University of Victoria | Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

BRYAN MOOD

MSc (University of Victoria, 2015)
BSc (Mount Allison University, 2013)

"Dendrohydrological reconstruction and hydroclimatic variability in southwestern British Columbia, Canada"

Department of Geography

Friday, November 1, 2019
10:00 A.M.
Clearihue Building
Room B017

Supervisory Committee:
Dr. Dan Smith, Department of Geography, University of Victoria (Supervisor)
Dr. David Atkinson, Department of Geography, UVic (Member)
Dr. Tobi Gardner, Integrated Water Services, Capital Regional District (Outside Member)

External Examiner:
Dr. Michael Pisaric, Department of Geography and Tourism Studies, Brock University

Chair of Oral Examination:
Dr. James Nahachewsky, Department of Curriculum and Instruction, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

The hydrology of southwestern British Columbia is influenced by the region's mountainous topography and climate oscillations generated from the Pacific Ocean. While much of the region is characterized as a temperate rainforest, recent summers are defined by record-breaking droughts that focus attention on the threat to regional water supply security likely to accompany future climate changes.

The limited length and distribution of hydrological records in southwestern British Columbia provide poor context for resource managers tasked with developing policy and water management strategies. The purpose of the dissertation was to describe long-term variability in several key hydroclimatic variables and hydroecological interactions to help inform water resource policy and management strategies. Specifically, the research focused on developing long-term proxy records of April 1 snow water equivalent (SWE), streamflow, lake levels, and salmon abundance from tree ring records. A secondary goal of the dissertation was to identify the role and influence of several key climate oscillations on regional long-term hydroclimatic and ecological variability.

Freshet contributions from melting snow are critical for sustained summer streamflow in southwestern British Columbia. Even so, few manual snow survey stations exist within the region that are of sufficient length to understand the full range of natural SWE variability. Long-term April 1 SWE records were constructed by establishing statistical relationships with the radial growth of subalpine trees and April 1 SWE records. Explaining 51% and 73% of the total variance in the instrumental SWE records in coastal and continental settings, the reconstructions provide high-resolution descriptions of April 1 SWE over the past three centuries and help position the remainder of the dissertation. Negative phases of the Pacific Decadal Oscillation (PDO) and El Niño-Southern Oscillation (ENSO) were shown to strongly influence April 1 SWE totals. Both reconstructions illustrate repeated step-changes in annual snowpack magnitudes during the last 300 years and show that April 1 SWE in coastal areas may be more sensitive to annual variability than those that accumulate in more continental locations.

Water shortages in the Greater Vancouver Regional District (GVRD) in recent summers are linked to low total winter snowpack and early spring melt. Dendrohydrological analysis of dry-season streamflow was conducted to determine if the instrumental range has been underestimated over the past several centuries. A regionalized record of July-August streamflow was modelled using tree-rings to 1711 water supplied by the Capilano and Seymour watersheds to the GVRD. Explaining 54% of total variance over the instrumental period, the models show that below-average streamflow events are becoming more frequent. When compared to those characterizing the past 300 years, streamflow totals from 1977 to present have consistently fallen well-below the average long-term discharge. Further analyses indicated that negative ENSO and PDO conditions strongly influenced July-August runoff trends since 1711, as have climate regimes related to the Pacific North American pattern (PNA).

The increased frequency in recent years of reduced summer runoff in southwestern British Columbia has led many communities to rely on natural and dammed reservoirs to supplement their water needs. Where communities rely on natural lakes, this dependence may have severe socioeconomic

consequences if lake levels fall below those necessary to supply built infrastructure. Unfortunately, there are few lake level records in southwestern British Columbia and none of sufficient duration to understand the full range of variability in natural lake systems. Harrison Lake is the only natural lake with a lake level record exceeding 50 years. Using the average April water level dataset, a dendrohydrological model was constructed that explained 49.5% of total variance. The model was used to reconstruct a proxy record of April water levels spanning the interval from 1711 to 1980. Averaging 9.37 m in depth, lake levels in Harrison Lake ranged from 8.9 to 10.0 m over the past 300 years. These variations were shown to be statistically associated with negative and positive phases of ENSO and positive phases of PDO. April water levels in Harrison Lake have been, on average, 0.13 m lower since the mid-1930s compared to the previous 200 years. This reduction in storage capacity amounts to a loss of almost 300-million litres of stored water since the start of instrumental records.

Salmon play a vital economic, cultural, and social role in many southwestern British Columbia communities. There is a mounting concern that salmon populations in the region are under threat, as changing climates alter and impact their spawning habitat. While various lines of research have sought to determine the response of salmon to these changing conditions, a complete understanding of impacts is hindered by population records that extend only to 1951. Two dendroecological models were constructed to provide a longer-term perspective of regional salmon-climate relationships. Explaining 48.2% and 48.9% of variance in observed Chinook and Coho salmon abundance since 1951, the models were used to construct proxy escapement records extending to the 1700s. Spectral analysis revealed that the reconstructions account for generational life histories and that low-frequency climate variability was associated with fluctuations in abundance. Both the Chinook and the Coho reconstructions show phase dependent relationships to climate oscillations generated from the Pacific Ocean. The Coho record is strongly linked to negative winter and spring ENSO, while the Chinook record was shown to be associated with negative PDO conditions. The identified relationships to teleconnections generated in the Pacific Ocean to our record indicates that both species are sensitive oceanic interactions prior to entering natal habitats. Taken together, the reconstructions illustrate that the observational record encompasses a period of lower-than-average abundance and that neither accounts for the full range of variability in annual abundance when considered over the past three centuries.

The proxy tree-ring records presented in this dissertation provide new information about climate-water resource relationships in southwestern British Columbia. Significant phase-dependent associations, especially to negative phases of the PDO and ENSO, were shown to exert long-term influences on the state of several critical hydroclimatic variables over the last 300 years. Additionally, the research illustrates that over the instrumental period, both streamflow and lake volumes in the region have consistently remained below those characterizing the previous two to three centuries. These findings are of direct use to resource managers tasked with developing new policy and strategies under present and future climate change, in that they offer singular insights into the full range of natural hydroclimatic in southwestern British Columbia.