Temperature monitoring of Canadian and Alaskan Yukon River tributaries (URE-25-11), final report to the Yukon River Panel

by

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Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

TEMPERATURE MONITORING ON SELECT YUKON RIVER TRIBUTARIES

FINAL REPORT TO THE YUKON RIVER PANEL

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ABSTRACT

As temperature affects many life history processes of salmon, and temperature within the Yukon River drainage is dynamic and varied along the mainstem and among tributaries, it is crucial to obtain water temperature data during months when adult salmon are migrating and spawning. The goals of this project were to continue adding water temperature data to the newly constructed database, deploy data loggers at priority locations within the Alaskan and Canadian Yukon, and compare water temperature data among the different data logger types. The field work for this project was completed by October 10, 2011. Data loggers were deployed at Emmonak, Eagle, and Pilot Station by ADF&G staff. Collaborators with USFWS deployed data loggers at the Andreafsky and Chena Rivers using in-kind funds. Within the Yukon Territory, data loggers were deployed in the Teslin River, Pelly River, McQuesten River, Takhini River, Nordenskiold River, Blind Creek and Tatchun Creek. The highest mean daily water temperature for 2011 was observed on two Yukon River tributaries: the mainstem Yukon River at Eagle, Alaska and in Tatchun Creek, Canada. Database development is complete and data will continue to be imported over the next few months.

Key words Yukon River, temperature, climate change, spawning habitat, Chinook salmon.

INTRODUCTION

It is widely accepted that climate change is having an impact on Arctic environments, including thinning sea ice, increase in sea and air temperature, melting permafrost, and the potential for some fisheries to decline due to changes in Arctic ecosystem dynamics (Euskirchen et al. 2009; Stram and Evans 2009; Wendler and Shulski 2009). As a result of climate change, environmental conditions such as flooding, elevated water temperatures, and extremely low water may become more frequent and variable. These environmental changes, particularly water temperature, could affect salmon productivity.

Water temperature is critically important to salmon survival, migration, spawning, and development. Most species of salmon, including Chinook salmon *Oncorhynchus tshawytscha*, migrate and spawn within a specific temperature range, generally from 3°C to 20°C (Richter and Kolmes 2005). However, temperature tolerance varies by species, and often stocks within a species, and is adaptive to the natal environment (Hodgson and Quinn 2002). It has been demonstrated that Columbia basin Chinook salmon migration progress is hindered at water temperatures ranging from 19°C to 23°C (McCullough et. al. 2001). Prolonged exposure to these elevated temperatures and associated low dissolved oxygen levels have been shown to impact adult survival through increased respiratory demands, depleted energy reserves, and metabolic stress (McCullough 1999). Further, the progeny of adult salmon exposed to temperatures from 17.5°C to 19.5°C may experience higher egg and post-hatch mortality, as well as increased likelihood of developmental abnormalities (Berman and Quinn 1990). Though the environment within the Yukon drainage is not identical to the Columbia basin, the effects of climate change within the Alaska and the Yukon Territory are widespread and salmon may be experiencing similar temperature regimes. Identifying specific areas within the drainage as thermal refugia will increase in importance as these effects continue to be felt throughout the Yukon River drainage. Therefore, there is a need to monitor water temperature throughout the region in order to track these changes and assess their potential impacts on Yukon River salmon.

Although water temperature is measured for several escapement monitoring sites, much of the currently available data are spread among agencies and time series do not overlap. In 2008, the U.S. Fish and Wildlife Service Office of Subsistence Management (USFWS OSM) initiated a collaborative effort with the Alaska Department of Fish and Game (ADF&G), Tanana Chiefs Council (TCC), Bureau of Land Management (BLM), and the Aquatic Restoration and Research

Institute to conduct long-term temperature monitoring at 30 salmon escapement sites within Alaska. These sites were within the Yukon, Kuskokwim, Southeast, Southcentral, and Southwest regions. An important component of this project was to ensure that water temperature data are being collected using standardized methods throughout the Yukon River drainage. It is especially critical that temperature is being measured in the same way at both U.S. and Canadian assessment projects. Cooperation among agencies currently monitoring temperature at escapement sites, including the Department of Fisheries and Oceans Canada (DFO) in Whitehorse, Yukon must be a top priority in order to achieve this objective. Further, ensuring that all U.S. assessment projects are utilizing comparable data loggers and monitoring techniques is critical if data are to be compared between sites within each region. This project aims to enhance the data collection process and improve the temperature monitoring that is currently ongoing, while identifying other sites that are not currently monitored, but are known to be important escapement and spawning tributaries.

OBJECTIVES

The main objectives of this project were to: 1) deploy temperature data loggers following a standardized protocol at streams identified as priority locations in Alaska and Canada; 2) further develop the database of existing data to set the stage for future analyses; and 3) compare water temperature data across different data logger types. These aims were to be accomplished through collaboration and open dialogue across State and Federal agencies, including those in Canada.

METHODS

TEMPERATURE INVENTORY

By networking with other agencies, such as USFWS, USGS, and DFO, as well as contacting staff within ADF&G, most of the known temperature data for escapement monitoring projects within the Yukon drainage was collected and compiled into Microsoft Excel[1] workbooks. These data were organized by country of origin and include detailed metadata regarding monitoring equipment used, site location, sampling duration, source of the data (i.e., from which agency) and name of project leader, where possible. Data were compiled into tables summarizing this metadata. Graphs were created for select data sets from U.S. and Canadian sites.

DATA STANDARDIZATION

We deployed a total of 30 iButton and 15 ProV2 data loggers during this field season (1–2 per site) at five Alaskan and seven Canadian Yukon sites. This includes current projects located in migration corridors and those at or near spawning habitat. Data loggers were installed and calibrated following a standardized protocol (see Dunham et al. 2005; von Finster 2010). Data loggers will remain at the sites for an entire year (through winter and breakup), if possible, and will be replaced at the end of the summer with new equipment to be recovered in the spring. This will avoid loss of entire data sets if loggers are lost or malfunction through the winter. A modified anchoring method employing a flow-through housing made of PVC pipe was used. This method was preferred to a closed housing as it allowed water to flow around the data logger, facilitating more accurate temperature data collection. In locations where year-long deployment was not possible due to environmental conditions, loggers were deployed at the

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

beginning of the summer and retrieved prior to ice build-up. Agency staff stationed at the chosen locations were asked to periodically monitor the loggers and report any problems that arose.

The HOBO Pro v2 water temperature data logger was used at U.S. sites, the Onsite Tidbit was used at Canadian sites, and iButtons were used at both Alaskan and Canadian sites. Installation location at each site was contingent upon local water conditions: water depth, freshwater input, and river width. At each new site, details of data logger placement, including inriver depth where possible, distance from the river bank, and landmarks along the banks, were noted, photographs were taken, and if necessary, a float demarcating the location of the instrument was utilized. Every effort was made to situate monitoring equipment in well-mixed areas in order to accurately represent inriver temperature (see von Finster 2010). Each data logger was programmed to record water temperature hourly, 24 hours per day, 7 days per week, from the time of deployment until retrieval. Hourly sampling ensured that minute changes in temperature throughout the day were recorded and accurately reflected the temperature regime at that site. All data were downloaded upon logger retrieval and imported into Microsoft Excel spreadsheets that can be imported into the database.

DATABASE DEVELOPMENT

The development of an information repository, created in SQL Server, was initiated to store all available temperature data compiled during this project and will include data across agencies including ADF&G, USFWS, USGS, BLM, the Yukon River Panel, and DFO. The water temperature data were incorporated into the existing ADF&G AYK Database Management System (DBMS). All data were imported in a standardized format, thus making all data comparable both within and across years and locations. When completed, the data will be accessible to other staff and the public via a website interface as part of the DBMS and will aim to present temperature data as clearly as possible. Further, database development will be ongoing and we will endeavor to continuously update the content every year.

RESULTS

DATA COLLECTION

Alaskan Sites

The field work for this project was completed by October 10, 2011 and data loggers were deployed at five locations: 1) Emmonak, 2) Eagle, 3) Pilot Station, 4) Andreafsky River, and 5) Chena River (Figure 1). The Andreafsky River and Chena River sites were included in this project in order to gain a larger drainage-wide perspective, however, only USFWS in-kind funds were used for those deployments. These sites are critical for monitoring water temperature during the spawning migration and are associated with ADF&G assessment projects. A list of water temperature monitoring sites within the Alaskan Yukon is presented in Table 1. Summer minimum and maximum temperatures are shown in Table 2. Seasonal temperature trends for Pilot Station (Figure 2), Eagle (Figure 3), Big Eddy (Figure 4) and Emmonak (Figure 5) show little diel variation, with increased mean temperatures during late July, and water cooling down into August and the fall months. In Figure 4 and 5, data points track well from late July to the end of the season; this is because Big Eddy and the Emmonak site are in close proximity to each other along the mainstem Yukon River.

Canadian Sites

Six priority locations were established during the 2010 project and those sites were visited in 2011 (see Figure 6 for a general location map). Hobo ProV2 and iButton data loggers were deployed concurrently with Onset tidbit data loggers already utilized by Al von Finster. A total of seven sites were established: 1) lower Teslin River, 2) Pelly River, 3) Tatchun Creek, 4) Blind Creek, 5) Nordenskiold River, 6) Takhini River, and 7) McQuesten River. Seasonal temperature trends for the Takhini River (Figure 7), Teslin River (Figure 8), Tatchun Creek (Figure 9), and the Nordenskiold River (Figure 10) show substantial diel variation, in contrast to the Alaskan sites. Data from 2010 is included in Figure 8 for comparison. Note the much higher spikes in temperature during the peak of the summer in 2010, compared to cooler temperatures with less variation in 2011. A sharp decline in temperature occurred from July 22–25 in the Teslin River, likely an affect of increased summer rain fall throughout the region in 2011. Summer minimum and maximum temperatures are shown in Table 2.

DATA LOGGER COMPARISON

Mean water temperature at Pilot Station, from both right (two-sample t-test, $P < 0.000$) and left banks (two-sample t-test, $P<0.000$), was significantly different between the Hobo ProV2 and the iButton data logger. Similarly, mean water temperature collected at Emmonak was also significantly different (two-sample t-test, $P<0.000$) between the two data loggers. Interestingly, the mean temperature measured at Pilot Station by the iButton was greater than the ProV2, however, the trend was the opposite at Emmonak for only one of two iButtons deployed. Datasets for the Takhini River, Tatchun Creek, and the Nordenskiold River were also compared. Two-sample t-tests yielded significant differences between iButton and Hobo mean temperatures, where the iButton mean temperature was greater (Takhini: $P<0.000$; Nordenskiold: $P<0.000$; Tatchun: $P<0.005$).

DATABASE DEVELOPMENT

A draft database structure was created within the existing Arctic-Yukon-Kuskokwim Database Management System (AYK DBMS). The database structure to incorporate the Yukon River temperature data has been completed and the searchable database can be viewed at the following URL:
http://www.adfg.alaska.gov/CommFishR3/Website/AYKDBMSWebsite/DataSelection.aspx.
The data inventory has been completed along with the initial gathering of the data and data were reformatted in order to be imported into the database. This process was slow due to the bulk of the data, difficulty in locating data, and difference in file types. Lack of staff time and the necessity to prioritize other ADF&G projects was one of the greatest challenges to database completion. Some of these projects already existed such as tower, weir, sonar sites; others were created just for remote sensors. The parent project contains some metadata about the project, such as GPS coordinates, air temperature, and specific locations of the data loggers. The database was structured such that each project may contain multiple locations and multiple sites at each location. It was also set up to capture equipment information and depth information. Water temperature data was loaded using the Region III Window Client Application. There were twenty-one different projects for a total of 132 project/year/collection site combinations that were loaded into the database (Table 4). There are six projects from Canada that still need to have the locations defined, we are not sure where the data was collected based on the given name. Discrepancies between datasets and how data was collected and stored among projects

created challenges when planning the overall structure of the database. In addition, incompleteness of some datasets posed problems when attempting to relate data to each other or match with specific dates and times. Understanding the drainage structure for these streams would provide context of location for each project. There are 102 project/year combinations that either did not have data or the data was incomplete, usually missing time identifier, thus these datasets have not been loaded. Most of these sites were within the Canadian portion of the drainage, including Fox Creek and the Chandindu River. More specific data for all projects is necessary to include them in the database. Figure 11 is a diagram of the database structure.

DISCUSSION

WATER TEMPERATURE SUMMARY

Summary data from selected 2011 projects presented here provide some insight as to the temperature regimes experienced by salmon as they migrate upstream to spawning grounds. Within the Yukon drainage, water temperature at mainstem locations such as Pilot Station, Big Eddy, Emmonak, and Eagle exhibited little diel fluctuation and temperatures remained within a 1–2 degree range for several days. Water temperatures rarely exceeded 18°C, except at Tatchun Creek, potentially impacting salmon movement upstream due to thermal stress (McCullough 1999). Rapid diel changes in temperature where salmon are exposed to elevated temperatures for a brief time, such as occurred in the Takhini and Nordenskiold Rivers, may also impact adult survival (McCullough 1999). In contrast to 2010, the summer of 2011 saw heavy rainfall throughout much of Western Alaska and the southern Yukon Territory, which kept river temperatures colder than normal through the summer. For example, the mean and maximum river temperatures at Pilot Station were 15.2°C and 18.7°C, respectively, in 2010, compared to a mean of 14.6°C and maximum of 18.1°C in 2011. In Canada, the maximum temperature reached at the Teslin River site was 16.9°C in 2011, while in 2010 the temperature peaked at 19.2°C. Most data loggers monitor surface water, however, the depth at which the loggers were placed was not recorded at any project locations. Data loggers are often placed in somewhat protected, but well mixed, areas to avoid being buried by silt and damaged by debris and bedload traveling down the deepest part of the waterway. Therefore, depths across stations would not be comparable, as deployment sites are selected based on specific conditions at each project. Knowing depth of placement is critical, however, as salmon migrating through mainstem river sections could swim deeper to avoid high temperatures at the surface, but may not be able to do so when migrating through very shallow tributaries.

The results of this project indicate that salmon within the Yukon drainage may be experiencing thermal regimes at the upper end of their physiological tolerance during years of low rainfall, but may experience little thermal stress during years of increased precipitation when rivers are cooler. Exposure to elevated water temperatures likely puts adults at risk for increased pre-spawning mortality or spawning failure (Schreck et al. 1994). This knowledge further highlights the importance of monitoring water temperature within the Yukon River mainstem and tributaries to better understand the changes occurring and their impacts on salmon from year to year.

DATA LOGGER COMPARISON

One main objective of this study was to compare data outputs across data logger types, i.e., between Hobo ProV2 and iButton data loggers. The mean temperature measured at Pilot Station by the iButton was higher than the ProV2, however, the trend was the opposite at Emmonak. This anomaly likely resulted from different deployment strategies at the Emmonak field site. One of the iButtons was placed within a non-flow through housing along with one Hobo, and the other was placed in a vacuum-sealed bag in a flow-through housing. The dataset with the lower mean temperature came from the iButton that was in direct contact with the water. Significant differences between iButton and Hobo mean temperatures were also observed in the Canadian sites, with iButtons at Tatchun Creek, Takhini River, and Nordenskiold River recording greater mean temperatures. This result has implications for future deployments, in that we ensure that all iButtons and Hobo loggers are placed in direct contact with the water to obtain the most accurate temperature measurement. All data loggers were calibrated together prior to deployment, but this highlights the need for simultaneous and accurate calibration to ensure that all readings are as comparable as possible. Further, this difference in mean temperature could also be attributed to difference in accuracy between the two technologies, the iButton with 0.5 °C and the Hobo with 0.2 °C. If in the future, this project would like to select one data logger type to use at all projects, rather than continue deploying three different technologies. Based on these results, it may be better to continue using the Hobo data logger because it is more accurate and water proof, though more expensive. If precision is not a major concern, and 0.5 °C of accuracy is acceptable, then the iButton is the better data logger as it is less costly and can be easily waterproofed.

DATABASE DEVELOPMENT

The development of an extension of the existing AYK DBMS was successful. Several old and many new projects have been added, along with their respective water temperature data. These data are now publicly available and can be queried by other agencies as well as the public for temperature data throughout the Alaskan and Canadian Yukon dating back to 1966, with more complete datasets beginning in 1981. Having this information readily available will aid the development of future projects investigating relationships between water temperature and other variables.

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TABLES AND FIGURES

Table 1.–Water temperature monitoring sites within the U.S. portion of the Yukon River drainage.

Location	Number of years	Collection frequency	Annual/Seasonal	Technology	Agency	Project	Watershed
Andreafsky	3	hourly	seasonal	data logger	USFWS	weir	Lower Yukon
Anvik	15	daily	seasonal	thermometer	ADF&G	sonar	Lower Yukon
		every 6 hours	seasonal	data logger	ADF&G	sonar	Lower Yukon
Beaver	2	hourly	seasonal	data logger	USFWS		Upper Yukon
Big Eddy	26	twice daily	seasonal	thermometer	ADF&G	test fish	Lower Yukon
Chandalar	1	hourly	seasonal	data logger	USFWS	weir	Upper Yukon
Chena	2	hourly	seasonal	data logger	USFWS	tower	Middle Yukon
Eagle	7	daily	seasonal	thermometer	ADF&G	test fish	Upper Yukon
		hourly; every 4 hours		data logger	ADF&G	sonar	
Emmonak		hourly	seasonal	data logger	ADF&G	test fish	Lower Yukon
Galena	2	hourly	seasonal	data logger	USFWS		Lower Yukon
Henshaw	1	hourly	seasonal	data logger	USFWS		Middle Yukon
HulaHula	1	hourly	seasonal	data logger	USFWS		Middle Yukon
Kantishna		every 4 hours	seasonal	data logger	ADF&G		Lower Yukon
Middle Mouth	25	daily; twice daily	seasonal	thermometer	ADF&G	test fish	
Mountain Village	1	hourly	seasonal	data logger	YDFDA	test fish	Lower Yukon
Pilot St.	16	daily	seasonal	thermometer	ADF&G	test fish	Lower Yukon
		every 4 hours		data logger	ADF&G	sonar	
Rapids	1	hourly	seasonal	data logger	USFWS		Middle Yukon
	9	hourly	seasonal	data logger	S. Zuray	video wheel	Middle Yukon
Salcha	2	hourly	seasonal	data logger	USFWS	tower	Middle Yukon
Selawik	2	hourly	seasonal	data logger	USFWS		
Sheenjek	30	daily	seasonal	thermometer	ADF&G	sonar	Upper Yukon
	2	hourly		data logger	ADF&G		Upper Yukon
Tanana	1	hourly	seasonal	data logger	USFWS	test fish	Middle Yukon
Tolovana	1	hourly	seasonal	data logger	USFWS		Middle Yukon

Table 2.–Seasonal minimum and maximum water temperatures for select Yukon River locations within Alaska and Canada, 2011.

Country	Location	Dates monitored	Water temperature, °C	
			Min	Max
U.S.				
	Emmonak	July 8 – August 31	12.8	16.7
	Big Eddy	July 16 – August 31	14.1	14.5
	Pilot Station (left bank)	July 11 – September 8	12.1	18.1
	Sheenjek River	August 12 – September 24	5.0	13
	Eagle	July 9 – October 10	0.05	17.6
Canada				
	Blind Creek[a]	July 18 – September 27	1.9	13.5
	McQuesten River[a]	July 1 – September 12	5.1	13.1
	Nordenskiold River[a]	August 2 – September 27	12.6	15.7
	Pelly River	July 18 – September 27	4.2	16
	Takhini River[a]	July 29 – September 30	–	–
	Tatchun Creek[a]	August 2 – September 27	17.4	19.2
	Teslin River at Hootalinqua	July 17 – September 18	9.4	16.9

[a] The iButtons at these locations are logging temperature through the winter.

Table 3.–Water temperature monitoring sites within the Canadian portion of the Yukon River drainage.

Location	Number of years	Collection frequency	Annual/Seasonal	Technology	Agency	Project	Watershed
Caribou Creek	1	hourly	seasonal	data logger	DFO		Upper Yukon
Chandindu River	2	hourly	seasonal	data logger	DFO		Upper Yukon
Christmas Creek	1	hourly	seasonal	data logger	DFO		Upper Yukon
Clinton Creek	3	hourly	seasonal	data logger	DFO		Upper Yukon
Croucher Creek	5	hourly	seasonal	data logger	DFO TKC		Upper Yukon
Deep Creek	1	hourly	seasonal	data logger	TKC		Upper Yukon
Fifteen Mile	1	hourly	seasonal	data logger	Bill Kendrick		Upper Yukon
Fishing Branch	2	hourly	seasonal	data logger	DFO	weir	Upper Yukon
Flat Creek	1	hourly	seasonal	data logger	TKC		Upper Yukon
Fox Creek	5	hourly	seasonal	data logger	DFO		Upper Yukon
Grayling Creek	1	hourly	seasonal	data logger	DFO		Upper Yukon
Horse Creek	1	hourly	seasonal	data logger	TKC		Upper Yukon
Joe Creek	1	hourly	seasonal	data logger	TKC		Upper Yukon
Klondike River	6	hourly	seasonal	data logger	DFO Bill Kendrick	sonar	Upper Yukon
Klusha Creek	2	hourly	seasonal	data logger	DFO		Upper Yukon
Laberge Creek	1	hourly	seasonal	data logger	TKC		Upper Yukon
Laurier Creek	1	hourly	seasonal	data logger	TKC		Upper Yukon
Mayo River	3	hourly	seasonal	data logger	DFO		Upper Yukon
Mica Creek	1	hourly	seasonal	data logger	DFO		Upper Yukon
Mickie Creek	3	hourly	seasonal	data logger	DFO		Upper Yukon
Sheep Rock	6	daily	seasonal	data logger	DFO	fish wheel	Upper Yukon

-continued-

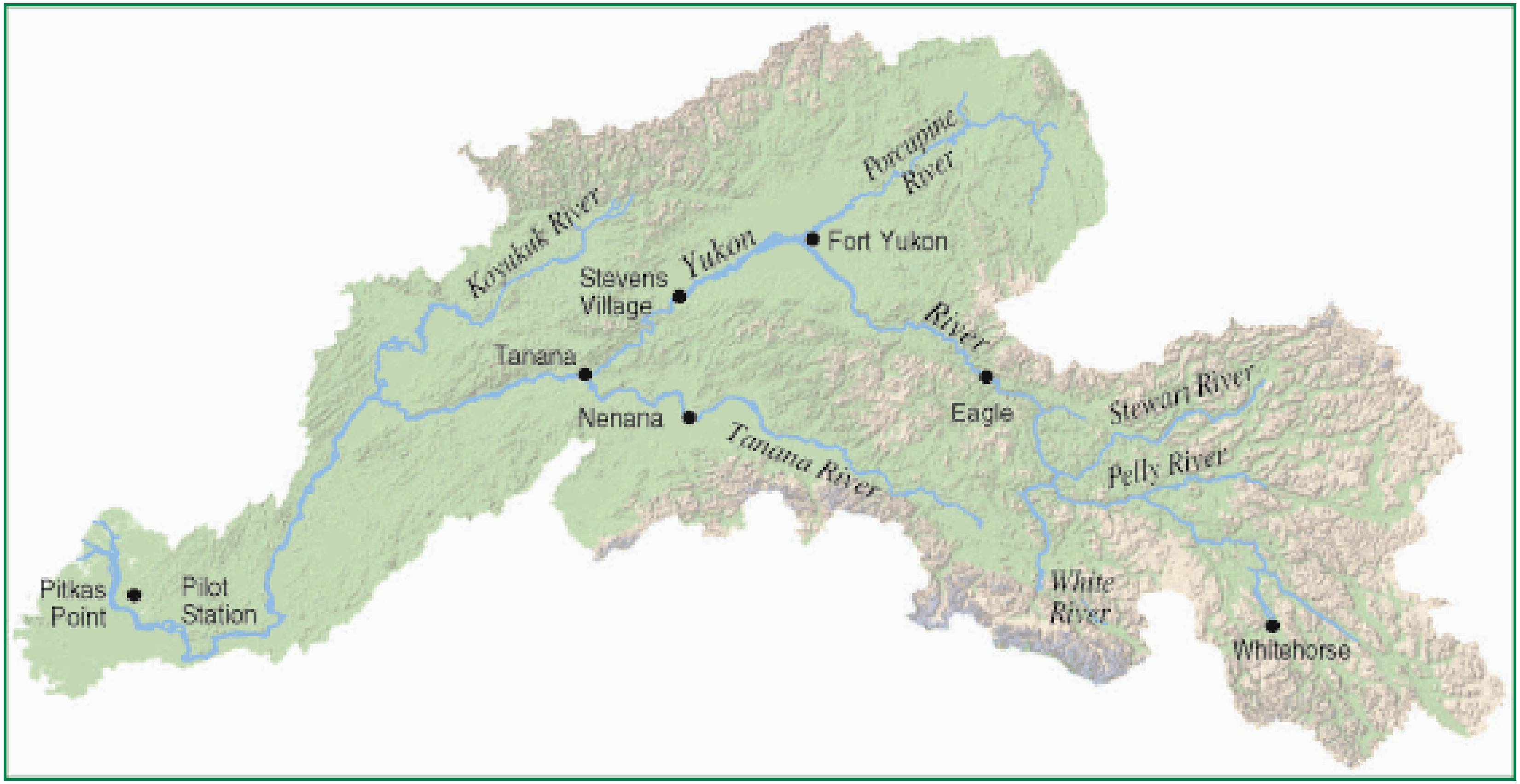
Table 3.–Page 2 of 2.

Location	Number of years	Collection frequency	Annual/Seasonal	Technology	Agency	Project	Watershed
Takhini River	1	hourly	seasonal	data logger	TKC		Upper Yukon
Tatchun Creek	1	hourly	seasonal	data logger	DFO		Upper Yukon
Teslin River	1	hourly	seasonal	data logger	DFO, TKC		Upper Yukon
Willow Creek	1	hourly	seasonal	data logger	DFO		Upper Yukon
Yukon River							
near Lake Laberge	1	hourly	seasonal	data logger	TKC		Upper Yukon
at Whitehorse hospital	1	hourly	seasonal	data logger	TKC		Upper Yukon
above Klondike River	1	hourly	seasonal	data logger	Bill Kendrick		Upper Yukon

Table 4.–Projects and years included in the water temperature database.

Project	Years	Location
East Fork Andreafsky River Escapement	1981-2011	Alaska
Pilot Station Escapement	1986-2011	Alaska
Anvik River Escapement	1972-2011	Alaska
Salcha River Escapement	1977-2010	Alaska
Chena River Escapement	1990-2009	Alaska
Fishing Branch River Escapement	1972-2009	Canada
Big Eddy Test Fishing	1974-2011	Alaska
Middle Mouth Test Fishing	1966-2011	Alaska
Sheep Rock Test Fishing	1988-2008	Canada
Tatchun Creek Ancillary ASL	1966, 1980-1990, 2006, 2010	Canada
Chandindu River Escapement	1994, 1995, 1999-2002	Canada
Eagle Escapement (Sonar, Yukon/Canadian Border Passage)	1992-1994, 2005-2011	Alaska
Caribou Creek Water Temperature	2005	Canada
Klondike River Water Temperature	2005-2009	Canada
Mayo River Water Temperature	2006-2008	Canada
Nordenskiold River Water Temperature	2005-2010	Canada
Beaver (USFWS) Water Temperature	2004-2005	Alaska
Galena (USFWS) Water Temperature	2004-2005	Alaska
Emmonak (USFWS) Water Temperature	2005	Alaska
Christmas Creek Water Temperature	1999,2007-2009	Canada
Clinton Water Temperature	2007-2009	Canada
Croucher Creek Water Temperature	2006-2009	Canada
Grayling Creek Water Temperature	2005	Canada
Willow Creek Water Temperature	2005	Canada
Klusha Creek Water Temperature	2000-2007	Canada
Mica Creek Water Temperature	2005	Canada
Mickie Creek Water Temperature	2007-2009	Canada

Figure 1.–Yukon River drainage, including some tributaries and towns in Alaska and the Yukon Territory.



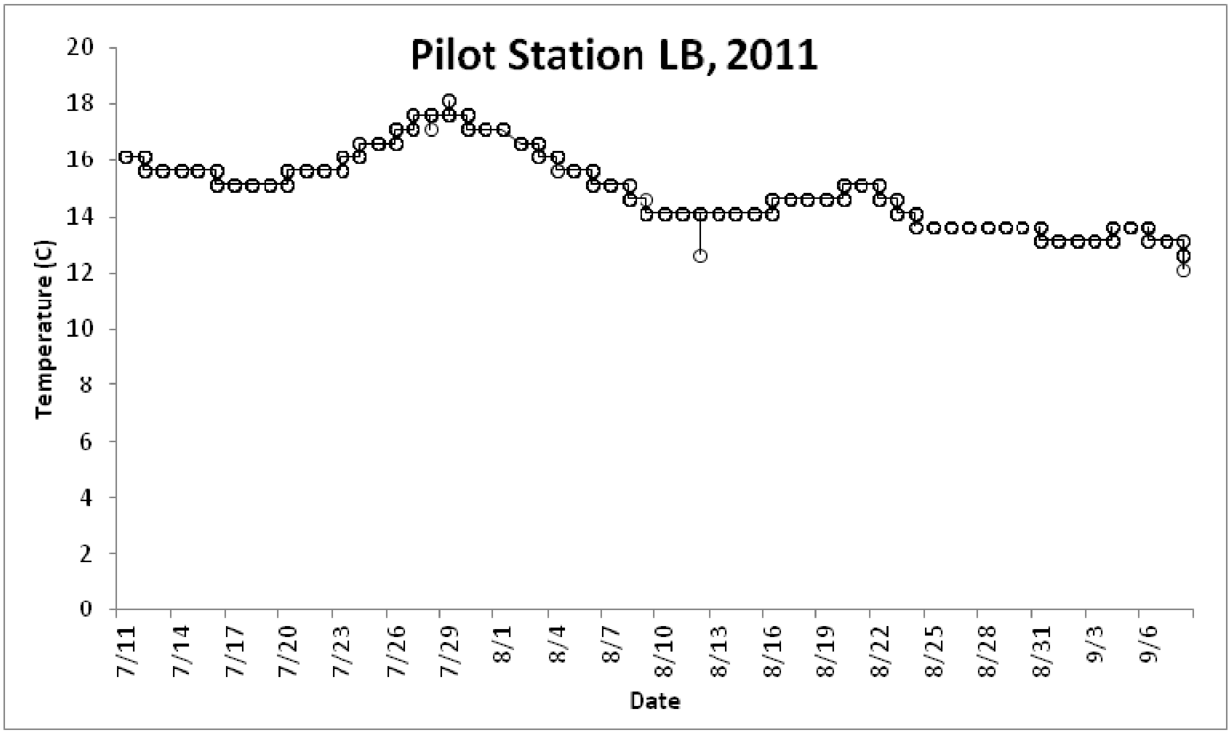


Figure 2.–Data were collected hourly via iButton at the left bank sonar site at Pilot Station, Alaska.

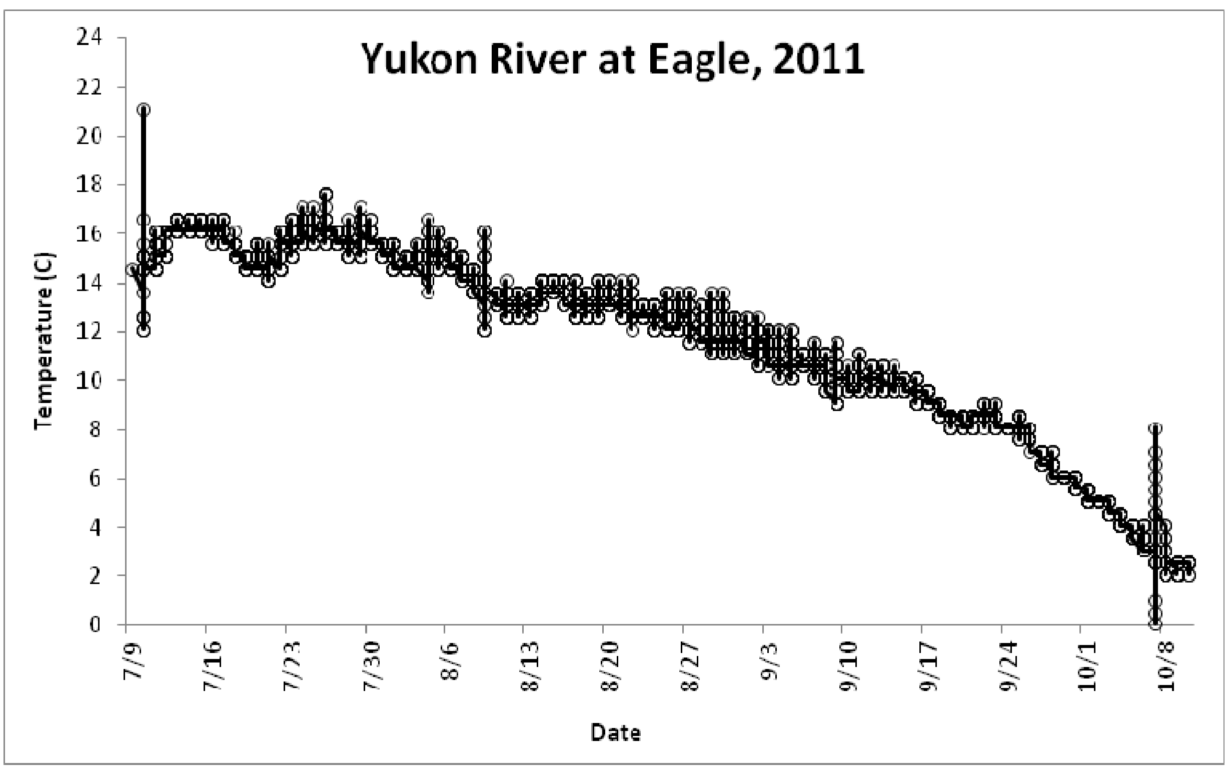


Figure 3.–Data were collected hourly via iButton at the sonar site at Eagle, Alaska..

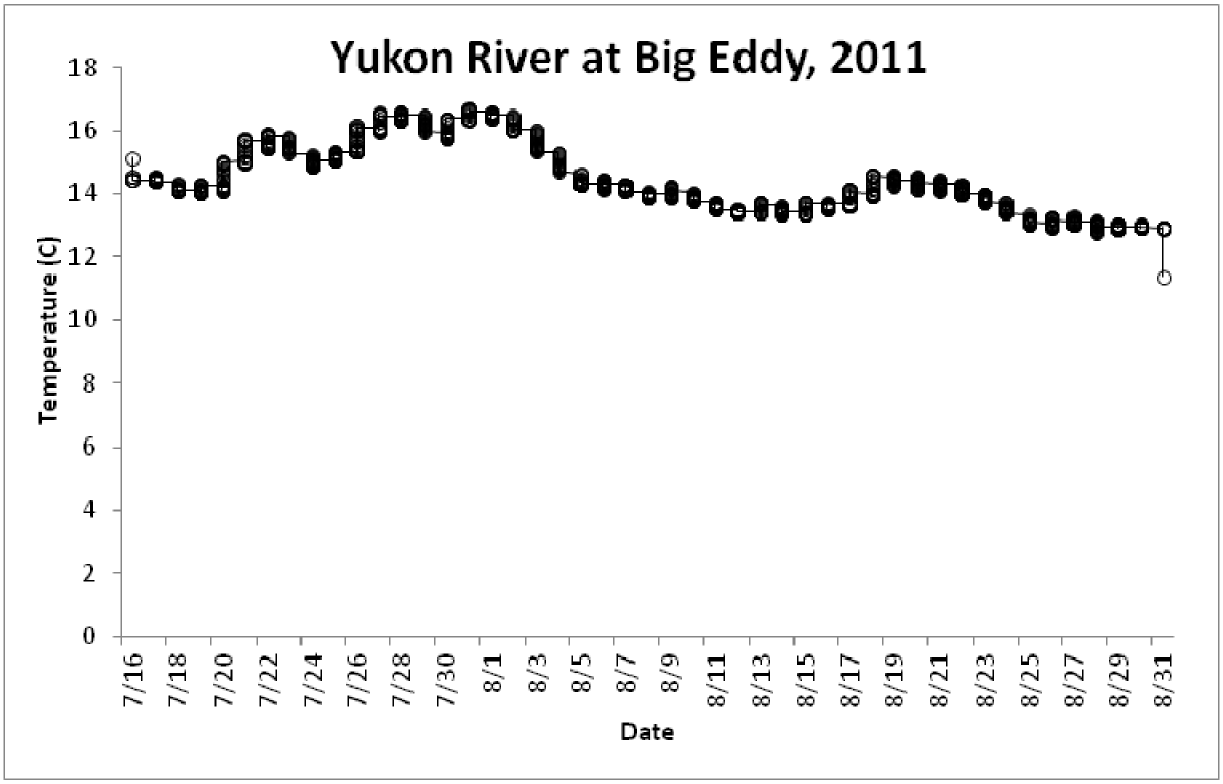


Figure 4.–Data were collected hourly at Big Eddy, the project site for the Lower Yukon Test Fishery.

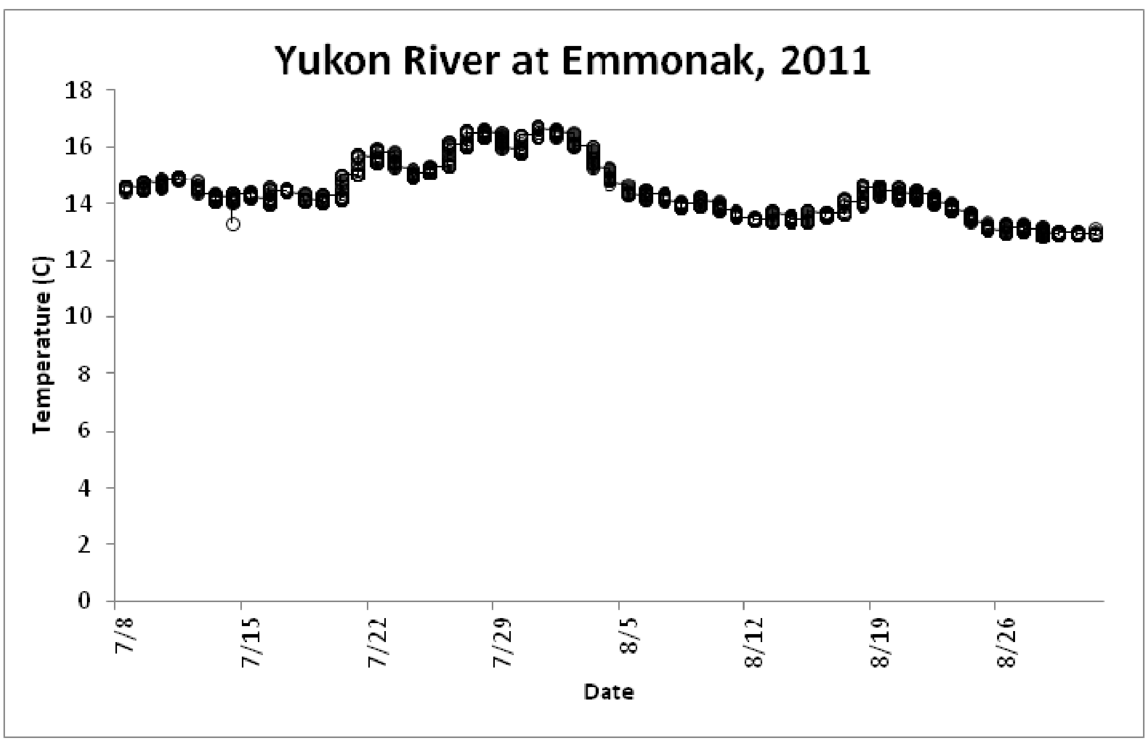
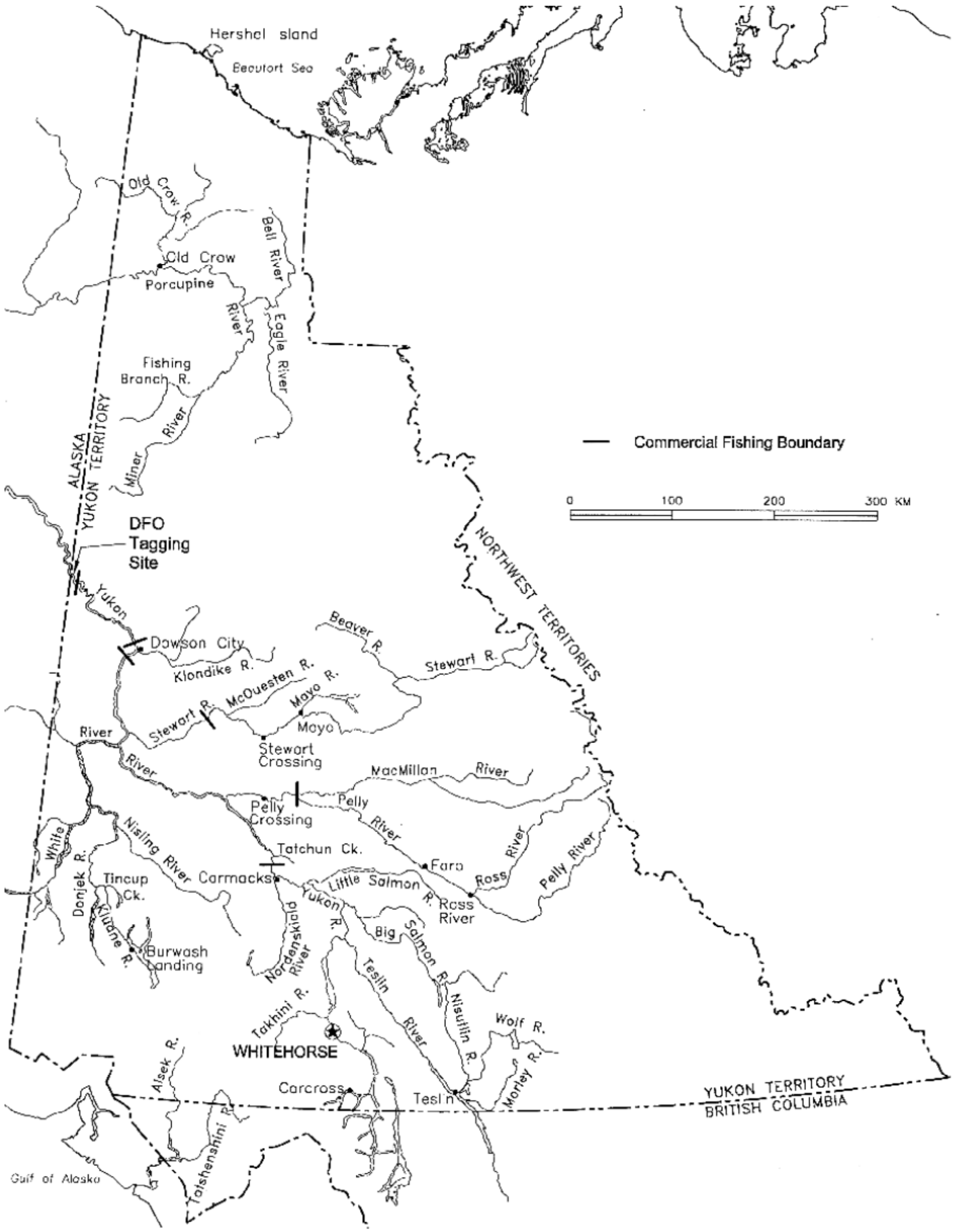


Figure 5.–Data were collected hourly at Emmonak using a Hobo ProV2.

Figure 6.–Tributaries and towns along the mainstem Yukon River in the Yukon Territory, Canada.



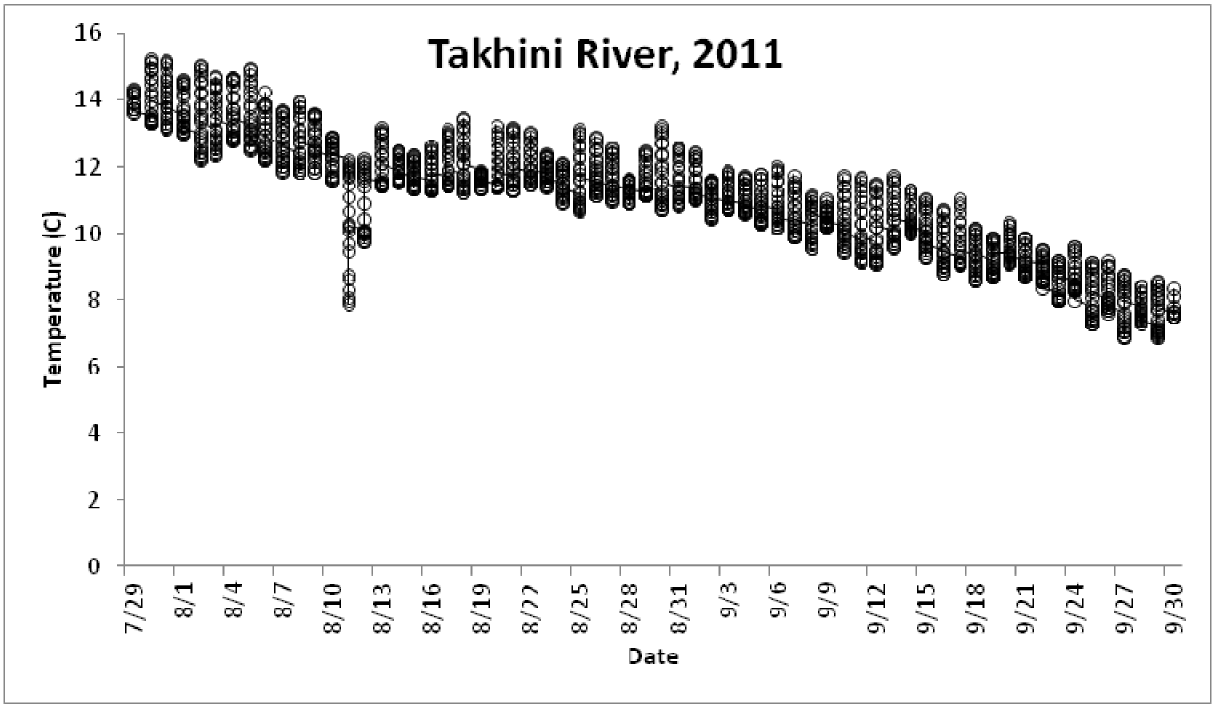


Figure 7.–Data were collected hourly from the Takhini River, a tributary to the Yukon River, in the Yukon Territory.

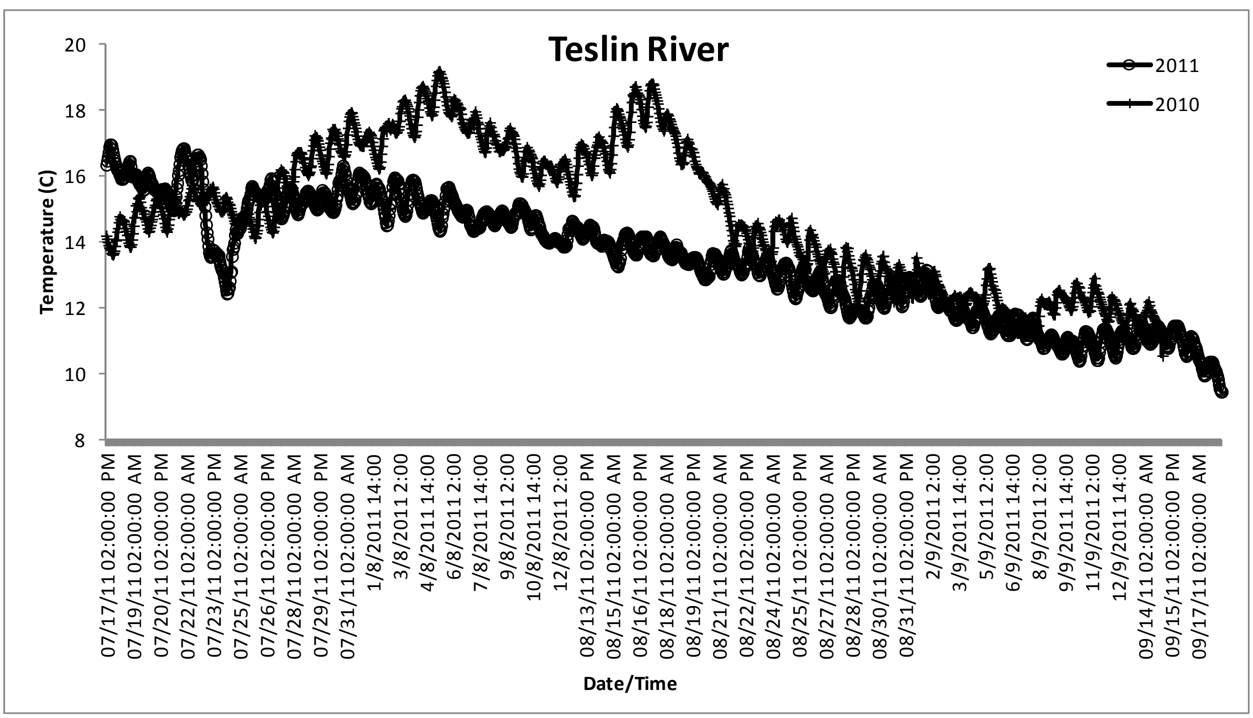


Figure 8.–Data were collected using an Onset Tidbit from the Teslin River, a tributary to the Yukon River, Yukon Territory, thus the difference in data format. Data from 2010 and 2011 are shown for comparison.

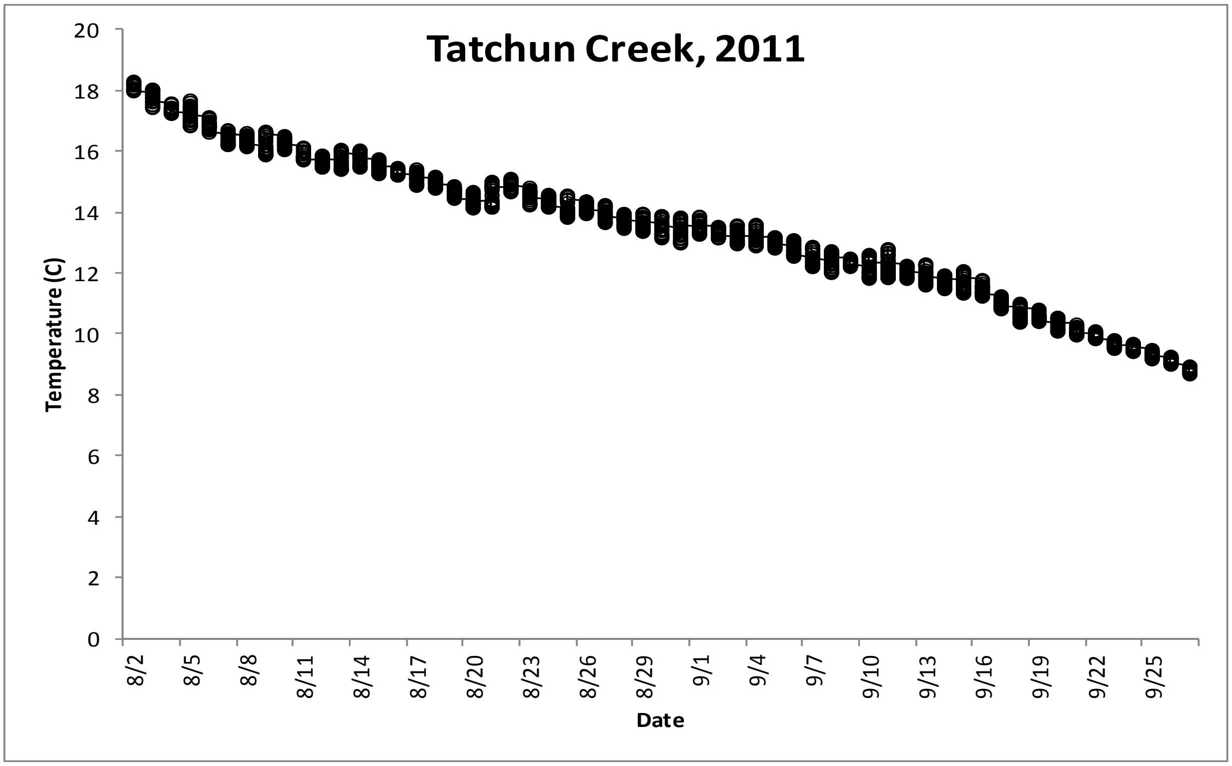


Figure 9.–Data were collected from Tatchun Creek, a tributary to the Yukon River, Yukon Territory.

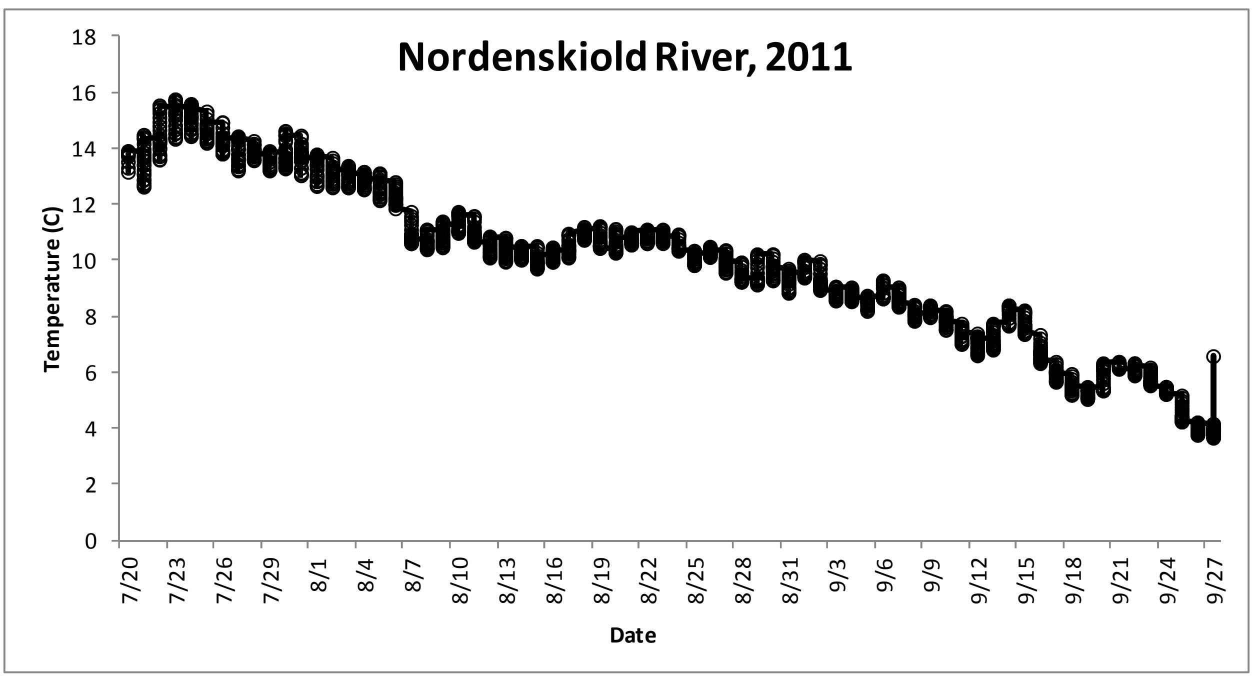


Figure 10.–Data were collected from the Nordenskiold River, Yukon Territory.

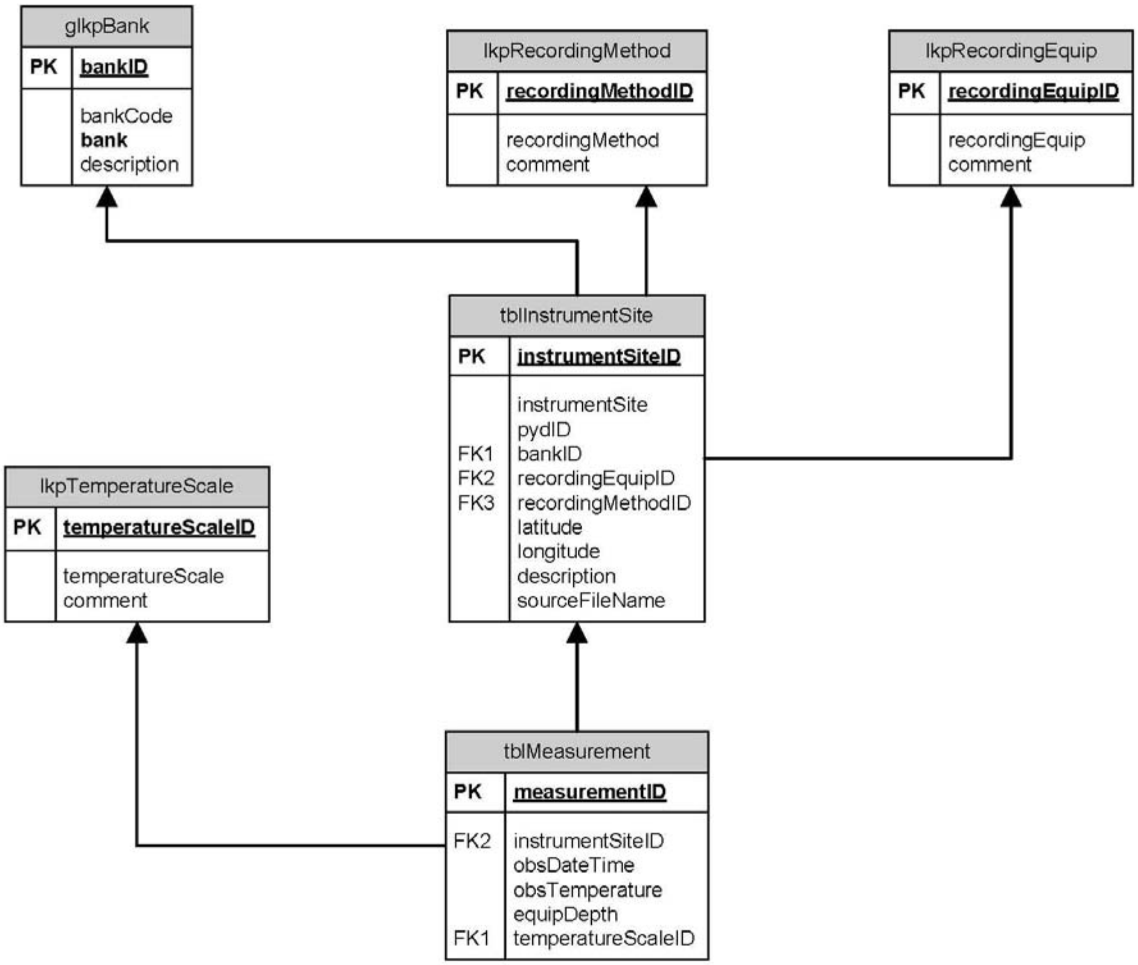


Figure 11.–Water temperature database diagram.