Ecological Research Series

Low Winter Dissolved Oxygen In Some Alaskan Rivers

National Environmental Research Center
Office of Research and Development
U. S. Environmental Protection Agency
Corvallis, Oregon 97330

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April 1974

LOW WINTER DISSOLVED OXYGEN IN SOME ALASKAN RIVERS

by

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Project 21ARX
Program Element 1BA021

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ABSTRACT

Water samples collected during the years 1969 through 1972, from 36 selected Alaskan rivers were analyzed for dissolved oxygen, pH, conductivity and alkalinity. Dissolved oxygen (D.O.) ranged from 0.0 to 15.3 ml/l (106 percent saturation); pH from 6.2 to 8.4; conductivity varied from 105 to 3000 (umho/cm); and alkalinity from 28 to 410 (mg/l). Severe D.O. depletion during winter was found in many river systems large and small, and located in a range of latitudes (70°N to 61°N). Sufficient data were collected on the Chena, Chatanika, and Salcha Rivers to reveal annual D.O. trends: near saturation during spring "breakup" and fall "freezeup" when water temperatures are near 0°C; somewhat lower D.O. concentrations during warm water summer periods; and yearly minimum concentrations during the winter (January-March) interval.

Data indicate that D.O. depression begins in October and continues into February. D.O. from stations near the mouth of a river were generally depressed more than at upper stations. The latter trend was observed in the Yukon River which contained 10.5 mg/l (73 percent saturation) at the Canadian Border but only 1.9 mg/l (13 percent) near the mouth. pH gradually decreased in some rivers although alkalinity and conductivity increased. The depressed winter D.O. concentrations and low winter discharge in many Alaskan rivers are more severe and widespread than present literature indicates. Winter conditions may already limit aquatic organisms in some systems.

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SECTION I

CONCLUSIONS

1. Severe winter D.O. depression may appear in any river located in Arctic-Subarctic Alaska. This winter phenomenon is the net result of a complex interaction of many "natural" factors. Data collected during 4 years of investigation and from 36 widely separated Alaskan Rivers revealed that a wide range of D.O. concentrations were found but that many rivers contained severely depressed D.O. concentrations.

2. Rivers of all size drainages and surface discharges may undergo severe natural D.O. depression. Furthermore, rivers located in widely separated localities may show D.O. depression.

3. In rivers exhibiting the depressed D.O. phenomenon, two patterns have been recognized. The D.O. concentration at any one station is gradually depressed from near saturation in October to severe depletion in February or March. Also, the D.O. delpetion usually becomes more severe when proceeding from the headwaters toward the mouth.

4. Annual low D.O. values are usually found during winter in Alaskan streams while annual low D.O. is usually found during summer in temperate areas such as Cincinnati, Ohio.

5. Annual high D.O. values are usually present during the short spring breakup and fall freezeup period in arctic and subarctic areas, but are usually found during winter in temperate areas.

6. An inverse relationship between D.O. and water temperatures is found only during the warm months of summer in arctic and subarctic areas, but is usually found throughout the year in temperate areas.

7. Conductivity, alkalinity and pH ranged widely from river to river and from station to station. Alkalinity and conductivity are generally higher in winter and are directly correlated in any one river system. The pH generally decreases when proceeding downstream during the winter. North Slope rivers tend to be slightly acidic and Interior rivers are usually slightly to moderately alkaline.

SECTION II

RECOMMENDATIONS

This study provides new data that establishes the low winter dissolved oxygen phenomenon as a major consideration in management decisions involving cold climate water resources. Because little information has been available from northern regions, many management decisions in cold climates are based on extrapolations made from studies conducted in temperate climates. It is recommended that future management decisions in cold regions rely heavily on information generated within the region.

Naturally occurring low dissolved oxygen concentrations are found during winter in streams and rivers of all sizes located over widespread geographic areas. From small streams, such as Gardiner Creek, to large rivers, such as the Yukon River, many aquatic systems in Alaska exhibit severe D.O. depression. It is recommended that any fresh water aquatic systems proposed as a receiving water be investigated during the winter as well as summer to determine the D.O. characteristics before discharge into the system is permitted.

Natural dissolved oxygen depression generally becomes more severe when progressing downstream. Thus, a waste discharge located in the upper watershed, where the D.O. concentration is high, may not be significantly detrimental at the immediate point of discharge or in the mixing zone. However, even a small reduction of the D.O. concentration in the upper areas could result in further depression in downstream reaches. Therefore, it is recommended that before an effluent discharge into a river system is permitted, all possible adverse effects be considered in the downstream reaches.

Winter discharge volumes for arctic and subarctic rivers are the lowest of the year; this combined with low winter D.O. concentrations, has serious management implications. The least desirable time to discharge waste effluents would be during the winter when both D.O. and stream flow are at annual low levels. The least offensive time would be at spring breakup when D.O. values are high and discharges are usually at the yearly maximum. It is recommended that any effluents discharged into arctic and subarctic rivers receive the best available treatment and consideration be given to waste discharge timed with both discharge and D.O. concentration in mind.

Protection of aquatic resources dictates that the D.O. of a stream be maintained above a specified minimum standard. Currently, the Alaska State-Federal Water Quality Standards specify minimum D.O. concentrations of 7 mg/l in freshwater, but recognize that the natural winter D.O. in some waters falls below this concentration. Under these conditions the standard becomes difficult to administer. It is recommended that the application of the Water Quality Standards and the administration of the discharge permit system incorporate studies that would evaluate any discharge effects on streams exhibiting low winter dissolved oxygen.

Cold climate rivers harbor large populations of economically important fishes. The relationship of these endemic fishes and their prey organisms to low D.O. phenomenon is unknown because no cold climate studies have been conducted. It is possible that these phenomenon already limit some aquatic populations. It is therefore recommended that studies be initiated to investigate these possible effects.

SECTION III

INTRODUCTION

General

Alaska's freshwater resources total approximately 40 percent (800 million acre feet) of the entire United States water resources (Johnson and Hartman, 1969) and are considered one of the continent's strategic resources (Norwood and Cross, 1968). Industry, municipal, and domestic enterprise presently utilize a small percentage of the total, although water problems already exist in many areas (U.S. Federal Field Committee, 1971). Wise management of this resource is handicapped by a general lack of information. By contrast, a great deal of limnological information has been gathered from the waters of the contiguous United States. Because of the availability of these data and lack of Alaskan information, management of Alaska resources too often has been based on data collected from temperate climates and extrapolated to subarctic and arctic regions. An example of such a generalization is that of Huet (1962) who states that the amount of D.O. in the water is dependent upon the amount of organic matter, underwater vegetation and most importantly, the water temperature. Certainly these factors affect the D.O. concentrations, but the relationship of D.O. to physical, chemical and biological environment is much more complex than he indicated. No reference is made to additional factors such as source water, light availability, and ice-snow cover which play significant roles in high latitudes.

Dissolved oxygen data from ice-covered rivers of the world are limited and references to low D.O. in these rivers even more limited. Drachev (1964) speaks of a general oxygen deficit in streams of the U.S.S.R., while Hynes (1970) cites one case of natural severe de-oxygenation which was recorded in the Siberian Ob River, by Mosevich (1947), and by Mossewitsch (1961). Hynes (1960) states that dissolved oxygen rarely drops to low concentrations in clean waters but that the lack of oxygen is of concern in polluted waters. He further states that in unpolluted waters, very low dissolved oxygen is found under only two conditions: continuous ice-cover for long periods <u>under rather special conditions</u>, and excessive autumnal leaf-fall into <u>pools in almost dry streams</u>. He concludes that freezing over and lack of oxygen is of little importance to invertebrates because some time is necessary for the total water mass in a river to reach 0°C, and because sufficient open water usually remains to allow replenishment of the small amounts of dissolved oxygen required for metabolism at 0°C. In some Russian rivers, the minimum level of oxygen concentration appears in the spring when water temperatures increase allowing decay of the organic material deposited in the fall (Greze, 1953). Similar effects of decaying organic material were described in intermittent middle west U.S. streams by Schneller (1955) and Larimore, <u>et. al</u>. (1959). Whitten (1972) states that few data exist on low D.O. in <u>natural</u> waters and that, when found, it is attributable to oxidations of hydrogen sulfide to sulfate. In general, these cases of low dissolved oxygen concentrations are regarded as exceptional examples caused by special conditions in limited areas.

Limnological data from Alaskan and Canadian arctic-subarctic waters are limited and winter D.O. data even more limited. Kalff (1968) collected water chemistry information from Alaskan and Northwestern Canadian waters and Lamar (1966) examined the chemical character of water in the Cape Thompson region, but both studies were conducted during the summer and did not measure D.O. Watson, et. al. (1966) recorded summer D.O. ranges from 8.6 to 12.6 mg/l from Ogotoruk Creek near Cape THompson. Morrow (1971) reports dissolved oxygen and other water chemistry data collected during summer from Chatanika River drainages. Winter D.O. from surface and ground water sources have been reported by Kogl (1965) and related to salmon survival in the Chena River. Data unpublished at present, have been collected along the proposed Prudhoe Bay to Valdez pipeline route by EPA personnel (Anonymous 1970). Physical and chemical characteristics of the Chena River are presented by Frey, et. al. (1970).

Flowing waters in both temperate and arctic-subarctic areas are subjected to similar environmental features such as reduced water temperatures, ice and snow cover, and low light incidence and intensity. However, areas within arctic and subarctic zones have additional features such as permafrost, stream ice forms, long periods of darkness, and the length of time that these phenomena persist. One of the more obvious differences is the length of time that water temperatures remain close to 0°C. Temperatures in the Little Miami River, near Cincinnati (Schwer, 1972) reach 0°C in December and generally remain low for short periods of time accompanied by some ice formations and snow cover. By contrast, arctic and subarctic waters approach 0°C during September-October and may remain until June with a sheet of ice and a blanket of snow gradually covering the entire stream surface in the interim. Since only limited data are available on physical and chemical characteristics of Alaskan stream systems, this study was directed toward advancing the knowledge of four common parameters of water quality. However, the primary focus is on winter dissolved oxygen because this characteristic alone may have more effect on aquatic populations than any other single parameter.

Location

The study area extends from the Beaufort Sea near 70°N latitude south to Prince William Sound near 63°N latitude, and from the Canadian Border at 141°W longitude west to the Bering Sea, near 165°W longitude. The area encompasses a wide range of environmental conditions from the Arctic southerly to the Subarctic and from the interior of Alaska westerly to the coast. More detailed locations of the rivers and streams that were sampled are presented in Figure 1 and Table 1.

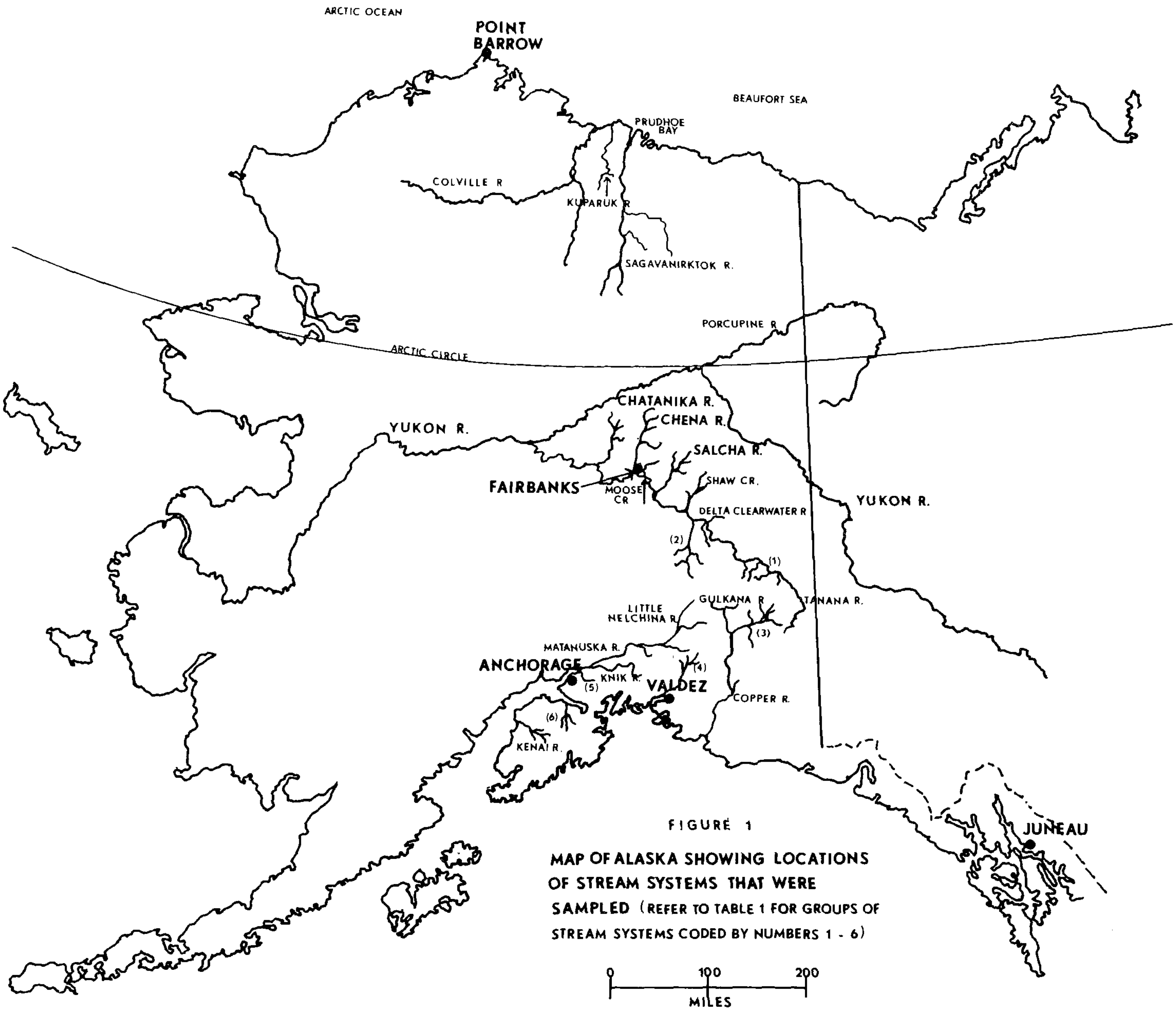


FIGURE 1

MAP OF ALASKA SHOWING LOCATIONS OF STREAM SYSTEMS THAT WERE SAMPLED (REFER TO TABLE 1 FOR GROUPS OF STREAM SYSTEMS CODED BY NUMBERS 1 - 6)

TABLE 1

GROUPS OF STREAM SYSTEMS THAT ARE LOCATED IN CONGESTED AREAS AND CODED BY NUMBERS 1 THROUGH 6 ON THE MAP OF ALASKA (FIGURE 1)

<u>Area 1 Includes</u>

Gerstle River
Johnson River
Robertson River
Tok River
Chisana River
Gardiner Creek

<u>Area 2 Includes</u>

Donnelly Creek
Ruby Creek
Phelan Creek

<u>Area 3 Includes</u>

Slana River
Chistochina River
Gakona River

<u>Area 4 Includes</u>

Tsina River
Tiekel River

<u>Area 5 Includes</u>

Eagle River

<u>Area 6 Includes</u>

Chickaloon River

OBJECTIVES

The objectives of this project were twofold: first, to develop an accurate and precise dissolved oxygen sampling technique under arctic and subarctic winter conditions and; second, to accurately determine winter dissolved oxygen concentrations and to collect pH, conductivity and alkalinity data from specific Alaskan streams and river systems.

Numerous sampling techniques utilizing electronic devices, spring powered entrapment tools, and siphon methods (Magnuson and Stuntz, 1970) have been described, but these techniques do not reliably provide means to obtain accurate results in the severe winter climates. Electronic devices may fail because of cold stress on batteries, wires and delicate instrument packages that were not designed for use in a harsh environment; mechanical devices may fail because of ice blocked tubes and valves; siphon samplers are not reliable because of ice formation in tubes. All these techniques result in air and/or ice-contaminated samples. As a result, a technique utilizing the immersion of BOD bottles containing nitrogen was developed and has been described by Schallock and Lotspeich (1974).

The new sampling technique was used to collect water samples, with the smallest bias possible, to provide an accurate determination of low winter D.O. concentrations. These precise data were then used to determine the severity of the D.O. depression. Furthermore, D.O. patterns were developed and when combined with the pH, conductivity, and alkalinity data, can be utilized to make recommendations for future water resource management decisions.

SECTION V

METHODS

Sampling for dissolved oxygen was achieved by using three sampling techniques. Initially, the Van Dorn bottle technique was the standard against which the other two field techniques were compared. This Van Dorn technique was retained as long as possible but was finally abandoned because of ice formation on all surfaces and apertures during cold temperatures. When used in air temperatures as cold as 40°C, the cold bottle was immediately covered with ice when submerged in the 0°C water. The ice problem prevented using the sampler more than once unless the ice was melted after each submersion. The other two methods use a standard BOD bottle as the sample container. One method consisted of immersing an air-filled BOD bottle in the stream and allowing the water to flow into the container with turbulent mixing during displacement of air. It became apparent that this mixing of air and water caused biased D.O. concentrations. The second method was an attempt to alleviate this problem by introducing nitrogen into the BOD bottle through a tube extended to the bottom. Schallock and Lotspeich (1974) further describe this technique and relate that samples collected using the nitrogren displacement technique were as much as 0.5 mg/l lower than those samples collected using air-filled bottles. A laboratory study of the nitrogen technique has been conducted and published by Lotspeich and Schallock (1972). All D.O. samples were analyzed using the azide modification of the Winkler Method (Standard Methods, American Public Health Association, 1966, pp 477-81).

Temperature, pH, conductivity and alkalinity were measured as soon as possible after collection, Whenever possible, samples were collected and quickly transported to the heated interior of a truck or aircraft where reliable instruments were used to analyze samples. Conductivity measurements were made using a Beckman Model RB3-338 bridge with an epoxy dip cell with a cell constant of 0.2. pH was measured with a Model 401 Orion specific ion meter. Alkalinity was measured by substituting methyl purple for the methyl orange indicator and then following the procedures specified in Standard Methods (American Public Health Association, 1966, pp 50-51).

In addition to error introduced by the sample procedures, other problems causing sample contamination were encountered. Floating ice could enter the sample bottle during submersion or when returning the bottle to the surface, thus affecting subsequent analysis. These errors were avoided wherever possible by cleaning the ice out of the auger hole or by putting the stopper in the neck while the bottle was submerged.

Thick ice also caused sampling problems. Unbiased sampling requires that the water sample be collected from flowing water which carries away any water aerated or agitated by the ice auger. Samples collected from the disturbed area could range as much as 2 mg/l higher than samples collected from undisturbed water (EPA, unpublished data). In areas where the ice thickness exceeded approximately 2 feet, an extension tool was used to hold the BOD bottle firmly and to transport it downward through the hole into the undisturbed water. A more detailed description of the device is provided by Gordon (1972).

In extreme cold temperatures, frozen samples were the most frequent problem. Exothermic chemical heaters were used to warm the insulated boxes housing the sample bottles and reagents. However, some samples did freeze when air temperatures were below minus 20°C if more than a few minutes lapsed between sampling and return to the heated vehicle. This happened most often when fixed wing aircraft could only land some distance from suitable sampling sites.

Success or failure of a winter field trip often depends upon the ice auger. Efforts to insure starting included keeping the powerhead warm by transporting it inside the heated vehicle; using starting fluid; and adding deicing solution to the fuel. The basic ice auger featured a lightweight powerhead (20 lbs) and removeable auger flites and handles. Modifications included addition of a Y-shaped handle for use by two men to control severe twisting when hard ice strata or stream bottom were encountered, and replacement of round shaft by square shaft ends on auger flites enabled quick alignment and pin placement when adding or removing flites. Large pins with thumb-sized heads permitted manipulation while wearing heavy mittens.

SECTION VI

RESULTS AND DISCUSSION

The dissolved oxygen concentration of water at any given time is the net result of a complex interrelationship of meteorological, geological, physical, chemical and biological factors. It is not the purpose of this report to describe in detail the factors that affect the dissolved oxygen concentrations. The importance of each factor varies from system to system and from time to time. For example, the factors affecting the D.O. of the Little Miami in Ohio are significantly different from those of a typical subarctic river in Alaska. March precipitation, as rain, may play a significant role in Midwest stream discharge. In subarctic Alaska discharge, however, such precipitation would normally be snow and would not significantly affect discharge. The maximum discharge of the Little Miami River, near Cincinnati, Ohio, would normally be expected during the February through April period (U.S.G.S., 1970). This coincides with the period of minimum discharge in the Chena River, near Fairbanks (U.S.G.S., 1969).

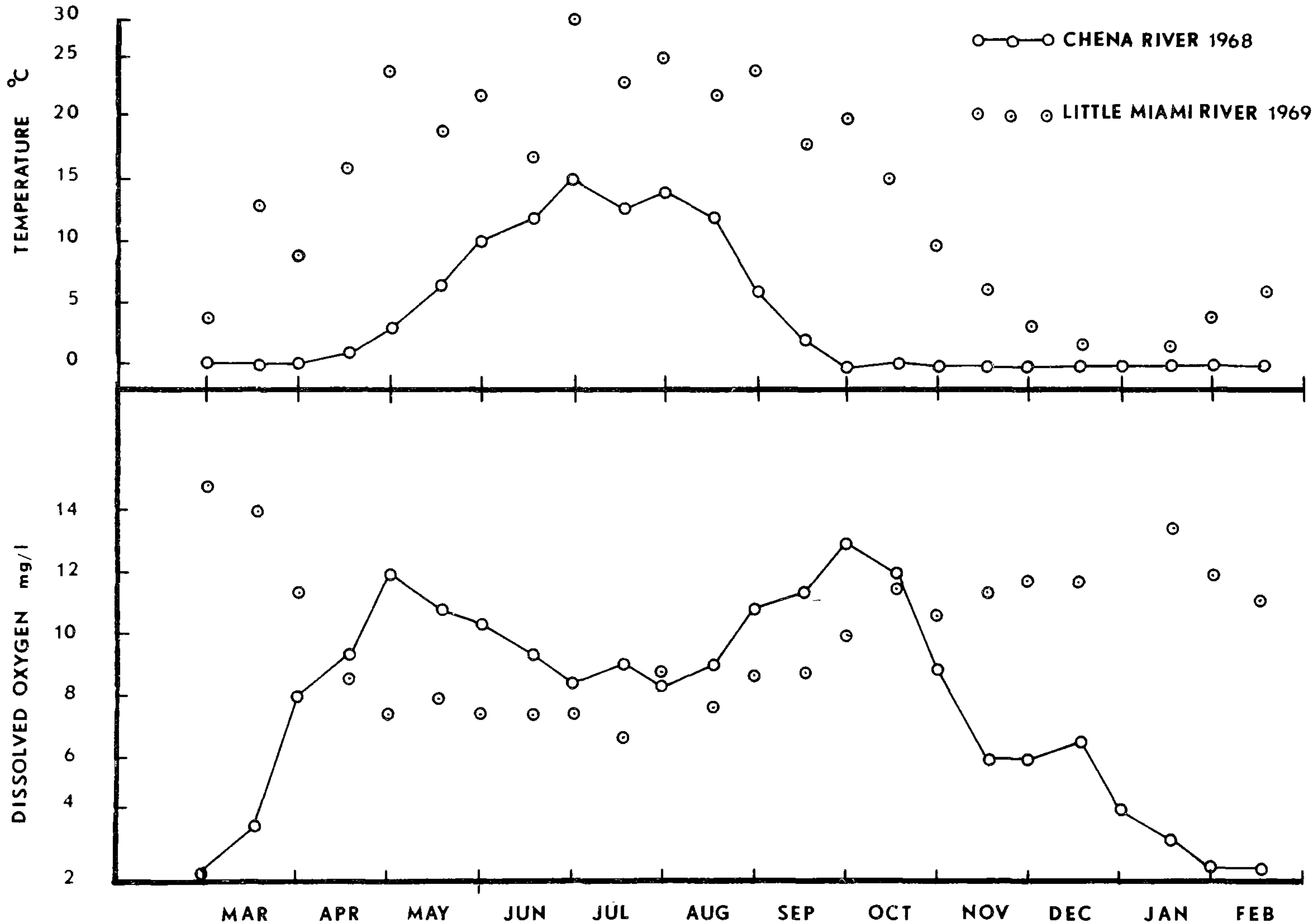
Little Miami River Near Cincinnati, Ohio

To clearly relate differences in the D.O. seasonal patterns of sub-arctic rivers and temperate rivers, a further comparison is made between the Chena River and the Little Miami River. Mr. A. E. Schwer, Jr. (personal communication, 1972), indicates that, while Little Miami River is within a densely populated area and "man-made pollution" is present, it does not adversely affect dissolved oxygen. The Little Miami River drains a 1713 square mile area and has a 6-year discharge average of 1574 CFS near the mouth (U.S.G.S., 1970). Water temperatures range from a low of approximately 1°C in January to a high of about 28°C in June (Figure 2). Dissolved oxygen vary sporadically from approximately 14.5 mg/l in March to about 6.5 mg/l in July (Schwer, 1972). Correlation of D.O. with temperature reveals an inverse relationship that has also been described by MacCrimmon and Kelso (1970) in the Grand River in southern Ontario. In both rivers, the D.O. concentrations are at the yearly low during the hot summer months, increasing gradually toward the annual high near saturation in winter.

Chena River

The drainage area and 21 year average discharge of the Chena River are similar to the Little Miami. The Chena drains 1980 square miles and its discharge averages 1520 CFS (U.S.G.S., 1969). Water temperatures range from 0°C in winter to nearly 17°C in July and dissolved oxygen varies from less than 2 mg/l (13 percent saturation) to approximately 13 mg/l (90 percent). However, the similarity between the rivers ends when correlations are made between D.O. trends and the annual temperature cycle.

Water temperatures and D.O. concentrations were correlated in an inverse relationship throughout the year in the Little Miami River. In the



TEMPERATURE & DISSOLVED OXYGEN DATA FROM THE LITTLE MIAMI RIVER & THE CHENA RIVER. CHENA DATA FROM FREY ET AL 1970.

FIGURE 2

Chena River, this relationship was found only during the summer, as it ended about the first of October when water temperature approached 0°C and the D.O. concentration reached one of two seasonal high values. Shortly thereafter, the long gradual winter D.O. depression began and continued until about March. The second seasonal high D.O. concentration was reached about spring breakup.

The importance of these seasonal trends is twofold: first the lowest D.O. concentrations were recorded during the winter; second, the D.O. depletion was severe. Annual low D.O. concentrations in the Chena River fell below 1.5 mg/l (10 percent saturation) during February and March. These conditions are different in magnitude and timing from the less severe summer season low of 6.5 mg/l observed in the Little Miami River.

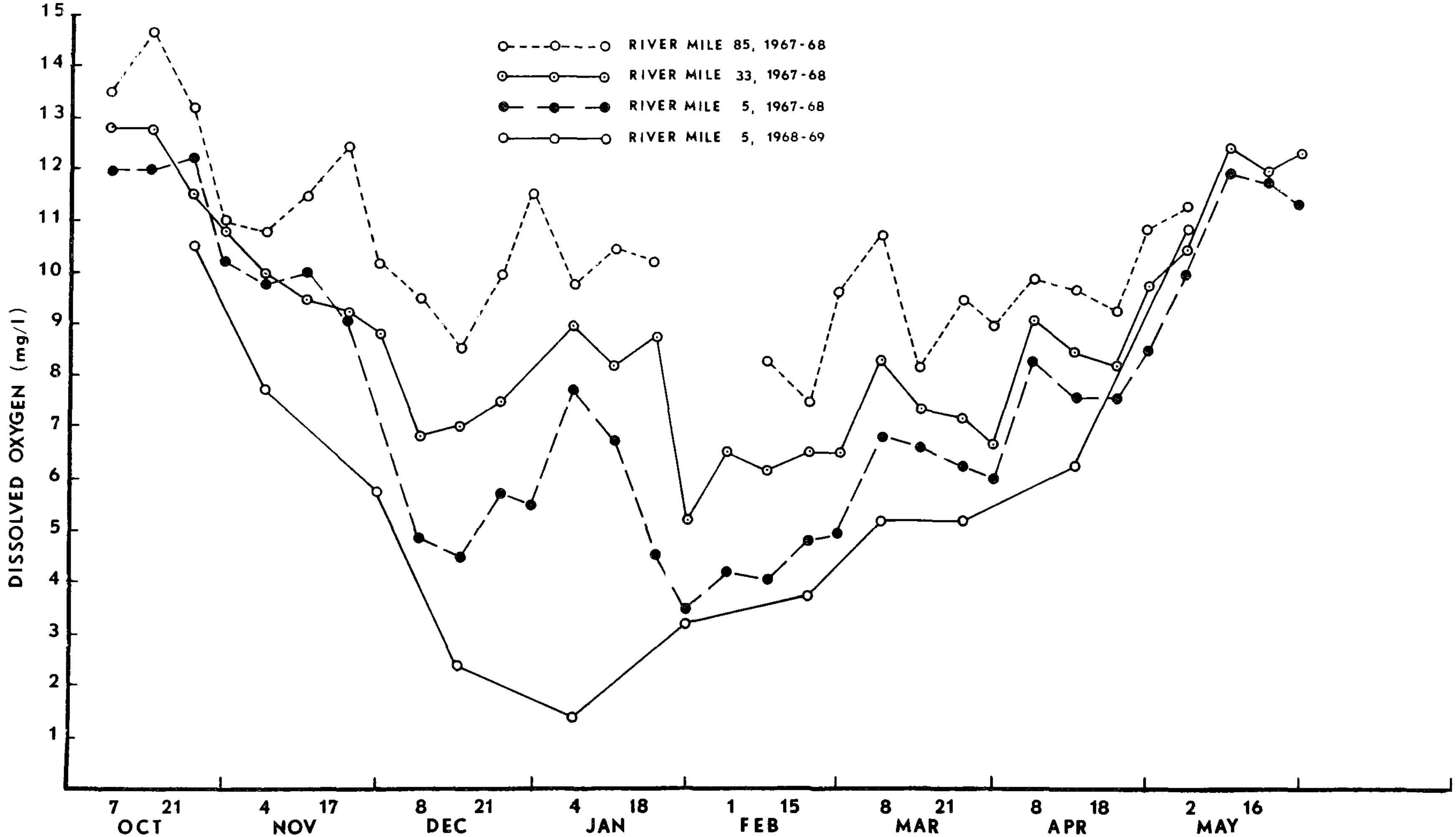
The Chena River data presented in Figure 2 were collected from a single station near the mouth and revealed seasonal D.O. patterns at that location. Data collected from three stations on the Chena River are plotted (Figure 3) to illustrate changes in D.O. concentrations from station to station along the river. These data reveal the D.O. was found in relatively high concentrations at all stations during "freezeup" and "breakup"; that some D.O. depression is found at all locations during the period between "freezeup" and "breakup"; and reaeration took effect at virtually the same time at all stations.

The most important feature of the Chena River data is that stations located in lower reaches, D.O. depression is more severe than at upper stations. Data collected at station C-800 located 135 km (85 miles) from the mouth of the Chena, revealed a minimum D.O. of approximately 7.5 mg/l (52 percent), while data collected from C-100, 8 km (5 miles) indicate concentrations as low as 4.5 mg/l (31 percent). Comparing data collected from C-100 in 1967-68 to data collected in 1968-69 reveals that depression is significantly more severe in some years than others.

Also of importance is the timing and magnitude of seasonal discharges of the Chena River (Figure 4). Although yearly variations are found from year to year, the largest discharges are generally found during spring-summer, and the lowest during winter. This generality is also valid for other streams and rivers in the arctic and subarctic. Larger rivers usually "breakup" and "freezeup" later than smaller river systems while those located further north usually "breakup" later and "freezeup" earlier.

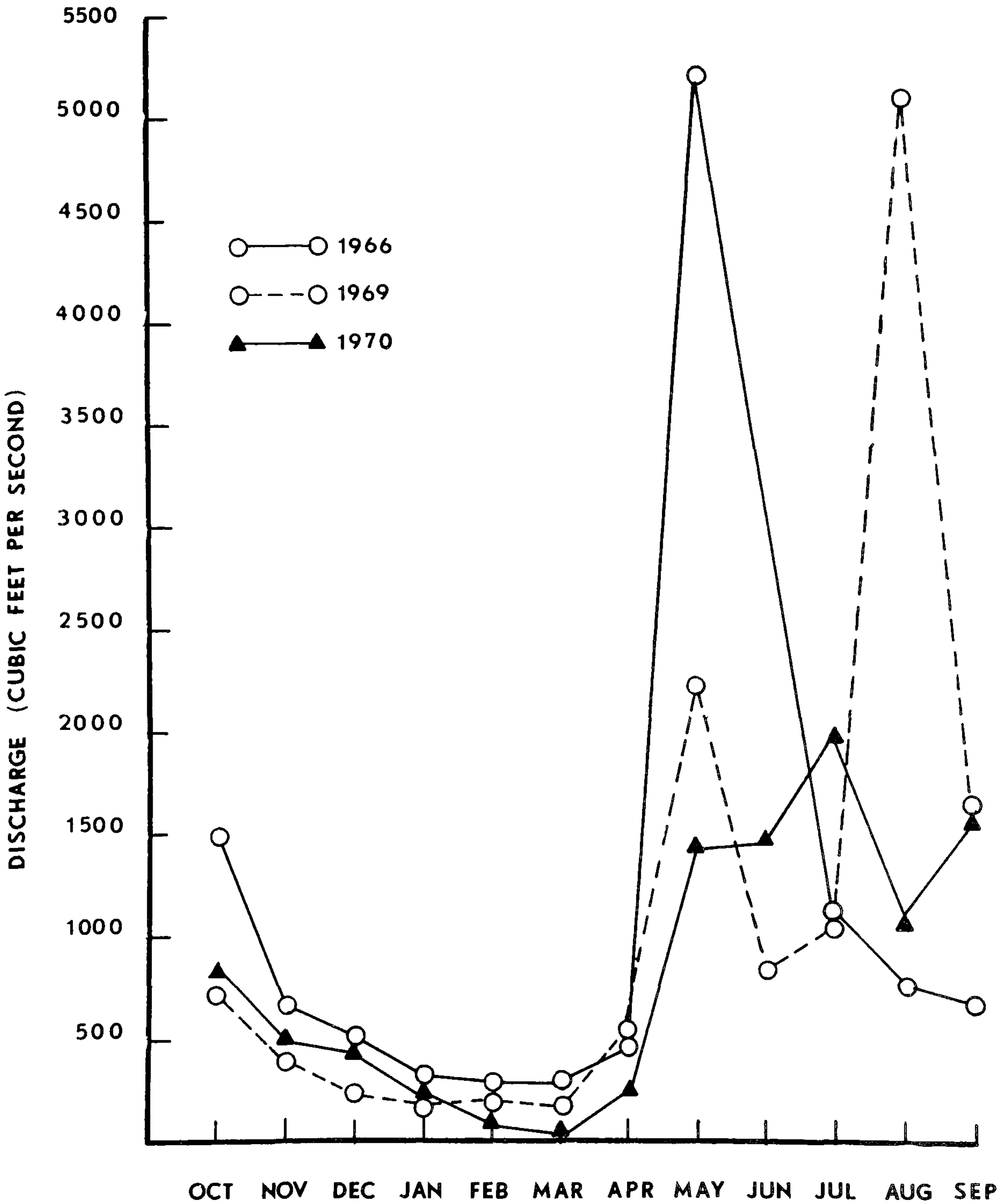
Chatanika and Salcha Rivers

The Chatanika and Salcha Rivers were chosen for comparison to determine if the Chena River was a typical subarctic river or if different D.O. trends could be detected in other subarctic Alaska systems. Both rivers are similar to the Chena in that all three are located in subarctic Alaska; the headwaters originate in the same foothill-mountain system; all are affected by the same general weather patterns; all are southwesterly flowing tributaries of the Tanana River; and drainage systems are adjacent and of the same relative magnitude (approximately 2,000 square miles) (U.S.G.S., 1969) with similar annual discharge of 1500-1700 CFS (U.S.G.S., 1969).



WINTER DISSOLVED OXYGEN DATA from THREE STATIONS on the CHENA RIVER (DATA FROM FREY ET AL, 1970)

FIGURE 3



CHENA RIVER MEAN MONTHLY DISCHARGE

(DATA FROM U.S.G.S.)

FIGURE 4

Dissolved oxygen data collected from Chatanika and Salcha Rivers during the 1968-71 winter field seasons have been plotted in Figure 5 and 6 respectively. Although collected over several years, the data correlate well and present distinct winter trends. Dissolved oxygen was depressed in both the Chatanika and Salcha Rivers. Data collected from the Chatanika during January-February 1969, show depression from near 11 mg/l at the 152 km station to near 7 mg/l at the 120 km station. Salcha D.O. data collected during 1968-69 shows similar depression from 10 mg/l at the 128 km station to 7 mg/l at the 2 km station. Also, data collected from both rivers indicates that the D.O. was gradually depressed at each station from October until January or February.

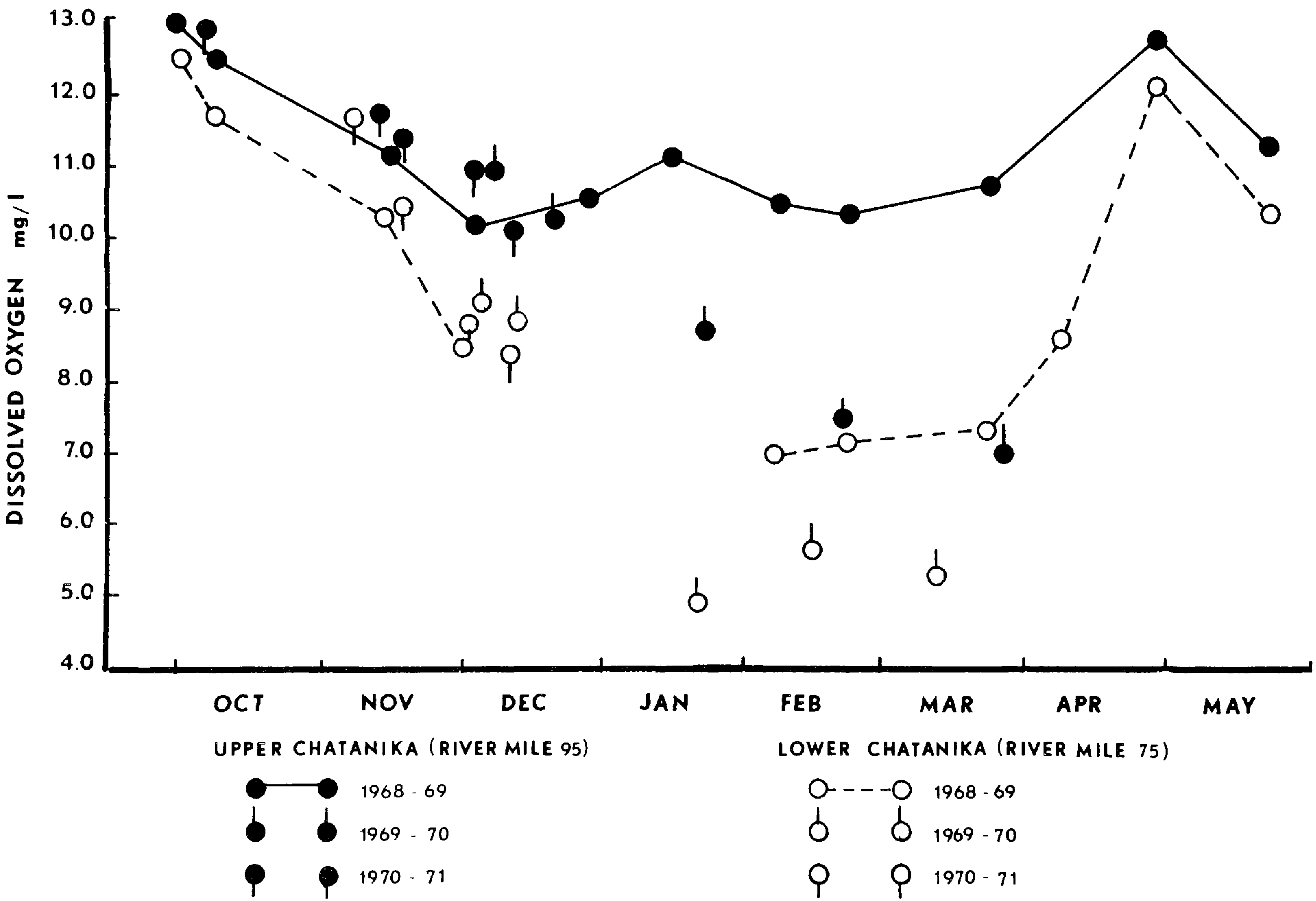
Dissolved oxygen depression in the Salcha River did not appear to be as severe as in the Chena. The minimum D.O. concentration near the mouth of the Salcha was 6.5 mg/l compared to 1.5 mg/l near the mouth of the Chena. A similar comparison from the Chatanika was not possible because a station was not established near the mouth.

Dissolved oxygen concentrations found in the Chatanika were higher than in the Chena. Concentrations of near 5.0 mg/l were found at the station located about 120 km from the mouth of the Chatanika. However, since this station was a considerable distance from the mouth, further depression is likely to be found in downstream reaches. The similarity of the D.O trends in these three rivers indicated that these patterns may be found in other subarctic rivers.

The Chena, Chatanika and Salcha drainages constitute a small percentage of the total land area of interior Alaska. The seasonal D.O. trends of these rivers could be different from those of river systems found in subarctic and arctic Alaska, Canada and Russia which may have different geological and hydrologic characteristics. Dissolved oxygen depression may be more apparent where causative factors operate more severely or are virtually nonexistent on other aquatic systems. To investigate these possibilities, extensive field trips were made to more isolated river systems.

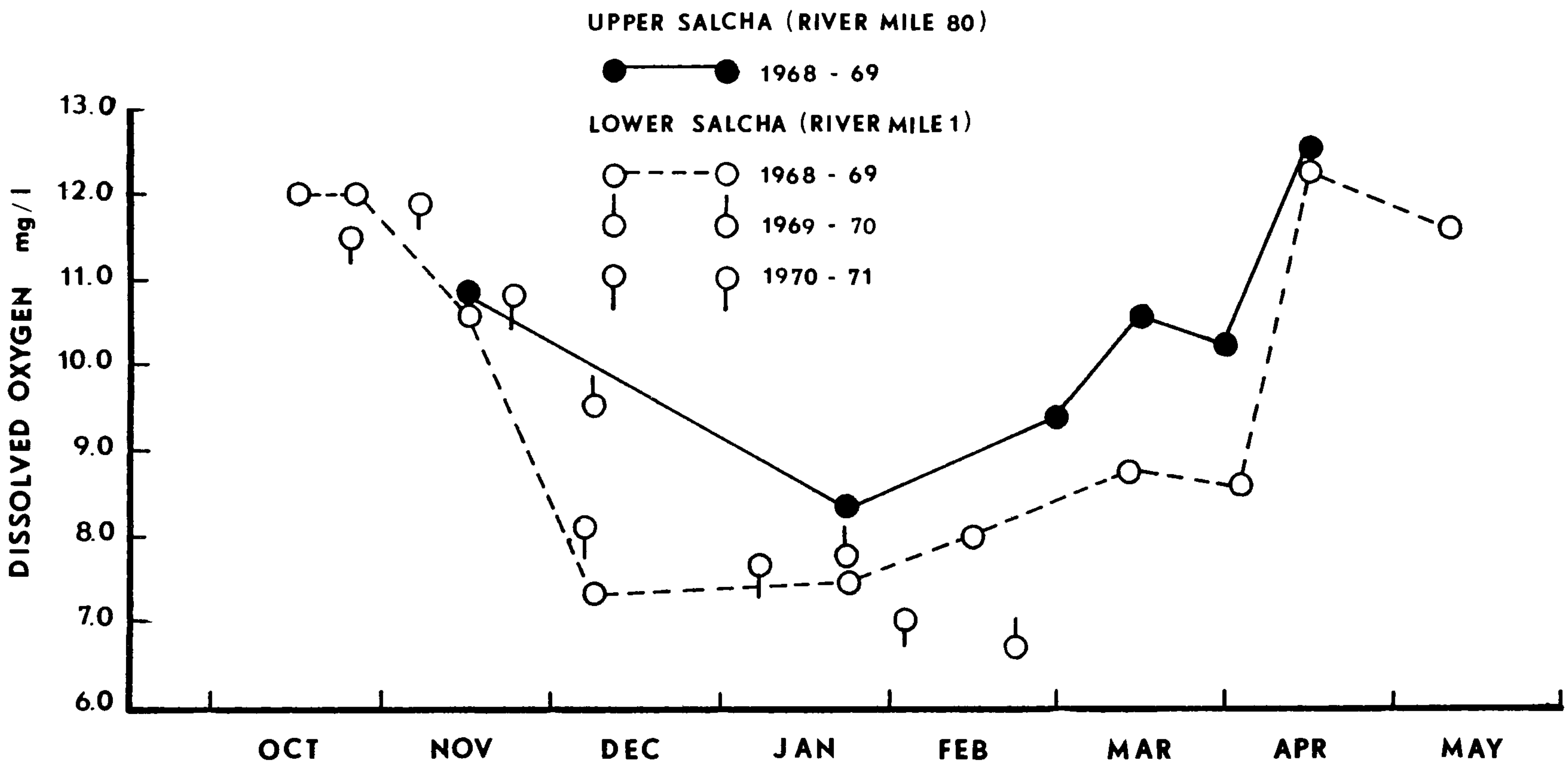
Sagavanirktok River

The Sagavanirktok River, located on Alaska's North Slope, and among the most isolated rivers in the State, was chosen for study because of its location, present oil exploration activities, and pending extensive future development. It flows north from the Brooks Range into the Beaufort Sea near Prudhoe Bay and will be transversed by the proposed Trans-Alaska 48-inch pipeline. The Sagavanirktok River ranks second in discharge only to the Colville River of all North Slope river systems. Near Sagwon, discharges ranged from 2800 CFS to 1990 CFS in the August 16 to 21, 1969, interval (U.S.G.S., 1969). These volumes are somewhat larger than the average late summer discharges of the Chena, Chatanika and Salcha Rivers.



WINTER DISSOLVED OXYGEN FROM TWO STATIONS ON THE CHATANIKA RIVER

FIGURE 5



WINTER DISSOLVED OXYGEN FROM TWO STATIONS ON THE SALCHA RIVER

FIGURE 6

Dissolved oxygen data from the summer reveal high concentrations with small differences along the length of the river (Figure 7). In addition, comparing D.O. data to temperature data from June and August reveals the same, although smaller, inverse relationship between D.O. and temperature than was observed in the Chena River. Further comparison of these summer data to the limited winter data supports the hypothesis that D.O. is more depressed at lower stations; the similarity of other patterns shown by the Sagavanirktok River and the Chena River indicates the possibility that this also exists.

Yukon River

The Yukon River, with its rich historical past, large fishing industry, outstanding waterfowl resource, high annual discharge, and international importance, is one of the most important rivers in North America. The headwaters originate in Canada and the lower 1000 miles transverse the entire state of Alaska from east to west. The Yukon annually discharges a total volume near 124,300,000 acre feet and an average daily volume of 171,600 CFS at Ruby, Alaska (U.S.G.S., 1969). It was therefore important to examine the winter D.O. trends present in this larger river system.

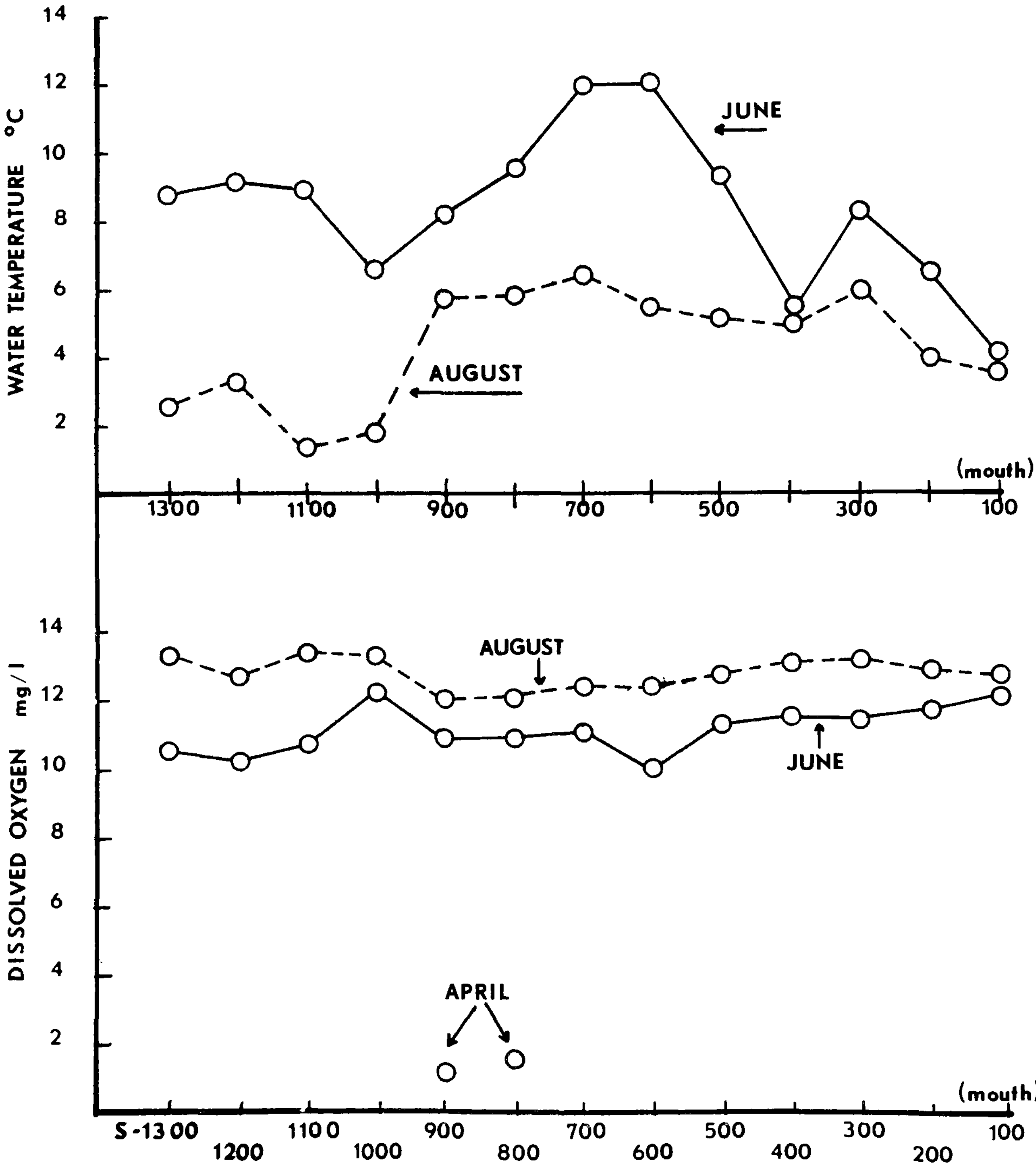
Two field trips were taken to the Yukon River during March 1971. A total of 14 samples were collected from 12 stations extending over 1664 km (1040 miles) between Eagle, near the Canadian border, and Alakanuk, near the mouth. The upper seven stations were sampled in early March and the lower seven stations were sampled in late March; the two intermediate stations near the Ray River, 1044 km (river mile 715), and the village of Tanana, 1016 km (river mile 635) were sampled both trips to provide overlap and continuity.

In the Yukon, as in other rivers studied, dissolved oxygen concentrations decrease when proceeding downstream (Figure 8). Water collected at the upper-most station at Eagle (1664 km) contained 10.5 mg/l (73 percent saturation) while water at Alakanuk near the mouth contained 1.9 mg/l (13 percent saturation). Some minor irregularities exist in the general trend but the only major anomaly was found at Ruby, 832 km (river mile 520). Here the sample was collected from an area of the river where no current could be detected; whereas, all others were collected from areas with detectable current. It is probable that the Yukon River also undergoes gradual D.O. depression during the winter and that the D.O. concentration gradually recovers in spring, in a manner similar to the Chena River.

Since the spring rise in D.O. concentration is related to "breakup", this phenomenon in the Yukon River probably occurs later than in the Chena River.

Tanana River

The Tanana River is very important to interior Alaska. It drains 25,600 square miles and in doing so discharges 17,600,000 acre feet per year



DISSOLVED OXYGEN & WATER TEMPERATURE DATA from 13 STATIONS on the SAGAVANIRKTOK RIVER (1969-1970)

FIGURE 7

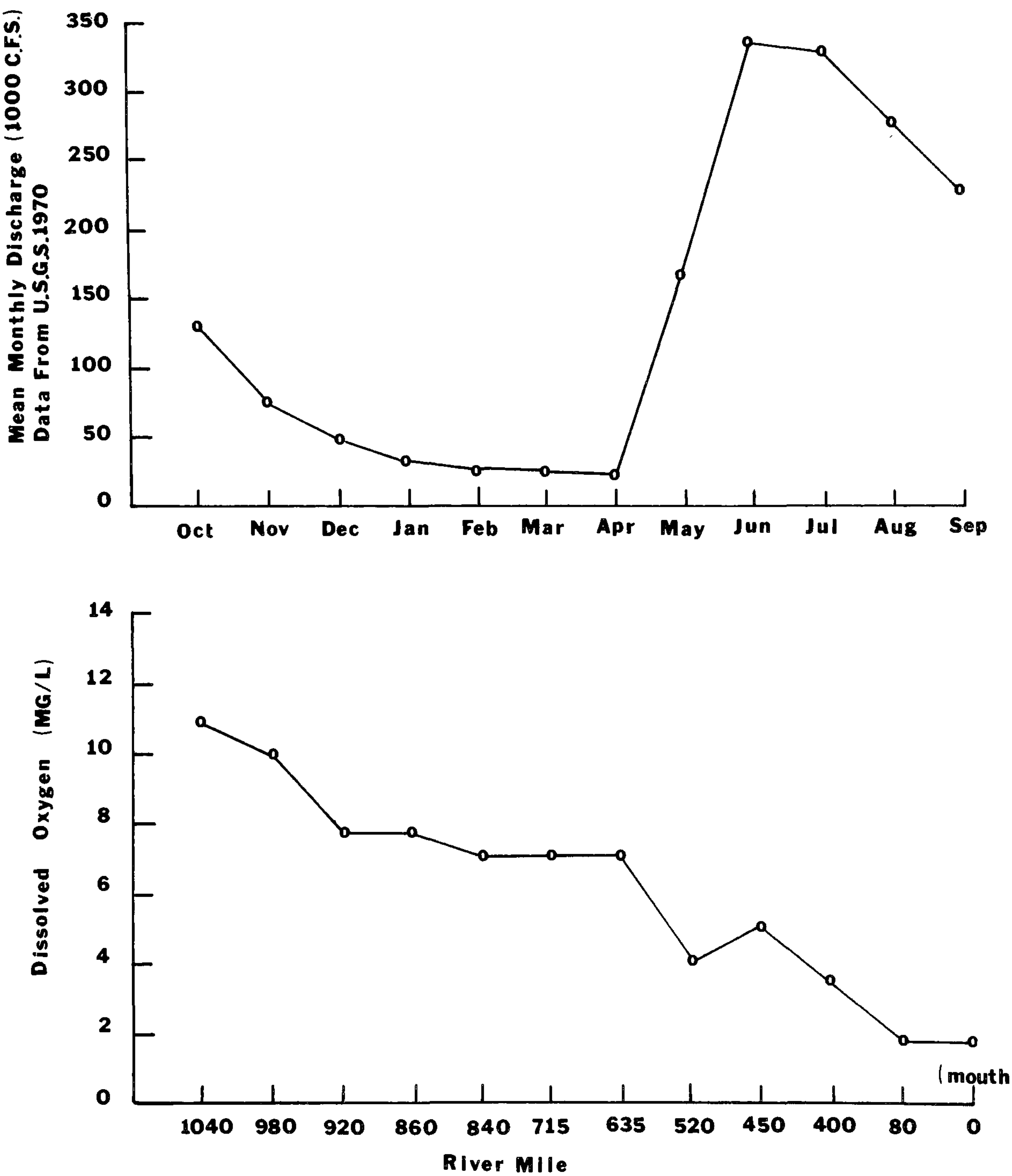


Figure 8 Mean Monthly Discharge (1970) And Winter Dissolved Oxygen (1971) Data From The Yukon River.

(U.S.G.S., 1971) while becoming the largest tributary to the Yukon River. Situated in this drainage are the communities of Fairbanks, Nenana, Tanana, North Pole, Eielson, Delta and Tok. These communities may already affect some of the physical, chemical and biological characteristics of the Tanana and it is expected that continued growth and further development will place even more demands upon this river system.

The D.O. pattern of the Tanana River was similar to that of the Yukon River. Data presented in Figure 9 revealed that D.O. concentrations were gradually and consistently depressed when proceeding downstream. The D.O. at station T-800, near the confluence with the Chena River, was about 10 mg/l while the concentration at station T-100, near the confluence with the Yukon River, was near 6.0 mg/l. Comparison of data from samples collected on February 23, at each station, to those collected on March 5, at the same respective stations, revealed that D.O. concentrations had increased at each station. It is probable that D.O. concentrations had been more severely depressed earlier in the winter.

Other Alaskan Rivers

Winter dissolved oxygen data from additional rivers in Alaska were collected during field trips timed to coincide with anticipated winter D.O. depression. Sample sites were located where the road crossed the river or where it was convenient and safe to land the aircraft with no concern given to whether the station was close to the mouth or contained open water in the area. Consequently, some sample sites were located on upper or open water reaches of a river where severe depression would not normally be expected.

As anticipated, D.O. concentrations ranged widely from 0.0 mg/l to 15.3 mg/l (Table 2). No pattern is readily apparent from these data since low D.O. was found under a variety of conditions. Data from streams with small discharges (near 20 CFS) such as Moose, Gardiner, and Shaw Creeks, reveal D.O. concentrations of less than 2.0 mg/l. Furthermore, rivers with larger discharges (summer discharges greater than 1000 CFS) such as the Colville and Copper Rivers, may contain depressed D.O. concentrations as low as 3.4 mg/l (24 percent saturation).

Rivers from different geographic locations such as the North Slope of Alaska flowing north (Sagavanirktok, Colville, Kuparuk); rivers of interior Alaska draining southwest (Yukon, Chena, Chatanika); rivers draining south (Gulkana, Copper); all contain depressed D.O. concentrations (Table 2).

Limited data from some rivers, such as the Kenai, Eagle, Knik, Matanuska, and Chickaloon, located south of the Alaska Range show that rivers near Anchorage contained D.O. concentrations near 13 mg/l (90 percent saturation). The Tiekel and Tsina Rivers near Valdez show similar winter D.O. concentrations. However, these data are not sufficient to conclude that these rivers do not undergo D.O. depression. In summary, many rivers, large and small, located from 70°N to 61°N latitudes, may contain waters with depressed D.O. during winters.

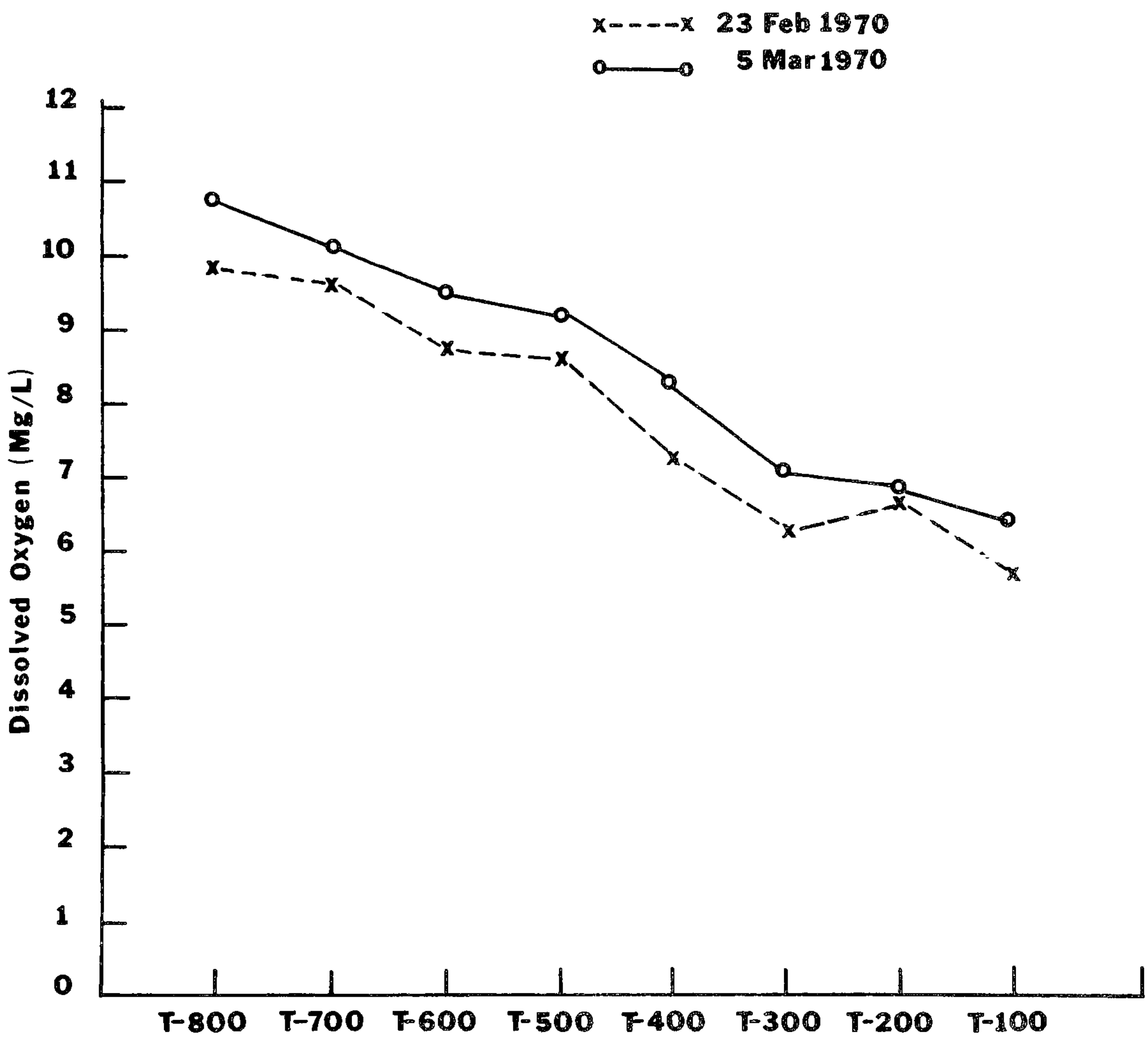


Figure 9. Winter Dissolved Oxygen Data From Eight Stations On The Tanana River.

TABLE 2

Winter Dissolved Oxygen from Various Rivers in Alaska
(Single Samples During Field Trip)

Stream	March 1969		February 1971	
	Dissolved Oxygen		Dissolved Oxygen	
	mg/l	% Sat.*	mg/l	% Sat.*
Tanana-Tetlin Junction	6.7	47	5.7	40
Moose Creek	----	---	----	---
Shaw Creek	1.1	---	1.3	9
Delta Clearwater (Lodge)[1]	11.6	81	10.3	72
Gerstle River	14.0	---	----	---
Johnson River[2]	----	---	13.3	92
Robertson River	13.1	91	----	---
Tok River (Tok Cutoff)	10.8	75	----	---
Chisana River	9.6	67	7.8	54
Gardner Creek[3]	----	---	0.0	0
Gulkana River	----	---	9.0	63
Slana River	8.0	56	7.7	53
Chistochina River[4]	12.4	86	12.9	90
Gakona River	14.0	97	15.3	106
Copper River	4.6	32	2.9	21
Tazlina River	11.4	79	10.9	76
Tsina River	----	---	13.0	90
Tiekel River	----	---	12.6	87
Donnelly Creek	----	---	9.3	65
Ruby Creek	8.5	59	----	---
Phelan Creek	----	---	12.0	83
Little Nelchina River	12.8	89	----	---
Chickaloon River	13.7	95	----	---
Matanuska River, Palmer	13.1	91	----	---
Matanuska River, below Palmer	12.9	90	----	---
Knik River	13.4	93	----	---
Eagle River	12.8	89	----	---
Kenai River	13.2	92	----	---
Porcupine River(near Old Rampart)	10.5	73	----	---
Colville River(4.8km E of Umiat)[5]	3.4	24	----	---
Colville River (at Umiat)	7.5	52	----	---
Kuparuk	8.4	58	8.4	58

* Calculated at 0°C

[1]Spring fed

[2]Overflow water

[3]Sulfurous odor

[4]Overflow water

[5]Under 4 m of ice

Water Chemistry

Discussion of water chemistry will be limited to presentation of data and to general trends shown by pH, conductivity and alkalinity, because data are insufficient to allow more detail. As would be expected, all three water quality parameters varied with time, from station to station within a stream system, and from river to river.

Winter pH from one station on the Chena River ranged from 7.7 to 6.2 and generally decreased during the winter season although abrupt deviations from the pattern are apparent (Figure 10). pH measured at 12 stations on the Yukon during March showed that the Yukon became more alkaline from the Canadian Border (7.3) to the first station below the confluence of the Yukon and Porcupine Rivers (8.3), at which point the trend reverses (Figure 9). The single pH value of 7.8 from the Porcupine River (Table 3) indicates that these waters may be exerting an influence toward lower pH in the Yukon. In general, these pH changes can be related, but not necessarily limited to: the depression of D.O.; the increase of free carbon dioxide which accumulates in the absence of photosynthetic activity; and the influence of surface runoff and ground water.

Alkalinity and Conductivity

Winter alkalinity and conductivity also vary widely with location and season. Alkalinity ranged from 28 mg/l in Kuparuk River to 410 mg/l in the Gakona River, but most were in the 40 to 150 mg/l range (Table 3). This is probably related to concentrations of anions of the carbon dioxide-bicarbonate equilibrium. Conductivity (umho/cm) ranged from 130 in the Kuparuk River to 3000 in the Sagavanirktok River at Deadhorse, although most streams were within the 200-400 range. Parallel seasonal trends are shown by conductivity and alkalinity data from two stations in the Chena River (Figure 11). Both parameters reveal some increase during the winter with an abrupt decrease at spring "breakup" and both show the highest values at the lower stations until "breakup" when a reversal appears (Frey, et. al., 1970).

Biological and Management Implications

Low D.O. may affect large populations of endemic and anadromous fish whether occurring in large or small drainages. For example, drainages as small as Shaw Creek support sizable populations of grayling, and larger watersheds such as the Chena harbor significant populations of grayling, chum and king Salmon, with potential for even larger runs of anadromous fish. The Gulkana-Copper River system supports populations of grayling throughout the year, as well as salmon in various stages of development. the biota of these particular lotic systems are not unique; other less known but equally important rivers support large populations of aquatic biota and contribute substantially to the total aquatic resources of Alaska.

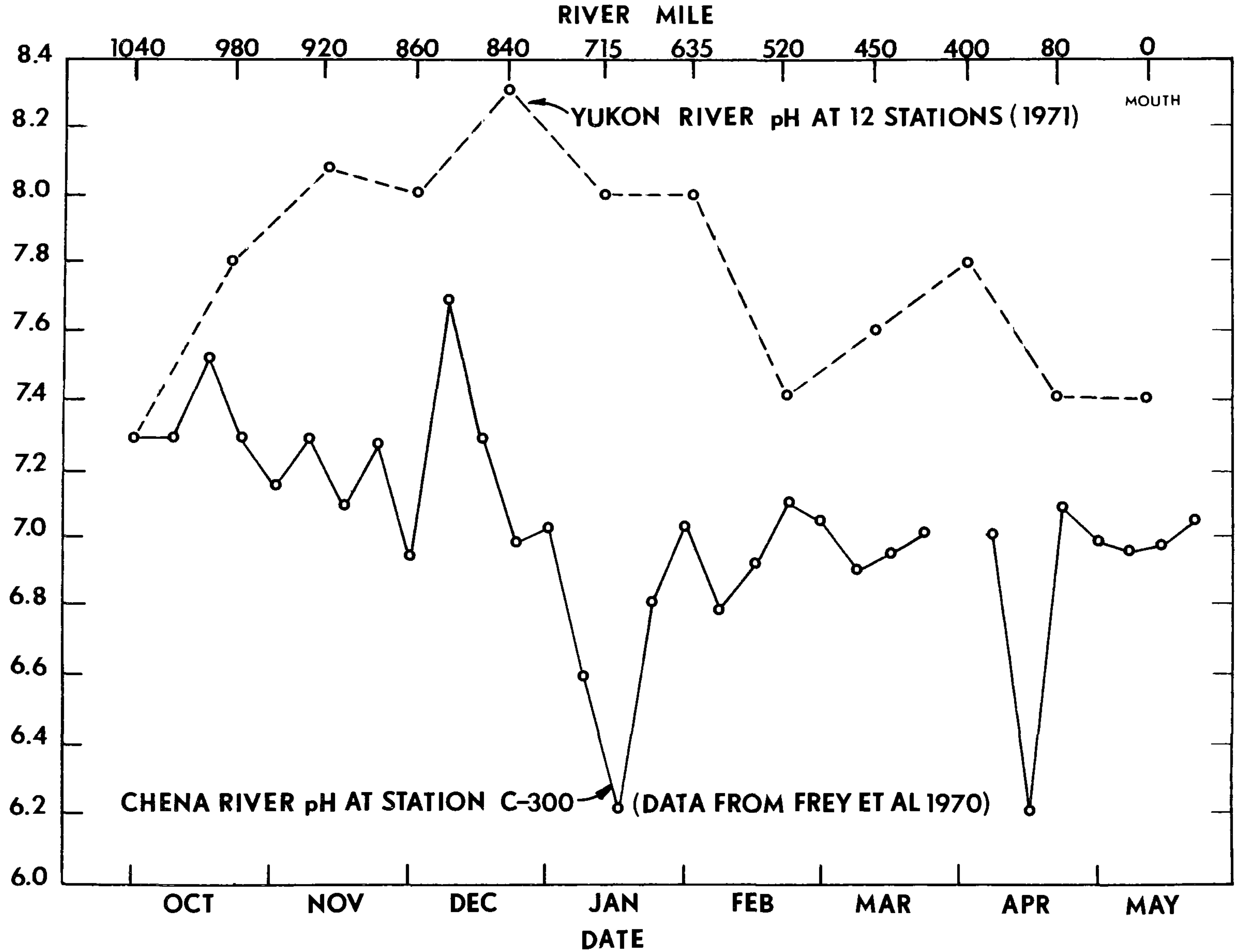


Figure 10. Winter pH Data On The Yukon River And The Chena River.

TABLE 3

Conductivity, alkalinity, and pH from Various Rivers in Alaska (February 1971)

Stream	Cond. (umoh/cm)	pH	Alkalinity (mg/l)
Tanana-Tetlin Junction	350	-	148
Tanana, below Nenana	-	-	-
Moose Creek	240	6.6	134
Shaw Creek	230	7.8	100
Delta Clearwater (Lodge)[1]	290	-	114
Gerstle River	-	-	-
Johnson River[2]	400	-	120
Robertson River	-	-	-
Tok River (Tok cutoff)	450	-	135
Chisana River	310	-	135
Gardiner Creek[3]	410	-	224
Gulkana River (Summit Lake)	105	7.4	46
Slana River	350	7.6	120
Chistochina River[4]	350	7.9	127
Gakona River	>800	7.4	410
Copper River	>800	7.1	310
Tazlina River	210	7.9	64
Tsina River	180	8.3	62
Tiekel River	140	8.0	44
Porcupine River (near old Rampart)	650**	7.8	160
Colville River (3 miles E of Umiat)[5]	1160	6.8	280
Colville River (at Umiat)	520	6.8	110
Sagavanirktok River (Sagwon)[6]	1700	6.9	>400
Sagavanirktok River (Deadhorse)[7]	3000	6.4	>400
Kuparuk[8]	130	6.4	28

** Data from 1969 (field kit measurements for alkalinity)

[1]Spring fed

[2]Overflow water

[3]Sulfurous odor

[4]Overflow water

[5]Under 12 foot of ice

[6]Slight organic odor

[7]Collected in May

[8]Some open water

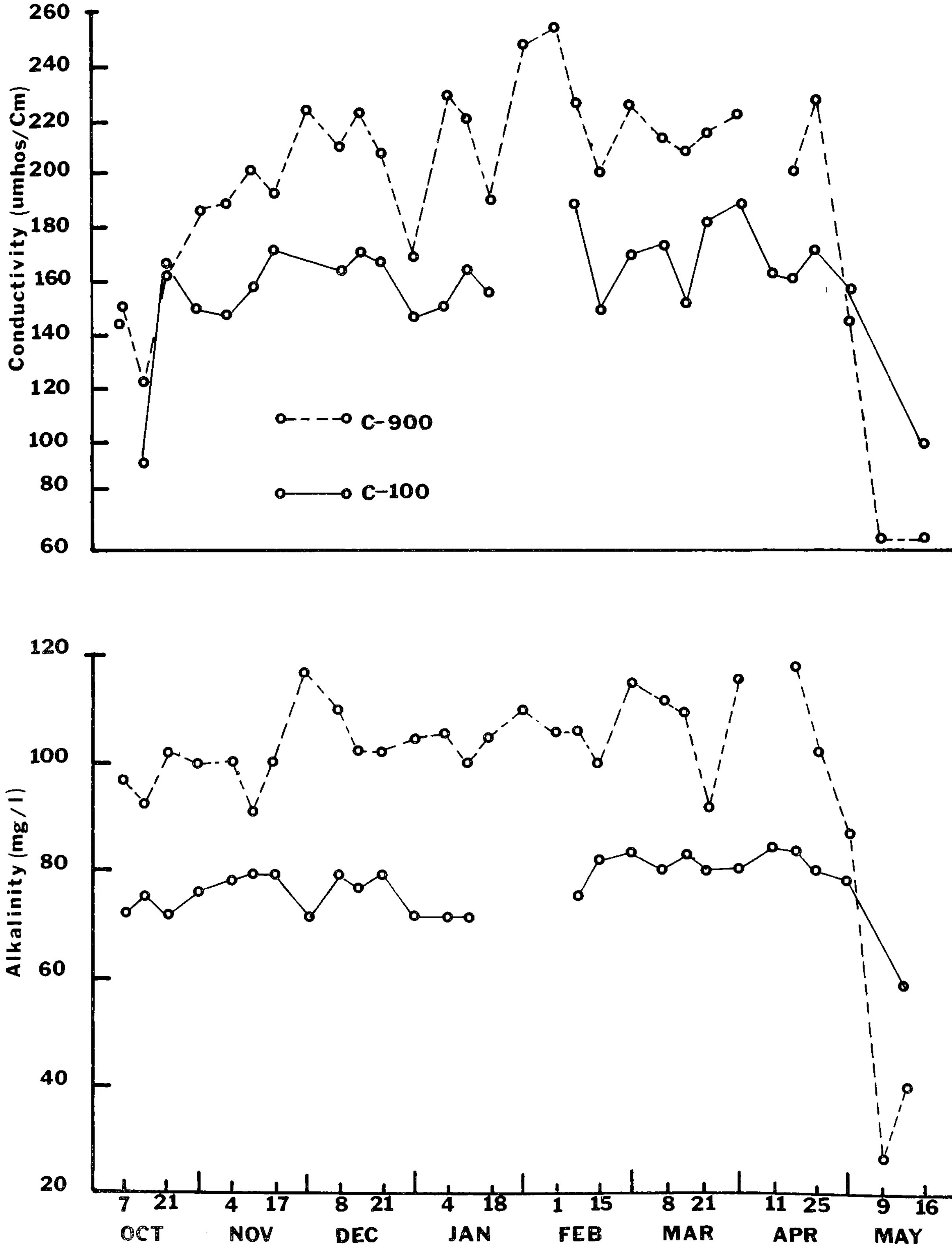


Figure 11. Alkalinity & Conductivity From Upper (C-900) & Lower (C-100) Stations On The Chena River. Data From Frey et al 1970

Severely depressed D.O. has the potential of affecting large numbers of several species of fish and other organisms that are directly or indirectly economically important. It is possible that lethal or other less apparent but nevertheless significant effects may already be limiting these populations. Doudoroff and Warren (1957) discuss the importance of adequate concentrations of D.O. necessary for survival of fishes. The influence of different oxygen concentrations on the growth rate of juvenile large mouth bass is described by Steward, et. al., (1967). Other sub-lethal effects, such as the influence of D.O. on the swimming performance of juvenile pacific salmon, have been discussed by Davis, et. al, (1963). Differences in the distribution of two plecopterans are related to dissolved oxygen by Madsen (1968). Unfortunately, these and other studies were generally conducted on organisms found in temperate climates at 10 to 20°C. At this time, no cold climate studies have been conducted to determine how low D.O. conditions at low temperatures affects endemic organisms. A research project that examines these areas has been initiated at the Arctic Environmental Research Laboratory to fill these needs.

The Alaska State Water Quality Standards (1973) currently classify all surface waters of the state for "growth and propagation of fish and other wildlife including waterfowl and fur bearers." The dissolved oxygen criteria established is "greater than 7 mg/l for fresh water." As can be seen from the data gathered in this study, many streams in Alaska under natural conditions fall below these criteria in winter. The Water Quality Standards recognize this natural phenomonon and state that "waters may have natural characteristics which would place them ouside the criteria" and that the criteria established "apply to man-made alterations to the waters of the state." The standards also contain a "non-degradation" clause.

The application of the Water Quality Standards and the administration of the National Pollutant Discharge Elimination System during the critical winter period in Alaska will not be easy. All discharges into the waters of the United States are required to be regulated by a permit under the Federal Water Pollution Control Act Amendments of 1972 (ref. PL 92-500). These permits are developed jointly by the principal State water quality control department and the U.S. Environmental Protection Agency, and are reviewed by other State and Federal agencies and the public. The development of these permits must take into consideration Alaska's complex winter stream dissolved oxygen phenomenon. Presently there are only a limited number of discharges into waters which undergo winter dissolved oxygen depression below the State criteria; however, expected industrial and municipal expansion in the state will result in many more such discharges.

Discharges occurring in the upper reaches of a river system will require careful consideration. The receiving water at the point of discharge may contain ample dissolved oxygen. However, if that river exhibits severe winter D.O. depression, the downstream areas are the most critically affected and may reflect and additional D.O. depression caused by upstream waste discharge.

Discharge permits developed for effluents into streams which exhibit this low dissolved oxygen phenomenon should only be issued after sufficient field studies have been coducted to establish the natural conditions in both summer and winter. This information should include not only dissolved oxygen measurements, but also other water quality parameters and a survey of aquatic organism populations. From these data, the level of waste treatment necessary to protect the water quality of the stream can be defined.

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1 Accession Number	2 Subject Field & Group	**SELECTED WATER RESOURCES ABSTRACTS** INPUT TRANSACTION FORM

5 Organization

U.S. Environmental Protection Agency, Office of Research and Development, NERC-Corvallis, Arctic Environmental Research Laboratory, College, Alaska

6 Title

Low Winter Dissolved Oxygen in Some Alaskan Rivers

10 Author(s)

Eldor W. Schallock and
Frederick B. Lotspeich

16 Project Designation

21 Note

U.S. Environmental Protection Agency report number EPA-660/3-74-008, April 1974

22 Citation

23 Descriptors (Starred First)

Low Dissolved Oxygen, Alaska, Rivers, Winter, Natural Conditions, Seasonal Patterns, Basin Patterns, Conductivity, Alkalinity, Hydrogen Ion Concentration, Water Temperature, Water Quality Standards, Yukon River, Sagavanirktok River, Chena River

25 Identifiers (Starred First)

*Alaska, *Rivers, *Low Dissolved Oxygen, Arctic, Subarctic

27 Abstract

Water samples collected during the years 1969 through 1972, from 36 selected Alaskan rivers were analyzed for dissolved oxygen, pH, conductivity and alkalinity. Dissolved oxygen (D.O.) ranged from 0.0 to 15.3 ml/l (106 percent saturation); pH from 6.2 to 8.4; conductivity varied from 105 to 3000 (umho/cm); and alkalinity from 28 to 410 (mg/l). Severe D.O. depletion during winter was found in many river systems large and small, and located in a range of latitudes (70°N to 61°N). Sufficient data were collected on the Chena, Chatanika, and Salcha Rivers to reveal annual D.O. trends: near saturation during spring "breakup" and fall "freezeup" when water temperatures are near 0°C; somewhat lower D.O. concentrations during warm water summer periods; and yearly minimum concentrations during the winter (January-March) interval.

Data indicate that D.O. depression begins in October and continues into February. D.O. from stations near the mouth of a river were generally depressed more than at upper stations. The latter trend was observed in the Yukon River which contained 10.5 mg/l (73 percent saturation) at the Canadian Border but only 1.9 mg/l (13 percent) near the mouth. pH gradually decreased in some rivers although alkalinity and conductivity increased. The depressed winter D.O. concentrations and low winter discharge in many Alaskan rivers are more severe and widespread than present literature indicates. Winter conditions may already limit aquatic organisms in some systems.

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