifies some stratification for grouping lakes into homogeneous units. Factors relating to productivity, fish distribution and use may then be used to model inherent similarities and differences within these map-based units.

## Field Parameter Selection and Measurement

### Productivity Related Parameters.

Factors influencing lake productivity have been grouped into three broad categories by Rawson (1955) and include edaphic (geologic characteristics of the watershed), morphometric and climatic conditions. Many variables representing each of these categories have shown relationships with fish yield, standing crop, invertebrate and phytoplankton production. Relationships between lake productivity and edaphic conditions, measured by total dissolved solids (TDS), conductivity, alkalinity, hydrogen ion concentration (pH), nitrogen, phosphorus and organic turbidity, have been shown by numerous authors (Moyle 1949, Rawson 1951, Carlander 1955, Moyle 1956, Northcote and Larkin 1956, Ryder 1961, Satomi 1962, Barsdate and Alexander 1971, and Wetzel 1975).

Parameters representing the morphometric category include mean depth, maximum depth, and shoreline development ratio (SDR). Relationships between these parameters and lake productivity have been shown by Rawson (1951, 1955), Carlander (1955), Northcote and Larkin (1956), Ryder (1961), Satomi (1962), Hayes and Anthony (1964) and by Ryder et al. (1974).

Climatic conditions represent a third category of parameters that has an effect on lake productivity. Significant correlates with lake productivity for this category include length of growing season, latitude, water temperature, and thermal stratification (Ryder 1961, Oglesby 1977). Water temperatures and thermal stratification are considered in this group when broad regional differences are examined. For localized studies these two parameters fall within the morphometric category.

The morphoedaphic index (MEI) represents both mophometric and edaphic categories. MEI has been shown as a significant correlate to fish yield and standing crop by Ryder (1965), Jenkins (1970), and is extensively reviewed by Ryder et al. (1974). Littoral area, secchi transparency and aquatic vegetation coverage may also be considered under the morphoedaphic category. All of these are related to depth (morphometric) and edaphic factors influencing nutrient supply and/or the concentration of inorganic matter in the water.

Field parameters used for modeling were selected based upon their performance from the literature in estimating relative productivity and were selected from morphometric, edaphic and combined categories. Climatic factors were not considered because they tend to represent broad regional differences which are out of the scope of this more localized study.

Table 1 lists parameters selected by categories including edaphic, morphometric and those representing both of these categories (morphoedaphic).

Table 1. Productivity related parameters.

| Edaphic | Morphometric | Morphoedaphic |
|---|---|---|
| Conductivity | Maximum Depth | Morphoedaphic Index |
| Total Alkalinity | Mean Depth | % Littoral Area |
| Total Hardness | Shoreline Development Ratio (SDR) | % Aquatic Vegetative Coverage |
| pH | Thermal Stratification Depth | Secchi Transparency |
| | % of Lake Volume with Dissolved Oxygen $<$ 5.0 mg/l | |

Total alkalinity, total hardness and pH were measured using a Hach Model FF-1 water chemistry kit. Conductivity was measured using a Hach Model 17250 Mini Conductivity Meter. Dissolved oxygen - water temperature profiles were measured using a YSI Oxygen-Temperature meter.

A Lowrance, Model X15, recording fathometer was used to obtain depth information for construction of depth profile maps and to determine maximum depth. Mean depth and volume were determined using depth contour maps and methods outlined by Welch (1948). Water transparency was measured using a Secchi disc. Percent littoral area was calculated by taking the percent area of the lake with light penetration to the bottom (as determined by Secchi transparency). All area measurements were determined using a planimeter. Percent of aquatic vegetation coverage was estimated from aerial and on the ground observations. The shoreline development ratio (SDR) was calculated according to the following equation:

$$SDR = \frac{s}{2\sqrt{a\pi}}$$

where "s" equals shoreline length (ft) and "a" equals the lake surface area (acres).

The Morphoedaphic Index (MEI), an index of lake productivity, was originally proposed by Ryder (1965) and was calculated by dividing total dissolved solids (TDS) by the lake mean depth (meters). For this study, MEI was calculated by dividing conductivity by lake mean depth (meters). Conductivity is a significant correlate with total dissolved solids (Hutchinson 1957) and should give directly comparable results. Since the original development of this index, both methods have been used to report MEI data. For the purpose of comparison with other studies, MEI-TDS values were calculated for all lakes sampled during 1984, using the "Conductivity-TDS Conversion Chart" formulated by Dodge et al. (1981). These values were 5% less than MEI-conductivity values ranging from 1 to 10, 20% less than MEI-conductivity values ranging from 10 to 100 and 25% less than values ranging from 100 to 500.

Fisheries Related Parameters.

Characteristics of the fish populations measured include those that reflect the habitat suitablility, species distribution, species relative abundance and growth.

Fish habitat suitability is indicated by the fish use of lakes broken down into three categories including unuseable, marginal use (those that may only be used for migration, spawning, rearing and for feeding) and suitable (those that meet all fish requirements for growth, reproduction and overwintering). Presence-absence data was used to distinguish unsuitabable from marginal and suitable habitat categories. Because of the absence of winter measurements, information from the literature and supporting physio-chemical data collected during the summer were used to distinguish between marginal lake habitat and suitable lake habitat.

Species distribution was measured by their frequency of occurrence in lakes classified by the map based units (model units). Relative abundance of fish was determined by gillnet catch-per-unit effort (CPUE) data. Experimental gill nets consisting of five 25 foot panels of 0.75, 1.0. 1.5, 2.0, and 2.5 inch bar mesh sizes were used for sampling fish. Net site selection was stratified according to different types of habitat in the lake. Normally two to four gillnets were used at each lake. More effort was used on larger lakes. Fork length (mm) and weight (g) were recorded for each fish collected. Stomachs from northern pike, sacrificed for age analysis, were examined for fish species not collected in gillnets.

Scales were used for determining age of whitefish, northern pike, and Arctic grayling. In addition to scales, cliethra were also used to age northern pike. Methods for age determination using cliethra were reported by Casselman (1974) and Harrison and Hadley (1979). Only age I through III growth of northern pike is presented in this report, for purposes of comparisons of lake productivity between the different classification groups. Age and growth of all species will be presented in a seperate comprehensive report following the 1986 field season.

## Map Parameter Selection and Measurement

Map parameters selected (model units) were presumed to represent significant differences in morphometric and edaphic characteristics that ultimately relate to lake productivity, fish distribution, abundance and growth. Four different map parameters were chosen including geographic location, lake type (lowland, oxbow, foothill), system type (river connected or no river connections) and flood probability.

Geographic location should primarily reflect regional variations in chemical characteristics of the lakes. These variations could be attributed to variations in nature of soils, geologic parent materials and vegetation of the watersheds. Geographic location was recorded by the refuge unit from which the lakes were located.

Lake types were determined, using U.S.G.S. 1:63,360 maps. Lakes were first categorized into lowland and foothill groups according to the surrounding contours on USGS 1:63,360 maps. Foothill lakes had surrounding contours exhibiting gradients greater than 100 feet/mile whereas lowland lake surrounding contours were less than 100 feet/mile. Oxbow lakes, those closely associated with larger river channels and formed from cutoff meanders of those channels, were separated from the lowland lake group to form a separate category. These three lake types generally represent different lake formation processes which relate primarily to variations in depth, and parameters significantly correlated with depth, between these groups. Foothill lakes are primarily of tectonic and glacial origin and generally exceed 10 meters in maximum depth. Lowland lakes were primarily formed from thawing of permafrost and/or beaver activity damming low lying areas along stream courses. Maximum depth of lowland lakes is generally less than 3 meters. Oxbow lakes exhibit depths moderating between lowland and foothill types.

The presence or absence of river connections is of particular importance to fish distribution and use of lake habitat. Rivers connecting marginal habitat provide a pathway for at least temporary use of this habitat. River connections may also affect chemical conditions of the lakes they enter by increasing nutrient and allocthonous organic input into these systems (Murphy et al. 1984, Whalen and Cornwell 1985).

Flooding may affect lakes in similar ways as described for river connected lakes. Lakes less than 1 mile from a major river channel (4th order or larger; Strahler 1957) and where surrounding terrain would not inhibit interchange of water from river to lake during flood periods were given a high flood probability rating. Lakes located farther than 1 mile from a major river channel were given a low flood probability rating.

### Statistical Analysis

In order to determine the best method for grouping lakes by map parameters according to model objectives, field parameter data for lakes were first grouped by map parameters and combinations of map parameters. Mean field parameter values for groups within each classification scheme were tested by one-way analysis of variance (ANOVA) to see if the map classification scheme showed significant differences ($P \leq 0.05$) between its respective groups. Those classification schemes showing significant differences were then tested by a Newman-Keuls Multiple Range Test, for unequal sample sizes, (Zar 1974) to determine which groups, within the classification scheme, were significantly different ($P \leq 0.05$).

The later procedure was done for all field parameters except for presence and absence of fish, where frequency data was used to evaluate differences in map parameter groupings. For this a two-way $Chi^2$ Analysis (Sokal and Rolf 1969) was performed testing the null hypothesis: if the proportions of lakes having fish were the same over the various map parameter groups. The null hypothesis was rejected where $P \leq 0.05$.

In order to test for association between field parameters, Pearson Product-Moment Correlations were used (Sokal and Rolf 1969). Correlation coefficient values were tested to see if they were significantly different from zero ($P \leq 0.05$ and $P \leq 0.01$).

## RESULTS AND DISCUSSION

This progress report was intended to determine which map parameters or combinations of map parameters best reflects differences in variables measured in the field. A singular classification method or model depicting productivity relationships, fish use, abundance distribution and growth would limit the amount of information which could be extracted from the later categories (for example river connections may be much more important in determining presence or absence of fish from lakes than determining lake productivity).

The following paragraphs will attempt to determine the best classification method (map parameters or combination of map parameters) for each of the model objectives (ie., lake productivity, fish use, species distribution, abundance, etc.) and also determine which field parameters can be significantly related to the map parameters.

### Lake Productivity Classification

Edaphic Component.

Variables associated with the edaphic component of productivity are shown in Table 2. These values have been categorized by all lakes and by the four map based model groups. Regional variation represented by Refuge location of the lakes is only directly applicable to edaphic characteristics and is not considered in evaluating the morphometric component of the productivity relationships.

Variables considered under the edaphic category include conductivity, total alkalinity, total hardness and pH. Initial observation of mean values for variables from Table 2 indicate high values associated with the Yukon Flats NWR, foothill lakes, lakes without river connections and lakes with low flood probability. Increased levels of productivity are generally associated with increased values for these variables.

One-way ANOVA was performed on mean edaphic parameter values for all map parameters and various combinations of map paramters (Table 3). In every case differences between mean values by refuge location exhibited a much stronger significance ($P < .0001$) than for differences between other map parameters and combinations of those parameters. This indicates a strong effect of regional variation on edaphic parameters.

Table 2. Mean values for edaphic parameters from data grouped by all lakes, Refuge, lake type, river connections and flood probability.

| Group (sample size) | Conductivity (umhos/cm) | Total Alkalinity (mg/l) | Total Hardness (mg/l) | pH |
|---|---|---|---|---|
| All lakes (69) | 98 | 66 | 67 | 7.2 |
| Innoko NWR (17) | 29 | 28 | 28 | 6.3 |
| Kanuti NWR (11) | 60 | 42 | 43 | 7.4 |
| Koyukuk NWR (24) | 80 | 57 | 62 | 7.1 |
| Nowitna NWR (2) | 68 | 34 | 34 | 6.5 |
| Tetlin NWR (7) | 87 | 44 | 68 | 8.0 |
| Yukon Flats NWR (8) | 371 | 236 | 201 | 8.7 |
| Foothill Lakes (10) | 188 | 124 | 121 | 7.8 |
| Lowland Lakes (41) | 93 | 63 | 64 | 7.3 |
| Oxbow Lakes (18) | 60 | 43 | 43 | 6.8 |
| River Connected (36) | 75 | 51 | 58 | 7.2 |
| Not Connected (33) | 126 | 87 | 79 | 7.4 |
| Low Flood Probability (39) | 121 | 85 | 83 | 7.4 |
| High Flood Probability (30) | 69 | 42 | 46 | 7.0 |

Table 3. One-way Analysis of Variance (ANOVA) for edaphic variables grouped by map parameters and combinations of map parameters ($P > 0.05$ is considered as not significant).

| Map Parameter Grouping | Degrees of Freedom | Significance Level | | | |
|---|---|---|---|---|---|
| | | Conductivity | Total Alkalinity | Total Hardness | pH |
| Refuge | 5/63 | < .0001 | < .0001 | < .0001 | < .0001 |
| Lake type (LT) | 2/66 | NS | .05 | .01 | .01 |
| River Connection (RC) | 1/67 | NS | NS | NS | NS |
| Flood Probability (FP) | 1/67 | NS | .05 | .01 | NS |
| LT + RC | 5/63 | NS | NS | .025 | NS |
| LT + FP | 3/65 | NS | NS | .025 | .01 |
| LT + RC + FP | 7/61 | NS | NS | .05 | NS |

Mean values for edaphic variables from Table 2 indicate three possible groupings of Refuges to classify Regional variation for these parameters. Innoko NWR had the lowest mean values followed with moderate values for Koyukuk, Nowitna, Kanuti and Tetlin refuges and high values for the Yukon Flats NWR. Significance levels (ANOVA) indicating the strength of differences between each edaphic variable and refuges grouped by all refuge data, by omitting Yukon Flats data only, by omitting Innoko Data only and by omitting both Innoko and Yukon Flats data are found in Table 4.

Table 4. One-way ANOVA for edaphic variables grouped by break-downs in Regional locations (Refuges) and data grouped by each refuge ($P > 0.05$ is considered as not significant).

| Map Parameter Grouping | Degrees of Freedom | Significance Level | | | |
|---|---|---|---|---|---|
| | | Conductivity | Total Alkalinity | Total Hardness | pH |
| All Refuges | 5/63 | < .0001 | < .0001 | < .0001 | < .0001 |
| Innoko Omitted | 4/56 | < .0001 | < .0001 | < .0001 | .001 |
| Yukon Flats Omitted | 4/47 | .025 | .01 | .001 | .001 |
| Innoko and Yukon Flats Omitted | 3/40 | NS | NS | NS | NS |

When Yukon Flats data is included and Innoko data is omitted the significance levels stay nearly the same as those for tests using data from all refuges. Significant differences also occur when Innoko data is included and Yukon Flats data is omitted, but at a lower level of significance. The later suggests that more variation is attributed to Yukon Flats data than to Innoko data. When both Innoko data and Yukon Flats data are omitted there are no significant differences ($P \leq 0.05$) relating edaphic variable to regional groupings.

It appears that Koyukuk, Nowitna, Kanuti and Tetlin may comprise one group that exhibits similar edaphic characteristics, with Innoko and Yukon Flats representing 2 other distinct groupings. A Newman-Keuls Multiple Range Test was used to test for significant differences between these groups and results are presented in Table 5.

Conductivity and total alkalinity are found to be significantly greater for Yukon Flats lakes than for lakes located at other refuges. Total hardness and pH separate into three significantly different groups with greatest values observed for the Yukon Flats, lowest values for Innoko and the third group with moderate values representing the other refuges.

These data indicate that regional location is the most important factor separating differences in edaphic parameter and can be grouped into a two-way or 3-way classification scheme. Further breakdown using other map parameters or combinations of those parameters produced no significant difference ($P \leq 0.05$) except for pH (for groups created from lake type and flood probability and from groups created by lake type, flood probability and river connections).

Table 5. Newman-Keuls Multiple Range Test of mean values of edaphic variables with data grouped into three regional location classes (underlined groups represent those exhibiting no significant differences for P = 0.05).

| Edaphic Variable | Rank (mean/group) 1 | 2 | 3 |
|---|---|---|---|
| Conductivity | 28.5<br>Innoko | 75.6<br>Other Refuges* | 370.6<br>Yukon Flats |
| Total Alkalinity | 28.0<br>Innoko | 50.2<br>Other Refuges | 236.3<br>Yukon Flats |
| Total Hardness | 28.01<br>Innoko | 57.3<br>Other Refuges | 201.0<br>Yukon Flats |
| pH | 6.3<br>Innoko | 7.3<br>Other Refuges | 8.7<br>Yukon Flats |

* Koyukuk, Nowitna, Kanuti and Tetlin NWR's combined.

## Morphometric Component

Morphometric parameters and those representing combined morphometric and edaphic categories are shown in Table 6. Morphoedaphic parameters are included in this section because they appear to be more dependent on morphometric characteristics.

One-way ANOVA for these parameters grouped by map parameters and combinations of map parameters are shown in Table 7. Group breakdowns with MEI values showed no significant differences ($P \leq 0.05$). None of the variables showed significant differences when data was grouped by the presence or absence of river connections. Only four of the nine variables exhibited significant differences when data was grouped by high and low flood probability. Data grouped by lake type (3 groups), lake type and river connections combined (6 groups), lake type and flood probability (4 groups; oxbow lakes had all high flood probability ratings and foothill lakes had all low flood probability ratings) and by the combination of lake type, river connections and flood probability (8 groups) exhibited significant differences for all parameters except MEI.

Three of the map parameter groupings were selected for further analysis based on their ability to distinguish significant differences among the field parameters tested. These groups included lake type, lake type and flood probability combined and the combination of lake type, flood probability and presence or absence of river connections. Although, the group combining lake type and river connections exhibited similar levels of significance as other groups for the parameters investigated, it was not included because of the absence of significant differences found when data was grouped by river connections alone. Because of the later, grouping by lake type and river connections combined would probably not give anymore information than just grouping by lake type alone.

Significant differences ($P \leq 0.05$) between groups within each of the three classification schemes is shown in Table 8. In order to evaluate the usefulness of these classification schemes the number of distinct groups

Table 6. Mean values for morphometric and morphoedaphic parameters from data grouped by all lakes, lake types, river connections and flood probability.

| | Morphometric Parameters | | | | | Morphoedaphic Parameters | | | |
|---|---|---|---|---|---|---|---|---|---|
| Group (sample size) | Max. Depth (m) | Mean Depth (m) | Shoreline Development Ratio | Thermal Stratification Depth (m) | Lake Volume with D.O. < 5.0 mg/l | MEI | Secchi (m) | % Littoral Area | % Aquatic Vegetation Coverage |
| All Lakes (69) | 6.0 | 2.4 | 2.04 | 1.2 | 12.2 | 51.9 | 1.5 | 43 | 21 |
| Foothill Lakes (10) | 17.5 | 6.3 | 1.71 | 3.4 | 3.0 | 39.8 | 3.0 | 41 | 10 |
| Lowland Lakes (41) | 2.9 | 1.4 | 1.68 | 0.5 | 2.9 | 67.0 | 1.4 | 52 | 29 |
| Oxbow Lakes (18) | 6.7 | 2.7 | 3.05 | 1.4 | 36.3 | 24.3 | 1.1 | 24 | 10 |
| River Connected (36) | 6.2 | 2.7 | 2.02 | 1.3 | 14.3 | 40.6 | 1.3 | 38 | 21 |
| Not Connected (33) | 5.7 | 2.1 | 2.07 | 1.1 | 9.6 | 66.7 | 1.8 | 50 | 21 |
| Low Flood Probability (39) | 6.8 | 2.6 | 1.66 | 1.4 | 1.6 | 62.9 | 2.0 | 58 | 23 |
| High Flood Probability (30) | 4.9 | 2.2 | 2.55 | 1.0 | 24.3 | 37.5 | 0.9 | 23 | 18 |

Table 7. One-way ANOVA for morphometric and morphoedaphic variables grouped by map parameters and combinations of map parameters ($P > 0.05$ is considered as not significant).

| | | Morphometric Parameters (F values/signif. level) | | | | | Morphoedaphic Parameters (F values/signif. level) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Degrees of Freedom | Max. Depth | Mean Depth | SDR | Thermal Strat. Depth | % of Lake Vol. with DO < 5.0 mg/l | % Littoral Area | % Veg. Area | MEI | Secchi |
| Lake Type (LT) | 2/66 | 52.52<br>< .0001 | 42.05<br>< .0001 | 29.61<br>< .0001 | 15.28<br>< .0001 | 20.29<br>< .0001 | 5.32<br>.0100 | 6.90<br>.0050 | NS | 11.45<br>.0001 |
| River Connections(RC) | 1/67 | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Flood Probability(FP) | 1/67 | NS | NS | 23.68<br>< .0001 | NS | 18.03<br>< .0001 | 26.59<br>< .0001 | NS | NS | 14.04<br>.0004 |
| LT + RC | 5/63 | 20.67<br>< .0001 | 20.99<br>< .0001 | 13.64<br>< .0001 | 6.04<br>< .0001 | 7.83<br>< .0001 | 2.45<br>.0500 | 2.81<br>.0250 | NS | 6.46<br>.0001 |
| LT + FP | 3/65 | 34.81<br>< .0001 | 27.62<br>< .0001 | 19.80<br>< .0001 | 10.05<br>< .0001 | 13.63<br>< .0001 | 11.22<br>< .0001 | 4.64<br>.0100 | NS | 10.26<br>< .0001 |
| LT + FP + RC | 7/61 | 14.49<br>< .0001 | 14.53<br>< .0001 | 10.45<br>< .0001 | 4.28<br>.0010 | 5.56<br>.0001 | 5.22<br>.0001 | 2.87<br>.0250 | NS | 5.76<br>< .0001 |

Table 3. Newman-Keuls multiple range comparison tests of mean values of morphometric and morphoedaphic parameters grouped by three different lake classification schemes (underlined groups represent those exhibiting no significant differences, P = 0.05).

**Combined Classification* (Mean/Group)**

| | RANK 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Secchi (m) | 0.72 LNCH | 0.74 LRCH | 0.82 ORC | 1.55 LRCL | 1.60 ONC | 1.64 LNCL | 2.38 FRC | 3.85 FNC |
| Maximum Depth (m) | 2.25 LRCH | 2.30 LNCH | 2.79 LNCL | 3.49 LRCL | 6.00 ORC | 8.08 ONC | 16.98 FNC | 17.88 FRC |
| Mean Depth (m) | 1.32 LRCL | 1.38 LNCL | 1.41 LRCH | 1.45 LNCH | 2.67 ORC | 2.75 ONC | 4.42 FNC | 7.47 FRC |
| SDR | 1.42 LNCH | 1.52 FRC | 1.54 LRCL | 1.72 LNCL | 1.99 LRCH | 2.00 FNC | 2.82 ORC | 3.49 ONC |
| Thermal Stratification Depth (m) | 0.29 LNCL | 0.38 LRCH | 0.50 LNCH | 0.95 LRCL | 1.33 ORC | 1.67 ONC | 3.25 FNC | 3.50 FRC |
| % Lake Volume w/ D.O. 5.0 mg/l | 0.60 LRCL | 1.43 LNCL | 2.50 FRC | 3.75 FNC | 4.75 LRCH | 9.25 LNCH | 32.67 ONC | 38.10 ORC |
| % Littoral Area | 11.0 LNCH | 18.8 ORCH | 28.6 LRCH | 34.2 ONC | 34.3 FRC | 50.5 FNC | 63.5 LRCL | 64.8 LNCH |
| % Vegetation Coverage | 7.3 ONC | 7.5 FRC | 11.3 ORC | 14.3 FNC | 22.1 LNCL | 24.3 LRCH | 34.2 LRCL | 52.9 LNCH |

**Lake Type and Flood Probability* (Mean/Group)**

| | RANK 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Secchi (m) | 0.70 LH | 1.10 O | 1.60 LL | 3.00 F |
| Maximum Depth (m) | 2.25 LH | 3.11 LL | 6.70 O | 17.52 F |
| Mean Depth (m) | 1.35 LL | 1.43 LH | 2.70 O | 6.30 F |
| SDR | 1.64 LL | 1.71 F | 1.80 LH | 3.05 O |
| Thermal Stratification Depth (m) | 0.42 LH | 0.54 LL | 1.44 O | 3.40 F |
| % Lake Volume w/ D.O. 5.0 mg/l | 1.08 LL | 3.00 F | 6.25 LH | 36.30 O |
| % Littoral Area | 22.8 LH | 23.9 O | 40.7 F | 64.2 LL |
| % Vegetation Coverage | 9.9 O | 10.2 F | 27.6 LL | 31.2 LH |

**Lake Type Only* (Mean/Group)**

| | RANK 1 | 2 | 3 |
|---|---|---|---|
| Secchi (m) | 1.10 O | 1.40 L | 3.00 F |
| Maximum Depth (m) | 2.90 L | 6.70 O | 17.50 F |
| Mean Depth (m) | 1.40 L | 2.70 O | 6.30 F |
| SDR | 1.68 L | 1.71 F | 3.05 O |
| Thermal Stratification Depth (m) | 0.50 L | 1.44 O | 3.40 F |
| % Lake Volume w/ D.O. 5.0 mg/l | 2.90 L | 3.00 F | 36.30 O |
| % Littoral Area | 23.9 O | 40.7 F | 52.0 L |
| % Vegetation Coverage | 9.9 O | 10.2 F | 29.0 LL |

* O = Oxbow, L = Lowland, F = Foothill, RC = River Connected, NC = Not Connected, L = Low Flood Probability, H = High Flood Probability

Oxbow lakes - all have high flood probability
Foothill Lakes - all have low flood probability

(groups which are significantly different and do not exhibit overlap) for each parameter were compared. There were no differences between groups formed by lake type and groups formed by the combination of lake type and flood probability except for % littoral area. When the data was grouped by lake type and flood probability combined, % littoral area formed two distinct groups including lowland-low flood (highest mean value) and the other classifications forming the second group. Distinct groups were not formed for % littoral area when data was used from lake type alone.

The classification combining lake type, flood probability and presence or absence of river connections showed much overlap between groups, with only four of the variables producing distinct groupings. This greater amount of overlap may be caused by the relatively smaller sample size created by breaking down the data into eight groups.

A summary of the resulting relationship from the later analysis is shown is Table 9.

Table 9. Lake classification grouping based on significant differences ($P \leq 0.05$) between group mean values for morphometric and morpho-edaphic parameters and relationship to lake productivity.

| Parameter | Productivity Relationship | Group Ranking |
|---|---|---|
| Secchi | (-) | 1 2 2<br>Foothill > Lowland=Oxbow |
| Max Depth | (-) | 1 2 3<br>Foothill > Oxbow > Lowland |
| Mean Depth | (-) | 1 2 3<br>Foothill > Oxbow > Lowland |
| SDR | (+) | 2 1 1<br>Oxbow > Foothill=Lowland |
| Thermal Stratification Depth | (-) | 1 2 2<br>Foothill > Oxbow=Lowland |
| % Lake Volume with D.O. < 5.0 mg/1 | (-) | 1 2 2<br>Oxbow > Foothill=Lowland |
| % Littoral Area | (+) | Lowland-Low Flood > Foothill=Oxbow= Lowland-High Flood |
| % Vegetation Coverage | (+) | 2 1 1<br>Lowland > Foothill=Oxbow |
| Sum of Ranks (excluding % Littoral Area) | | Lowland=15, Oxbow=12, Foothill=8 |

In Table 9, the overall sum of ranks (highest sum indicating greatest productivity rating according to morphometric considerations) shows lowland lakes greater than oxbow lakes greater than foothill lakes.

To further facilitate relating these parameters to lake productivity, it is necessary to differentiate significant correlates among them. Maximum depth and mean depth are probably the most previously used morphometric parameters relating to lake productivity and have shown inverse correlation to productivity at all trophic levels (Rawson 1955, Northcote and Larkin 1956, Satomi 1962, Hayes and Anthony 1964, Ryder 1965). Depth has been related to other parameters including littoral zone area, temperature, thermal stratification, circulation and dilution of nutrients (Rawson 1951, 1952). Correlation analysis of maximum and mean depth with other morphometric parameters resulted in a highly significant ($P \leq 0.01$) positive correlation with thermal stratification depth and secchi transparency and a negative correlation with % littoral area and % aquatic vegetation coverage.

Other morphometric parameters that were significantly correlated included SDR with % of lake volume with dissolved oxygen less than 5.0 mg/l (positive correlation). High SDR values were associated with oxbow lakes which are sheltered from the wind limiting atmospheric diffusion of oxygen into the water.

In view of the literature and cross correlation of depth with other morphometric parameters it appears that depth may be the best morphometric variable to relate to productivity. Both maximum and mean depth exhibit the highest F values and consequent significance (Table 7) for differences between groups created from map parameters.

Productivity Classification Summary.

Regional variation was the primary factor affecting differences among edaphic variables and can be classified into three groups in order of increasing productivity; Group I - lakes on Innoko NWR, Group II - lakes on Koyukuk, Nowitna, Kanuti and Tetlin NWR, and Group III - Yukon Flats NWR lakes. Mean values for conductivity, total alkalinity and total hardness for Yukon Flats lakes were aproximately 10 times greater than for Innoko lakes and 5 times greater than the average of those from the other refuges.

Higher conductivity, alkalinity, and pH values for lakes on the Yukon Flats NWR may be attributed to carbonate deposits found within the area. Bicarbonates and carbonates have been correlated with productivity in freshwater lakes (Moyle 1956). They provide an inorganic pool of carbon for photosynthetic metabolism by aquatic macrophytes and algae and also buffer waters against rapid changes in pH. Trona deposits (sodium carbonate) are located throughout the Yukon Flats (personal communication - Yukon Flats NWR office). These deposits can be seen from the air and appear as white areas in dried up lake beds. The White Mountains, which form the southern boundary of Yukon Flats NWR is reported to have considerable amounts of limestone; calcium carbonate (personal communication - Alaska Geological Survey, Fairbanks). The USDA Soil Conservation Service office in Fairbanks stated that soil pH values are near 8.0 in the Yukon Flats. In contrast to that, soil pH values is the Tanana Valley are around 4.5.

The lake type map parameter is an effective way of grouping according to differences in morphometric variables. Depth parameters were significantly correlated with other morphometric variables and are perhaps the best variable to be considered for comparing lake productivity. Strong differences in depth between map parameter groups were indicated by ANOVA tests. Generally productivity increases with decreasing lake depth.

The combination of the edaphic and morphometric components could create up to a maximum of nine different productivity level classifications with the highest level for lowland lakes on the Yukon Flats NWR and lowest level for oxbow lakes on Innoko NWR (oxbow was used here because there are no foothill lakes on Innoko NWR). The final report will attempt to qualify these levels in more detail and relate to lake trophic levels (oligotrophic, eutrophic, etc.).

More data will become available for Nowitna, Yukon Flats and Tetlin refuges after the 1986 field season. This will provide sample sizes of approximately 15 to 25 lakes sampled for each of the refuges. Data will be similarly processed and re-evaluated for the final report.

## Fish Distribution

### General Distribution

A total of 12 species of fish have been collected during 1984 and 1985 field seasons and are listed in Table 10.

Table 10. List of common and scientific names of fish collected from Interior National Wildlife Refuge lakes during 1984 and 1985.

| Common Name | Abbreviation | Scientific Name |
|---|---|---|
| Northern pike | NP | Esox lucius |
| Arctic grayling | GR | Thymallus arcticus |
| Sheefish | SF | Stenodus leucichthys |
| Lake trout | LT | Salvelinus namayacush |
| Humpback whitefish | HWF | Coregonus pidschian |
| Broad whitefish | BWF | Coregonus nasus |
| Round whitefish | RWF | Prosopium cylindraceum |
| Least cisco | LCI | Coregonus sardinella |
| Longnose sucker | LNS | Catostomus catostomus |
| Alaska blackfish | AB | Dallia pectoralis |
| Slimy sculpin | SSC | Cottus cognatus |
| Ninespine stickelback | NSB | Pungitius pungitius |

The percentage of lakes surveyed having fish populations is shown in Table 11. From this table it is apparent that river connections play the most important role in determining presence or absence of fish in these waters (100% of all river connected lakes had fish present). Fish populations were also found more frequently in lakes with high flood probability. The presence of river connections and/or high flood probability for all oxbow lakes accounts for fish being collected from all of the lakes in this category.

A Two-way $Chi^2$ analysis was used to test the null hypothesis: if the proportions of lakes having fish were the same over the various map parameter groupings. First, river connected lakes vs. not connected lakes were compared, resulting in a highly significant difference ($P \leq 0.005$) in fish presence between the two groups. Because fish were found in all of the river connected lakes, no further analysis of this parameter broken down by other map parameters was necessary. Lakes that were not connected to rivers were broken down by flood probability, by lake type and by the combination of lake type and flood probability however no significant difference ($P \leq 0.05$) were found. When lakes without river connections were grouped by lowland and

Table 11. Percentage of lakes with fish present (sample size) from 69 lakes surveyed during 1984 and 1985.

| | All Lakes | River Connected | No River Connections | Low Flood | High Flood |
|---|---|---|---|---|---|
| All Lakes | 83 (69) | 100 (36) | 74 (33) | 77 (39) | 90 (30) |
| Foothill Lakes | 80 (10) | 100 (6) | 50 (4) | 80 (10) | -- (0) |
| Lowland Lakes | 76 (41) | 100 (18) | 57 (23) | 76 (29) | 75 (12) |
| Oxbow Lakes | 100 (18) | 100 (11) | 100 (7) | -- (0) | 100 (18) |
| River Connected Lakes | -- | -- | -- | 100 (18) | 100 (18) |
| No River Connections | -- | -- | -- | 57 (21) | 75 (12) |

foothill lakes combined and by oxbow lakes there was a significant difference (P 0.05) in the proportions of lakes having fish populations between the two groups. This may indicate that oxbow lakes, located in very close proximity to large river channels, may be more susceptible to colonization from flooding than lowland lakes, which are in many cases located farther away from the river channels. Also, oxbow lakes were at one time connected to rivers providing a pathway for colonization prior to being cutoff from the river. The depth of many oxbow lakes is also more suitable for sustaining fish populations through the winter than the depth observed for lowland lakes. Nickum (1970) stated that for lakes in South Dakota maximum depths of 3 meters are typical of winterkill lakes and winterkill rarely occurs in lakes with maximum depths greater than 5 meters. Nine lakes were surveyed with low potential for overwintering capability (maximum depths less than 3 meters, no river connections and low flood probability). Six of these lakes had fish and 3 did not have fish. Northern pike and Alaska blackfish were the only species found where these conditions occurred. It appears that these two species are capable of surviving in very marginal habitat.

The use of habitat by fish can be summarized into the following categories:

<u>Unuseable</u> - This category depends on the ability of fish to gain access into a lake and where shallow depth would preclude year-round habitation. Tentative map parameter classification would include most lowland lakes (where maximum depth was less than 3 meters) that have no river connections and have low flood probability.

<u>Marginal Use</u> - This group represents lakes that are used only during the ice-free season and includes river connected and/or high flood probability lowland lakes (where maximum depth was less than 3 meters).

<u>Suitable</u> - This group represents lakes that can be used throughout the year. Depth is the primary factor involved in defining suitable lakes and would include almost all oxbow and foothill lakes.

Species Distribution.

Frequency of occurrence of fish species by lake classification groups is shown in Table 12. Northern pike was the most ubiquitous species, occurring in 91% of all lakes that had fish present and found in all of the lake categories represented in Table 11. They were collected more frequently from lowland and oxbow lakes than from foothill lakes. Broad whitefish, least cisco and humpback whitefish were collected from 37 to 47% of all lakes and were most frequently found in oxbow lakes, lakes with river connections and lakes with high flood probability. Alaska blackfish were collected from 26% of the lakes that had fish present and found in lowland and oxbow lakes but not in foothill lakes. This species was also collected more frequently from lakes without river connections than lakes with river connections. Seven other species collected were found in only 2 to 8% of all lakes. Ninespine stickleback and sheefish were found only in oxbow lakes. Arctic grayling, slimy sculpin, lake trout, and round whitefish were found only in foothill lakes. Longnose suckers were found, infrequently, in all three lake types.

Table 12. Percent frequency of occurrence of fish species from lakes (with fish populations) sampled during 1984 and 1985.

| Species | All Lakes | Foothill Lakes | Lowland Lakes | Oxbow Lakes | River Connected | No Connection | Low Flood Probability | High Flood Probability |
|---|---|---|---|---|---|---|---|---|
| sample size | (57) | (8) | (31) | (18) | (36) | (21) | (30) | (27) |
| Northern Pike | 91 | 63 | 94 | 100 | 89 | 95 | 90 | 93 |
| Broad Whitefish | 47 | 13 | 42 | 72 | 53 | 38 | 20 | 78 |
| Least Cisco | 47 | 50 | 39 | 61 | 50 | 43 | 23 | 74 |
| Humpback Whitefish | 37 | 13 | 35 | 50 | 44 | 24 | 10 | 67 |
| Alaska Blackfish | 26 | 0 | 35 | 22 | 19 | 38 | 27 | 26 |
| Longnose Sucker | 8 | 13 | 6 | 6 | 8 | 5 | 3 | 11 |
| Ninespine stickleback | 6 | 0 | 0 | 17 | 3 | 10 | 0 | 11 |
| Arctic Grayling | 6 | 38 | 0 | 0 | 8 | 0 | 10 | 0 |
| Sheefish | 4 | 0 | 0 | 11 | 3 | 5 | 0 | 7 |
| Slimy Sculpin | 4 | 25 | 0 | 0 | 0 | 10 | 7 | 0 |
| Lake Trout | 2 | 13 | 0 | 0 | 0 | 5 | 3 | 0 |
| Round Whitefish | 2 | 13 | 0 | 0 | 3 | 0 | 3 | 0 |
| No. of Species | 12 | 9 | 6 | 8 | 10 | 10 | 10 | 8 |

A more comprehensive breakdown (evaluated by combination of map parameters) of species distribution will be completed for the final report after all field data collection is accomplished.

## Fish Abundance

Catch-per-unit-effort (CPUE) data is shown in Table 13. The mean total gillnet CPUE for all lakes was 0.89 fish/hr. One-way ANOVA was performed on CPUE data grouped by individual map parameters and combinations of those parameters and is shown in Table 14.

Total fish CPUE was the only variable that showed a significant difference between map parameter groups and only with flood probability and the combination of flood probability with lake type.

Table 14. One-way ANOVA for CPUE data grouped by map parameters and combinations of map parameters ($P > 0.05$ is considered as not significant).

| Grouping | CPUE (Fish/Gn-Hr) | | | |
|---|---|---|---|---|
| | Total Fish | Northern Pike | Broad and Humpback Whitefish combined | Least Cisco |
| Refuge | NS | | | |
| River Connections (RC) | NS | | | |
| Flood Probability (FP) | 0.05 | No | Significant | |
| Lake Type (LT) | NS | | | |
| LT + RC | NS | | Differences | |
| LT + FP | 0.025 | | | |
| LT + RC + FP | NS | | | |

Results of a Newman-Keuls Multiple Range Test of total fish CPUE by lake type and flood probability combined shows the following relationship:

| Rank: | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Mean Value: | 0.499 | 0.909 | 0.980 | 1.726 |
| Group: | Lowland-Low Flood | Oxbow | Foothill | Lowland-High Flood |

Two overlapping groups were formed by the test, making a distinction between the highest mean value, for lowland-high flood probability lakes, and the lowest mean value for lowland-low flood probability lakes. Many of the lakes in the lowland-high flood probability group were connected to rivers or had recently flooded (June 1985) and this probably reflects the use of these lakes, by riverine populations, for spawning and for summer feeding. Although there was no significant difference for mean total fish CPUE values between oxbow lakes and lowland-high flood probability lakes, the later exhibited a much higher CPUE. This may indicate a preference by fish in using lowland-high flood probability lakes over using oxbow lakes. Reasons for this may include poorer oxygen conditions found in oxbow lakes and/or greater productivity of lowland lakes, providing better rearing-feeding habitat (which would concur with the lake type productivity grouping in the previous section).

Table 13. Mean gillnet catch-per-unit-effort (number/hr) for lakes stratified by lake type, river connections and flood probability.

| | Total Fish CPUE | | | Northern Pike CPUE | | | Combined Humpback, Broad Whitefish | | | Least Cisco CPUE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\bar{x}$ | S.D. | n | $\bar{x}$ | S.D. | n | $\bar{x}$ | S.D. | n | $\bar{x}$ | S.D. | n |
| All Lakes | 0.89 | 1.02 | 56 | 0.49 | 0.53 | 52 | 0.36 | 0.41 | 28 | 0.43 | 0.76 | 22 |
| Foothill Lakes | 0.98 | 1.48 | 7 | 0.46 | 0.26 | 5 | 0.05 | 0.04 | 2 | 0.02 | 0.01 | 2 |
| Lowland Lakes | 0.86 | 1.12 | 31 | 0.44 | 0.51 | 29 | 0.55 | 0.54 | 13 | 0.64 | 1.09 | 10 |
| Oxbow Lakes | 0.91 | 0.61 | 18 | 0.58 | 0.63 | 18 | 0.21 | 0.10 | 13 | 0.30 | 0.28 | 10 |
| River Connected | 0.92 | 0.96 | 35 | 0.51 | 0.56 | 32 | 0.30 | 0.30 | 20 | 0.34 | 0.44 | 16 |
| No River Connection | 0.84 | 1.13 | 21 | 0.47 | 0.51 | 20 | 0.51 | 0.60 | 8 | 0.68 | 1.33 | 6 |
| Low Flood Prob. | 0.62 | 1.02 | 29 | 0.40 | 0.46 | 27 | 0.38 | 0.73 | 6 | 0.02 | 0.01 | 3 |
| High Flood Prob. | 1.18 | 0.95 | 27 | 0.59 | 0.60 | 25 | 0.35 | 0.30 | 22 | 0.50 | 0.80 | 19 |

Correlation of CPUE with all physio-chemical parameters produced only a few significant relationships ($P \leq 0.05$) and are shown in Table 15. Inverse relationships between % littoral area and CPUE for all species combined, broad and humpback whitefish combined and least cisco were determined. This relationship most likely reflects the greater abundance of whitefish and cisco collected in lakes associated with rivers, where secchi transparency was lower which consequently reduced % littoral area values. These species were also collected frequently from oxbow lakes where % littoral area was low due to both low transparency and greater depth.

The morphoedaphic index correlated with total fish CPUE and with northern pike CPUE, when only lakes with low flood probability and maximum depths greater than 3.0 meters were used in the correlation. This data stratification eliminated lakes that may only be used for summer habitat and either abandoned through fall migrations, in those lakes with river connections, or impacted by winter kill in those without river connections.

Table 15. Relationship between CPUE and physio-chemical variables.

| CPUE (No./Gn-Hr) with | Variable | $r^1$ | n |
|---|---|---|---|
| [2]All Species Combined | % Littoral Area | -.221* | 57 |
| [3]All Species Combined | Morphoedaphic Index | .525* | 14 |
| [2]Northern Pike | No Correlations | -- | 52 |
| [3]Northern Pike | Morphoedaphic Index | .659* | 13 |
| Broad and Humpback Whitefish-Combined | % Littoral Area | -.461** | 28 |
| Least Cisco | Morphoedaphic Index | .562** | 22 |
| | % Aquatic Vegetation | .540** | 22 |
| | pH | .539** | 22 |
| | % Littoral Area | -.375* | 22 |

1) Probability: *=.05, **=.01, that $r \neq 0$.
2) All lakes with fish.
3) Data from lakes with low flood probability and maximum depths greater than or equal to 3.0 meters.

Least cisco showed positive correlation with the Morphoedaphic Index, for all lakes, and also with pH and percent aquatic vegetation coverage.

## Fish Growth

Early age growth of northern pike was used to determine differences in productivity of various lake classification groups (Table 16). Noticeable differences in growth were seen for Age I-III northern pike when data was grouped by lake type, where growth of northern pike was greater in lowland lakes than oxbow and foothill lakes.

Table 16. Fork length at annulus formation (mm) of northern pike (aged by scales) from lakes surveyed during 1984 and 1985.

| | Age I | | | Age II | | | Age III | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\bar{x}$ | S.D. | n | $\bar{x}$ | S.D. | n | $\bar{x}$ | S.D. | n |
| All Lakes | 118 | 20.6 | 44 | 216 | 30.6 | 44 | 302 | 39.5 | 44 |
| Foothill Lakes | 114 | 5.6 | 5 | 196 | 12.4 | 5 | 285 | 24.7 | 5 |
| Lowland Lakes | 124 | 20.8 | 24 | 229 | 30.5 | 24 | 315 | 41.0 | 24 |
| Oxbow Lakes | 106 | 19.2 | 15 | 202 | 25.5 | 15 | 288 | 35.6 | 15 |
| River Connected | 119 | 20.5 | 26 | 218 | 31.1 | 26 | 304 | 43.3 | 26 |
| No River Connection | 114 | 21.0 | 18 | 213 | 30.4 | 18 | 300 | 34.4 | 18 |
| Low Flood Prob. | 120 | 19.8 | 23 | 217 | 30.0 | 23 | 299 | 36.1 | 23 |
| High Flood Prob. | 115 | 21.6 | 21 | 215 | 31.9 | 21 | 305 | 43.6 | 21 |

One-way ANOVA was used to determine if significant differences existed between early age pike growth with various map parameter groupings and groups formed by combinations of map parameters (Table 17).

Table 17. One-way ANOVA for early age growth of northern pike grouped by map parameters and combinations of map parameters ($P > 0.05$ is considered as not significant).

| Grouping | Northern Pike Fork Length at Annulus Formation (mm) | | |
|---|---|---|---|
| | Age I | Age II | Age III |
| Refuge | NS | NS | NS |
| Lake Type (LT) | 0.025 | 0.005 | NS |
| River Connections (RC) | NS | NS | NS |
| Flood Probability (FP) | NS | NS | NS |
| LT + RC | NS | NS | NS |
| LT + FP | 0.025 | 0.005 | 0.01 |
| LT + RC + FP | NS | 0.025 | 0.05 |

Significant differences in pike growth occurred when the data was grouped by lake type alone, lake type and flood probability combined, and for data grouped by lake type, river connections and flood probability combined. No significant differences in growth could be attributed to regional variation (data grouped by refuges). Differences exhibiting greatest significance occurred for growth up to formation of the second annulus. Differences in data grouped by lake type and combined lake type and flood probability exhibited the greatest significance and were used for further analysis (Table 18).

The map parameter classifications presented in Table 18 show basically the same results with growth of pike being significantly greater in lowland lakes than in foothill and oxbow lakes. However, when data was grouped by lake type and flood probability there was a distinct separation of lowland-high flood probability lakes from lowland-low flood probability lakes. Lowland-low flood lakes also showed the greatest CPUE values (from the previous section).

Table 18. Newman-Keuls Multiple Range Tests of mean fork length values of northern pike at annulus formation with data grouped by lake type and flood probability and for lake type alone (underlined groups represent those exhibiting no significant differences for P=0.05).

| | *Lake Type and Flood Prob. (Mean/Group) Rank | | | | *Lake Type (Mean/Group) Rank | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| | 106.4 | 114.4 | 121.0 | 134.5 | 106.4 | 114.4 | 124.4 |
| AGE I | O | F | LL | LH | O | F | L |
| | 196.4 | 201.5 | 222.2 | 248.8 | 196.4 | 201.5 | 228.8 |
| AGE II | F | O | LL | LH | F | O | L |
| | 284.8 | 288.0 | 303.4 | 349.0 | No Significant Differences | | |
| AGE III | F | O | LL | LH | | | |

* O=oxbow, F=foothill, L=lowland, LL=lowland-low flood, LH=lowland-high flood

Correlation analysis of northern pike growth with physio-chemical variables supports the results that indicate greater growth in lowland lakes. This is represented by the significant ($P \leq 0.05$) inverse correlation between growth and mean depth.

## Fisheries Summary

The presence of fish populations in Interior Alaska lakes is primarily dependent on the presence of river connections, as fish were found in all lakes with river connections. Fish were also collected from all oxbow lakes. In oxbow lakes not connected to rivers, the presence of fish may be related to their close proximity to large river channels, and initial colonization pathways through prior connection to rivers along with adequate depth to provide for overwintering.

Northern pike was the most frequently occurring species collected. Other species commonly collected included broad whitefish, humpback whitefish, and least cisco. Species found in lowland and oxbow lakes were generally similar. Grayling, lake trout, slimy sculpin and round whitefish were only found in foothill lakes.

A significant difference in total fish CPUE was found where the data was grouped by lake type and flood probability. Results of a Newman-Keuls Test indicated two groupings with lowest values including a group formed by lowland-low flood probability lakes, oxbow lakes and foothill lakes and with highest values in a group formed by lowland-high flood probability lakes, oxbow and foothill lakes.

CPUE appears to be related to the proximity of lakes to large river channels and where fish can gain access to these waters from the rivers. This is apparent by the high mean total CPUE value for lowland-high flood probability lakes. Oxbow lakes also meet these requirements, however the much lower mean CPUE value might suggest a difference in productivity levels between these lakes and lowland-high flood lakes.

Correlation analysis showed positive relationships between total CPUE and northern pike CPUE with the Morphoedaphic Index, when only lakes with characteristics suitable for overwintering were used.

Early age growth of northern pike showed significant differences when lakes were grouped by lake type and combined lake type and flood probability. Length at formation of the second annulus was broken down into three groups exhibiting significant differences with lowest values for the group formed by foothill and oxbow lakes, a moderate value for lowland-low flood probability lakes and the highest value for lowland-high flood probability lakes.

## RECOMMENDATIONS

1. Increase sample size for lakes from Nowitna, Tetlin and Yukon Flats refuges and for foothill lakes. Re-evaluate map parameters with increased sample size for final report.

2. Link edaphic and morphometric productivity groupings into a singular index and relate to trophic levels (i.e.; oligotrophic, mesotrophic, etc.). Collect chlorophyll a and total phosphorous data to interrelate trophic levels with the productivity quality index.

3. Test gillnet CPUE for sampling variability.

4. Investigate and evaluate the use of aerial photos to aid in characterization of lake habitat.

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APPENDIX

Table 19. Locations of lakes sampled during 1984 and 1985

| Lake No | Map Name | Quad+ITM | T R Sec | Long | Lat |
|---|---|---|---|---|---|
| 384-1 | Tokusatatquaten | Bettles A3 | 15N7W 17,20 | 151.11 | 66.08 |
| 384-2 | Sithylemenkat | Bettles A3 | 15N18W 16,17,20 | 151.24 | 66.08 |
| 384-3 | Old Dummy | Bettles A4 | 15N20W 7 | 151.51 | 66.09 |
| 384-4 | Unnamed | Bettles A4 | 15N20W 4 | 151.47 | 66.10 |
| 384-5 | Unnamed | Bettles A4 | 15N20W 4,9 | 151.48 | 66.09 |
| 484-1 | Unnamed | Kateel R. B2 | 1S11E 22 | 156.35 | 65.24 |
| 484-2 | Unnamed | Kateek R. C3 | 3N8E 23,24,26 | 157.08 | 65.38 |
| 584-1 | Unnamed | Ruby C3 | 9S22E 27 | 154.26 | 64.42 |
| 584-2 | Unnamed | Ruby C3 | 11S22E 11,12,14 | 154.24 | 65.33 |
| 784-1 | Fern | Nebesna C3 | 11N17E 30 | 142.18 | 62.42 |
| 784-2 | Unnamed | Nebesna C3 | 10N16E 14 | 142.22 | 62.39 |
| 784-3 | Jatahmund | Nebesna C2 | 10N18E 28 | 142.00 | 62.37 |
| 784-4 | Unnamed | Nebesna C2 | 10N18E 35 | 142.00 | 62.36 |
| 784-5 | Unnamed | Nebesna D2 | 12N19E 11 | 141.47 | 62.50 |
| 784-6 | Fish Camp | Tanacross A3 | 16N17E 19 | 142.16 | 63.08 |
| 784-7 | Tlocogn | Tanacross A3 | 16N17E 20 | 142.13 | 63.08 |
| 884-1 | Lower Halfway | Fort Yukon A6 | 15N4E 32 | 146.57 | 66.05 |
| 884-2 | Unnamed | Fort Yukon A5 | 15N6E 26 | 146.25 | 66.06 |
| 884-3 | Unnamed | Fort Yukon A6 | 15N5E 17 | 146.45 | 66.07 |
| 884-4 | Unnamed | Fort Yukon A6 | 15N5E 15 | 146.40 | 66.07 |
| 884-5 | Unnamed | Fort Yukon A5 | 15N6E 35 | 146.25 | 66.10 |
| 884-6 | Ninemile | Fort Yukon A5 | 16N5E 22,23,26 | 146.39 | 66.11 |
| 884-7 | Canvasback | Fort Yukon B5 | 18N6E 13 | 146.21 | 66.23 |
| 884-8 | Unnamed | Fort Yukon A6 | 16N5E 1,2,11,12 | 146.39 | 66.14 |
| 285-1 | Unnamed | Ophir C4 | 21S5E 35 | 157.50 | 63.37 |
| 285-2 | Unnamed | Ophir C4 | 22S5E 22,23 | 157.50 | 63.34 |
| 285-3 | Unnamed | Ophir C4 | 22S5E 33,34 | 157.55 | 63.32 |
| 285-4 | Unnamed | Ophir C4 | 23S5E 4,9 | 157.55 | 63.31 |
| 285-5 | Unnamed | Ophir B5 | 24S4E 6,7 | 158.10 | 63.26 |
| 285-6 | Unnamed | Ophir A5 | 26S3E 13 | 158.12 | 63.14 |
| 285-7 | Unnamed | Ophir A5 | 26S3E 21 | 158.18 | 63.13 |
| 285-8 | Unnamed | Ophir A5 | 27S4E 2,3 | 158.04 | 63.10 |
| 285-9 | Unnamed | Ophir A5 | 26S4E 23 | 158.02 | 63.13 |
| 285-10 | Unnamed | Ophir A5 | 27S3E 35 | 158.12 | 63.06 |
| 285-11 | Unnamed | Ophir C5 | 21S4E 25,26 | 158.01 | 63.38 |
| 285-12 | Unnamed | Ophir A6 | 27S1W 21,22 | 158.51 | 63.08 |
| 285-13 | Unnamed | Ophir C5 | 22S3E 24,25 | 158.11 | 63.33 |
| 285-14 | Unnamed | Ophir C3 | 22S8E 9,17 | 157.21 | 63.35 |
| 285-15 | Unnamed | Ophir C4 | 21S7E 28 | 157.32 | 63.37 |
| 285-16 | Unnamed | Ophir C4 | 22S6E 20 | 157.45 | 63.34 |
| 285-17 | Unnamed | Ophir C4 | 21S6E 6 | 157.46 | 63.43 |
| 385-1 | Konedsin | Bettles B4 | 18N21W 24 | 151.58 | 66.22 |
| 385-2 | Unnamed | Bettles B4 | 18N21W 24,25 | 151.59 | 66.22 |
| 385-3 | Kodosin | Bettles B5 | 18N21W 23 | 152.00 | 66.22 |
| 385-4 | Unnamed | Bettles A4 | 15N21W 11 | 151.56 | 66.08 |
| 385-5 | Mingkoket | Bettles B5 | 19N21W 5,6 | 152.08 | 66.30 |
| 385-6 | Minnkokut | Bettles C4 | 20N19W 17,18 | 151.40 | 66.34 |

Table 19. Continued.

| Lake No | Map Name | Quad+ITM | T R Sec | Long | Lat |
|---|---|---|---|---|---|
| 485-1 | Unnamed | Kateel R. C3 | 3N8E 10,11 | 157.10 | 65.41 |
| 485-2 | Unnamed | Kateel R. B3 | 3S8E 1 | 157.08 | 65.15 |
| 485-3 | Louis | Kateel R. A3 | 3S9E 16 | 157.01 | 65.14 |
| 485-4 | Unnamed | Kateel R. A2 | 3S11E 23 | 156.33 | 65.12 |
| 485-5 | Unnamed | Kateel R. A3 | 5S8E 18 | 157.20 | 65.04 |
| 485-6 | Unnamed | Kateel R. A3 | 5S9E 32 | 157.06 | 65.00 |
| 485-7 | Tachanlowa | Kateel R. B3 | 1N8E 9 | 157.10 | 65.30 |
| 485-8 | Unnamed | Kateel R. B4 | 1S6E 22,23 | 157.35 | 65.23 |
| 485-9 | Unnamed | Kateel R. B3 | 1N7E 24 | 157.20 | 65.28 |
| 485-10 | Upper Birch | Kateel R. D3 | 5N8E 35 | 157.09 | 65.47 |
| 485-11 | Unnamed | Kateel R. D2 | 7N10E 30 | 156.50 | 65.58 |
| 485-12 | Evan | Kateel R. D2 | 5N11E 7 | 156.38 | 65.51 |
| 485-13 | Clay | Kateel R. D2 | 5N11E 20 | 156.35 | 65.49 |
| 485-14 | Crow | Kateel R. D2 | 4N10E 9 | 156.49 | 65.46 |
| 485-15 | Unnamed | Kateel R. D2 | 4N10E 5 | 156.50 | 65.47 |
| 485-16 | Tsedolalindin | Kateel R. C2 | 3N11E 27 | 156.34 | 65.37 |
| 485-17 | Unnamed | Kateel R. D1 | 5N13E 27 | 156.07 | 65.48 |
| 485-18 | Unnamed | Melozitna C6 | 3N14E 2 | 155.52 | 65.43 |
| 485-19 | Unnamed | Kateel R. C2 | 2N10E 7 | 156.53 | 65.36 |
| 485-20 | Hadokhten | Melozitna C6 | 3N15E 11,12 | 155.40 | 65.41 |
| 485-21 | Hahanudan | Melozitna C6 | 4N16E 32,33 | 155.32 | 65.43 |
| 485-22 | Klymunget | Melozitna C5 | 3N17E 17 | 155.22 | 65.40 |

Table 20. Physio-chemical data for all lakes sampled on Innoko NWR, 1985.

| Lake No. | Lake Type[1] | System Type[2] | Flood Prob.[3] | Surface Area(ha) | Max. Depth(m) | Mean Depth(m) | Secchi (m) | % Littoral Area | SDR | MEI | Cond. (umhos/cm) | T. Alk. (mg/l) | T. Hdn. (mg/l) | pH | % Veg. Coverage | Elevat. (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 285-1 | O | RC | H | 225 | 2.7 | 1.6 | 0.8 | 25 | 3.34 | 13.8 | 22 | 17 | 17 | 6.5 | 35 | 110 |
| 285-2 | O | RC | H | 104 | 4.0 | 2.0 | 0.5 | 18 | 3.75 | 17.0 | 34 | 34 | 34 | 6.5 | 20 | 105 |
| 285-3 | L | RC | L | 624 | 1.5 | 0.8 | 1.1 | 80 | 1.16 | 10.0 | 8 | 17 | 17 | 6.0 | 20 | 107 |
| 285-4 | L | NC | L | 343 | 1.5 | 0.8 | 1.1 | 80 | 2.22 | 5.0 | 4 | 17 | 17 | 6.0 | 15 | 115 |
| 285-5 | O | RC | H | 115 | 7.6 | 3.6 | 1.5 | 26 | 2.03 | 6.4 | 23 | 17 | 17 | 6.5 | 20 | 95 |
| 285-6 | L | RC | H | 646 | 2.7 | 1.9 | 0.5 | 7 | 1.02 | 17.9 | 34 | 34 | 34 | 6.0 | 0 | 67 |
| 285-7 | L | RC | H | 189 | 1.8 | 1.5 | 0.7 | 13 | 1.28 | 20.0 | 30 | 34 | 34 | 6.5 | 2 | 60 |
| 285-8 | L | RC | H | 327 | 1.8 | 1.5 | 0.6 | 13 | 1.61 | 33.3 | 50 | 34 | 34 | 6.5 | 10 | 60 |
| 285-9 | L | NC | L | 55 | 1.5 | 0.8 | 1.5 | 100 | 1.12 | 8.8 | 7 | 17 | 17 | 6.0 | 10 | 143 |
| 285-10 | L | RC | H | 159 | 2.7 | 1.6 | 0.8 | 22 | 2.60 | 17.5 | 28 | 34 | 34 | 6.0 | 0 | 60 |
| 285-11 | O | NC | H | 195 | 6.1 | 2.2 | 0.5 | 12 | 4.19 | 15.5 | 34 | 34 | 34 | 6.5 | 5 | 85 |
| 285-12 | O | RC | H | 98 | 7.0 | 1.5 | 0.5 | 25 | 3.77 | 38.7 | 58 | 51 | 51 | 6.5 | 0 | 70 |
| 285-13 | O | RC | H | 75 | 8.2 | 2.3 | 0.6 | 16 | 3.32 | 21.7 | 50 | 34 | 34 | 6.5 | 0 | 72 |
| 285-14 | O | NC | H | 61 | 3.4 | 1.9 | 1.5 | 37 | 3.04 | 22.6 | 43 | 34 | 34 | 6.5 | 4 | 121 |
| 285-15 | L | NC | L | 135 | 0.9 | 0.5 | 0.9 | 100 | 1.61 | 12.0 | 6 | 17 | 17 | 6.0 | 10 | 95 |
| 285-16 | L | NC | L | 63 | 0.9 | 0.5 | 0.9 | 100 | 1.52 | 14.0 | 7 | 17 | 17 | 5.8 | 5 | 120 |
| 285-17 | L | RC | H | 128 | 1.8 | 1.1 | 0.6 | 27 | 3.03 | 41.8 | 46 | 34 | 34 | 7.3 | 2 | 110 |

1 Lake Type: L = lowland, O = oxbow, F = foothill.

2 System Type: RC = river connected, NC = not connected to a river.

3 Flood Probability: H = high, L = low.

Table 21. Physio-chemical data for all lakes sampled on Kanuti NWR, 1984 and 1985.

| Lake No. | Lake Type[1] | System Type[2] | Flood Prob.[3] | Surface Area(ha) | Max. Depth(m) | Mean Depth(m) | Secchi (m) | % Littoral Area | SDR | MEI | Cond. (umhos/cm) | T. Alk. (mg/l) | T. Hdn. (mg/l) | pH | % Veg. Coverage | Elevat. (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 384-1 | F | RC | L | 140 | 0.9 | 0.9 | 0.9 | 100 | 1.25 | 17.5 | 16 | 17 | 34 | 7.3 | 5 | 1190 |
| 384-2 | F | RC | L | 630 | 12.2 | 5.1 | 3.7 | 33 | 1.04 | 9.7 | 50 | 34 | 34 | 7.3 | 15 | 720 |
| 384-3 | L | NC | H | 202 | 3.4 | 2.1 | 1.2 | 11 | 1.12 | 31.6 | 166 | 51 | 51 | 7.0 | 60 | 530 |
| 384-4 | L | NC | H | 47 | 1.2 | 0.6 | 0.3 | 7 | 2.00 | 85.2 | 52 | 68 | 34 | 9.5 | 50 | 530 |
| 384-5 | L | NC | H | 62 | 1.2 | 1.2 | 0.6 | 11 | 1.23 | 43.1 | 53 | 34 | 51 | 7.0 | 50 | 530 |
| 385-1 | L | RC | L | 139 | 3.7 | 1.9 | 1.7 | 35 | 1.82 | 37.8 | 72 | 51 | 68 | 9.0 | 30 | 520 |
| 385-2 | L | RC | L | 37 | 5.8 | 2.5 | 1.9 | 35 | 1.16 | 36.8 | 92 | 68 | 68 | 7.5 | 10 | 515 |
| 385-3 | L | RC | L | 157 | 5.5 | 2.0 | 2.1 | 52 | 1.89 | 31.0 | 62 | 51 | 34 | 7.5 | 30 | 512 |
| 385-4 | L | NC | L | 68 | 1.5 | 0.8 | 1.0 | 65 | 1.15 | 42.5 | 34 | 34 | 34 | 7.0 | 60 | 560 |
| 385-5 | L | RC | L | 364 | 12.8 | 1.8 | 1.2 | 31 | 2.11 | 12.8 | 23 | 34 | 34 | 6.5 | 40 | 555 |
| 385-6 | L | RC | L | 275 | 1.2 | 0.6 | 0.5 | 41 | 1.12 | 56.7 | 34 | 34 | 34 | 6.0 | 70 | 510 |

1 Lake Type: L = lowland, O = oxbow, F = foothill.

2 System Type: RC = river connected, NC = not connected to a river.

3 Flood Probability: H = high, L = low.

Table 22. Physio-chemical data for all lakes sampled on Koyukuk NWR and Nowitna NWR, 1984 and 1985

| Lake No. | Lake Type[1] | System Type[2] | Flood Prob.[3] | Surface Area(ha) | Max. Depth(m) | Mean Depth(m) | Secchi (m) | % Littoral Area | SDR | MEI | Cond. (umhos/cm) | T. Alk. (mg/l) | T. Hdn. (mg/l) | pH | % Veg. Coverage | Elevat. (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 484-1 | O | NC | H | 220 | 9.8 | 3.5 | 4.0 | 61 | 3.16 | 21.8 | 77 | 51 | 34 | 7.5 | 10 | 195 |
| 484-2 | L | NC | L | 77 | 4.9 | 2.2 | 1.5 | 39 | 2.41 | 58.0 | 130 | 68 | 68 | 8.0 | 15 | 190 |
| 485-1 | L | RC | L | 314 | 1.5 | 0.8 | 1.5 | 100 | 1.06 | 125.0 | 100 | 86 | 86 | 7.5 | 5 | 282 |
| 485-2 | L | NC | L | 221 | 3.7 | 1.4 | 0.9 | 39 | 1.22 | 11.4 | 16 | 17 | 34 | 6.5 | 5 | 220 |
| 485-3 | L | NC | L | 169 | 1.5 | 1.2 | 0.7 | 24 | 1.98 | 7.5 | 9 | 34 | 34 | 6.0 | 7 | 220 |
| 485-4 | L | NC | L | 229 | 1.5 | 0.8 | 1.2 | 80 | 1.50 | 100.0 | 80 | 51 | 51 | 7.7 | 5 | 215 |
| 485-5 | O | RC | H | 145 | 5.5 | 3.3 | 1.2 | 12 | 2.17 | 20.3 | 67 | 51 | 51 | 6.5 | 5 | 120 |
| 485-6 | O | RC | H | 180 | 4.3 | 3.2 | 0.8 | 6 | 2.80 | 16.9 | 54 | 34 | 34 | 6.5 | 10 | 130 |
| 485-7 | O | NC | H | 388 | 7.9 | 2.0 | 1.8 | 62 | 4.66 | 32.0 | 64 | 51 | 34 | 7.0 | 10 | 140 |
| 485-8 | O | NC | H | 237 | 14.6 | 4.0 | 0.9 | 14 | 2.73 | 23.5 | 94 | 68 | 68 | 7.0 | 5 | 135 |
| 485-9 | O | RC | H | 222 | 11.0 | 4.8 | 0.8 | 12 | 3.37 | 22.9 | 110 | 68 | 86 | 6.8 | 5 | 135 |
| 485-10 | L | RC | L | 74 | 1.5 | 0.8 | 1.5 | 100 | 1.02 | 118.8 | 95 | 68 | 86 | 7.8 | 30 | 241 |
| 485-11 | L | RC | L | 123 | 1.8 | 0.8 | 0.7 | 48 | 2.40 | 22.5 | 18 | 17 | 17 | 6.0 | 25 | 182 |
| 485-12 | O | RC | H | 115 | 5.5 | 1.7 | 0.7 | 25 | 2.48 | 21.8 | 37 | 34 | 68 | 6.5 | 10 | 157 |
| 485-13 | O | RC | H | 70 | 6.4 | 2.6 | 0.6 | 12 | 1.72 | 12.7 | 33 | 34 | 34 | 6.5 | 5 | 150 |
| 485-14 | L | RC | L | 115 | 1.2 | 0.6 | 1.2 | 100 | 1.90 | 91.7 | 55 | 51 | 68 | 7.5 | 30 | 204 |
| 485-15 | L | RC | L | 72 | 2.4 | 1.4 | 1.8 | 65 | 1.67 | 34.3 | 48 | 34 | 68 | 7.0 | 10 | 200 |
| 485-16 | O | RC | H | 78 | 4.3 | 1.6 | 0.9 | 31 | 2.24 | 87.5 | 140 | 86 | 86 | 7.5 | 5 | 165 |
| 485-17 | L | NC | L | 212 | 1.5 | 0.8 | 1.5 | 100 | 2.42 | 117.5 | 94 | 51 | 51 | 7.8 | 7 | 166 |
| 485-18 | L | NC | L | 166 | 1.8 | 1.6 | 0.6 | 4 | 1.16 | 13.1 | 21 | 34 | 34 | 7.0 | 20 | 176 |
| 485-19 | L | NC | H | 110 | 3.4 | 1.9 | 0.8 | 15 | 1.31 | 51.6 | 98 | 51 | 51 | 7.5 | 20 | 140 |
| 485-20 | L | NC | L | 438 | 7.3 | 2.1 | 6.1 | 95 | 1.38 | 104.8 | 220 | 137 | 154 | 8.0 | 20 | 185 |
| 485-21 | L | NC | L | 536 | 5.5 | 3.1 | 3.0 | 50 | 1.18 | 70.8 | 220 | 154 | 171 | 8.5 | 15 | 208 |
| 485-22 | L | RC | H | 197 | 1.5 | 0.8 | 0.6 | 40 | 2.19 | 58.8 | 47 | 34 | 34 | 6.8 | 35 | 215 |
| 584-1 | O | NC | H | 68 | 6.7 | 2.9 | 0.9 | 19 | 3.21 | 24.0 | 69 | 34 | 34 | 6.5 | 10 | 210 |
| 584-2 | O | RC | H | 90 | 5.5 | 3.8 | 0.9 | 17 | 2.84 | 17.8 | 68 | 34 | 34 | 6.5 | 20 | 225 |

1 Lake Type: L = lowland, O = oxbow, F = foothill.

2 System Type: RC = river connected, NC = not connected to a river.

3 Flood Probability: H = high, L = low.

Table 23. Physio-chemical data for all lakes sampled on Tetlin NWR and the Yukon Flats NWR, 1984.

| Lake No. | Lake Type[1] | System Type[2] | Flood Prob.[3] | Surface Area(ha) | Max. Depth(m) | Mean Depth(m) | Secchi (m) | % Littoral Area | SDR | MEI | Cond. (umhos/cm) | T. Alk. (mg/l) | T. Hdn. (mg/l) | pH | % Veg. Coverage | Elevat. (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 784-1 | F | RC | L | 39 | 27.4 | 10.8 | 1.2 | 10 | 1.72 | 5.9 | 64 | 51 | 51 | 7.5 | 5 | 2300 |
| 784-2 | F | RC | L | 35 | 15.2 | 6.9 | 2.1 | 22 | 1.33 | 7.8 | 54 | 68 | 68 | 7.0 | 5 | 2600 |
| 784-3 | F | NC | L | 1070 | 27.4 | 6.7 | 6.4 | 55 | 2.24 | 5.2 | 35 | 34 | 51 | 7.5 | 2 | 2200 |
| 784-4 | F | NC | L | 60 | 9.8 | 3.9 | 3.4 | 40 | 2.96 | 8.1 | 32 | 34 | 51 | 7.0 | 5 | 2200 |
| 784-5 | L | NC | L | 52 | 3.1 | 1.2 | 3.1 | 100 | 1.35 | 26.0 | 32 | 34 | 51 | 7.0 | 70 | 1750 |
| 784-6 | L | NC | H | 88 | 3.1 | 2.1 | 0.6 | 11 | 2.56 | 116.8 | 250 | 51 | 137 | 10.0 | 70 | 1650 |
| 784-7 | L | NC | H | 112 | 2.4 | 0.8 | 1.5 | 96 | 1.66 | 170.7 | 140 | 34 | 68 | 10.0 | 75 | 1650 |
| 884-1 | F | RC | L | 132 | 22.0 | 9.5 | 2.4 | 21 | 1.47 | 21.2 | 200 | 137 | 137 | 8.7 | 10 | 730 |
| 884-2 | F | RC | L | 307 | 29.6 | 11.6 | 4.0 | 19 | 2.32 | 28.4 | 330 | 221 | 221 | 8.4 | 5 | 700 |
| 884-3 | F | NC | L | 97 | 12.8 | 5.5 | 2.4 | 22 | 1.28 | 162.4 | 890 | 514 | 428 | 9.3 | 10 | 640 |
| 884-4 | F | NC | L | 250 | 17.9 | 1.6 | 3.2 | 85 | 1.52 | 131.3 | 210 | 128 | 138 | 8.3 | 40 | 640 |
| 884-5 | L | RC | L | 244 | 3.4 | 1.9 | 1.8 | 38 | 1.33 | 110.8 | 215 | 128 | 120 | 9.0 | 75 | 420 |
| 884-6 | L | NC | L | 340 | 2.7 | 2.4 | 2.1 | 58 | 1.12 | 151.3 | 360 | 222 | 222 | 9.0 | 60 | 390 |
| 884-7 | L | NC | L | 340 | 3.1 | 1.1 | 2.4 | 99 | 2.07 | 566.4 | 640 | 462 | 256 | 9.5 | 80 | 390 |
| 884-8 | L | RC | L | 331 | 4.9 | 2.0 | 0.9 | 3 | 3.36 | 60.3 | 120 | 86 | 86 | 7.5 | 20 | 380 |

[1] Lake Type: L = lowland, O = oxbow, F = foothill.

[2] System Type: RC = river connected, NC = not connected to a river.

[3] Flood Probability: H = high, L = low.

Table 24. Number of fish collected, species composition, length, and catch-per-unit-effort from lakes sampled during 1984.

| Lake Species | Sample Size | % Comp. | Mean Fork Length(mm) | Length Range(mm) | Gillnet CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | YUKON FLATS NWR | | |
| Lower Halfway Lake 884-1 | | | | | |
| Northern Pike | 14 | 73.6 | 517 | 176-725 | 0.31 |
| Broad Whitefish | 4 | 21.0 | 724 | 90-724 | 0.02 |
| Least Cisco | 1 | 5.4 | 225 | 225 | 0.02 |
| Lake 884-2 | | | | | |
| Northern Pike | 40 | 100.0 | 343 | 84-655 | 0.44 |
| Least Cisco | | Northern Pike Stomach Contents | | | |
| Lake 884-3 | | | No Fish Collected | | |
| Lake 884-4 | | | No Fish Collected | | |
| Lake 884-5 | | | | | |
| Northern Pike | 32 | 100.0 | 172 | 136-201 | 0.17 |
| Ninemile Lake 884-6 | | | No Fish Collected | | |
| Canvasback Lake 884-7 | | | No Fish Collected | | |
| Lake 884-8 | | | | | |
| Northern Pike | 26 | 52.0 | 512 | 94-790 | 1.91 |
| Humpback Whitefish | 1 | 2.0 | 493 | 493 | 0.08 |
| Broad Whitefish | 23 | 46.0 | 519 | 376-582 | 1.77 |
| Least Cisco | | Northern Pike Stomach Contents | | | |

Table 24. Continued.

| Lake Species | Sample Size | % Comp. | Mean Fork Length(mm) | Length Range(mm) | Gillnet CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | KANUTI NWR | | |
| Tokusatatquaten Lake 384-1 | | | | | |
| Grayling | 27 | 90.0 | 220 | 155-337 | 3.86 |
| Round Whitefish | 3 | 10.0 | 369 | 324-400 | 0.43 |
| Sithylemenkat Lake 384-2 | | | | | |
| Northern Pike | 12 | 92.3 | 556 | 431-790 | 0.92 |
| Humpback Whitefish | 1 | 7.7 | 402 | 402 | 0.08 |
| Old Dummy Lake 384-3 | | | No Fish Collected | | |
| Lake 384-4 | | | | | |
| Broad Whitefish | 2 | 5.6 | 529 | 518-540 | 0.25 |
| Humpback Whitefish | 4 | 11.1 | 416 | 364-490 | 0.50 |
| Least Cisco | 30 | 83.3 | 311 | 280-362 | 3.38 |
| Lake 384-5 | | | | | |
| Northern Pike | 36 | 37.9 | 392 | 45-568 | 0.50 |
| Humpback Whitefish | 37 | 38.9 | 454 | 361-519 | 0.58 |
| Longnose Sucker | 1 | 1.1 | 474 | 474 | 0.00 |
| Least Cisco | 21 | 22.1 | 332 | 291-408 | 0.33 |
| Blackfish | | Northern Pike Stomach Contents | | | |

Table 24. Continued.

| Lake Species | Sample Size | % Comp. | Mean Fork Length(mm) | Length Range(mm) | Gillnet CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | TETLIN NWR | | |
| Fern Lake 784-1 | | | | | |
| Grayling | 32 | 7.9 | 231 | 130-328 | 0.30 |
| Longnose Sucker | 373 | 92.1 | 120 | 51-228 | 0.26 |
| Lake 784-2 | | | | | |
| Grayling | 16 | 100.0 | 140 | 84-228 | 0.10 |
| Jatahmund Lake 784-3 | | | | | |
| Northern Pike | 73 | 93.6 | 398 | 140-668 | 0.32 |
| Lake Trout | 3 | 3.8 | 540 | 529-552 | 0.01 |
| Least Cisco | 2 | 2.6 | 394 | 378-410 | 0.01 |
| Slimy Sculpin | | Northern Pike Stomach Contents | | | |
| Lake 784-4 | | | | | |
| Northern Pike | 32 | 100.0 | 391 | 69-638 | 0.34 |
| Least Cisco | | Northern Pike Stomach Contents | | | |
| Lake 784-5 | | | No Fish Collected | | |
| Fish Camp Lake 784-6 | | | No Fish Collected | | |
| Tlocogn Lake 784-7 | | | No Fish Collected | | |
| | | | NOWITNA NWR | | |
| Lake 584-1 | | | | | |
| Northern Pike | 27 | 65.9 | 397 | 252-870 | 0.36 |
| Humpback Whitefish | 3 | 7.3 | 406 | 343-444 | 0.05 |
| Broad Whitefish | 2 | 4.8 | 523 | 502-543 | 0.03 |
| Least Cisco | 9 | 22.0 | 302 | 180-367 | 0.14 |
| Lake 584-2 | | | | | |
| Northern Pike | 31 | 31.6 | 453 | 162-824 | 0.40 |
| Humpback Whitefish | 10 | 10.2 | 383 | 258-441 | 0.14 |
| Broad Whitefish | 9 | 9.2 | 487 | 352-593 | 0.12 |
| Least Cisco | 47 | 48.0 | 316 | 209-406 | 0.64 |
| Sheefish | 1 | 1.0 | 280 | 280 | 0.01 |

Table 24. Continued.

| Lake Species | Sample Size | % Comp. | Mean Fork Length(mm) | Length Range(mm) | Gillnet CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | KOYUKUK NWR | | |
| Lake 484-1 | | | | | |
| Northern Pike | 58 | 100.0 | 413 | 109-1010 | 0.86 |
| Least Cisco | | | Northern Pike Stomach Contents | | |
| Ninespine Stickleback | | | Northern Pike Stomach Contents | | |
| Lake 484-2 | | | No Fish Collected | | |

Table 25. Number of fish collected, species composition, length, and catch-per-unit-effort from lakes sampled during 1985.

| Lake Species | Sample Size | % Comp. | Mean Fork Length(mm) | Length Range(mm) | Gillnet CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | KOYUKUK NWR | | |
| Lake 485-1 | | | | | |
| Northern Pike | 20 | 80.0 | 434 | 301-695 | 0.294 |
| Broad Whitefish | 2 | 8.0 | 529 | 498-559 | 0.029 |
| Alaska Blackfish | 3 | 12.0 | 142 | 132-150 | 0.044 |
| Lake 485-2 | | | | | |
| Northern Pike | 23 | 100.0 | 360 | 286-492 | 0.174 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |
| Lake 485-3 | | | | | |
| Northern Pike | 19 | 100.0 | 368 | 210-725 | 0.226 |
| Lake 485-4 | | | | | |
| Northern Pike | 8 | 44.4 | 436 | 380-542 | 0.089 |
| Alaska Blackfish | 10 | 55.6 | 155 | 127-187 | 0.111 |
| Lake 485-5 | | | | | |
| Northern Pike | 3 | 14.3 | 727 | 675-780 | 0.063 |
| Broad Whitefish | 5 | 23.7 | 507 | 470-533 | 0.104 |
| Humpback Whitefish | 6 | 28.6 | 453 | 406-489 | 0.125 |
| Least Cisco | 6 | 28.6 | 295 | 250-405 | 0.125 |
| Longnose Sucker | 1 | 4.8 | 460 | - | 0.021 |
| Lake 485-6 | | | | | |
| Northern Pike | 13 | 19.7 | 671 | 590-850 | 0.213 |
| Broad Whitefish | 7 | 10.6 | 515 | 483-545 | 0.115 |
| Humpback Whitefish | 14 | 21.2 | 441 | 338-490 | 0.230 |
| Least Cisco | 32 | 48.5 | 272 | 190-393 | 0.525 |

Table 25. Continued.

| Lake Species | Sample Size | % Comp. | Mean Fork Length(mm) | Length Range(mm) | Gillnet CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | KOYUKUK NWR (cont.) | | |
| Lake 485-7 | | | | | |
| Northern Pike | 1 | 33.3 | 413 | - | 0.050 |
| Alaska Blackfish | 1 | 33.3 | 261 | - | 0.050 |
| Least Cisco | 1 | 33.3 | 201 | - | 0.050 |
| Lake 485-8 | | | | | |
| Northern Pike | 39 | 86.7 | 407 | 198-625 | 0.848 |
| Broad Whitefish | 6 | 13.3 | 477 | 458-515 | 0.130 |
| Ninespine Stickleback | | | Northern Pike Stomach Contents | | |
| Sheefish | | | Northern Pike Stomach Contents | | |
| Lake 485-9 | | | | | |
| Northern Pike | 6 | 9.2 | 427 | 326-720 | 0.125 |
| Broad Whitefish | 4 | 6.2 | 509 | 472-535 | 0.083 |
| Humpback Whitefish | 17 | 26.2 | 412 | 317-497 | 0.354 |
| Least Cisco | 38 | 58.4 | 290 | 161-400 | 0.792 |
| Lake 485-10 | | | | | |
| Northern Pike | 3 | 100.0 | 336 | 234-500 | 0.072 |
| Lake 485-11 | | | | | |
| Northern Pike | 13 | 44.8 | 391 | 230-600 | 0.257 |
| Broad Whitefish | 13 | 44.8 | 499 | 473-525 | 0.257 |
| Humpback Whitefish | 2 | 6.9 | 474 | 447-500 | 0.040 |
| Least Cisco | 1 | 3.5 | 282 | - | 0.020 |
| Lake 485-12 | | | | | |
| Northern Pike | 13 | 61.9 | 490 | 315-755 | 0.325 |
| Broad Whitefish | 6 | 28.5 | 520 | 496-560 | 0.150 |
| Humpback Whitefish | 2 | 9.6 | 440 | 395-484 | 0.050 |

Table 25. Continued.

| Lake Species | Sample Size | % Comp. | Mean Fork Length(mm) | Length Range(mm) | Gillnet CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | KOYUKUK NWR (cont.) | | |
| Lake 485-13 | | | | | |
| Northern Pike | 15 | 60.0 | 491 | 322-890 | 0.428 |
| Broad Whitefish | 8 | 32.0 | 499 | 470-572 | 0.229 |
| Humpback Whitefish | 1 | 4.0 | 358 | - | 0.029 |
| Least Cisco | 1 | 4.0 | 191 | - | 0.029 |
| Lake 485-14 | | | | | |
| Northern Pike | 5 | 100.0 | 315 | 293-342 | 0.125 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |
| Lake 485-15 | | | | | |
| Northern Pike | 6 | 100.0 | 539 | 330-658 | 0.167 |
| Least Cisco | | | Northern Pike Stomach Contents | | |
| Lake 485-16 | | | | | |
| Northern Pike | 39 | 62.9 | 446 | 318-654 | 0.918 |
| Broad Whitefish | 7 | 11.3 | 551 | 513-577 | 0.164 |
| Least Cisco | 16 | 25.8 | 278 | 198-343 | 0.376 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |
| Lake 485-17 | | | | | |
| Northern Pike | 1 | 100.0 | 506 | - | 0.040 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |
| Lake 485-18 | | | | | |
| Northern Pike | 10 | 100.0 | 413 | 268-883 | 0.155 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |

Table 25. Continued.

| Lake Species | Sample Size | % Comp. | Mean Fork Length(mm) | Length Range(mm) | Gillnet CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | KOYUKUK NWR (cont.) | | |
| Lake 485-19 | | | | | |
| Northern Pike | 23 | 39.7 | 432 | 258-618 | 0.383 |
| Broad Whitefish | 23 | 39.7 | 493 | 165-577 | 0.383 |
| Humpback Whitefish | 3 | 5.2 | 467 | 442-4882 | 0.050 |
| Least Cisco | 9 | 15.4 | 298 | 289-355 | 0.150 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |
| Lake 485-20 | | | | | |
| Northern Pike | 157 | 99.4 | 465 | 250-765 | 1.725 |
| Broad Whitefish | 1 | 0.6 | 617 | - | 0.011 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |
| Lake 485-21 | | | | | |
| Northern Pike | 18 | 100.0 | 348 | 216-550 | 0.350 |
| Lake 485-22 | | | | | |
| Broad Whitefish | 1 | 4.3 | 499 | - | 0.018 |
| Humpback Whitefish | 1 | 4.3 | 420 | - | 0.018 |
| Least Cisco | 16 | 69.6 | 322 | 194-385 | 0.281 |
| Alaska Blackfish | 5 | 21.8 | 155 | 151-163 | 0.088 |
| | | | KANUTI NWR | | |
| Lake 385-1 | | | | | |
| Northern Pike | 17 | 100.0 | 405 | 246-860 | 0.333 |
| Lake 385-2 | | | | | |
| Northern Pike | 12 | 100.0 | 563 | 329-890 | 0.308 |

Table 25. Continued.

| Lake Species | Sample Size | % Comp. | Mean Fork Length(mm) | Length Range(mm) | Gillnet CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | KANUTI (cont.) | | |
| Lake 385-3 | | | | | |
| Northern Pike | 19 | 100.0 | 395 | 153-600 | 0.442 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |
| Lake 385-4 | | | No Fish Collected | | |
| Lake 385-5 | | | | | |
| Northern Pike | 12 | 100.0 | 356 | 208-531 | 0.266 |
| Lake 385-6 | | | | | |
| Northern Pike | 1 | 100.0 | 196 | - | 0.021 |
| | | | INNOKO NWR | | |
| Lake 285-1 | | | | | |
| Northern Pike | 39 | 84.8 | 442 | 236-759 | 0.574 |
| Broad Whitefish | 7 | 15.2 | 486 | 453-530 | 0.103 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |
| Ninespine Stickleback | | | Northern Pike Stomach Contents | | |
| Lake 285-2 | | | | | |
| Northern Pike | 61 | 78.2 | 553 | 80-735 | 0.884 |
| Broad Whitefish | 14 | 17.9 | 487 | 380-560 | 0.203 |
| Humpback Whitefish | 1 | 1.3 | 440 | - | 0.014 |
| Least Cisco | 2 | 2.6 | 352 | 339-364 | 0.029 |
| Lake 285-3 | | | | | |
| Northern Pike | 56 | 100.0 | 521 | 277-765 | 0.967 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |
| Lake 285-4 | | | | | |
| Northern Pike | 16 | 100.0 | 410 | 302-604 | 0.267 |

Table 25. Continued.

| Lake<br>Species | Sample<br>Size | %<br>Comp. | Mean Fork<br>Length(mm) | Length<br>Range(mm) | Gillnet<br>CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | INNOKO NWR (cont.) | | |
| Lake 285-5 | | | | | |
| Northern Pike | 18 | 100.0 | 430 | 210-600 | 0.493 |
| Lake 285-6 | | | | | |
| Northern Pike | 6 | 2.7 | 487 | 145-747 | 0.087 |
| Broad Whitefish | 61 | 27.9 | 430 | 372-528 | 0.884 |
| Humpback Whitefish | 33 | 15.1 | 418 | 359-452 | 0.478 |
| Least Cisco | 119 | 54.3 | 316 | 190-363 | 1.725 |
| Lake 285-7 | | | | | |
| Northern Pike | 18 | 52.9 | 567 | 152-965 | 0.429 |
| Broad Whitefish | 11 | 32.4 | 471 | 427-510 | 0.262 |
| Humpback Whitefish | 2 | 5.9 | 447 | 415-478 | 0.048 |
| Least Cisco | 3 | 8.8 | 295 | 262-322 | 0.071 |
| Lake 285-8 | | | | | |
| Northern Pike | 22 | 33.8 | 624 | 188-910 | 0.386 |
| Broad Whitefish | 14 | 21.5 | 486 | 443-536 | 0.246 |
| Humpback Whitefish | 25 | 38.5 | 456 | 408-514 | 0.439 |
| Least Cisco | 4 | 6.2 | 343 | 306-374 | 0.070 |
| Lake 285-9 | | | No Fish Collected | | |
| Lake 285-10 | | | | | |
| Northern Pike | 96 | 68.1 | 218 | 122-960 | 1.811 |
| Broad Whitefish | 18 | 12.8 | 470 | 408-524 | 0.340 |
| Humpback Whitefish | 9 | 6.4 | 437 | 379-484 | 0.170 |
| Least Cisco | 17 | 12.0 | 303 | 207-384 | 0.321 |
| Longnose Sucker | 1 | 0.7 | 521 | - | 0.019 |

Table 25. Continued.

| Lake Species | Sample Size | % Comp. | Mean Fork Length(mm) | Length Range(mm) | Gillnet CPUE(fish/hr.) |
|---|---|---|---|---|---|
| | | | INNOKO NWR (cont.) | | |
| Lake 285-11 | | | | | |
| Northern Pike | 12 | 54.5 | 490 | 288-820 | 0.261 |
| Broad Whitefish | 10 | 45.5 | 516 | 457-588 | 0.217 |
| Lake 285-12 | | | | | |
| Northern Pike | 51 | 100.0 | 186 | 133-751 | 2.833 |
| Lake 285-13 | | | | | |
| Northern Pike | 19 | 52.8 | 423 | 234-642 | 0.487 |
| Broad Whitefish | 4 | 11.1 | 502 | 457-558 | 0.103 |
| Humpback Whitefish | 1 | 2.8 | - | - | 0.026 |
| Least Cisco | 12 | 33.3 | 322 | 206-375 | 0.307 |
| Lake 285-14 | | | | | |
| Northern Pike | 14 | 100.0 | 387 | 257-900 | 0.378 |
| Alaska Blackfish | | | Northern Pike Stomach Contents | | |
| Lake 285-15 | | | | | |
| Northern Pike | 8 | 100.0 | 425 | 235-646 | 0.182 |
| Lake 285-16 | | | No Fish Collected | | |
| Lake 285-17 | | | | | |
| Northern Pike | 23 | 65.7 | 547 | 272-661 | 0.597 |
| Broad Whitefish | 8 | 22.9 | 492 | 240-558 | 0.208 |
| Humpback Whitefish | 1 | 2.9 | 443 | - | 0.026 |
| Least Cisco | 3 | 8.5 | 376 | 356-389 | 0.078 |

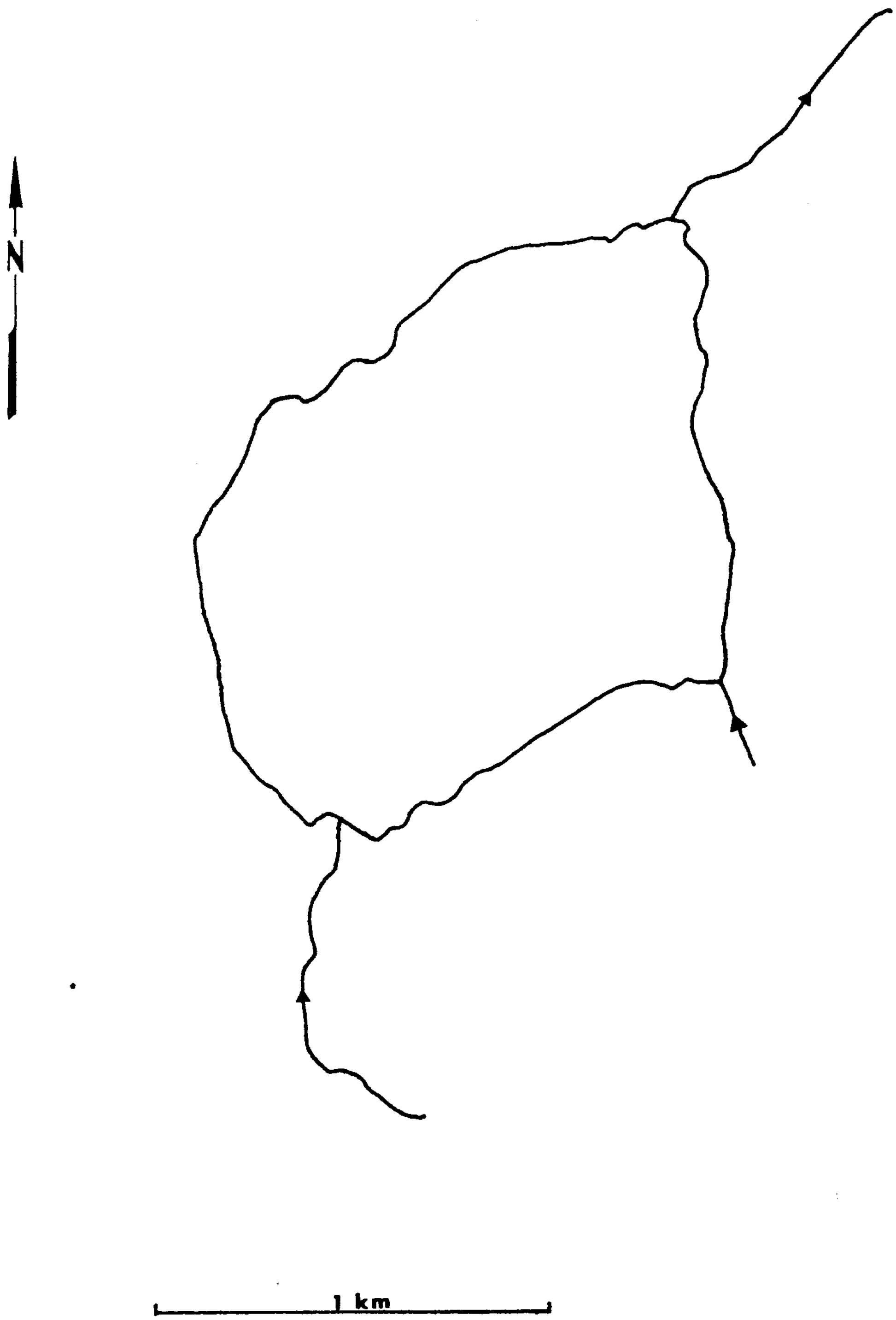


Figure 2. Bathymetric map, lake no. 384-1, Tokusatatquaten Lake, Kanuti NWR, Bettles A3, 15N 7W sec. 17, 20, 5ft. contours. Maximum depth less than 5 ft.


Figure 3. Bathymetric map, lake no. 384-2, Sithylemenkat Lake, Kanuti NWR, Bettles A3, 15N 18W sec. 16, 17, 20, 5ft. contour intervals.