Ta'an Kwäch'än Council

Monitoring Fresh Water Thermal Regimes

A Technical Context

Contents

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Monitoring Water Temperatures in the Southwest Yukon: a Geographical, Administrative and Temporal Context

Introduction

Ta'an Kwäch'än Council (TKC) became a self-governing First Nation on April 1, 2002. They have since been developing an administrative structure and building capacity for the management of their lands and resources. Water is a primary resource. It is recognized as such in the Final Agreement between TKC and the governments of Canada and Yukon. TKC now have the capacity and the interest to increase their participation in the management of water. This includes collection and management of data for use in both the near - and long term.

TKC, the "People of Lake Labarge", understand that water has a wide range of values. The salmon and freshwater fish using the lake, its tributaries and adjacent waters are valued highly. These fish have sustained them since both the fish and the people moved into the present Traditional Territory as the glaciers retreated. There have been periods of change since then, and the people have adapted to the changing conditions. Adaptation to the current period of climate change will be guided by traditional knowledge and by scientific/technical knowledge. The focus of this paper is the development of scientific/technical knowledge relevant to the thermal regimes of waters within the TKC Traditional Territory (TKC TT).

Water temperatures are one of the most important determinants of the productivity of fish habitats (Eaton & Scheller, 1996; McCullough, 1999). High resolution, continuous records of water temperatures are lacking for most of the Yukon and for the TKC TT. As a first step to address this, TKC has initiated a Water Temperature Data Collection Program. This Program will include three projects: first, to determine the effect of Lake Laberge on the downstream thermal regime of the Yukon River; second, to determine thermal regimes of smaller tributaries and of the Takhini River; and third, to determine the thermal regimes of discharges of local and regional ground water. Local ground water has short flow paths and short residency and is the equivalent of hyporheic flows. Regional groundwater has long flow path and long residency. Data collected in the program will be directly applicable to TKC TT. TKC will be able to use the data for management and planning purposes in their on-going process of adaptation to the direct and indirect effects of climate change.

The data will allow calibration of stream temperature models as they are developed or modified by other governments for use in the southwest Yukon. These models are a dominant form of scientific/technical knowledge. Many have been developed in the south (Bartholow, 2002; Cassie, 2006). All are based on data from lower latitudes, and were developed by governments and institutions to meet specific purposes.

TKC is a member of a community of governments. In Canada this community includes First Nations, provinces, territories and the federal government. In the United States it includes tribes, states and the federal government. Many of the other members of this community have similar types of fisheries resources to which they attribute similar societal values. Some have already experienced the climatic conditions that are anticipated for the TKC TT. Their experiences and actions are, and will be, a valuable resource for TKC in planning and implementing adaptive measures.

This paper will first describe the geographical, administrative and temporal setting for the TKC program. Predictions of climate change on hydrology and on the development of water temperature models will then be presented. A discussion of the effects of climate change on fish and fish habitats will follow. It will include summaries of effects and of adaptive measures undertaken by jurisdictions to the south. The conclusion will outline future opportunities.

Geographical Setting

The geographical setting provides the underlying structure. It comprises the land and the water and includes the effects of slow and fundamental processes. The building and erosion of mountains and the filling of seas, the effects of glacial advances and retreats, and the establishment and re-establishment of drainage systems are the foundation upon which life exists.

The TKC TT is located in the Canadian Cordillera, which is part of the North American Cordillera (Bostock, 1948). The North American Cordillera extends from Mexico through Alaska. It is a series of mountain ranges, or orogenic belts, and intervening plateaux that lie roughly parallel to the Pacific coast and extend inland from it.

Within the North American Cordillera tributary rivers generally flow parallel to the orogenic belts. Main rivers, such as the Columbia, Fraser, Skeena, Stikine, Taku, Alsek and Copper Rivers penetrate the belts and empty to the Pacific Ocean. The Yukon River is the exception, as it flows to the west and eventually outflanks the orogenic belts to empty in the Bering Sea.

Prevailing westerly winds carry moisture inland from the Pacific Ocean. Most falls on the west, or coastal side of the first major mountain range. A rain shadow lies behind this range (Wahl, 2004).

In southern areas extreme summer temperatures may cause deserts to form. In areas at higher altitudes or latitudes temperatures are cooler. The rain shadow effect is mitigated by lower potential evaporation from water bodies and the land surface, and lower transpiration rates from plants. This is collectively referred to as evapotranspiration. Streams crossing the plateau immediately behind the coastal band of mountains also receive flow from remaining glaciers in interior drainage basins (Stahl & Moore, 2006).

The TKC TT is in the rain shadow of the Coastal Mountains. The core area of the Traditional Territory is trisected by the Takhini and Yukon Rivers. These rivers have high late summer flows due to glacial melt (Moore et al, 2008). Flows in all other streams depend on snowmelt and precipitation. Water stored on the surface as lakes and underground in aquifers provide flows during droughts and winter periods. Rivers and most smaller streams have winter flows (Smith et al, 2004) reflecting significant volumes of stored water. Winter in-channel flows in smaller streams may only be located downstream from groundwater discharge areas within the creek (Bradford, 2001). Flows between the ground water discharge area may be on-or through icings, or aufeis, that have filled the stream channel.

Most of the North American Cordillera north of the US/Canadian border, and all of the TKC TT, was glaciated during past glacial periods. Deposits of inorganic materials were left on the land surface as the glaciers melted. Particles, from clay to boulder size, were included. The deposits are characterized by their origin and are described as: glacial till, which was deposited directly by glaciers; glaciofluvial deposits, which were deposited by moving water associated with glaciers, and which are usually composed of sand, gravel or cobble; and glaciolacustrine deposits composed of fine materials which were carried into lakes in suspension and subsequently slowly settled. Some lakes, such as Lake Laberge, remain in glacial trenches eroded into bedrock. Others have formed in areas of deposition. These are generally smaller and are located in glaciofluvial materials. Of importance is that the glaciofluvial materials, either as deposited or as re-worked to become alluvial or fluvial deposits, have the capacity to store large quantities of water (Wel et al, 2009).

Administrative setting

The administrative setting provides the structure for management of water and other natural resources. A critical component of management is scientific and technical research. Ideally, research will lead to understanding, and understanding to implementation. However, research tends to be funded when it satisfies a societal need. Societies order themselves within jurisdictions. Some jurisdictions, such as Canadian provinces and the American states in the Pacific Northwest are large, rich and populous. They have developed tremendous capacities for research and management. These capacities will largely determine the environment in which climate change is described and adaptive measures developed. An overview of the existing administrative environment is therefore advisable.

The community of governments is composed of jurisdictions. Mandates are provided by constitutions and modified by agreements. Each mandated government structures their own administrative processes. The structure chosen, or evolved, reflects each jurisdictions legal system, history and needs. The structures are further modified by treaties with other nations. These include treaties between the United States and Canada, and treaties with each country's respective First Nations. The resulting web of mandates, laws, agreements, etc. form the administrative setting.

The TKC Traditional Territory lies within the boundaries of the Yukon Territory. The Yukon Territory is bounded by the State of Alaska to the west and the province of British Columbia to the south. The Northwest Territories lie to the east. The United States Pacific Northwest (USPNW) of the continental United States does not share a boundary with the Yukon Territory. However, the North American Cordillera extends through the southern United States to the Yukon and has similar land forms, hydrological networks and fisheries resources. Importantly, the USPNW has already experienced climatic and settlement pressures that TKC may have to in the future and, for this reason, will be included in the following discussion.

The United States is a federation. States generally govern resources within their boundaries, with the exception of lands administered by the federal government. These include Tribal Lands and comprise significant portions of all western states and Alaska. Each state has a primary agency to administer water. Other state agencies may have responsibilities for specific aspects of water management. There are also federal rights and interests. A wide range of federal agencies conduct water research and management activities, including the Environmental Protection Agency, Bureau of Land Management, US Fish and Wildlife Service, US Geological Service and the US Forest Service. Capacity is being developed for Tribes to administer specific components of the federal water programs on their lands.

Of specific relevance to surface and ground water temperature research and monitoring, the US federal Clean Water Act (CWA) Section 303(c) requires States and authorized Tribes to adopt Water Quality Standards (WQS). Section 303(h) of the CWA specifies that water temperature is one of the water quality standards. The WQS of the western states and Alaska are based on the effects of high water temperatures on fish, and specifically on salmonids. Due to development pressures in the USPNW, this has resulted in significant data collection programs regarding fish utilization and summer water temperatures. The result has been the development of a sophisticated understanding of summer thermal regimes in USPNW rivers (Ebersole et al, 2003; Johnson, 2004) and the effects of high water temperature on the fish using them. Existing fisheries data for the USPNW was summarized and reviewed (Lestelle et al, 2005; McCullough, 1999; Poole & Berman, 2000). Generally, then, the preponderance of water temperature data collected in the USPNW has been to address a critical but narrow socio-regulatory need, that of the effects of high summer water temperatures on valued fish. Effects of other components of the thermal regime on the aquatic environment have been less studied.

Canada is also a federation. The Constitution Act (1982) defines federal and provincial areas of responsibility: of relevance, fisheries and shipping are federal, while water and land are provincial. The Government of Canada (GC) has some degree of interest in waters flowing across provincial boundaries and represents Canada in treaties concerning waters, fish, wildlife and other matters that cross national boundaries. GC collects water data through the Water Survey of Canada (WSC) either directly or through agreements with the provinces. Provinces generally collect hydrometric data for their own purposes.

In British Columbia, the Water Act (BCWA) is the primary instrument for the administration of water. The Ministry of the Environment is the lead agency. Secondary instruments include the BC Fish Protection Act (BCFPA) and the BC Forest Act (BCFA). Significant research into the effects of forest harvesting on stream temperatures has been conducted (Melina et al, 2002; Moore, 2006). This is due to the dominance of the BC forest industry in the provincial economy. Federal interests in water temperatures have primarily been through the administration of the habitat provisions of the Government of Canada's Fisheries Act (GCFA). Salmon have been a focus of the administration of this Act. There has been considerable scientific support for the administration of the habitat provisions of the GCFA. In particular, determining the effects of forest harvesting and hydroelectric development on water temperatures, and the effects of the resulting temperature changes on salmonids.

There are no water temperature standards in either provincial or federal legislation. However, the BCWA is undergoing renewal. There is a wide expectation that water temperature standards will be included in the new law.

In the Yukon Territory, the Water Act (YWA) is the primary instrument for the administration of water. The Yukon Land Claims Umbrella Final Agreement (UFA) and specific Final Agreements place additional responsibilities on the Government of Yukon in respect of the management of natural resources. This includes water. Yukon Environment (YE) and Yukon Energy, Mines and Resources (YEMR) are the two lead agencies for the administration of the YWA. Both Agencies collect water temperature data. Neither does so for the express purpose of the determining the potential effects of temperature on aquatic ecosystems. Federal interests in water temperatures are similar to those in BC, but there has been a much smaller amount of scientific support. There are no water temperature standards in either the YWA or the UFA, and neither are likely to be amended to allow this. However, protection of water quality is specifically mentioned in Section 14.8.0 of the UFA. As noted above, other jurisdictions accept temperature as an essential quality of water. As an adaptive measure to the effects of climate change, a strong case can be made to the Government of Yukon that the water temperature be considered an essential quality of water.

Temporal Setting

The geographical setting provides the underlying structure and the administrative setting outlines the regulatory and related accountability structure. The temporal setting is to some degree integrative in describing climate change, as it is change over time. Climate change has affected components of the geographical setting. The administrative setting determined how these changes were identified, perceived, studied, and adapted to. The temporal setting also extends into the future. Of necessity, it includes speculation, however well informed.

Past and Present

It has been 114 years since the role of carbon dioxide as an agent of global warming was identified (Arrhenius, 1896). It has been 12 years since the first signatures were placed on the United Nations Framework Convention on Climate Change. A total of 192 countries have now signed. Societies have accepted that climate change has occurred, is occurring and will continue to occur. Scenarios have been developed to forecast the changes (Allali et al, 2007). The scenarios allow measures to be considered to ease the process of adaptation.

A strategy in forecasting change scenarios for aquatic environments is to re-construct past environments. Sources of information may include scientific/technical records, historical records, Aboriginal Traditional Knowledge or the analysis of inorganic or organic material that reflects past climates. It is important to consider that these four sources to some extent blend into each other.

The focus of this paper is scientific/technical information. This includes information reported for specific, short term projects and long term continuous measurements or estimates such as that produced by meteorological or hydrometric stations.

Project reports generally include summaries of water temperature data collected, or products of analysis (Cleugh et al, 1978; Bradford et al, 2008). Details of the site characteristics, instruments used, etc. are usually lacking. Some projects are based on discrete sampling events, and provide good snapshots of the conditions prevailing at the time (Laberge, 1996). The information is generally interesting and often useful, but forms a poor basis for trend analysis.

Meteorological data is easier to collect than hydrometric data. It often (such as at airports) serves a critical function for human safety and health. Hydrometric data is difficult to collect because capital and maintenance costs may be high and there are many logistical challenges. Rivers and any structures within them are subject to the effects of ice jams at both freeze-up and break-up. Hydrometric stations are often in remote areas. The stations have to be calibrated at all flow levels to develop an accurate rating curve. In natural channels calibration has to be repeated to accommodate any change in the river bed. Stations are often placed in a specific location to meet a specified purpose (WSC, 2009) and may not be in the best location to collect low flow data. Lowest flows generally occur in the winter, and are critical habitat for overwintering fish. Recognizing these qualifications, hydrometric data is adequate to provide insight into flows during the recent past and extending to the present. Flows are important as there is usually an inverse relationship between summer stream flows and temperatures: as stream flows rise, temperatures fall (Boyd & Sturdevant, 1997; Brown & Hannah, 2007). In the Canadian portion of the Yukon River Basin, Whitfield and Cannon (2000) compared hydrometric data collected between 1976-1985 to that collected between 1986-1995. They found a general increase in discharge throughout the year and an earlier onset of snowmelt. Stations in mountainous areas had lower stream flows in summer and fall. Fleming and Clarke (2003) selected stations with long data records on watersheds with and without active glaciers in the southwest Yukon and north west BC. They found that the total flows from the glacial streams were generally trending upward. Total flows from the non-glacial streams were trending downward. Minimum (winter) flows at almost all stations trended upward. Janowicz (2008) analysed data from a wide range of stations in the Yukon and adjacent jurisdictions in Canada. He aggregated the flows by permafrost zones and did not distinguish between glacial and non-glacial streams. He found that the sporadic permafrost zone, in which the TKC TT lies, had a slight increase in total annual flows, a slight decrease in maximum annual flows, and a strong increase in annual minimum (winter) flows. Brabets and Walvoord (2009) analysed data from hydrometric stations collected between 1944 and 2005. They found that there had been a statistically significant upward trend in winter flows (Oct – March) and in April flows.

Overall, these analyses indicate that smaller streams in the southwest Yukon have been affected by climate change. The increased winter flows have probably been a net benefit to the fish and other organisms that overwinter there. However, it has been at the expense of decreased summer flows. As high water temperatures are most likely to be associated with low flows, this increases the vulnerability of fish utilising the streams in the summer.

Historical information blends into current local information: today's actions are tomorrow's history. There is some historical information specific to Yukon fish and fish habitat (and by extension environmental conditions). Discussion is beyond the scope of this paper. Brown et al (1976) collected historical information on fish and fish habitats in preparation for the Alaska Highway Gas Pipeline proposal of the day. Siegel and McEwan (1984) collected information on the salmon and fresh water fisheries for the Department of Fisheries and Oceans. Cox (1999) conducted archival research on Yukon River salmon and their habitats for the Yukon River Panel in preparation for the Yukon River Salmon Agreement. The majority of historical information collected to date has been from government sources, leaving other sources largely untouched.

Aboriginal Traditional Knowledge is generally collected by Yukon First Nations for internal use. Some general information is publicly available through the writings of non-aboriginal anthropologists. A great deal of information on past aquatic environments may be interpreted from ethnographical publications such as McClennan (1975) and Cruikshank (1991). Cruikshank (2001 & 2005) addresses glaciers and climate change directly.

The analysis of organic and inorganic materials to reconstruct past climatic conditions is a rapidly developing field. Sediment cores taken from lake bottoms may provide insight far into the past. Anderson et al (2005a & 2005b) used carbonate oxygen isotopes from a small lake in the southwest Yukon and isotopes and radiocarbon dating of samples from a second lake to infer past climates for the last ~7500 years. Sediment cores from a number of smaller lakes were collected in 2009 by a team of researchers from the McGill and Queen's Universities and the federal ministries of Parks and Fisheries and Oceans. A wide range of analyses will be conducted to reconstruct past climates (D. Selbie, personal communication, 2009).

Present and Future

Once Climate Change was recognized, governments sought to determine the rate that it was occurring at and what the future effects might be. The Intergovernmental Panel on Climate Change's Fourth Assessment Report: Climate Change 2007 (Allali et al, 2007) provided a number of scenarios to predict the future. The scenarios were based on government action, or lack of action, in controlling green house gas emissions.

All scenarios predict that the TKC Traditional Territory will experience increasing mean annual air temperatures. Precipitation will increase, particularly in the fall and winter. Total runoff will increase and much or most of the increase will occur earlier in the year. Summer flows will decrease. Extreme temperature and precipitation events will be more frequent including droughts and floods. Both may contribute to increased land erosion. More sediment will be deposited in streams and lakes. Lakes will be ice covered for shorter periods and the ice will not be as thick. Permafrost will melt and will affect land stability. Ground water flow paths will change. Recharge areas for ground water may be affected and the seasonality of recharge will change. Glaciers will continue to waste and may disappear. Surface water temperatures will rise, and may contribute to algal blooms.

The Climate Change Scenarios are continental in scope. They provide broad predictions of rates of change. Local monitoring will determine the actual rates of change in specific areas. In the southwest Yukon, the Wolf Creek Research Basin (WCRB) will probably provide the majority of scientific information upon which rates of climate change in the south west Yukon will be determined. The WCRB is located just to the south of the TKC TT. It is a world class climatologic and hydrologic facility and has operated since 1993 (Pomeroy et al, 2004). Much credit is due to the people who initiated studies in the basin and who have been able secure funding to maintain it as a research basin. It may be anticipated that the data collected there will also inform stream temperature models for the southwest Yukon.

The TKC Water Temperature Collection Program will augment water temperature data collected at the WCRB. Stream-specific water temperature data will be collected from streams in the TKC TT. Each of the watersheds of these streams is roughly equivalent in area to the Wolf Creek Research Basin, but each has different biophysical characteristics. Biophysical watershed characteristics are a major determinant of water temperatures in streams. Water temperature is a critical water quality component in the general productivity of the aquatic environment. The health and sustainability of fish stocks largely depends on the productivity of the aquatic environment. The ability to support a fishery in turn depends on the health and sustainability of the fish stocks.

Fish and Fish Habitat

The Kwäch'än people utilise the following fresh water fish species: lake trout (Salvelinus namaycush); lake (humpback) whitefish (Coregonus clupeaformis); broad whitefish (Coregonus nasus); Arctic grayling (Thymallus arcticus); inconnu (Stenodus leucichthys); northern pike (Esox lucius); and burbot (Lota lota). Lake trout, inconnu, northern pike and burbot feed on smaller fish, including least cisco (Coregonus sardinella); round whitefish (Prosopium cylindraceum); longnose sucker (Catostomus catostomus); slimy sculpin (Cottus cognatus) and lake chub (Couesius plumbeus). Arctic grayling, round whitefish, and long nosed sucker migrate up all unobstructed tributary streams in the summer and return to overwintering habitats in lakes or larger rivers (von Finster, 2003). At least some burbot, inconnu, broad and lake whitefish, and least cisco migrate from Lake Laberge to the Yukon River upstream of the lake. The freshwater fish, the invertebrates that they feed on, the birds and animals that prey on them, and the people who utilize the fish form an ecosystem with Lake Laberge as its heart.

The Ta'än Kwäch'än people also utilize anadromous salmon. Within the Traditional Territory this is predominantly Yukon River Chinook salmon (Onchorynchus tshawytcha). Adult salmon migrate through the Traditional Territory from late July until early September. In the spring, the young of the year juvenile salmon emerge from the gravel. Most will migrate into tributary streams and feed, or rear, there all summer. They will remain in the small tributaries over winter. Survivors then migrate to the Bering Sea the following spring (Moodie et al, 2000; Bradford et al, 2001). Salmon passing through the TKC TT contribute to a much larger ecosystem that extends from the headwaters of the Yukon River to the Bering Sea.

With the exception of the northern pike and the burbot, all fish directly utilised and highly valued by the Ta'än Kwäch'än people are salmonids. A sub-group of the salmonids, the salmoninae, include the trouts, charrs and salmon. This group is valued by TKC and by Aboriginal and non-aboriginal governments and peoples occupying the North American Cordillera from California to Alaska. Within the salmoninae, Pacific salmon have a dominant social, cultural and economic value. Other salmoninae such as trouts and charrs are also important and may be locally dominant in areas where anadromous salmon are absent. All salmoninae are cold water species.

Environmental conditions related to climate change have already affected salmon habitats in the USPNW and southern British Columbia. It is unlikely that the TKC TT will experience temperatures as high or land use pressures as severe as in certain of those jurisdictions. However, a brief overview of the challenges, tactics and strategies of adaptation that have been developed by other jurisdictions to address the changing environmental conditions is useful.

In the USPNW, habitat use by many salmoninae stocks is thermally limited (USFWS 2008, McCullough 1999). This is in part due to the cumulative effects of human actions. Most drainage basins in USPNW have been subject to landscape level land surface modifications from agriculture, grazing, forestry and residential development. All of these activities disrupt hydrological processes. Consumptive uses of water include irrigation and municipal/residential withdrawals. Peak demand occurs during summer low flows when fish are already stressed. Many or most rivers have been impounded for water supply or hydroelectric power generation (Willson 1997). Water management has become integral to the hydrology of most rivers. This includes manipulation of river and stream temperatures. Management actions include releases of cold water from reservoirs where facilities exist to do so, and activities which decrease the energy flux into streams from direct sunlight. Activities which are encouraged (and funded) include increased shading of the stream through riparian planting, limiting livestock access to stream banks through fencing, and decreasing the ratio of stream surface to depth through construction (Boyd & Sturdevant, 1997). A recent initiative is to enhance the recharge of aquifers during high water periods. The water is then discharged naturally or pumped to streams when required to meet water temperature standards. Finally, significant efforts have been expended on field studies to determine the habitat requirements of salmoninae species during specific life stages (Ebersole et al, 2003) such as migration, incubation, etc.

In Canada, the Fraser River drains the south central interior of British Columbia. Some lower river tributaries of the Fraser are impounded for hydroelectric development. The mainstem is free flowing. The most important species of salmon in the river is the sockeye. Some sockeye stocks migrate upstream through the rain-shadow, desert zone east of the Coast Ranges to spawn in the upper lakes. Sockeye migrating to the upper Fraser do so during the warmest part of the year. In some years almost all these salmon die before spawning (Crossin et al, 2008) as a direct or indirect result of high water temperatures during upstream migration. Societal concerns with these sockeye stocks have resulted in significant investments in management and research activity. This included fine scaled investigations of specific stocks to determine in-river adaptive behaviour to high temperatures (Rand et al 2006). An analysis of the period 1953 – 2000 showed that the river had been warming and the spring freshet has shifted to earlier in the year (Foreman, 2001).

There has been a negative trend in the mass balance of glaciers in south and central British Columbia. In the southern portion, the glaciers have retreated to the extent that there has been a downward trend in flows in rivers with significant glacial influence (Moore et al, 2008). The declining flows have been associated with pre-spawn mortalities in sockeye salmon (Mathes et al 2010).

The size of the Fraser River has limited options for adaptive measures. Managers can only monitor the returning salmon stocks and river temperatures. In the short term, management actions are limited to restrictions or closures on the fisheries. In the longer term, the monitoring will provide insight into the adaptive capabilities of the salmon themselves.

Smaller streams provide a wider range of options for management actions. The most valued salmon species using small streams in southern British Columbia is the coho. Stock declines started in the 1970's and were notable by the 1980's (Routledge & Wilson, 1999). Stream temperatures were implicated. There were no legislated water temperature standards and governments resisted the concept of climate change. Management staff initiated programs that addressed rising stream temperatures under the rubric of "restoration" or "rehabilitation". Specific activities to mitigate high water temperatures were applied. These have included, but were not limited to: riparian planting to increase stream shading, stabilize channels and allow channel processes to develop; the addition of large woody debris to streams to create deep scour holes and intercept cooler, hyporheic flows; the construction of ground water fed spawning and rearing habitats; fencing of streambanks to control the trampling of stream banks by livestock; removal of obstructions/creation of fish passage to environments with cooler water; and construction of water storage projects at higher altitudes to allow releases of cold water as required. Guidebooks were prepared by both GC and GBC (Envirowest, 1990; Slaney & Zaldokas, 1997). Programs were implemented, and evaluations of both funding programs (McElligott et al, 2002) and of techniques and methods (Miles & Hartman, 1995) were conducted.

When climate change was accepted by the Government of BC risks from increasing water temperatures could be dealt with more directly. Stream restoration works and activities continued. New initiatives included the development of scientifically based management regimes for mandated water management, forest harvesting and other activities (Nelitz et al, 2007).

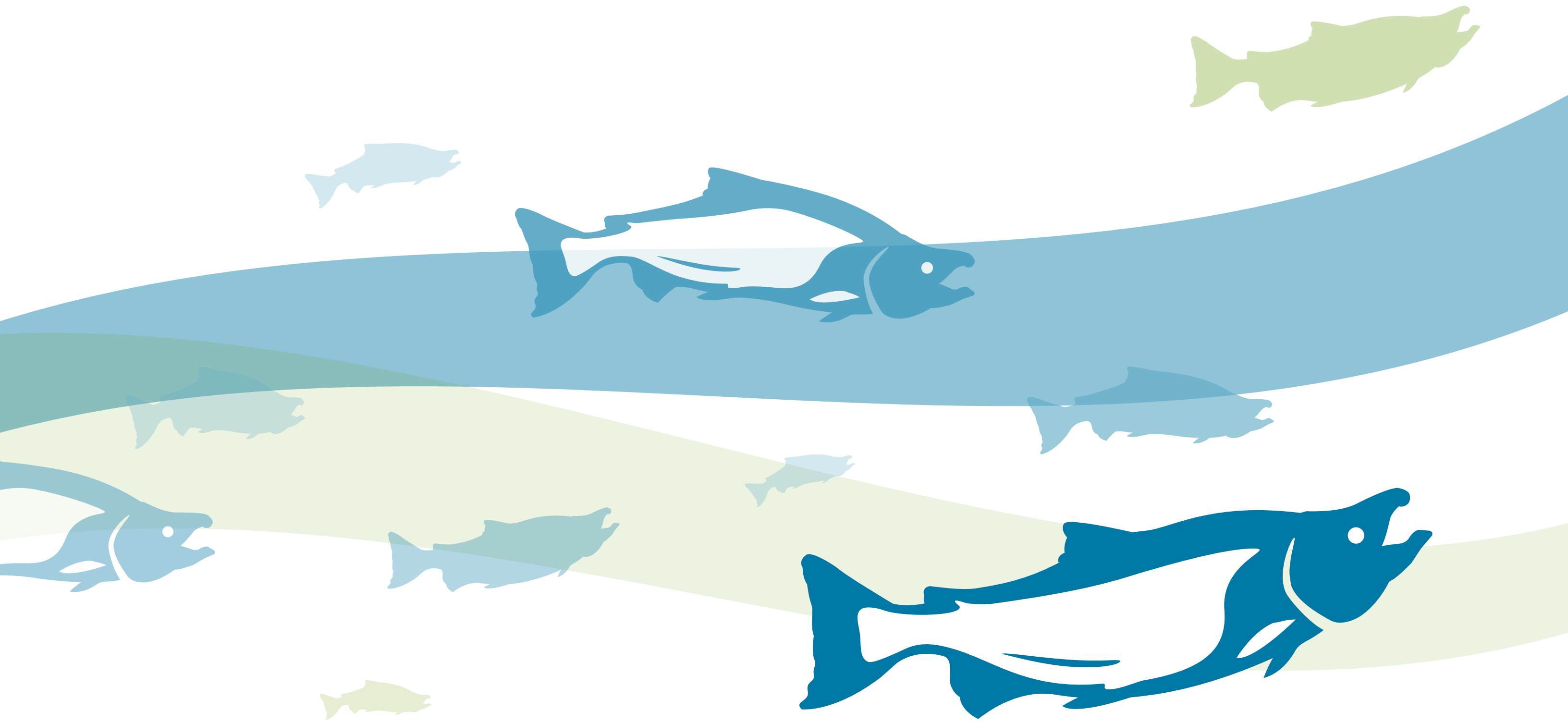
Conclusion

TKC shares the responsibility for stewardship of the fresh water within the TKC TT with other governments. Many areas south of the Yukon have experienced increased surface water temperatures that affect valued fish species. Governments have started to collect data to characterize the thermal regimes of their streams to determine areas of vulnerability. The data collected has been used to develop, implement and evaluate adaptation measures and strategies to address the effects of these increases.

The pathways by which climate change will result in increasing water temperatures in the

TKC TT are known. Overall rates of change and local variability are not known. The data required to characterize the thermal regimes of streams in the TKC TT have not been collected, and without this information areas of vulnerability cannot be determined.

The TKC Water Temperature Data Collection Program will begin to gather the information needed to identify existing and emerging vulnerabilities. The data will provide a baseline from which future TKC citizens, staff and leadership will be able to quantitatively measure rates of change and, in partnership with other governments, make informed management decisions and long term management plans.



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