Moncrieff, C., and B.G. Bue. 2012. Natural Indicators of Salmon Run Timing and Abundance. In: G.H. Kruse, H.I. Browman, K.L. Cochrane, D. Evans, G.S. Jamieson, P.A. Livingston, D. Woodby, and C.I. Zhang (eds.), Global Progress in Ecosystem-Based Fisheries Management. Alaska Sea Grant, University of Alaska Fairbanks. doi:

Natural Indicators of Salmon Run Timing and Abundance

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Abstract

Natural indicators are empirical observations that correlate with specific ecological phenomena. These ecosystem-based observations have been made by Alaska Native fishermen and women over numerous generations and have been critical to their success and, ultimately, their survival. While local and traditional knowledge (LTK) can aid in the understanding of environmental variability that influences fluctuations in almost all animal and plant populations, our focus is on Pacific salmon returning to the Yukon River drainage. Inputs of Pacific salmon to the ecosystem have been shown to be important for the success of many species, with recent studies demonstrating that diversity within a salmon population is important for the long-term sustainability of a salmon population. Proper fisheries management that optimizes the diversity within a salmon population will ultimately be beneficial to all plant and animal species in the area. Our overall goal focuses on how LTK can assist in a more holistic way with the understanding of salmon abundance, run timing, and population health. The objective of the project component presented here is to begin to understand the mechanisms that allow natural indicators to be of value as well as to identify specific data sources for further evaluation.

Introduction

Yukon River fishers have relied on local and traditional ecological knowledge (LTK) to predict salmon run timing and abundance for generations (Moncrieff et al. 2009). This knowledge is based on observations of the natural surroundings and has been passed from one generation

to the next in an oral fashion. LTK is typically specific to an area. For example, fishermen in the middle Yukon River have long correlated the release of *Populus* spp. seeds or "cotton" with the arrival of Chinook salmon (*Oncorhynchus tshawytscha*) while fishermen at the mouth of the river use observations of migrating birds to indicate salmon arrival. Environmental observations that appear to correlate with salmon run timing and behavior, as well as aspects of the subsistence round (annual cycle of harvesting, processing, and storing of subsistence food) are termed "natural indicators" by the authors. A person who has learned the observation techniques from their Elders and has actively practiced these observation techniques throughout their life is a "natural indicator practitioner."

This project began when the nonprofit Yukon River Drainage Fisheries Association (YRDFA) and the Alaska Department of Fish and Game, Subsistence Division (ADFG), interviewed 61 knowledgeable Elders and active fishers in the five lower and middle Yukon River villages of Hooper Bay, Emmonak, St. Mary's, Grayling, and Kaltag (Fig. 1) about natural indicators they use to predict salmon run timing and abundance (Moncrieff et al. 2009). Natural indicators are defined as empirical observations of the environment that correlate with specific ecological phenomena. This initial study demonstrated that many fishermen and women still make observations of the phenology of the plants, birds, and salmon, and use these observations to improve their success with salmon fishing.

Local and traditional knowledge recognizes a variety of relationships in the natural environment and it was thought that combining LTK with run timing and run strength indicators collected by ADFG, Division of Commercial Fisheries, may improve the accuracy of inseason fisheries management decisions. Mundy (1982) found that the timing of Chinook salmon migration into the Yukon River may depend on factors related to air temperature, while more recently Mundy and Evenson (2011) found significant correlations between the entry timing of Chinook salmon into the Yukon River with spring sea surface temperatures, spring ice cover, and spring air temperatures in the vicinity of the mouth of the Yukon River. Other researchers (Ruggerone 2004, Anderson and Beer 2009, Blackbourn 1987) have also found useful correlations between salmon timing and environmental variables. While LTK typically does not directly measure the environmental variables examined in these previous studies, it does provide observations of other physical factors and biological taxa that may be influenced by the same environmental inputs. Salmon in the Yukon River are rarely observed unless caught and the ability to infer salmon behavior using readily available observations has tremendous advantages.

Natural indicators or LTK can add to the fishery managers' tool kit by informing questions about salmon behavior. The results of Moncrieff

Figure 1. Map of Alaska portion of the Yukon River showing the study communities of Hooper Bay, Emmonak, St. Mary's, Grayling, and Kaltag.

et al. 2009 was discussed at two meetings between LTK holders from the Yukon River, Western scientists, and Yukon River managers in May and October 2010 with the purpose of identifying areas where LTK and traditional fisheries science may be integrated. This paper discusses the result of those meetings and identifies the study questions that showed the greatest potential for obtaining a better understanding of the mechanisms behind the natural indicators and Yukon River salmon migratory behavior and abundance.

Local and traditional ecological knowledge

Today's local and traditional knowledge is built on hundreds or thousand of years of environmental observations, including weather, plants, birds, and other animals, and has been passed down through the generations (Berkes 2008). This knowledge was the primary source of information that guided people in preparation for the salmon arrival, and the timing and location of other subsistence resources prior to Western

contact and influence. Generations ago, the knowledgeable Elders were the scientists and teachers for their communities, and were turned to for advice and guidance—a role that is still carried on today.

There is growing acknowledgement from the science community that LTK may provide informed ecological understanding and value in addressing modern-day environmental issues (Berkes 2008). Scientists are interested in LTK partly because of its rich time-depth and place-based value. Applied environmental anthropologists are promoting the value of community-based alternatives to top-down management by government agencies, and the incorporation of observations and knowledge of fishers into fisheries management (McCay 2001, Smith 1982, Wilson and Kleban 1992). There are challenges in working with LTK, including assessing the information that is often encoded in cultural beliefs and behavior (Huntington 2000), and how to make that knowledge compatible with scientific research and management (Nadasdy 1999). In today's environment, it makes sense to include local people in management discussions because they spend more time on the river or land and can see more things and for longer periods of time. LTK holders can bring a different perspective to the discussion and can compliment the tools and techniques of scientists (Usher 2000).

Materials and methods

This project is in a research scoping phase in which we facilitated discussions between LTK holders from the Yukon River and scientists whose expertise correlates with each natural indicator to be examined. The goal of this phase was to select a set of projects that showed a promise for immediate results, to prepare to implement those projects, and to secure working partners and funding. The first meeting took place in May 2010 in Fairbanks and was attended by two scientists for every LTK holder from the Yukon River. During this meeting the natural indicators were discussed at length and clarified by a question and answer session. Between May and October, environmental variables and potential data sets were identified that correlated to each natural indicator, and limited research into the robustness and practical use of each data set was conducted. A second meeting was held in Anchorage in October in which the same LTK holders attended along with scientists selected to match best with the natural indicator projects that had the most potential for immediate research. The October 2010 meeting focused on three projects that met the criteria: useful to fishers; useful to managers; with available data sets; researchable questions; and potentially fundable.

Common to all of the projects envisioned is the fisheries information collected and maintained by the Alaska Department of Fish and Game. Run timing information is available from test fisheries

near Emmonak (1989-present), a village near the mouth of the Yukon River, and the Pilot Station sonar site (1986-present; ADFG unpubl.). Abundance information from Pilot Station (1995 and 1997-2009) and Eagle (2005-2009) is also available (JTC 2010).

Results

According to LTK, Chinook salmon entry into the Yukon River is correlated with the appearance of migrating birds, a certain level of plant growth, and winter winds along the Bering Sea coast of western Alaska. A greater understanding of the seasonal phenology may show a relationship that is useful information for salmon managers who base regulatory decisions on Chinook salmon run-timing. Migrating birds, plant growth, and winds were selected from the long list of natural indicators observed by fishers from the Yukon River because of their potential to quickly provide information to assist fishery managers and the availability of appropriate data sets.

Birds

Natural indicator observations from Yukon River fishers report that migrating bird arrival indicates Chinook salmon arrival, migrating bird abundance correlates with salmon abundance, and the duration of migrating bird presence correlates with salmon abundance. In addition, Yukon River fishers report that clutch size of sandpiper or snipe is an indicator of salmon abundance (Moncrieff et al. 2009).

In Emmonak and St. Mary's, fishers report that migrating bird arrival timing correlates with Chinook salmon arrival timing. Villagers anticipate the arrival of Chinook salmon when they see the migrating white fronted geese (*Anser albifrons frontalis*) or Taverner Canada geese (*Branta hutchinsii taverneri*). In both villages, observations of the migrating bird arrival timing, speed, arrival patterns, and path are closely watched and Chinook salmon reportedly mimic the birds' behavior. In Hooper Bay, Emmonak, and Mountain Village fishers observe the cliff swallows (Hirundinidae) as an indicator of Chinook salmon arrival. Fishers say that the activity level, behavior, and arrival timing of the cliff swallows are indicators of Chinook salmon arrival timing.

The Yukon Delta is one of the largest migratory waterfowl–producing areas in the world. The U.S. Fish and Wildlife Service (USFWS) has a long history of conducting field research on migratory birds in the Yukon-Kuskokwim Delta and have had annual field projects operating on a consistent basis there since 1985 (Fischer et al. 2009). Past studies have demonstrated the effects of weather on migratory timing (Lindberg et al. 1997; Dau and Mickelson 1979; Hupp et al. 2006, 2008) and it is quite possible that the same weather phenomena that are factors in bird

migration also play a role in the migration of Chinook salmon, making migratory birds possible indicators of salmon migration.

Migratory bird nesting information is published in Fisher et al. 2009 and bird arrival and presence information by species is kept in field notebooks at several sites in the Yukon Delta. These data have the potential of providing arrival timing of migratory birds, which could be compared with Chinook salmon arrival timing to determine if relationships exist.

A preliminary examination of the usefulness of using cackling goose (*Branta hutchinsii*) hatch timing to predict Chinook salmon run timing into the Yukon River shows a significant correlation ($p < 0.001$) but is probably not useful for predicting Chinook salmon arrival (Fig. 2). While the hatch dates for cackling goose generally occur after the critical arrival points for Chinook salmon management, the strong correlation between the data sets supports the LTK and indicates there may be more useful information available.

In St. Mary's and Koyukuk fishers report that migrating bird abundance indicates salmon abundance in their communities. In St. Mary's fishers also note that the longer the migrating birds stay around their community, the more salmon there will be that season. Emmonak fishers watch nesting birds for clutch size, which they use as an indicator for salmon abundance. To investigate this series of questions, bird abundance records from the USFWS Yukon-Kuskokwim Delta could be compared to Chinook salmon arrival timing and abundance records from ADFG.

Plants

Natural indicator practitioners from most of the communities included in the study by Moncrieff et al. (2009) reported that Chinook salmon arrival correlated with plant growth and salmon abundance correlated with the abundance of plant growth. A better understanding of the mechanisms behind the phenology of plants may lead to better predictions of salmon migratory behavior.

Plant growth; including appearance of flowers in Kaltag; cotton blowing (north of Alaska Range = balsam poplar *Populus balsamifera,* south of Alaska Range = black cottonwood *Populus tricocarpa*) in St. Mary's, Grayling, and Kaltag; and grass height, willow and alder leafing out, and rhubarb (*Rheum rhabarbarum*) growth in St. Mary's, Emmonak, and Kaltag are all indicators of Chinook salmon arrival timing. Plant growth can be an indicator of salmon abundance in Grayling where natural indicator practitioners watch for the amount of cotton produced, and in St. Mary's where they watch the grass height and other plants.

Under normal growing conditions, the development rate from emergence to maturity for locally adapted plants depends primarily on

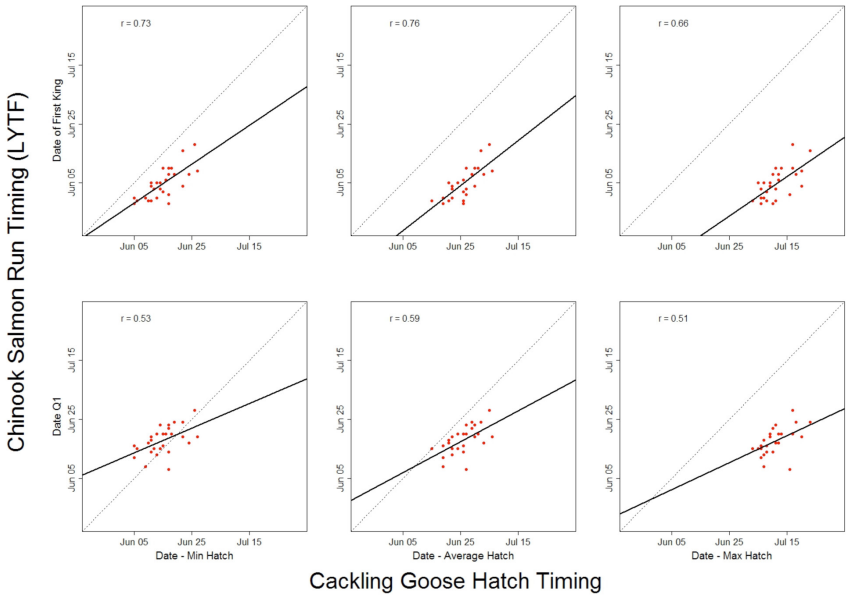

Figure 2. Relationship of Chinook salmon run timing at the Lower Yukon River test fishery to hatch timing for cackling goose in the Yukon-Kuskokwim Delta for the 1985-2009 seasons. The solid line indicates the best linear fit to the data while the fine dotted line indicates where salmon run timing and hatch timing occur on the same date.

the daily air temperature (Glenn Juday, University of Alaska Fairbanks, pers. comm.). Because many developmental events of plants depend on the accumulation of specific quantities of heat, it is possible to predict when these events should occur during a growing season regardless of differences in temperatures from year to year. The accepted method of estimating the amount of heat accumulated by plants is growing degree days or growing degree units (Womach 2005).

Work may need to be done to determine the number of growing degree days required to get the indicator plants to the appropriate growing stage. The historical database of temperature data maintained by the National Oceanic and Atmospheric Administration (NOAA) could be used to estimate the date at which the critical value for growing degree days was reached for past years at a location. That date could then be compared to arrival timing information to determine whether a significant correlation existed. If a correlation exists, it would be relatively

easy for fishery managers to monitor daily temperature information to estimate salmon arrival.

Wind

Fishers from the villages around the mouth of the Yukon River rely heavily on observations of wind direction and speed to predict which mouth of the Yukon River the salmon will enter. In the village of Emmonak, fishers report that dominant winds from the north during December, January, and February indicate salmon will primarily enter the south mouth while prevailing winds from the south during the same months indicate salmon will be most abundant in the north mouth.

NOAA has a long time series of wind data, which could be compared to salmon catches at the ADFG test fisheries in the south, middle, and north mouths of the Yukon River to determine if there is a relationship between prevailing wind direction in the winter and where salmon enter the Yukon River.

To pursue this study question, years of predominant north or south winter winds will be identified using NOAA wind data and compared to catch information from the ADFG Lower Yukon River Test Fishery. Wind data are recorded hourly in the Yukon River south mouth community of Emmonak (Fig. 3).

Database

In addition to the three science projects discussed above, a database is being developed that will be a repository for natural indicator observations. This database will be a place where Elders, fishers, students, and others can develop a record of quantitative information (annual observations) that can be tied to records of salmon variability and environmental variability. The database idea was presented at both 2010 natural indicator meetings and fully supported by both the fishers and the scientists. This database will be accessible online for registered users to input data. Natural indicator observations will be recorded with each participating village documenting information specific to their location. Examples of these data include (1) bird arrival information such as the number of birds by species by day, and the number of eggs in a nest; (2) insect information such as the type of insect, date observed, and abundance; (3) plant growth observations such as the date particular flowers appear, date that grass reaches knee height, date that *Populus* sp. cotton begins blowing, the relative abundance of cotton in air, date that willow and alder leaves fully expand, and rhubarb growth; (4) fish information such as sheefish (*Stenodus leucichthys*) presence and abundance, the date of arrival and abundance of salmon (*Oncorhynchus* spp.), smelt (*Thaleichthys pacificus*), and eel (*Lampetra tridentata*), and date of presence of phenotypic varieties of Chinook salmon (blueback, blacknose, whitenose); (5) river information including water level, change in

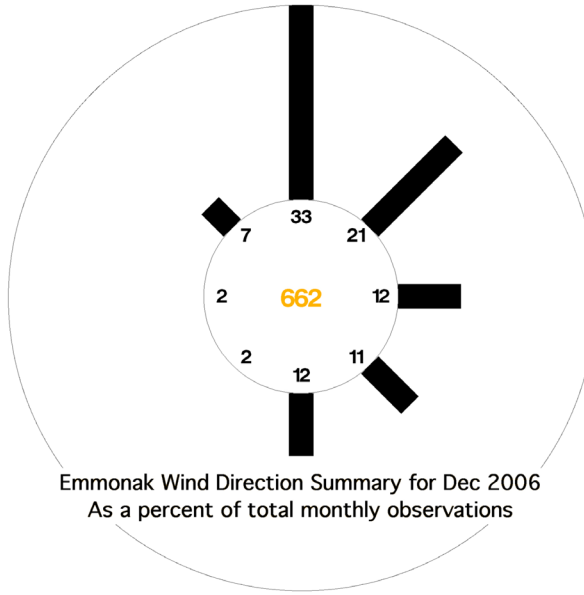

Figure 3. Summary of wind observations at Emmonak during December 2006. Of 662 hourly observations, 33% were from the north, 21% were from the northeast, and 12% were from the south.

water level, temperature, and date of snowmelt; and (6) observations of the moon to include the shape of the moon and position in the sky. The database may also include Elders' predictions or observations related to wind and other weather events.

Discussion

Salmon management on the Yukon River is a complicated and imperfect system. The length of the river, diversity of the user groups, and international treaty obligations all contribute to the complexity of the fishery and put a tremendous demand on state and federal managers. In addition, the unpredictable nature of Pacific salmon returns is not well understood, with recent declines in abundance putting even more pressure on the ecosystem and resource managers. Fishery scientists are beginning to look to LTK for insight in designing research studies and it is hoped that this project will be of assistance in those endeavors.

It has long been acknowledged that salmon provide nutrients and food for freshwater and terrestrial ecosystems (e.g., Cederholm 1999,

Moore et al. 2008, Quinn et al. 2009), and in return, these ecosystems provide the habitat essential for the success of the freshwater life stages of salmon (e.g., Helfield and Naiman 2001, Mossop and Bradford 2004). It is logical that salmon, plants, and other animal species would be linked and that population characteristics such as timing and abundance would be shared. It is the strength of these relationships that will ultimately determine the usefulness of a natural indicator or group of indicators in predicting salmon arrival and abundance sufficiently well to improve fisheries management.

Alaska Native fishers have long relied on observations of their surroundings to predict when and where salmon can be found. Salmon was and still is an important food source for Alaska Native fishers, and the ability to accurately predict when and where to fish makes food gathering more efficient. The problem is that salmon are found in larger, mostly turbid waters in the lower Yukon River, which makes direct observation nearly impossible. The association of migratory bird arrival and state of plant growth to indicate when to fish, coupled with winter wind information indicating where to fish could be extremely important for the fisher's continued survival.

The authors recognize that migratory bird behavior, plant growth, and the direction of winter winds may not directly influence salmon. Rather, it is more likely that the same factors influencing salmon are also influencing other aspects of the environment. For example, spring temperatures dictate the timing of snow and ice melting on the tundra, which influences the timing of bird arrival and nesting. The same temperatures influence the timing of sea and river ice melting, which also determines migration timing of salmon. Plant growth generally reflects the amount of heat that has accumulated in an area, which relates directly to river and nearshore ocean conditions and ultimately salmon migration timing. How the direction of winter winds influences which river mouth salmon will arrive at is unknown to these authors but may be more apparent to others.

The successful incorporation of LTK into salmon management will require both the possessors of LTK and scientists to work together and to continue the dialog that has begun between the groups. Information exchange between cultures as well as scientific disciplines is essential if future work is going to be successful. While the authors of this paper acknowledge that some Western scientists are not ready for investigations based on or inspired by LTK, we also are aware that there is a growing group of scientists who are ready for this type of partnership and are looking for new approaches to help explain the phenomena taking place today. We are not looking for scientific confirmation of LTK; instead we are trying to understand the mechanisms that have made the observations of natural indicator practitioners reliable predictors of salmon run timing and abundance.

As the three proposed studies and database proceed, the authors of this project suggest that weather, and temperature in particular, may prove to be a common factor influencing run timing and other variables within the ecosystem. The birds, plant growth, and salmon may all be keyed to temperature influences. This leads to the concerns raised by LTK holders over their observed changes in the environment and concern by others for climate change. While beyond the scope of this paper, climate change and its resulting effects such as permafrost melt, increasing temperature, and wholesale changes to the environment raise more questions about the future of salmon management than answers.

Acknowledgments

The authors of this paper would like to primarily thank the Elders and fishers of the Yukon River for sharing their knowledge and supporting this work. In addition, we would like to thank the Yukon River communities and tribal offices of Hooper Bay, Emmonak, St. Mary's, Kaltag, and Grayling. We appreciate and thank our partners: Alaska Department of Fish and Game, U.S. Fish and Wildlife Service, University of Alaska, Alaska Climate Research Center, Yukon Delta National Wildlife Refuge, and U.S. Geological Survey. Finally, we thank the organizations that funded this research: Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative, Alaska Sustainable Salmon Fund, National Oceanic and Atmospheric Administration, Rasmuson Foundation, and Lannan Foundation.

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