SCIENCE, PERCEPTION AND SCALE: AN INTERDISCIPLINARY ANALYSIS OF ENVIRONMENTAL CHANGE AND COMMUNITY ADAPTIVE CAPACIY

by

Jesse E. Grunblatt

A Dissertation Submitted in Partial Fulfillment of the Requirements

for the Degree of

Doctor of Philosophy

in

Environmental Science and Communication: Interdisciplinary

University of Alaska Fairbanks

May 2020

Approved:

Mark Wipfli, Committee Chair
Barbara Adams, Committee Co-chair
Courtney Carothers, Committee Member
John Monahan, Committee Member
Diane Wagner, Chair
Department of Biology and Wildlife
Kinchel C. Doerner, Dean
College of Natural Science and Mathematics
Michael Castellini, Dean *Graduate School*

Abstract

The discrepancy between science-based assessments of climate change and public acknowledgement of climate change has been extensively documented at a national level. The relationship of science-based assessments and public awareness of environmental change at the local community level is less studied. An understanding of how science-based information informs local perception is important to ensure that science communication effectively supports community decision making.

This dissertation explores the gap between science-based assessments and local perception of environmental change within a framework of adaptive capacity. The research is divided into three interrelated studies that provide: 1) an assessment of community perception of local environmental change, 2) a local study that illustrates science-based assessment and reporting, and 3) an evaluation of the role news media plays in communicating science to the public.

The first study implemented a survey of residents on Alaska's Kenai Peninsula to evaluate individual perception of environmental change as well as attitudes regarding climate change and natural resource management. Differences in perception of local environmental change were identified among respondents as well as shared perceptions. The use of property regulation to protect the Kenai River was identified as a divisive issue; however, there was a shared concern regarding the condition of local salmon populations. A second science-based ecological study was developed that examined those issues and linked conservation of riparian vegetation to juvenile salmon rearing habitat. This study examined the diet of stream-rearing juvenile Coho Salmon (*Oncorhynchus kisutch)* and determined that the proportion of invertebrates which enter the stream from riparian habitats varied based on vegetation type for three streams in the Kenai watershed. The third study investigated how news media play a role in the interpretation of technical, science-based reporting for the public. It demonstrated that local news media provide a unique opportunity to promote communication of science-based information to their audiences by providing content that is familiar and relevant, offering a variety of topical framings, developing authoritative or trusted voices, and providing frequent exposure to content.

Table of Contents

Page

List of Figures

Page

List of Tables

Page

Acknowledgements

I would like to thank my committee members Drs. Mark Wipfli, Barbara Adams, Courtney Carothers, and John Monahan for their support and guidance through the diverse topics and analyses that comprise this interdisciplinary dissertation. I am also grateful to Dr. Maher Al-Badri for serving as external examiner.

Many thanks to EPSCoR cohort members Pips Veazey, Tim Petty, Jon Skinner, and Jessica Garron for their counsel, example, and humor. The cohort fostered a sense of community and commitment that helped me negotiate this process. I would especially like to thank Dr. Barbara Adams who led the cohort through our various intellectual and personal challenges with warmth and insight. I also appreciate the support provided by Dr. Lilian Alessa for the formation of the cohort and her collaboration on my research.

A huge thank you to Elsa and Jenni for their patience, encouragement, and understanding throughout this process. There were many walks, skis, and shared moments that were lost to this endeavor.

Finally, I would like to dedicate this dissertation to Hilda and Dr. Jacques Grunblatt. Their commitment to service and love of learning continues to inspire me.

Chapter 1: Introduction

1.1 Background

Climate change and global warming are large-scale processes that are drivers of environmental change at local scales and have broad implications for human and natural systems (IPCC 2001, 2007, 2014). While the science-based consensus on climate change is clear: climate change is occurring and human activities are a driver of those changes (Oreskes 2004; Doran and Zimmerman 2009; Cook et al. 2013), public opinion regarding climate change remains diverse and many Americans remain doubtful or dismissive (Maibach et al. 2009; Roser-Renouf et al. 2014; Cook et al. 2016). This discrepancy between science-based assessments of climate change and public acknowledgement of climate change has been extensively documented at a national level (e.g., Kahan, Jenkins-Smith, and Braman 2011; Lewandowsky et al. 2015; Lewandowsky, Gignac, and Vaughan 2013). The relationship of science-based assessments and public awareness of environmental change at the local, community level is less studied.

Research suggests that perception of climate change and its associated local environmental impacts may be nuanced by scale. Spence et al. (2012) proposed that framing climate change in terms of local events and geography can make issues associated with climate change more salient. Similarly, the impact of evidence on personal attitudes has been shown to be generally related to the level of personal involvement with a particular issue (Petty and Cacioppo 1984; Corner et al. 2012). A study of flood risk management noted a trend toward decentralized, local management to accommodate varied perceptions of risk among those affected and the complexity of issues associated with response (Fuchs et al. 2017). Lawhon et al. (2018) found differences between global and local environmental imaginaries and suggested that news can be significant in differentiating perception of environmental concern at a local level.

This dissertation investigated community perception of local environmental change and considered the role that science-based information plays in informing those perceptions. The term community has a broad range of definitions and in this analysis it describes a group of people with common locality, interests and similar governance (Smit and Wandel 2006).

Community in the context of this study includes the general population of the Alaska's Kenai Peninsula (Figure 1.1). Fish and salmon in particular are a prominent ecosystem service throughout the region. Overlapping local, federal and state jurisdictions result in an institutional governance context that is larger than individual communities.

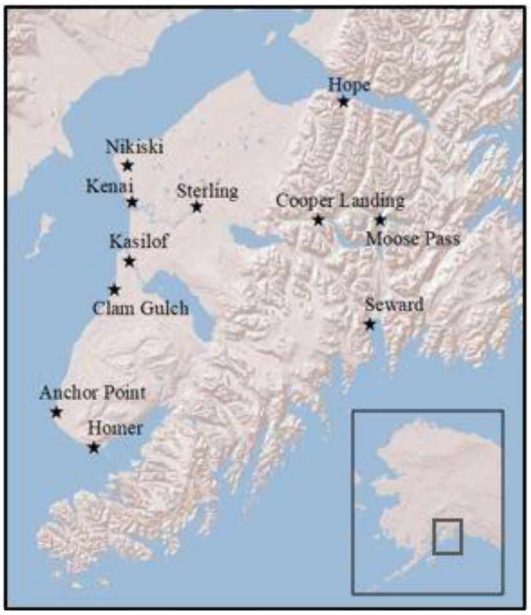


Figure 1.1: Alaska Kenai Peninsula study area.

Community perception of local environmental change was compared with perception of climate change and science-based measurements of local environmental change. Differences in community perceptions of local environmental change and attitudes regarding natural resource management were identified along with shared perceptions and attitudes. The use of property regulation to protect the Kenai River was identified as a divisive issue; however, there was a shared concern regarding the condition of local salmon populations. These results were used to develop an ecological study that described a significant relationship between riparian vegetation type and juvenile salmon rearing habitat and provided an example of science-based reporting. The technical content and format of science-based reporting can impede broad dissemination of results to non-technical audiences. A third study investigated how national and local news media play a role in the interpretation of climate and environmental change science for the public. Understanding how news media interpret science-based information is important to ensure that science communication effectively supports community decision making.

This dissertation is interdisciplinary in design and uses both quantitative and qualitative methods to explore topics of perception, ecology, and communication in an adaptive capacity framework. Adaptive capacity refers to latent ability of a system to modify or change its characteristics or behavior to better cope with existing or anticipated stress (Adger 2004; Smit and Wandel 2006). Risk perception and information resources are identified as components of

adaptive capacity that influence consensus and impact decision making (Ospina and Heeks 2010; Grothmann et al. 2013).

Cognitive and social theories of risk perception are used in this analysis to develop a socio-cognitive model of decision making that incorporates consideration of scale. News media are considered within a model of science communication that focuses on their role in interpreting science-based information to inform public perception of risk. The following sections of this chapter provide a summary of the theoretical background for this research and an overview of the research design.

1.1.1 Science Communication

Ziman (1991) identified three general models of science communication that describe different relationships between scientist and audience: the deficiency model, the rational choice model, and the context model. The deficiency model assumes that ignorance is the primary problem in the communication of science. In this model, the role of an expert is to reduce the 'information deficit' by providing more scientific information to those they seek to inform. Frequently, those who take the deficit perspective assume that the audience is motivated to understand scientific information and that they will ultimately accept the scientists' interpretation if enough information is provided (Krieger and Gallois 2017). The rational choice model focuses on finding out what knowledge is needed to allow people to better function. Information is presented as is appropriate to the circumstance in which it is being used, and the scientist must decide what information is appropriate for audience and purpose. The context model recognizes that the public integrates scientific knowledge with the rest of their experience. Personal context shapes what people want to know about and how they use information. This leaves room for a person's idiosyncratic judgment and suggests that personal and science-based positions might not converge (Condit et al. 2012).

While each model of science communication may be appropriate in a given situation, this research adopts a context model of communication, recognizing that public perception of environmental change is independent of science-based assessments. As a result, community perception of environmental change may be composed of diverse perspectives based on the life-

experiences and requirements of each resident. How those diverse perspectives are collectively resolved as a community confronts environmental change can be evaluated within a framework of adaptive capacity.

1.1.2 Vulnerability, Resilience, and Adaptive Capacity

The concept of adaptive capacity has its origins in evolutionary biology where adaptedness is defined as the ability of a population to survive and reproduce in a given set of environments (Dobzhansky 1968). Adaptive capacity overlaps with the concepts of vulnerability and resilience; however, adaptive capacity has implications that are especially relevant to social-ecological systems (Gallopín 2006; Smit and Wandel 2006). It is useful to consider the distinctions among these concepts.

Vulnerability can be defined as the tendency of a human or natural system to undergo significant change as a result of disturbance (Adger 1999, 2006). Vulnerability is an inherent, latent attribute of a system that exists prior to disturbance and is described in terms of capacity of response, exposure, and sensitivity (Gallopín 2006). Capacity of response can be thought of as the ability of a system to cope with change by minimizing damage or taking advantage of opportunities. Exposure describes the probability of occurrence, type, magnitude, intensity, speed, and persistence of change. Finally, sensitivity is the amount of transformation that a system undergoes as a result of change in the absence of response (Adger et al. 2004; Adger 2006; Gallopín 2006).

Resilience is a concept that is also applied to natural and human systems (Adger et al. 2004; Adger 2006; Gallopín 2006). It describes the persistence of a system that experiences disturbance and implies an ability of that system to maintain its functional state (Brose 2015). The state of a system can be described in terms of multiple domains of attraction which represent differing functional optimums for the system (Folke 2006; Folke et al. 2010). Change, in the form of movement between these domains of attraction, can be good or bad and can occur easily or require significant disturbance. The term adaptive cycle describes the recovery and reorganization of the system that occurs after change (Gallopín 2006).

While the response of natural systems to change is generally reactive, the response of human systems can be both reactive and proactive (Smithers and Smit 1997). Consequently, application of these concepts to social-ecological systems requires consideration of both the capacity of that system to react to change as well as its capacity to recognize potential change and intentionally adapt (Gallopín 2006). Adaptive capacity, more than either resilience or vulnerability, broadly encompasses this quality of adjustment in anticipation of change (Gallopín 2006). Adaptive capacity can provide a useful framework for the evaluation of community decision making in anticipation of or in response to change.

1.1.3 Adaptive Capacity Framework

Adaptive capacity research centers on an assessment of the tangible and intangible resources that are available to a system. Smit and Pilifosova (2003) state that determinants of adaptive capacity include economic and social conditions that enable or constrain the development or implementation of adaptive measures. For example, to measure institutional adaptation Fitzsimons et al. (2009) identified factors that included intellectual, social, economic, and political capital. The Africa Climate Change Resilience Alliance and the Intergovernmental Panel on Climate Change further identify information resources as components of adaptive capacity (Adger et al. 2004; Jones 2011). Ospina and Heeks (2010) maintain that information resources enable local awareness of need within a community. Consequently, the way in which a system generates awareness through the collection, analysis, and dissemination of information can be considered as a component of adaptive capacity.

Awareness only partly determines if an adaptive response is taken. Theoretical development on adaptive capacity also considers motivation. While awareness is indicative of a person's knowledge, motivation identifies what a person wants to do with that awareness (Grothmann and Patt 2003). Grothmann et al., (2013) proposed consideration of risk perception (adaptation motivation) and coping appraisal (adaptation belief) in explaining human response to natural hazard assessment in a model of institutional adaptive capacity. Risk perception and coping appraisal are formed as an individual evaluates conditions and considers alternative responses.

This study investigates perception of change within an adaptive capacity framework using the perspective of risk perception. Research in risk perception frequently focuses on social and cognitive models of analysis.

1.1.4 Social Models of Risk Perception

Embedded in social theories of risk perception are the concepts of culture, values, and attitudes, and it is helpful to consider the differences between these concepts. Culture can be considered as the normative set of learned beliefs and behaviors that are shared by a group of people and include attitudes and values (Weller 2007). Attitudes and values represent acquired behavioral tendencies that are shaped by past history, group membership, and experience and focus human perception through mental activities such as categorization, organization, and choice (Campbell 1963; Bergman 1998). Attitude can be defined as a tendency toward a particular response by an individual and can be thought of as dispositions toward action (Rensis Likert 1932; Bergman 1998). Attitudes have qualities such as extremity (like or dislike), certainty (confidence), centrality (importance), and salience (relevance to one's life) (Eagly and Chaiken 1995). Values can be considered as a set of attitudes that are held by a group. They are specific, stable, and broad enough to represent a group's past and motivate their future intentions and behaviors (Bergman 1998). Social and political theorists are interested in these broad group processes and describe values as fixed modes such as grid groups (i.e. egalitarian, collectivist, individualistic, and hierarchical) (Douglas 2007). Cultural cognition theory suggests that there is a cultural link to perception of risk that is derived from shared group values. However, Bergman (1998) counsels that each of us has personal agency. While a person has attitudes and values that motivate behavior, any individual through their own agency can form new attitudes and values based on experience and learning. The fixed quality of attitudes and values that is implied by cultural cognition does not incorporate this dynamic aspect of personal agency (Fielding and Hornsey 2016).

The social identity approach similarly suggests that our concept of self is derived from group identity (social identity) where one has a sense of inclusion in a larger group and a shared perspective; however, it also recognizes a personal, idiosyncratic sense of identity (self-characterization) (Tajfel 1974; Fielding and Hornsey 2016). An individual may choose between

a personal or group motivated position based on the particular context of circumstances. As a result, the social identity approach departs from cultural cognition with its focus on context-dependent rather than values-based nature of identity. A social identity approach is used in this analysis to provide a flexible lens with which to view individual as well as group aspects of risk perception.

1.1.5 Cognitive Models of Risk Perception

An individual constantly acquires information from diverse sources, such as media, personal experience, and social networks. This information can be used to make conscious, deliberate, and rational decisions through structured analytical processes. Alternatively, diverse information sources may be thought of as forming an 'affective pool' of information that is accessed through fast, intuitive, and unconscious information processing referred to as heuristic processes (Slovic et al. 2004; Weber 2006; Helgeson et al. 2012). As a result, affective 'gut' and 'best guess' heuristic solutions can replace logic, probability, or utility driven analytical decisions (Slovic et al. 2004).

Construal-level theory (CLT) describes how individuals access cognitive processes as they consider information. It proposes four dimensions of psychological distance (temporal, spatial, social, and certainty) that determine how a person considers objects or events; greater psychological distance promotes more general and abstract construal, while less psychological distance is associated with more specific and contextually detailed construal (Liberman et al. 2007). As a result, greater cognitive distance facilitates abstract consideration of issues and promotes alignment of those issues with an individual's 'core' values while reducing cognitive distance promotes the salience of a particular issue (Cash et al. 2002; Spence et al. 2012).

Decision making can be subject to cognitive biases. Motivated reasoning and confirmation bias describe the tendency to interpret information to fit an individual's current beliefs (Kunda 1990; Nickerson 1998; Maibach et al. 2009). Motivated reasoning affects perceived personal experience among those that have strongly held beliefs about global warming (Myers et al. 2013; Howe and Leiserowitz 2013). Other biases include the "availability heuristic" which suggests that risk perceptions will be more influenced by recent or common

events that are more "available" (Kahneman and Tversky 1972). Tendencies to be overly optimistic about the future or to focus on the present rather than the future are other cognitive biases that influence decision making (Weinstein 1980; Marx et al. 2007; Akerlof et al. 2013).

1.1.6 Research Overview

This dissertation considers public perception of environmental change within an adaptive capacity framework and investigates the role that science-based information plays in informing public perception of environmental change. Three interrelated studies comprise this research:

1) A community survey of environmental change and attitudes was implemented to assess community perception of environmental change and attitudes regarding natural resource management. Analysis of this survey was intended to address the following questions: Can community resident responses be partitioned into groups that represent different perceptions of environmental change? Do these groups share other attitudes and perceptions that may promote community consensus? Does community perception of environmental change agree with science-based assessments? How does perception of climate change and local environmental change differ at a local level?

2) An ecological study was developed that investigated riparian vegetation as a component of juvenile fish habitat and illustrated science-based analysis and reporting. Community perceptions of local environmental change were used to inform this research. This study addressed the question: How does riparian vegetation type influence invertebrate prey availability for juvenile salmon?

3) News media content regarding environmental change was compared between national and local news sources and the role of media in interpreting science-based research for the public was explored. This study addressed the question: How does the scale of media reporting influence content and framing of environmental change reporting?

1.1.7 Socio-Cognitive Model

This research combined social and cognitive models of risk perception to form a simple socio-cognitive model of perception (Figure 1.2) that identified three different modes of decision making. Cognitive processes are used to form an axis that represents a transition from heuristic to analytical decision making. Reliance on heuristic cognitive processes result in affective or 'gut' based solutions while analytical cognitive processes promote science-based decision

making. Cognitive distance is proposed as a separate axis that represents scale, where increasing cognitive distance moves focus from contextual detail and personal assessment towards to abstract construal and a focus on social identity.

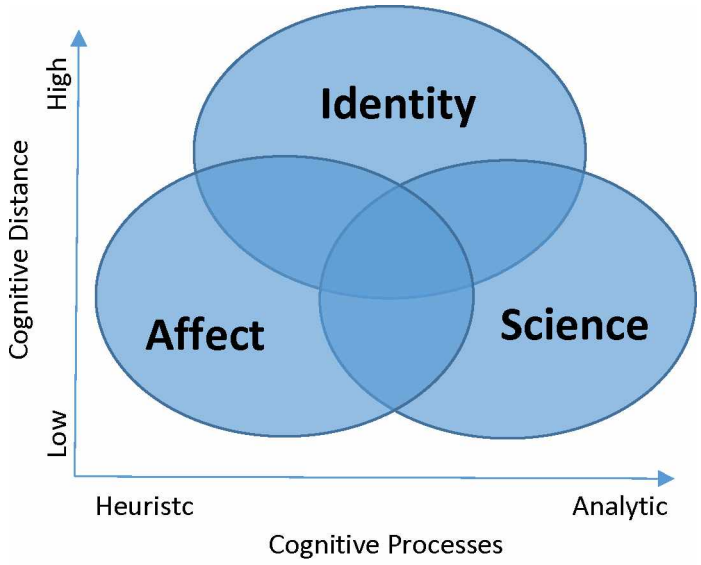


Figure 1.2: Socio-cognitive model of decision making.

1.1.8 Global Warming, Climate Change, and Environmental Change

Climate change and global warming are large-scale processes that are drivers of environmental change at local scales (IPCC 2001, 2007, 2014). We can conceptualize global warming and climate change as abstract phenomenon that are manifest through environmental

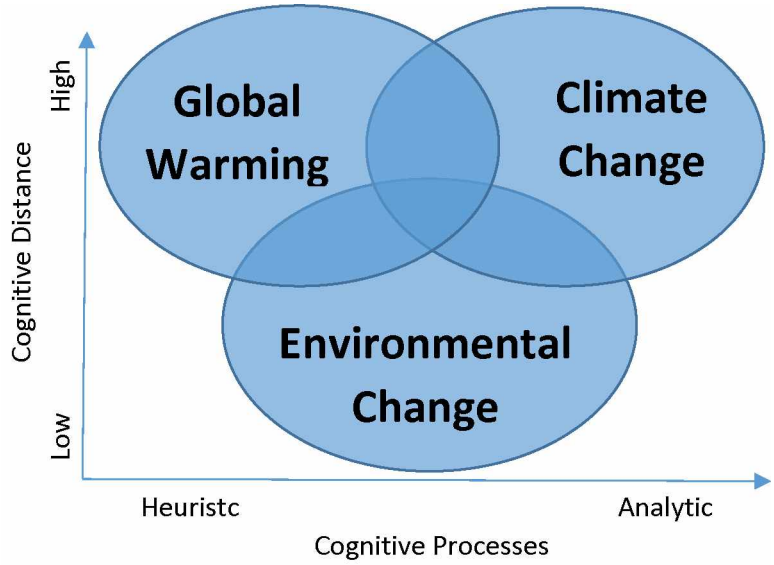


Figure 1.3: Global warming, climate change, and environmental change in a cognitive distance framework.

change. This conceptualization fits within our proposed cognitive model. Global warming and climate change are described as more cognitively distant than environmental change. Therefore, it would be expected that consideration of global warming or climate change would be closely associated with group identity (Figure 1.3). Environmental change is more cognitively proximate and more accessible to analytic cognitive processes. Consequently, we would expect less of a relationship between identity and environmental change. The relationship between identity and perception of climate change and global warming has been extensively documented at the national level in climate change literature (Maibach et al. 2009; Kahan 2012; Akerlof et al. 2013). In this study, we consider the extent to which perception of local environmental change is similarly linked to identity.

1.2 Methods

An explanatory, sequential, mixed methods approach was used in designing this research. Quantitative social science methods were used to provide an initial assessment of community perception of environmental and climate change at individual and group levels of analysis. A quantitative, ecological analysis was undertaken to illustrate a science-based assessment of potential environmental change. Quantitative and qualitative content analyses were then used to explore local and national news media reporting of environmental and climate change.

1.2.1 Research Approach

The work undertaken in this dissertation is interdisciplinary in nature. It combines social and natural sciences in research that is problem focused and addresses issues that have social as well as technical relevance (Bruce et al. 2004). Because this interdisciplinary research crosses domain boundaries, it is important to identify a conceptual theoretical perspective that supports the research approach.

The theoretical perspective adopted in this research is pragmatic. Pragmatism focuses on practical consequences of actions and recognizes that research occurs in social, historical, and political contexts; however, pragmatists also recognize an external world independent of the human observer (Creswell 2014; Moon and Blackman 2014). Rather than trying to reconcile humanist and positivist perspectives, pragmatism draws on each to direct research and draw conclusions (Bernard 2011; Creswell 2014). Pragmatism embraces the use of a variety of

approaches to derive knowledge about a problem and allows the researcher to consider the intended consequences of their research (Creswell 2014). As a result, pragmatism provides a flexible theoretical perspective for this interdisciplinary research.

1.2.2 Organization of the Dissertation

Chapters 2, 3, and 4 of this dissertation have been written for three different peer reviewed journal publications. Therefore, this dissertation follows the manuscript publication guidelines outlined by the University of Alaska Fairbanks for journal publications within a dissertation. Each chapter contains a manuscript as published by or submitted to the respective journal.

Study 1: Role of Perception in Determining Adaptive Capacity: Communities Adapting to Environmental Change

Overview: A community-level survey was conducted in which residents were asked to respond to questions about environmental change perception as well as attitudes regarding natural resource management. Results of this analysis suggested that shared community perceptions and attitudes could be identified despite diverse individual perceptions of environmental change.

Methods: A psychometric scale was developed from a community level survey and used to partition survey respondents into four statistically significant ($p = .05$) environmental change perception groups based on perception of local environmental change. As measure of construct validity, binary logistic regression was used to demonstrate that environmental perception groups could be independently predicted from respondent answers to questions about attitudes regarding natural resource management (Gliner et al. 2009). Further analysis identified shared perceptions of environmental change among respondent groups using a cultural consensus model.

Study 2: Invertebrate Prey Contributions to Juvenile Coho Salmon Diet from Riparian Habitats along Three Alaska streams: Implications for Environmental Change

Overview: Controversial, local ordinances created habitat protection areas (buffers) within riparian areas of the Kenai River watershed. Land use and clearing are restricted within these habitat protection areas. Results from the community-level survey identified use of property

regulation to protect the Kenai River as a divisive issue among respondents. The survey also found there was shared concern among respondents regarding the condition of local salmon populations. This case study provides a science-based assessment of the importance of riparian habitat to juvenile salmon. The findings highlight the role riparian vegetation plays in moderating the movement of invertebrate prey between terrestrial and stream ecosystems within three tributaries of the Kenai River. This allows us to better understand how environmental or anthropogenic change in riparian vegetation might affect juvenile salmon rearing habitat within the Kenai watershed. These results help reframe the importance of habitat protection areas using the shared concern for local salmon populations. The analysis associated with this study is an example of science-based assessment of environmental change.

Methods: In this study we measured contributions of invertebrate prey to the diet of stream-rearing juvenile Coho Salmon *Oncorhynchus kisutch* within the Kenai River watershed of southcentral Alaska. Three study stream reaches were identified that are representative of common riparian vegetation types found within the watershed and broader region. Vegetation adjacent to the streams was classified via LiDAR into broad vegetation types (grass/sedge, shrub, and tree). Juvenile salmon stomach contents were sampled from each study stream over a two-year period, and ingested invertebrates were identified by taxa, origin, and life stage. Contributions to juvenile salmon diet by terrestrial, aquatic resident (aquatic stages of aquatic invertebrates), and aquatic winged adult invertebrates were compared among the three study streams.

Study 3: Role of Local Media in Promoting Science Communication

Overview: Communication of science-based assessments of environmental and climate change can be difficult due to the technical content and format of scientific reporting. Media promotes communication of science-based technical reporting to the public by providing interpretations of that reporting for its audiences. Studies of environmental news reporting generally focus on national or international media, and the importance of local reporting has received less attention. Local media coverage can be expected to be different from national reporting as it provides content that is relevant to the everyday lives of its audience and emphasizes local voices of authority. Research describes a shift in media content from local news media toward larger

nationally oriented sources. Characterization of the differences between local and national level environmental reporting is therefore important to help us recognize and better understand the significance of this shift.

Methods: This study investigated frequency of occurrence of content (term frequency), voice (named entity), and sentiment within media reporting. Frequency was chosen as a primary metric as prior studies have shown that public concern about environmental issues tended to be more affected by the amount of media attention issues received rather than the substantive content of the reporting. A corpus of 832 articles was compiled from two national news media sources and a local media source. Automated content analysis was used to compare frequency of terms and named entities among media sources. Differences in article sentiment among sources were evaluated using manual coding. This study investigated the use of an unsupervised, extractive content summary technique to maintain frequency (i.e. number of articles) yet reduce the volume of material for manual coding.

1.3 Literature Cited

Adger, W. N. 1999. Social Vulnerability to Climate Change and Extremes in Coastal Vietnam. World Development 27(2):249–269.

Adger, W. N. 2006. Vulnerability. Global Environmental Change 16(3):268–281.

Adger, W. N., N. Brooks, G. Bentham, M. Agnew, and S. Eriksen. 2004. New indicators of vulnerability and adaptive capacity. Tyndall Centre for Climate Change Research, Norwich.

Akerlof, K., E. W. Maibach, D. Fitzgerald, A. Y. Cedeno, and A. Neuman. 2013. Do people "personally experience" global warming, and if so how, and does it matter? Global Environmental Change 23(1):81–91.

Bergman, M. M. 1998. A Theoretical Note on the Differences Between Attitudes, Opinions, and Values. Swiss Political Science Review 4(2):81–93.

Bernard, H. R. 2011. Research methods in anthropology: Qualitative and quantitative approaches. Rowman Altamira.

Brose, D. A. 2015. Developing a Framework for Measuring Community Resilience. The National Academies Press, Washington, D.C.

Bruce, A., C. Lyall, J. Tait, and R. Williams. 2004. Interdisciplinary integration in Europe: the case of the Fifth Framework programme. Futures 36(4):457–470.

Campbell, D. T. 1963. Social Attitudes and Other Acquired Behavioral Dispositions. Pages 94–172 Psychology: A study of a science. Study II. Empirical substructure and relations with other sciences. Volume 6. Investigations of man as socius: Their place in psychology and the social sciences. McGraw-Hill, New York, NY, US.

Cash, D., W. C. Clark, F. Alcock, N. M. Dickson, N. Eckley, and J. Jäger. 2002. Salience, credibility, legitimacy and boundaries: Linking research, assessment and decision making. KSG Working Papers Series RWP02-046. doi:10.2139/ssrn.372280.

Condit, C. M., J. Lynch, and E. Winderman. 2012. Recent rhetorical studies in public understanding of science: Multiple purposes and strengths. Public Understanding of Science 21(4):386–400.

Cook, J., D. Nuccitelli, S. A. Green, M. Richardson, B. Winkler, R. Painting, R. Way, P. Jacobs, and A. Skuce. 2013. Quantifying the consensus on anthropogenic global warming in the scientific literature. Environmental Research Letters 8(2):024024.

Cook, J., N. Oreskes, P. T. Doran, W. R. L. Anderegg, B. Verheggen, E. W. Maibach, J. S. Carlton, S. Lewandowsky, A. G. Skuce, S. A. Green, D. Nuccitelli, P. Jacobs, M. Richardson, B. Winkler, R. Painting, and K. Rice. 2016. Consensus on consensus: a synthesis of consensus estimates on human-caused global warming. Environmental Research Letters 11(4):048002.

Corner, A., L. Whitmarsh, and D. Xenias. 2012. Uncertainty, scepticism and attitudes towards climate change: biased assimilation and attitude polarisation. Climatic Change 114(3–4):463–478.

Creswell, J. W. 2014. Research Design Fourth Edition. Sage, Thousand Oaks, California.

Dobzhansky, T. 1968. On Some Fundamental concepts of Darwinian Biology. Evolutionary Biology. Springer.

Doran, P. T., and M. K. Zimmerman. 2009. Examining the Scientific Consensus on Climate Change. Eos, Transactions American Geophysical Union 90(3):22.

Douglas, M. 2007. A history of grid and group cultural theory. Toronto, Canada: University of Toronto.

Eagly, A. H., and S. Chaiken. 1995. The psychology of attitudes. Harcourt, Brace, & Janovich, Fort Worth.

Fielding, K. S., and M. J. Hornsey. 2016. A Social Identity Analysis of Climate Change and Environmental Attitudes and Behaviors: Insights and Opportunities. Frontiers in Psychology 7.

Fitzsimons, P. J., T. O. Chan, C. Pettit, E. Liu, and L. Tiller. 2009. Towards Creating an Adaptive Capacity Index for Climate Change Adaption Using the National Spatial Data Grid. Pages 978–1000 Proceedings of the Surveying and Spatial Science Institute. Adelaide.

Folke, C. 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. Global Environmental Change 16(3):253–267.

Folke, C., S. R. Carpenter, B. Walker, M. Scheffer, T. Chapin, and J. Rockström. 2010. Resilience thinking: integrating resilience, adaptability and transformability. Ecology and Society 15(4):20.

Fuchs, S., K. Karagiorgos, K. Kitikidou, F. Maris, S. Paparrizos, and T. Thaler. 2017. Flood risk perception and adaptation capacity: a contribution to the socio-hydrology debate. Hydrology and Earth System Sciences 21(6):3183–3198.

Gallopín, G. C. 2006. Linkages between vulnerability, resilience, and adaptive capacity. Global Environmental Change 16(3):293–303.

Gliner, J., G. Morgan, and N. Leech. 2009. Research Methods in Applied Settings: An integrated Approach to Design and Analysis, 2nd edition. Taylor and Francis.

Grothmann, T., K. Grecksch, M. Winges, and B. Siebenhüner. 2013. Assessing institutional capacities to adapt to climate change: integrating psychological dimensions in the Adaptive Capacity Wheel. Natural Hazards and Earth System Science 13(12):3369–3384.

Grothmann, T., and A. Patt. 2003. Adaptive Capacity and Human Cognition. Open Meeting of the Global Environmental Change Research Community. Montreal, Canada.

Helgeson, J., S. van der Linden, and I. Chabay. 2012. The role of knowledge, learning and mental models in public perception of climate change related risks. Wageningen Academic Publishers, The Netherlands.

Howe, P. D., and A. Leiserowitz. 2013. Who remembers a hot summer or a cold winter? The asymmetric effect of beliefs about global warming on perceptions of local climate conditions in the U.S. Global Environmental Change 23(6):1488–1500.

IPCC 2001. Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

IPCC 2007. Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds.,. Cambridge Univ. Press, Cambridge, UK.

IPCC 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland.

Jones, L. 2011. Towards a holistic conceptualisation of adaptive capacity at the local level: insights from the Local Adaptive Capacity framework (LAC). Overseas Development Institute (ODI).

Kahan, D. M. 2012. Cultural cognition as a conception of the cultural theory of risk. Handbook of risk theory. Springer.

Kahan, D. M., H. Jenkins-Smith, and D. Braman. 2011. Cultural cognition of scientific consensus. Journal of Risk Research 14(2):147–174.

Kahneman, D., and A. Tversky. 1972. Subjective Probability: A Judgement of Representativeness. Cognitive Psychology 3:430–454.

Krieger, J. L., and C. Gallois. 2017. Translating Science: Using the Science of Language to Explicate the Language of Science. Journal of Language and Social Psychology 36(1):3–13.

Kunda, Z. 1990. The case for motivated reasoning. Psychological Bulletin 108(3):480–498.

Lawhon, M., J. Pierce, and R. Bouwer. 2018. Scale and the construction of environmental imaginaries in local news. South African Geographical Journal 100(1):1–21.

Lewandowsky, S., J. Cook, K. Oberauer, S. Brophy, E. A. Lloyd, and M. Marriott. 2015. Recurrent fury: Conspiratorial discourse in the blogosphere triggered by research on the role of conspiracist ideation in climate denial. Journal of Social and Political Psychology 3(1):142–178.

Lewandowsky, S., G. E. Gignac, and S. Vaughan. 2013. The pivotal role of perceived scientific consensus in acceptance of science. Nature Climate Change 3(4):399–404.

Liberman, N., Y. Trope, S. M. McCrea, and S. J. Sherman. 2007. The effect of level of construal on the temporal distance of activity enactment. Journal of Experimental Social Psychology 43(1):143–149.

Maibach, E., C. Roser-Renouf, and A. Leiserowitz. 2009. Global Warming's Six Americas 2009: An Audience Segmentation Analysis. Yale University and George Mason University. New Haven, CT.

Marx, S. M., E. U. Weber, B. S. Orlove, A. Leiserowitz, D. H. Krantz, C. Roncoli, and J. Phillips. 2007. Communication and mental processes: Experiential and analytic processing of uncertain climate information. Global Environmental Change 17(1):47–58.

Moon, K., and D. Blackman. 2014. A Guide to Understanding Social Science Research for Natural Scientists: Social Science for Natural Scientists. Conservation Biology 28(5):1167–1177.

Myers, T. A., E. W. Maibach, C. Roser-Renouf, K. Akerlof, and A. A. Leiserowitz. 2013. The relationship between personal experience and belief in the reality of global warming. Nature Climate Change 3(4):343–347.

Nickerson, R. S. 1998. Confirmation Bias: A Ubiquitous Phenomenon in Many Guises. Review of General Psychology Vol. 2(No. 2):175–220.

Oreskes, N. 2004. The Scientific Consensus on Climate Change. Science 306(5702):1686.

Ospina, A. V., and R. Heeks. 2010. Linking ICTs and Climate Change Adaptation: A Conceptual Framework for e-Resilience and e-Adaptation. Institute for Development Policy and Management.

Petty, R. E., and J. T. Cacioppo. 1984. The effects of involvement on responses to argument quantity and quality: Central and peripheral routes to persuasion. Journal of Personality and Social Psychology 46(1):69–81.

Rensis Likert. 1932. Likert Technique for Attitude Measurement. Social Psychology: Experimentation, Theory, Research, Sahakian, WS (Ed.). Intext Educational Publishers, Scranton, USA., ISBN-13 1059690887:101–119.

Roser-Renouf, C., N. Stenhouse, J. Rolfe-Redding, E. W. Maibach, and A. Leiserowitz. 2014. Engaging diverse audiences with climate change: message strategies for global warming's six Americas. Routledge Handbook of Environment and Communication, Routledge, London.

Slovic, P., M. L. Finucane, E. Peters, and D. G. MacGregor. 2004. Risk as Analysis and Risk as Feelings: Some Thoughts about Affect, Reason, Risk, and Rationality. Risk Analysis 24(2):311–322.

Smit, B., and O. Pilifosova. 2003. Adaptation to climate change in the context of sustainable development and equity. Sustainable Development 8(9):879-912.

Smit, B., and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. Global Environmental Change 16(3):282–292.

Smithers, J., and B. Smit. 1997. Human adaptation to climatic variability and change. Global Environmental Change 7(2):129–146.

Spence, A., W. Poortinga, and N. Pidgeon. 2012. The Psychological Distance of Climate Change: Psychological Distance of Climate Change. Risk Analysis 32(6):957–972.

Tajfel, H. 1974. Social identity and intergroup behaviour. Social Science Information 13(2):65–93.

Weber, E. U. 2006. Experience-Based and Description-Based Perceptions of Long-Term Risk: Why Global Warming does not Scare us (Yet). Climatic Change 77(1–2):103–120.

Weinstein, N. D. 1980. Unrealistic optimism about future life events. Journal of Personality and Social Psychology 39(5):806–820.

Weller, S. C. 2007. Cultural Consensus Theory: Applications and Frequently Asked Questions. Field Methods 19(4):339–368.

Ziman, J. 1991. Not Knowing, Needing to Know and Wanting to Know. Pages 13–20 When Science Meets the Public. American Association for the Advancement of Science.

Chapter 2: Role of Perception in Determining Adaptive Capacity: Communities Adapting to Environmental Change[1]

2.1 Abstract

In this study, we investigate perception of likely environmental change as a factor of community adaptive capacity. A comparison of perceived change with science-based assessment of change is proposed to better understand community risk assessment and decision-making. Based on this analysis, we identify shared attitudes and perceptions of change that can be used to develop communication about environmental change in a manner that is appropriate within the context of the community. A community level survey was conducted to sample differences in individual perception of likely environmental change as well as attitudes regarding climate change and natural resource management among residents of Alaska's Kenai Peninsula. We compare perceptions of likely environmental change to science-based assessments of change using a conceptual framework that recognizes socio-cognitive processes associated with decision making. We evaluate the relationship of those perceptions to attitudes using quantitative methods. A binary logistic model is used to investigate the predictive relationship between perception and attitudes regarding climate change and natural resource management. A cultural consensus model is then used to determine areas of shared community perception of change and attitudes. Results of this analysis suggest that despite diverse individual perception of environmental change, shared community perceptions, and attitudes can be identified.

2.2 Introduction

Adaptive capacity can be thought of as the ability or potential of an individual, community or social-ecological system to adjust to changing conditions. High adaptive capacity allows maintenance of a desirable state or enables favorable transformation if the current conditions are undesirable (Adger et al. 2004; Adger and Vincent 2005; Engle 2011; IPCC 2007; Lockwood et al. 2015; Smit and Pilifosova 2003; Smit and Wandel 2006).

---

[1]Grunblatt, Jess and Lilian Alessa. 2017. Role of Perception in Determining Adaptive Capacity: Communities Adapting to Environmental Change. Sustainability Science 12(1):3–13. doi.org/10.1007/s11625-016-0394-0.

Environmental change at a local level can be described in terms of individual perception as well as science-based measurements. If perceptions are widely shared within a community, then comparison of perceived environmental change with measured change can provide an understanding of community assessment of risk and decision-making. Large differences between perceived likely change and measured change can be expected to adversely impact community adaptive capacity (Adger et al. 2009; Alessa et al. 2008; Grothmann and Patt 2005).

A community level survey was used to investigate individual perception of likely environmental change as well as attitudes regarding climate change and natural resource management. Perception of change is compared with science-based measurements of change using a socio-cognitive framework that recognizes heuristic processes, motivated reasoning, and cognitive biases that are associated with an individual's perception of risk. The relationship between respondent perception of change and attitudes regarding climate is further investigated using quantitative models. More specifically this work considers several hypotheses:

1) H1: A scale can be constructed that effectively partitions respondents into groups with differing levels of environmental change perception (ECP).
2) H2: ECP can be predicted from respondent attitudes using a binary logistic model.
3) H3: ECP shared attitudes and perceptions of likely change can be identified using a cultural consensus model.

The goal of this analysis is to identify community perceptions and attitudes in a manner that can improve the communication of science-based information and contribute to a better understanding of community adaptive capacity. Finding a means by which science can better communicate environmental change requires better understanding of the affective, cognitive, and attitudinal processes that contribute to the interpretation of scientific information by the general public (Pearce et al. 2015). The results of this analysis will be used to identify associative frames that can facilitate communication about environmental change within the context of the local community.

2.3 Background

While much research has focused on technological, demographic, and economic factors that are associated with environmental change and adaptive capacity, less attention has been given to identifying factors that influence decisions and behavior by individuals (Adger et al. 2007; Burton et al. 2005; Engle 2011; Jones 2011; Jones, Ludi, and Levine 2010; Mimura et al. 2014). Adger et al., (2009) suggests that there are individual and social characteristics such as risk perception that interact with values to form subjective limits to adaptation. Consideration of socio-cognitive processes that influence the perception of environmental change can contribute to a better understanding of subjective limits to adaptation and can facilitate the development of strategies that promote communication of science based information and improve adaptive capacity (Clayton et al. 2015; Grothmann and Patt 2005; Helgeson, van der Linden, and Chabay 2012; Kunda 1990; Marx et al. 2007; Spence, Poortinga, and Pidgeon 2012; Wiest, Raymond, and Clawson 2015).

The consequences of environmental change can be considered an "un-situated risk" as those consequences are generally future oriented, uncertain, and frequently detached from personal relevance (Helgeson et al. 2012; Hulme 2009). Given these cognitive uncertainties, risk perception suggests that individuals may tend toward heuristic interpretations that circumvent cognitive processes. As a result, perception may not be based on rational logic, probability, and utility but instead rely on simplified representations or heuristic solutions that are formed through fast, intuitive, and unconscious information processing (Helgeson et al. 2012; Slovic et al. 2004; Weber 2006). Under this model, an individual acquires general understanding of environmental change from diverse sources such as media, personal experience, and social networks. These diverse sources form an "affective pool" that contribute to heuristic decision-making and take the place of more deliberate, rational and cognitive processes (Slovic et al. 2004).

Construal level theory (CLT) describes how perception accesses mental processes that influence how a person considers information (Liberman et al. 2007). CLT proposes four dimensions of psychological distance (temporal, spatial, social, and certainty) and suggests that psychological distance determines how a person mentally represents perception. Greater

psychological distance promotes more general and abstract construal while less psychological distance is associated with more concrete construal and specific contextual detail (Spence et al. 2012). Focusing on distant concepts and abstract goals enhances the processing of psychologically distant information. As a result, greater psychological distance promotes consideration of high-level abstractions and can be expected to lead to perceptions that are defined idiosyncratically by an individual and conform to an individual's values (Spence et al. 2012).

Perception of change in the local environment can also be subject to cognitive biases due to an individual's existing attitudes and values. Motivated reasoning and confirmation bias describe the tendency to interpret information to fit an individual's current beliefs (Kunda 1990; Maibach, Roser-Renouf, and Leiserowitz 2009; Nickerson 1998). Motivated reasoning affects perceived personal experience among those that have strongly held beliefs about global warming (Howe and Leiserowitz 2013; Myers et al. 2013). Other biases include the "availability heuristic" in human cognition, which suggests that risk perceptions will be more influenced by recent or common events that are more "available". Tendencies to be overly optimistic about the future, and to focus on the present rather than the future are other biases that influence people's ability and motivation to respond in effective ways to long-term, gradually developing environmental changes and their related risk (Akerlof et al. 2013; Marx et al. 2007; Weinstein 1980).

Heuristic processes, CLT, and cognitive biases suggest that rational cognition is often circumvented in risk assessment and decision-making. Grothmann et al., (2013) incorporates adaptation motivation (threat appraisal or risk perception) and adaptation belief (coping appraisal) to explain subjective human responses to natural hazard assessment in a model of institutional adaptive capacity. Adaptive motivation and adaptation belief are intended to represent psychological factors of adaptive capacity that result from the subjective perception of objective conditions.

In our analysis, we propose to investigate adaptive capacity by evaluating the difference between perceived (subjective) and measured (objective) environmental change as a component

of adaptive motivation. We then explore the relationship between respondent perceptions of change and attitudes within a socio-cognitive framework that can inform our communication of environmental change through science-based information.

Science-based information is frequently considered by individuals in a manner that conforms to their personal sense of identity and cultural membership within the community (Kahan 2015). Agreement with the scientific consensus on climate change is not necessarily increased by providing more scientific information (Kahan 2012; Kahan et al. 2012; Maibach et al. 2009). Analysis of community perceptions, attitudes and experiences can allow better understanding of how science-based measurements are perceived and contribute toward improved adaptive capacity by making the communication of science-based information more effective within the context of a particular community.

2.4 Study Area

The Kenai Peninsula in southcentral Alaska (Figure 2.1) has grown rapidly from a population of approximately 4,830 in 1950 to over 57,000 in 2013. Salmon are a central focus of life on the Kenai Peninsula supporting local personal use fisheries, regionally important commercial salmon harvests and a world-famous sport fishing industry. The Kenai area is directly adjacent to Anchorage, Alaska's largest city (population 305,000). Alaska residents and a large seasonal influx of tourists from outside Alaska make the Kenai Peninsula and the Kenai River important recreational destinations. Archaeological evidence suggests that the area has been continuously occupied by native Alaskans since 1000 B.C. and the modern Kenaitze tribe continues to hold salmon as central to their cultural heritage. Fish, salmon in particular, form the basis of strong economic and cultural identities for all residents within this area and represent a prominent ecosystem service.

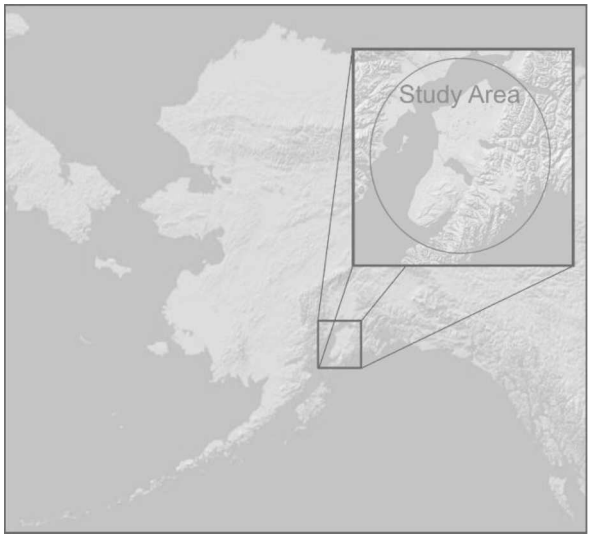


Figure 2.1: Study area location: Kenai Peninsula, Alaska.

2.5 Methods/Results

A community level survey instrument was designed in collaboration with an interdisciplinary science panel. A component of the survey focused on Kenai Peninsula residents' perception of change within three dimensions: environment (air/land/water), development (tourism/infrastructure), and salmon (ecosystem service). Perception of change within the study area was evaluated using five point questions (Table 2.1). Responses were coded: 1=Very unlikely; 2=Unlikely; 3=Neutral; 4=Likely; 5=Very likely. The survey instrument also included questions on respondent attitudes regarding climate change and natural resource management that used five point questions (Table 2.2). Responses were coded: 1=Strongly disagree; 2=Somewhat disagree; 3=Unsure; 4=Somewhat agree; 5=Strongly agree. Demographic information was collected and included age, occupation, level of education, ethnicity, income, length of residence in Alaska and the Kenai Peninsula, and outdoor activities. The survey instrument was pilot tested on university students and adjusted for clarity.

Table 2.1: Perception of likely change questions.

Environmental: Land/Air/Water
Drying of wetlands areas
Increase in average yearly temperatures
Less snow in winter months
Increase in summer stream temperatures
Increase in fire occurrence
Changes in sea level
Ecosystem Service: Salmon
Changes in the timing of salmon runs
Increased year to year variability in runs
Decrease in the size of adult salmon
Decrease in king salmon runs
Decrease in red salmon runs
Development: Infrastructure/Tourism
Increase in residential development
More roads
Increase in oil and gas industry
More tourists

The survey was administered as a mixed mode survey in three rounds: 1) 1500 surveys were mailed in round 1 with a $2 incentive (21% response rate), 2) 1000 surveys were mailed in round 2 without $2 incentive (12% response rate), and 3) 1000 invitations were mailed in round 3 that requested participation in an online survey with no $2 incentive (7% response rate). Addresses for the mailings were randomly selected from Kenai Peninsula zip codes purchased from InfoUSA. A total of 528 responses were received resulting in an overall response rate of 15.23%.

2.5.1 Construction of Environmental Change Perception Scales

Initial work focused on developing a scale that broadly described respondent perception of likely environmental change within the study area using the five point environmental (land/air/water) change questions (Table 2.1). Listwise deletion of respondents for perception of change questions resulted in a final analysis dataset (n=321). Environmental change scale values were calculated as the mean of the environmental perception questions for each respondent. Internal consistency of the environmental change scale was satisfactory with Cronbach's Alpha=0.88 (Bernard 2011; Ogilvie et al. 2008). Factor analysis and scree plot of scale items showed high loading on the first component, which explained 62.75% of the total variance.

Table 2.2: Attitude questions and variable names.

Humans are changing the planet's climate (Human_CC)
Climate is changing on the Kenai (Kenai_Chg)
I am worried about changes in land and water on the Kenai (K_Worry)
We should base our planning decision on science (Base_Plan)
Government has a role in managing natural resources (Gov_Role)
The process used to generate regulations on the Kenai is fair (Reg_Fair)
I would support more property regulations to protect the Kenai River (Property)
It is not appropriate to put a dollar value on benefits we receive from nature (Val_Nature)
It is easy to get information on environmental change (Env_Info)

Environmental scale values were used to partition respondents into environmental change perception groups (ECP). Respondents in ECP1 perceive environmental change as very unlikely and scored between 1 and 2 on the environmental change perception scale. Respondents in ECP2 perceive change as unlikely with scale values of greater than 2 to 3. ECP3 respondents perceive change as likely and scored greater than 3 to 4. ECP4 respondents view environmental change as very likely and had environmental change scale values of greater than 4.

Table 2.3: Environmental perception group mean values.

ECP Group	Mean	Std. Dev.	n
ECP1:Very Unlikely	1.72	0.37	32 (10%)
ECP2:Unlikely	2.74	0.26	85 (26%)
ECP3: Likely	3.69	0.28	144 (45%)
ECP4:Very Likely	4.58	0.30	60 (19%)

There was a statistically significant difference between ECP groups as determined by one-way ANOVA ($F(3,317) = 908$, $p < 0.001$). Post-hoc comparison of means (t-test) showed statistically significant difference between ECP1 and ECP2, ECP2 and ECP3 as well as ECP3 and ECP4 (p=0.01) (Hypothesis 1).

2.5.2 Demographics

Comparison of respondent demographics with U.S. census data indicated a response bias in favor of male, educated, and retired respondents. Therefore, the results of this survey cannot be considered representative of the area residents based on basic demographics. These data do provide a diverse pool of respondents in terms of the key study variable of environmental change perception. A nationally representative survey that described public perception of climate change provides a check of external validity (Maibach et al. 2009). This study identified six groupings of perception (ordered from disagreement to agreement): Dismissive (7%); Doubtful (11%); Disengaged (12%); Cautious (19%); Concerned (33%); and Alarmed (18%). Combining these six levels to four groups yields: Dismissive (7%); Doubtful and Disengaged (23%); Cautious and Concerned (52%); and Alarmed (18%). These percentage groupings are similar to the respondent percentages for ECPs that were identified in this work (Table 2.3).

ANOVA results for ECP show no significant difference in mean age, length of residence in Alaska, or residence on the Kenai Peninsula ($p>0.10$). Chi-squared results for ECP and age cohort, educational level, time spent outdoors, occupation, and income categories were not significant ($p>0.10$).

2.5.3 Climate/Environmental Change Attitudes

Three attitude questions focus on respondent perception of climate change. The first question asks about respondent attitude regarding human caused global climate change (Human_CC). The second question asks about climate change in the study area with no mention of human causation (Kenai_Chg). In a third question, respondents are asked about land and water change in the study area with no explicit link to climate change (K_Worry). Table 2.4 summarizes responses for these three questions by ECP group. Combined disagree and unsure responses for the question: "Humans are changing the planet's climate" for ECP1 and ECP2 were 82% and 59% respectively while ECP3 and ECP4 were 25% and 7%. Percentages for

combined disagree and unsure responses for the question "Climate is changing on the Kenai" increased to 94% and 65% for ECP1 and ECP2 and decreased to 20% and 0% for ECP3 and ECP4. Response percentages (combined disagree and unsure) for the question: "I am worried about changes in land and water on the Kenai" declined to 60% and 41% for ECP1 and ECP2 and were 20% and 2% for ECP3 and ECP4.

Table 2.4: Respondent skepticism of change (combined disagree and unsure responses).

	ECP1	ECP2	ECP3	ECP4
Humans are changing the planet's climate	82%	59%	25%	7%
Climate is changing on the Kenai	94%	65%	20%	0%
I am worried about changes in land and water on the Kenai	60%	41%	20%	2%

Table 2.5: Estimated coefficients of independent variable from the binary logistic regression.

Variable	B	S.E.	Wald	df	Significance	Exp(B)
Val_Nature	-0.907	0.354	6.563	1	0.010*	0.404
Human_CC	1.234	0.365	11.447	1	0.001*	3.435
Property	1.219	0.365	11.169	1	0.001*	3.384
Kenai_Chg	2.494	0.363	47.242	1	0.000*	12.108
Reg_Fair	-0.759	0.412	3.392	1	0.066	0.468
Env_Info	-0.355	0.347	1.047	1	0.306	0.701
Base_Plan	-0252	0.403	0.390	1	0.532	0.777
Gov_Role	-0.364	0.431	0.712	1	0.399	0.695
K_Worry	0.368	0.400	0.848	1	0.357	1.445
Constant	-1.205	0.509	5.601	1	0.018	0.300

2.5.4 Binary Logistic Model

Binary logistic regression was used to investigate the probability that perception of environmental change could be predicted based on respondent answers to attitude questions (Table 2.2). ECP were recoded to a dichotomous dependent variable where 0 means perceived environmental change is unlikely (ECP1 + ECP2) and 1 indicates that perceived environmental change is likely (ECP3 + ECP4). Attitude responses were also recoded to dichotomous independent variables (0= disagree and unsure; 1 = agree). The logistic regression model was statistically significant, $\chi^2(5) = 141.485$, $p < 0.0005$. The model explained 52.6% (Nagelkerke R^2) of the variance and correctly classified 82.3% of the ECP cases. Attitude questions Human_CC, Property and Kenai_Chg were significant at $p < 0.001$ while question Val_Nature

was significant at $p < 0.01$ (Hypothesis 2). The remaining independent variables did not contribute significantly to the logistic regression model (Table 2.5).

2.5.5 Cultural Consensus Model

Culture can be considered as the normative set of learned beliefs and behaviors that are shared by a group of people (Weller 2007). CCM is a collection of analytical techniques and models that can be used to estimate shared group beliefs. CCM first estimates individual competencies and then uses those competencies to estimate respondent answers to questions as well as respondent confidence in each answer. Aggregation of individual answers is used to estimate shared, culturally correct answers (Borgatti and Halgin 1997; Romney, Weller, and Batchelder 1986; Weller 2007).

Table 2.6: Cultural Consensus Model (CCM) shared consensus of perception and attitudes for ECP groups 1 and 4. (1=disagree (attitude) or unlikely (perception); 3=agree (attitude) or likely (perception)).

	Environmental Scale Interval	**ECP1**	**ECP4**
	Negative Competency	**0**	**0**
	Eigenvalue Ratio	**3.5**	**12.5**
	Number of Respondents	**29**	**57**
Perception of Change	Changes in the timing of salmon runs	1	3
	Increased year to year variability in runs	3	3
	Decrease in the size of adult salmon	3	3
	Decrease in king salmon runs	3	3
	Decrease in red salmon runs	1	3
	Increase in residential development	3	3
	More roads	3	3
	Increase in oil and gas industry	3	3
	More tourists	3	3
Attitudes	Humans are changing the planet's climate	1	3
	Climate is changing on the Kenai	1	3
	I am worried about changes in land and water on the Kenai	1	3
	I would support more property regulations to protect the Kenai River	1	3
	The process used to generate regulations on the Kenai is fair	1	1
	We should base our planning decisions on science	3	3
	Government has a role in managing natural resources	3	3
	It is not appropriate to put a dollar value on benefits we receive from nature	3	3
	It is easy to get information on environmental change	3	3

The CCM covariance method was used in the analysis of ECP for shared perception of change as well as attitudes. Perceptions of likely change questions for salmon (ecosystem service) and development (infrastructure/tourism) were used in this analysis (Table 2.1) along with attitude questions (Table 2.2). Five point responses were recoded to three point responses for Perception: 1=Very unlikely and Unlikely; 2=Neutral; 3= Very likely and Likely as well as for Attitude: 1=Strongly disagree and Somewhat disagree; 2=Unsure; 3= Somewhat agree and Strongly agree. Listwise deletion resulted in a final data set of 295 respondents.

CCM analysis of ECP2 and ECP3 revealed a number of negative competencies for group perceptions of change and attitudes as well as weak eigenvalue ratios. This indicates a lack of fit to the consensus model and suggests that respondents from ECP2 and ECP3 were drawn from a mix of cultures. Results of ECP1 and ECP4 had no negative competencies for perceptions of change and attitude questions. Both ECP1 and ECP4 had eigenvalue ratios greater than three which indicated a good fit to CCM and suggests that respondents in each ECP were drawn from a shared culture (Table 2.6) (Hypothesis 3) (Borgatti and Halgin 1997; Romney et al. 1986; Weller 2007).

2.6 Discussion

2.6.1 Perception and Variability

Table 2.7 summarizes the grouped perception of likely environmental change (land/air/water) for all respondents, as well as science-based assessments of likely change. Science based assessments identify environmental change as likely for all environmental change factors considered in this analysis (Bauret and Stuefer 2013; Berg et al. 2009; Berg and Anderson 2006; Deb, Butcher, and Srinivasan 2015; Dial et al. 2007; Klein, Berg, and Dial 2005;

Table 2.7: Grouped perception of likely environmental change and science estimate of likely change. ([1]Response = Very Unlikely+Unlikely+Neutral; [2]Response=Very Likely+Likely).

Environmental: Land/Air/Water	Unlikely[1]	Likely[2]	Science
Drying of wetlands areas	60%	40%	Likely
Increase in average yearly temperatures	43%	57%	Likely
Less snow in winter months	55%	45%	Likely
Increase in summer stream temperatures	44%	56%	Likely
Increase in fire occurrence	36%	64%	Likely
Changes in sea level	50%	50%	Likely

Lynch et al. 2002; Mauger 2013; Stafford, Wendler, and Curtis 2000; Wolken et al. 2011). Respondents are almost equally distributed between those that have a low expectation of environmental change (very unlikely + unlikely + neutral) and those that feel confident that environmental change will occur (likely + very likely).

There are a wide variety of factors that influence individual perception of change. For the purposes of this analysis where we are evaluating the relationship between perceived and measured change within a socio-cognitive framework, it is important to consider the natural variability of environmental change and its relationship to individual perception of change (Akerlof et al. 2013; Finnis, Sarkar, and Stoddart 2015; Meze-Hausken 2004; Myers et al. 2013). For example, mean annual air temperature as recorded at the local Kenai airport from the 1950s through 2014 exhibit a long term (>40 years) trend that shows significant increase in temperature (Table 2.8). Analysis of shorter time series fails to identify significant trend due to the high natural variability in air temperatures (Bauret and Stuefer 2013). Consequently, discerning trend through personal observation of air temperature is difficult since variability requires long periods of careful observation of change.

*Table 2.8: Significance of Mann-Kendall trend of Kenai Airport air temperatures. Trends are positive unless otherwise indicated as negative (neg). (National Weather Service). *** p =0.001 ** p =0.01 * p =0.05 + p =0.1*

Years	**1947-2014**	**1955-2014**	**1965-2014**	**1975-2014**	**1985-2014**	**1995-2014**	**2005-2014**
# Years	**68**	**60**	**50**	**40**	**30**	**20**	**10**
January	*		*				
February	*		+				
March							
April	**	**	+				
May	***	**	**	*	+		
June	***	***	***	***	*		
July	***	***	**	*	*		*neg
August	**	**	*		+		
September	+	+		*			*neg
October							
November							
December	*	*	+				
Annual	***	***	**	+			
Summer	***	***	**	*	*		
Winter	***	*	***				

High natural variability over time is a characteristic of the environmental change factors considered in this analysis. Psychological distancing associated with high natural variability and anticipated future conditions allows idiosyncratic interpretation of change that conforms to an individual's values. This results in diverse personal perceptions of likely change despite the apparent significance of science-based measurements. Careful consideration and communication of variability is an important consideration in the communication of science-based measurement of change.

2.6.2 Perception and Attitudes

Climate change is widely recognized within the scientific community as an important driver of environmental change; however, research finds that public awareness and concern regarding climate change varies widely. In the United States, strong predictors of climate change risk perception include belief in causes of climate change, perception of local temperature, and attitudes supporting government environmental preservation. Studies have also found that ideological polarization in the United States frequently drives the perception of climate change risk (Lee et al. 2015; Maibach et al. 2009).

The majority of respondents within ECP1 (85%) and ECP2 (59%) disagreed or were unsure of the statement: "Humans are changing the planet's climate". Despite the lack of reference to human causation, the combined disagree and unsure responses increased for ECP1 (95%) and ECP2 (65%) with the more geographically specific question: "Climate is changing on the Kenai". This suggests that among respondents within ECP1 and ECP2, bias and heuristic processes that are associated with the idea of climate change are intensified as consideration of climate change becomes more local and contextualized (Table 2.4).

Binary logistic regression identified a significant ($P<0.001$) predictive relationship between ECP and attitudes including: "Humans are changing the planet's climate" (Human_CC), "I would support more property regulation" (Property) and "Climate is changing on the Kenai" (Kenai_Chg) (Table 2.5). These results suggest that framing communication of risk associated with environmental change in terms of climate change and property regulation would tend to reinforce biased, heuristic response.

More generally, these results underline research that suggests individuals at least partially construct perceptions of change based on beliefs or attitudes and point to the role of motivated reasoning and cognitive bias in reinforcing both positive and negative perceptions of change (Akerlof et al. 2013; Howe and Leiserowitz 2013; Maibach et al. 2009; Myers et al. 2013). These results emphasize that within ECP1 and ECP2, discussion of environmental change as a component of climate change would not be effective.

CCM was used to identify shared respondent attitudes and perceptions of change (Table 2.6). This analysis identified shared perceptions of change between ECP1 and ECP4 for all development change items and most salmon change items. While ECP1 and ECP4 differed on attitudes about climate change, CCM identified shared attitudes regarding the statements: "Government has role in managing natural resources", "We should base our planning decisions on science", "It is not appropriate to put a dollar value on benefits we receive from nature", and "It is easy to get information on environmental change". These shared attitudes and perceptions of change suggest areas of common perspective between ECP1 and ECP4 despite apparent differences in perception regarding climate change and property regulation.

In the CCM analysis, both ECP1 and ECP4 identify a shared perception of likely decrease in king salmon runs however, ECP4 respondents also felt that red salmon runs were likely to diminish (Table 2.6) despite the fact that red salmon returns are expected to remain stable (Willette and Shields, 2015). This result shows a bias in future-oriented perception of likely change by respondents that acknowledge environmental/climate change.

2.6.3 Perception, Adaptive Capacity, and Communication

The ECP scale identified a range of respondent perceptions of local environmental change including low ECP scores where change was perceived as unlikely and suggests that risk perception varies among residents. This contrasts with science based assessment of likely environmental change within the study area. Further analysis using a binary logistic model showed that respondents with low ECP scores could be differentiated from those with high ECP scores according to specific attitudes. Framing communication of risk associated with environmental change in the context of those attitudes would be expected to be divisive within

this community. Despite the polarizing impact of particular attitudes, shared perception and attitudes were identified among respondents using a cultural consensus model. These shared perceptions and attitudes can be used to frame communication that facilitates community agreement and promotes community adaptive motivation.

The quantitative approach used in this case study allowed a structured evaluation of respondent perceptions of change and attitudes which is broadly applicable. Comparison of perceived likely environmental change and measured change provided a meaningful assessment of adaptive motivation as a component of community adaptive capacity.

2.7 Conclusions

Change at a local level can be described in terms of individual perceptions as well as science-based measurements. Comparison of perceived change with measured change provides a suggestion of individual awareness of risk and can provide a better understanding of community assessment of risk and decision-making. Large differences between perceived likely change and measured change can be expected to reduce adaptation motivation and adversely impact community adaptive capacity.

This study used a socio-cognitive framework to investigate the relationship between community perception of environmental change and science-based measurement of change. While most individuals strive to base perception of change on logic, probability, and utility those perceptions are conditioned by heuristic processes, cognitive biases, environmental cues, and socio-cultural considerations. This study identified as an impediment to perception of change, the distancing created through uncertainty, complexity, social group, and future timeframe (construal level theory) that is associated with consideration of environmental change. Communication about phenomenon that exhibit high natural variability may benefit from analysis that includes accessible descriptions of change that engage heuristic processes by acknowledging distancing.

A binary logistic model identified a predictive relationship between respondent perception of environmental change and attitudes. These results suggest that framing

communication of risk associated with environmental change in terms of climate change and property regulation could tend to reinforce biased, heuristic response within segments of this community that do not perceive likely environmental change.

A cultural consensus model was used to identify perceptions and attitudes that were broadly shared within the community. Linking environmental change dialog with shared attitudes and perceptions in a manner that acknowledges the uncertainties in environmental data will allow the framing of communication based on themes of agreement regarding environmental change that are relevant to the community.

The deficit model of science communication maintains that the general public is not properly informed and needs to be educated. Too frequently this model becomes the default position when a scientist, in presenting their data, responds to disagreement by providing more data. An alternate paradigm suggests that inclusive dialog and engagement are more effective means of communication (Pearce et al. 2015). This study describes a general quantitative approach that is broadly applicable in structuring that dialog and engagement. The results of this approach can also be used to help define qualitative studies that would allow further exploration of community perception of change and adaptive capacity using an explanatory sequential mixed methods design (Creswell and Plano Clark 2011).

2.8 Acknowledgements

This study was supported by the Alaska Experimental Program to Stimulate Competitive Research (Alaska EPSCoR) NSF award #OIA-1208927 and the State of Alaska. Data from the Kenai General Population Survey: Your Values and Experiences on the Kenai were kindly provided by Drs. Sarah Wandersee and Chad Farrell. We gratefully acknowledge Dr. Barbara Adams for her review and comments on this manuscript as well as those provided by three anonymous reviewers.

2.9 Literature Cited

Adger, W. N., S. Agrawala, M. M. Q. Mirza, C. Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit, and K. Takahashi. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge, UK, 717-743.

Adger, W. N., N. Brooks, G. Bentham, M. Agnew, and S. Eriksen. 2004. New indicators of vulnerability and adaptive capacity. Tyndall Centre for Climate Change Research, Norwich.

Adger, W. N., S. Dessai, M. Goulden, M. Hulme, I. Lorenzoni, D. R. Nelson, L. O. Naess, J. Wolf, and A. Wreford. 2009. Are there social limits to adaptation to climate change? Climatic Change 93(3–4):335–354.

Adger, W. N., and K. Vincent. 2005. Uncertainty in adaptive capacity. Comptes Rendus Geoscience 337(4):399–410.

Akerlof, K., E. W. Maibach, D. Fitzgerald, A. Y. Cedeno, and A. Neuman. 2013. Do people "personally experience" global warming, and if so how, and does it matter? Global Environmental Change 23(1):81–91.

Alessa, L. (Na'ia), A. (Anaru) Kliskey, P. Williams, and M. Barton. 2008. Perception of change in freshwater in remote resource-dependent Arctic communities. Global Environmental Change 18(1):153–164.

Bauret, S., and S. Stuefer. 2013. Kenai Peninsula Precipitation and Air Temperature Trend Analysis. 19th International Northern Research Basins Symposium and Workhop. Southeast Alaska.

Berg, E. E., and R. S. Anderson. 2006. Fire history of white and Lutz spruce forests on the Kenai Peninsula, Alaska, over the last two millennia as determined from soil charcoal. Forest Ecology and Management 227(3):275–283.

Berg, E. E., K. M. Hillman, R. Dial, and A. DeRuwe. 2009. Recent woody invation of wetlands on the Kenai Peninsula Lowlands, south-central Alaska: a major regime shift after 18,000 years of wet Spahgnum-sedge peat recruitment. Canadian Journal of Forest Research 39:2033–2046.

Bernard, H. R. 2011. Research methods in anthropology: Qualitative and quantitative approaches. Rowman Altamira.

Borgatti, S. P., and D. S. Halgin. 1997. Consensus analysis. A companion to cognitive anthropology:171–190.

Burton, I., B. Lim, E. Spanger-Siegfried, E. L. Malone, and S. Huq. 2005. Adaptation policy frameworks for climate change: developing strategies, policies, and measures. Cambridge University Press, Cambridge, UK ; New York.

Clayton, S., P. Devine-Wright, P. C. Stern, L. Whitmarsh, A. Carrico, L. Steg, J. Swim, and M. Bonnes. 2015. Psychological research and global climate change. Nature Climate Change 5(7):640–646.

Creswell, J. W., and V. L. Plano Clark. 2011. Designing and Conducting Mixed Methods ResearchSecond Edition. Sage, Los Angeles.

Deb, D., J. Butcher, and R. Srinivasan. 2015. Projected Hydrologic Changes Under Mid-21st Century Climatic Conditions in a Sub-arctic Watershed. Water Resources Management 29(5):1467–1487.

Dial, R. J., E. E. Berg, K. Timm, A. McMahon, and J. Geck. 2007. Changes in the alpine forest-tundra ecotone commensurate with recent warming in southcentral Alaska: Evidence from orthophotos and field plots. Journal of Geophysical Research: Biogeosciences (2005–2012) 112(G4).

Engle, N. L. 2011. Adaptive capacity and its assessment. Global Environmental Change 21(2):647–656.

Finnis, J., A. Sarkar, and M. C. J. Stoddart. 2015. Bridging science and community knowledge? The complicating role of natural variability in perceptions of climate change. Global Environmental Change 32:1–10.

Grothmann, T., K. Grecksch, M. Winges, and B. Siebenhüner. 2013. Assessing institutional capacities to adapt to climate change: integrating psychological dimensions in the Adaptive Capacity Wheel. Natural Hazards and Earth System Science 13(12):3369–3384.

Grothmann, T., and A. Patt. 2005. Adaptive capacity and human cognition: The process of individual adaptation to climate change. Global Environmental Change 15(3):199–213.

Helgeson, J., S. van der Linden, and I. Chabay. 2012. The role of knowledge, learning and mental models in public perception of climate change related risks. Pages 322–346. Wageningen Academic Publishers, The Netherlands.

Howe, P. D., and A. Leiserowitz. 2013. Who remembers a hot summer or a cold winter? The asymmetric effect of beliefs about global warming on perceptions of local climate conditions in the U.S. Global Environmental Change 23(6):1488–1500.

Hulme, M. 2009. Why we disagree about climate change: understanding controversy, inaction and opportunity. Royal Institute of International Affairs 85(6):1261–1262.

IPCC 2007. Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds.,. Cambridge Univ. Press, Cambridge, UK.

Jones, L. 2011. Towards a holistic conceptualisation of adaptive capacity at the local level: insights from the Local Adaptive Capacity framework (LAC). Overseas Development Institute (ODI).

Jones, L., E. Ludi, and S. Levine. 2010. Towards a characterisation of adaptive capacity: a framework for analysing adaptive capacity at a local level. Overseas Development Institute.

Kahan, D. M. 2012. Ideology, motivated reasoning, and cognitive reflection: an experimental study. Judgment and Decision Making 8:407–24.

Kahan, D. M. 2015. Climate-Science Communication and the Measurement Problem. Political Psychology 36:1–43.

Kahan, D. M., E. Peters, M. Wittlin, P. Slovic, L. L. Ouellette, D. Braman, and G. Mandel. 2012. The polarizing impact of science literacy and numeracy on perceived climate change risks. Nature Climate Change 2(10):732–735.

Klein, E., E. E. Berg, and R. Dial. 2005. Wetland drying and succession across the Kenai Peninsula Lowlands, south-central Alaska. Canadian Journal of Forest Research 35(8):1931–1941.

Kunda, Z. 1990. The case for motivated reasoning. Psychological Bulletin 108(3):480–498.

Lee, T. M., E. M. Markowitz, P. D. Howe, C.-Y. Ko, and A. A. Leiserowitz. 2015. Predictors of public climate change awareness and risk perception around the world. Nature Climate Change 5(11):1014–1020.

Liberman, N., Y. Trope, S. M. McCrea, and S. J. Sherman. 2007. The effect of level of construal on the temporal distance of activity enactment. Journal of Experimental Social Psychology 43(1):143–149.

Lockwood, M., C. M. Raymond, E. Oczkowski, and M. Morrison. 2015. Measuring the dimensions of adaptive capacity: a psychometric approach. Ecology and Society 20(1).

Lynch, J. A., J. S. Clark, N. H. Bigelow, M. E. Edwards, and B. P. Finney. 2002. Geographic and temporal variations in fire history in boreal ecosystems of Alaska. Journal of Geophysical Research 108(D1):801–817.

Maibach, E., C. Roser-Renouf, and A. Leiserowitz. 2009. Global Warming's Six Americas 2009: An Audience Segmentation Analysis. Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication.

Marx, S. M., E. U. Weber, B. S. Orlove, A. Leiserowitz, D. H. Krantz, C. Roncoli, and J. Phillips. 2007. Communication and mental processes: Experiential and analytic processing of uncertain climate information. Global Environmental Change 17(1):47–58.

Mauger, S. 2013. Stream Temperature Monitoring Network for Cook Inlet Salmon Streams, 2008-2012. Cook Inletkeeper.

Meze-Hausken, E. 2004. Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia. Climate research 27:19–31.

Mimura, N., R. Pulwarty, D. M. Duc, I. Elshinnawy, M. H. Redsteer, H. Q. Huang, J. N. Nkem, and R. A. Sanchez Rodriguez. 2014. Climate Change 2014: Chapter 15: Adaptation Planning and Mitigation: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 869-898.

Myers, T. A., E. W. Maibach, C. Roser-Renouf, K. Akerlof, and A. A. Leiserowitz. 2013. The relationship between personal experience and belief in the reality of global warming. Nature Climate Change 3(4):343–347.

Nickerson, R. S. 1998. Confirmation Bias: A Ubiquitous Phenomenon in Many Guises. Review of General Psychology Vol. 2(No. 2):175–220.

Ogilvie, D., R. Mitchell, N. Mutrie, M. Petticrew, and S. Platt. 2008. Perceived characteristics of the environment associated with active travel: development and testing of a new scale. International journal of behavioral nutrition and physical activity 5(1):32.

Pearce, W., B. Brown, B. Nerlich, and N. Koteyko. 2015. Communicating climate change: conduits, content, and consensus: Communicating climate change. Wiley Interdisciplinary Reviews: Climate Change 6(6):613–626.

Romney, A. K., S. C. Weller, and W. H. Batchelder. 1986. Culture as consensus: A theory of culture and informant accuracy. American anthropologist 88(2):313–338.

Slovic, P., M. L. Finucane, E. Peters, and D. G. MacGregor. 2004. Risk as Analysis and Risk as Feelings: Some Thoughts about Affect, Reason, Risk, and Rationality. Risk Analysis 24(2):311–322.

Smit, B., and O. Pilifosova. 2003. Adaptation to climate change in the context of sustainable development and equity. Sustainable Development 8(9):879-912.

Smit, B., and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. Global Environmental Change 16(3):282–292.

Spence, A., W. Poortinga, and N. Pidgeon. 2012. The Psychological Distance of Climate Change: Psychological Distance of Climate Change. Risk Analysis 32(6):957–972.

Stafford, J. M., G. Wendler, and J. Curtis. 2000. Temperature and precipitation of Alaska: 50 year trend analysis. Theoretical and Applied Climatology 67(1–2):33–44.

Weber, E. U. 2006. Experience-Based and Description-Based Perceptions of Long-Term Risk: Why Global Warming does not Scare us (Yet). Climatic Change 77(1–2):103–120.

Weinstein, N. D. 1980. Unrealistic optimism about future life events. Journal of Personality and Social Psychology 39(5):806–820.

Weller, S. C. 2007. Cultural Consensus Theory: Applications and Frequently Asked Questions. Field Methods 19(4):339–368.

Wiest, S. L., L. Raymond, and R. A. Clawson. 2015. Framing, partisan predispositions, and public opinion on climate change. Global Environmental Change 31:187–198.

Willette, M., and P. Shields. 2015. 2016 Upper Cook Inlet Sockeye Salmon Forecast. Alaska Department of Fish and Game, Division of Commercial Fisheries. News Release. pp4. Alaska Department of Fish and Game.

Wolken, J. M., T. N. Hollingsworth, T. S. Rupp, F. S. Chapin, S. F. Trainor, T. M. Barrett, P. F. Sullivan, A. D. McGuire, E. S. Euskirchen, P. E. Hennon, E. A. Beever, J. S. Conn, L. K. Crone, D. V. D'Amore, N. Fresco, T. A. Hanley, K. Kielland, J. J. Kruse, T. Patterson, E. A. G. Schuur, D. L. Verbyla, and J. Yarie. 2011. Evidence and implications of recent and projected climate change in Alaska's forest ecosystems. Ecosphere 2(11):1-35.

Chapter 3: Invertebrate Prey Contributions to Juvenile Coho Salmon Diet from Riparian Habitats along Three Alaska Streams: Implications for Environmental Change[2]

3.1Abstract

Stream fish rely on a mix of terrestrial and aquatic prey sources. While the importance of terrestrial invertebrates as a food source for stream fish is well documented, the role of aquatic insects that emerge from the stream as winged adult insects (aquatic winged adults) and return to the stream as prey is less understood. In this study we determine the proportion of total diet for stream-rearing juvenile Coho Salmon (*Oncorhynchus kisutch)* that is derived from terrestrial and aquatic winged adult invertebrates which enter the stream from riparian habitats and consider how those cross-ecosystem prey contributions vary based on riparian habitat type. Study reaches were identified in three streams within the Kenai River watershed of Alaska that were representative of habitats found throughout the region and riparian vegetation was classified into grass/sedge, shrub, and tree types using LiDAR. Juvenile Coho Salmon stomach contents were sampled seasonally in study reaches over a two-year period and ingested invertebrates were identified by taxa, life stage, and origin. Our results show that aquatic winged adult prey contributions to juvenile salmon diet were significantly lower in the grass/sedge study reach, and cross-ecosystem invertebrate prey represented a significantly higher proportion of juvenile salmon diet in the tree study reach. Invertebrate prey in the grass/sedge reach were composed primarily of the larval life stage of aquatic winged adults. These results suggest that change in riparian vegetation from tree/shrub to grass/sedge along Kenai streams as projected by regional climate change models, or that results from anthropogenic modification, will likely lead to lower availability of cross-ecosystem prey for stream fish. Management of riparian buffers along streams to preserve or increase occurrence of trees and shrubs is likely to help mitigate impacts of those possible changes.

3.2 Introduction

Streams are connected to adjacent terrestrial habitats by the movement of prey and other resources between ecosystems (Polis et al. 1997; Baxter et al. 2005; Richardson et al. 2010).

---

[2]Grunblatt, Jess, Benjamin E. Meyer, and Mark S. Wipfli. 2019. Invertebrate Prey Contributions to Juvenile Coho Salmon Diet from Riparian Habitats along Three Alaska Streams: Implications for Environmental Change. Journal of Freshwater Ecology 34(1):617–31.

Terrestrial invertebrates that enter streams supplement in-situ prey sources for stream-rearing salmonids and often provide half or more of their annual energy intake (Hunt and Krokhin 1975; Wipfli 1997; Kawaguchi and Nakano 2001). Terrestrial prey represented 50% of the seasonal biomass ingested by juvenile salmonids in several southeast and southcentral Alaska streams (Wipfli 1997; Roon et al. 2018). Kawaguchi and Nakano (2001) found terrestrial invertebrates supported 49% of annual prey consumption by salmonids in forested stream reaches and 53% in grassland reaches of a northern Japanese stream. Over the course of the summer, terrestrial invertebrate prey generally become more numerous and increase in availability while larval aquatic invertebrate densities generally decrease due to predation and emergence from streams as adults (Merritt and Cummins 1996; Kawaguchi and Nakano 2001; Sweka and Hartman 2008). Terrestrial prey can comprise 50-90% of fish diet during summer months (Garman 1991; Wipfli 1997; Baxter et al. 2005).

Riparian vegetation type plays a major role in determining the quantity of terrestrial invertebrates that enter streams. Riparian vegetation overhanging streams promotes in-fall of terrestrial invertebrates to streams (Cadwallder et al. 1980), and different riparian tree species contribute different quantities of terrestrial invertebrate biomass to streams (Mason and Macdonald 1982). In Alaska, dense shrub understory associated with riparian alder increased terrestrial invertebrate subsidies to streams, and deciduous trees supported more foliar invertebrate mass than conifers (Wipfli 1997; Allan et al. 2003). Edwards and Huryn (1995) found that terrestrial invertebrates made only a small contribution to trout diet in a New Zealand pasture stream, and Kawaguchi and Nakano (2001) found that the annual input of terrestrial invertebrates was 1.7 times greater for forested than grassland stream reaches in a low-order Japanese stream.

The larval life stages of aquatic winged adult taxa such as Plecoptera, Trichoptera, Ephemeroptera, and Diptera are abundant in many lotic environments and represent an important prey resource for stream fishes especially during seasons when terrestrial inputs are low. These taxa emerge as winged adults from streams during hatching events and enter riparian habitats (Collier and Smith 1997; Petersen et al. 1999; Briers et al. 2005). The return of aquatic winged adult insects from riparian habitat to the stream represents a potentially important source of prey

for stream fishes however this trophic pathway is not well understood. This study is intended to address this knowledge gap and more generally consider the implications of riparian habitat change on invertebrate prey contributions to fish diet.

After aquatic winged adult insects emerge from the stream, swarming, mating, foraging, and sheltering occur in riparian habitats (Figure 3.1). Lateral movement of those insects away from the stream is influenced by streamside vegetation (Jackson and Fisher 1986; Bohonak and Jenkins 2003; Winterbourn et al. 2007), and dispersal behavior appears selective based on habitat preferences for food and shelter (Kuusela and Huusko 1996; Petersen et al. 1999; Delettre and Morvan 2000) as well as weather conditions and insect flying ability (Briers et al. 2003; Parkyn and Smith 2011; Greenwood 2014). Riparian shrubs reduced lateral dispersal of aquatic winged adult insects (Ephemeroptera, Plecoptera, Trichoptera, and Megaloptera) when compared to grasslands in New Zealand (Greenwood 2014). Delettre and Morvan (2000) found that in open agricultural landscapes of Brittany, adult chironomids moved away from their natal stream, with extent of lateral dispersal related to landscape openness. Movement by aquatic winged adults away from their natal stream reduces their chances of returning to the stream and becoming potential prey for stream fishes (Jackson and Fisher 1986; Briers and Gee 2004).

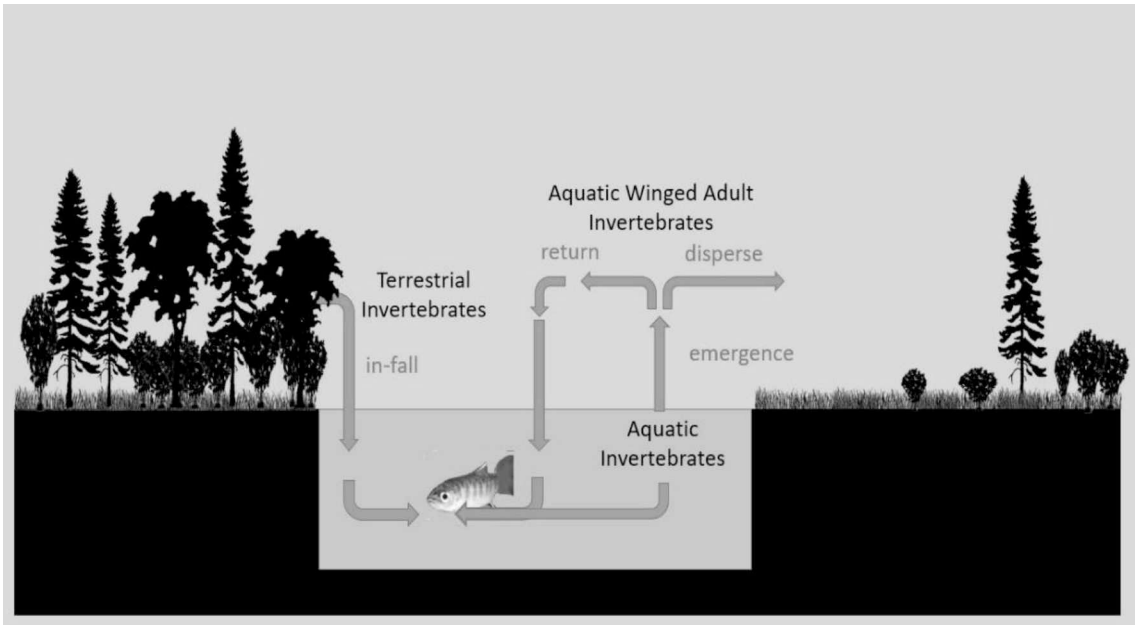


Figure 3.1: Movement of invertebrate prey between riparian habitats and streams.

In this study we measured contributions by terrestrial, aquatic, and aquatic winged adult invertebrates to the diet of stream-rearing juvenile Coho Salmon *Oncorhynchus kisutch* within the Kenai River watershed of southcentral Alaska and calculated the total invertebrate contribution derived from invertebrates that enter the stream from riparian habitats (cross-ecosystem). Invertebrate contributions to juvenile salmon diet were compared among three study reaches representative of common riparian vegetation types found within the Kenai watershed. We hypothesized that terrestrial and aquatic winged adult invertebrates were an important component of juvenile Coho Salmon diet that is moderated by vegetation type. Our prediction was that the fractional contribution to juvenile salmon diet of aquatic winged adult and cross-ecosystem invertebrates would be lower in streams with more open riparian habitats (grass/sedge) than those in shrub or tree riparian habitats.

3.3 Materials and Methods

3.3.1 Study Area

This study was conducted within the Kenai River watershed of southcentral Alaska which covers approximately 5,600 sq km and includes over 2,600 km of mapped tributary streams and

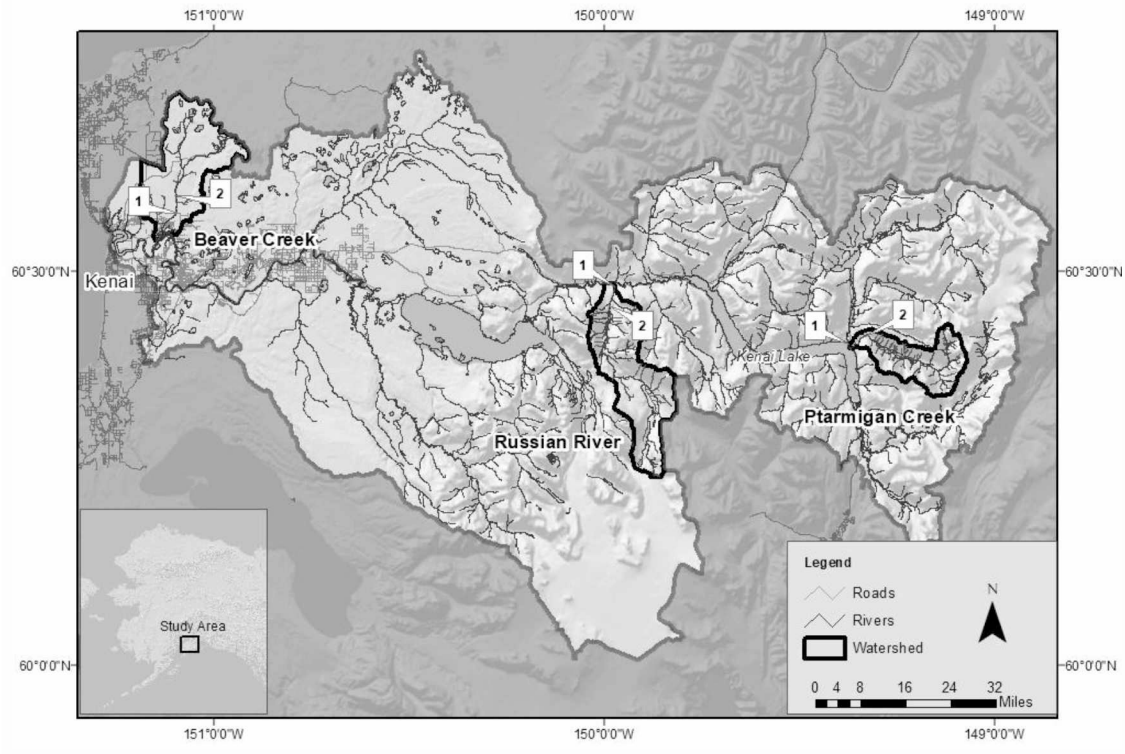


Figure 3.2: Study watersheds within the Kenai River watershed of Southcentral Alaska. Fish sampling sites on each study reach are indicated by numbers 1 and 2.

rivers (Figure 3.2). The Kenai River watershed supports Pink Salmon *O. gorbusha*, Chum Salmon *O. keta*, Sockeye Salmon *O. nerka*, Chinook Salmon *O. tshawytscha*, Coho Salmon, and Rainbow Trout and Steelhead *O. mykiss*.

Extended homogeneous study reaches within three salmon-rearing tributaries (Beaver Creek, Ptarmigan Creek, and Russian River) of the Kenai River were chosen for study that were representative of the most common vegetation types (grass/sedge, shrub, and tree) occuring along streams in the Kenai watershed (Figure 3.3). These extended study reaches were selected to avoid mixing of invertebrate input from diverse vegetation types or the movement of juvenile salmon among riparian habitats (Wipfli 1997; Allan et al. 2003; Roon et al. 2016). Sampling replicates of similar extended homogeneous reaches was not practical, consequently we could not statistically assess effects of riparian type. This study therefore provides a statistical comparison of study reaches and considers how observed differences in prey contributions could be attributed to variation in riparian type.

	Beaver Creek	Ptarmigan Creek	Russian River
			
Reach Length (m)	5100	5500	5000
Reach Width (m)	5	10	15
Reach Slope (%)	1	2	1
Reach Elevation (m)	55	390	460
Watershed Area (sqkm)	156	86	163
Dominant Vegetation	Grassland	Shrubland	Mixed Forest

Figure 3.3: Reach and watershed information for study stream reaches.

Beaver Creek (BC) is a lowland stream with an overall 2% average gradient and 0% direct glacial influence. Vegetation adjacent to the BC study reach was predominately grass and sedge (*Calamagrostis* spp., *Deschmapsia* spp., *Arctogrostis* spp., and *Carex* spp.). Ptarmigan Creek (PC) is a higher elevation glacially-fed stream with an overall 14% average gradient and 7% glacial watershed coverage. Vegetation adjacent to the PC study reach was predominantly shrubs (*Alnus* spp. and *Salix* spp.) as well as deciduous (*Betula* spp. and *Populus* spp.) and

coniferous trees (*Picea* spp.). Russian River (RR) is a montane tributary with an overall 9% average gradient and has minor (< 1%) glacial coverage within its watershed. Vegetation adjacent to the RR study reach is dominated by mixed deciduous and coniferous trees (*Betula* spp., *Populus* spp., and *Picea* spp.) with deciduous shrub (*Alnus* spp. and *Salix* spp.) understory. While areas within the lower Kenai River watershed have experienced substantial human development, the study reaches were generally undeveloped, and as a result riparian habitats were relatively intact and undisturbed.

3.3.2 Characterizing Vegetation Type

Remote sensing data are useful for mapping ecological patterns (Dauwalter et al. 2017), and in this study we used LiDAR data to classify vegetation type adjacent to the three study reaches according to height. The LiDAR data were collected at a horizontal resolution of 1.2m with an expected vertical accuracy of 0.15m. Vegetation height categories were chosen based on vegetation classes defined for Alaska vegetation (Viereck et al. 1992): grass/sedge 0.0-0.6 m shrub >0.6-6.0 m, and tree > 6.0 m. Vegetation was classified 150m upstream/downstream and 20m inland from the stream bank at fish sampling sites and along the study reaches.

3.3.3 Juvenile Salmon Sampling

Fish sampling sites of 150 m were identified at the upper and lower end of each of the three study reaches. Repeat sampling of juvenile Coho Salmon occurred at each sample site during Spring (June), Summer (July), and Fall (August-September) for 2015 and 2016 (Figure 3.2). At each sampling event, six to 12 Gee® minnow traps with 6.4mm mesh were randomly placed. Traps were baited with sterilized salmon roe in perforated Whirl-Pak® bags and submerged 15-45 cm. A total of 1302 traps were set for an average period of 2.5 ± 1.4 hours (mean ± SD).

Captured juvenile salmon were anesthetized by submersion in a bath of AQUI-S 20E™ administered at 20 mg/L for two to three minutes or until fish exhibited total loss of equilibrium. Fork length was measured to the nearest millimeter, and weight was measured to the nearest tenth of a gram with an electronic balance. Gastric lavage sampling of a random subset of captured fish with fork length greater than 50 mm was conducted to determine diet. Stomach contents were preserved in 70% ethanol. All fish were released near the point of capture when

sampling was complete at the end of each day. Juvenile Coho Salmon with no stomach contents or with salmon eggs as stomach contents were not included in the analysis (Table 3.1).

Table 3.1: Fish sampling site, dates, and number of fish sampled within each study reach.

Beaver Creek			Ptarmigan Creek			Russian River		
Site	Date	Fish Sampled	Site	Date	Fish Sampled	Site	Date	Fish Sampled
1	Jun 7, 2015	8	1	Jun 23, 2015	4	1	Jun 8, 2015	1
1	Jul 13, 2015	15	1	Jun 25, 2015	9	1	Jun 9, 2015	1
1	Aug 10, 2015	15	1	Jul 30, 2015	15	1	Jul 14, 2015	10
2	Jun 6, 2015	8	1	Aug 25, 2015	12	1	Aug 11, 2015	16
2	Jul 2, 2015	15	2	Jun 24, 2015	14	1	Jun 19, 2015	6
2	Aug 7, 2015	16	2	Jul 16, 2015	12	2	Jul 15, 2015	11
1	May 25, 2016	14	2	Jul 31, 2015	4	2	Aug 12, 2015	11
1	Jun 20, 2016	10	2	Aug 26, 2015	7	2	May 31, 2016	8
1	Jul 20, 2016	8	1	Jun 5, 2016	6	1	Jul 18, 2016	7
1	Aug 16, 2016	7	1	Jul 1, 2016	8	1	Aug 9, 2016	9
2	May 26, 2016	5	1	Aug 10, 2016	11	1	Sep 2, 2016	9
2	Jun 22, 2016	10	1	Sep 17, 2016	8	1	Jun 1, 2016	10
2	Jul 22, 2016	9	2	Jun 6, 2016	1	2	Jun 30, 2016	9
2	Aug 17, 2016	10	2	Jul 2, 2016	7	2	Aug 6, 2016	10
			2	Aug 11, 2016	9	2	Sep 3, 2016	10
	Total Sampled	150			127			128

Identifiable invertebrates from stomach samples were classified to Family, or the next highest reliable taxa and life stage (Merritt and Cummins 1996). Length of partially digested prey were estimated based on intact individuals of the same taxon that appeared similar in size (Wipfli 1997). Estimation of prey dry mass was based on measured invertebrate body length with the allometric formula $W = aL^b$, where W is total dry body mass, L is total body length, and a and b are constants of the regression between W and L (Ricker 1973). Length-mass regression constants a and b were derived from a database of allometric juvenile salmon prey length-weight relationships (B.E. Meyer, unpublished data).

Invertebrate taxa were grouped into three primary prey categories based on origin and life stage: aquatic (larval and adult life stages of invertebrates that originate and reside in-stream), terrestrial (invertebrates that originate and reside in the terrestrial environment), and aquatic

winged adult (aquatic-born invertebrates that emerge from the stream to the terrestrial environment as winged adults). The origin of some adult Diptera prey taxa were unknown and were categorized as Diptera of unknown origin. The cross-ecosystem contribution to juvenile salmon diet that resulted from the movement of invertebrates from the terrestrial environment to the stream was calculated as the sum of terrestrial, aquatic winged adult, and adult Diptera of unknown origin categories.

The percentage of total invertebrate prey consumed (dry mass) was calculated for each prey category in each study reach to allow comparison of invertebrate prey consumption among study reaches. Dry mass values of fish stomach contents were standardized for fish length to minimize fish-size bias. Arcsine-square-root transformation of percentages was used to standardize variance and improve normality of the data for statistical analysis. One-way analysis of variance (ANOVA-SPSS v.24) of transformed values was used to evaluate the difference between study reaches for invertebrate prey categories using a robust test of equality of means (Welch) and post-hoc Games-Howell tests where equal variances are not assumed (SPSS v.24) were used to conduct pairwise comparison of means between study reaches. Values were considered significant at $\alpha < 0.05$. Lack of replication in treatment categories limits inference to the three study reaches.

3.4 Results

3.4.1 Vegetation Type

The composition of vegetation types adjacent to sample sites differed substantially between study reaches (Figure 3.4). Grass/sedge represented 89%, 12%, and 8%; shrubs 8%, 55%, and 43%; and trees represented 3%, 33%, and 49% at sample sites on BC, PC, and RR respectively. Riparian vegetation types along study reaches were similar to vegetation type found at sampling sites (Figure 3.4).

3.4.2 Invertebrate Contributions to Juvenile Salmon Diet

Stomach contents of 405 juvenile Coho Salmon were analyzed during the 2015 (n=210) and 2016 (n=195) field seasons. In 2015, 76 distinct combinations of taxa and life stage were identified among 2,481 total diet items while in 2016, 96 distinct combinations of taxa and life stage were identified among 6,822 total diet items. The dominant aquatic taxa ingested by

juvenile salmon were similar for all study reaches and consisted primarily of larval life forms of aquatic winged adults including: fly larvae (Diptera), caddisfly larvae (Trichoptera), mayfly larvae (Ephemeroptera), and stonefly larvae (Plecoptera)) (Table 3.2). These taxa represented 92%, 88%, and 95% of the aquatic biomass in juvenile salmon diet for BC, PC, and RR. Wasps and ants (Hymenoptera) were the largest contributors of terrestrial invertebrate biomass for each

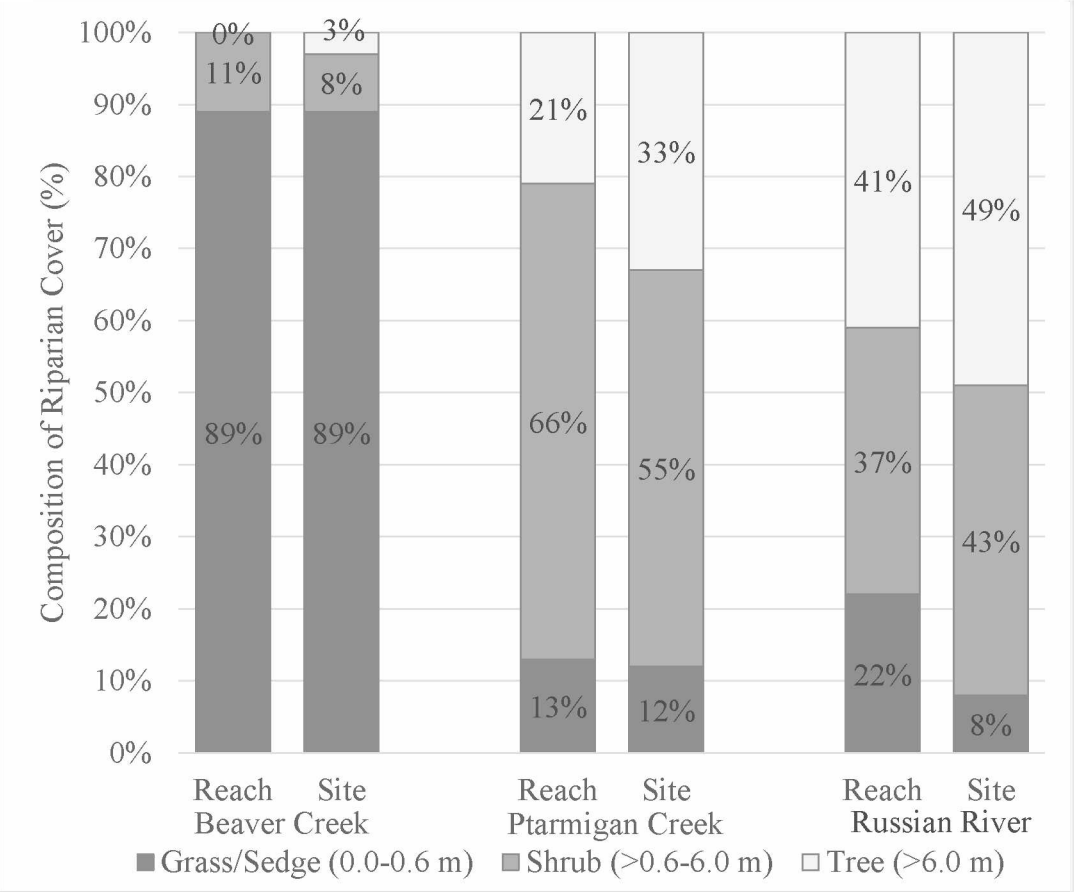


Figure 3.4: Percent composition of riparian cover by vegetation category along study reaches and at fish sampling sites.

of the study reaches providing 39%, 39%, and 31% of the total terrestrial contribution for BC, PC, and RR. Butterfly/moth larvae (Lepidoptera) represented a larger percentage by weight of total invertebrates consumed by salmonids within PC (20%) and RR (9%) as compared to BC (0%); however, they were infrequent in stomach contents (n=17) during the 2015-2016 sampling periods. The combined aquatic winged adult contributions to juvenile salmon diet by adult fly (Diptera), adult mayfly (Ephemeroptera), and adult caddisfly (Trichoptera) represented 100% and 96% within BC and PC respectively for those study reaches. Those taxa represented 74% of

aquatic winged adult invertebrates consumed by juvenile salmon in RR and adult stonefly (Plecoptera) represented 26%.

Table 3.2: Percent of total dry mass consumed by juvenile salmon by taxa for invertebrate prey categories within each study reach.

Invertebrate Prey Category/Taxa	Beaver Creek	Ptarmigan Creek	Russian River
Aquatic			
Caddisfly immature (Trichoptera)	43%	12%	15%
Mayfly immature (Ephemeroptera)	7%	16%	25%
Stonefly immature (Plecoptera)	0%	17%	10%
Fly immature (Diptera)	42%	43%	45%
Diving beetle adult (Coleoptera)	7%	9%	2%
Other	1%	3%	3%
Terrestrial			
Wasp/Ant adult (Hymenoptera)	39%	39%	31%
Beetle adult (Coleoptera)	26%	12%	12%
Butterfly immature (Lepidoptera)	0%	20%	9%
Spider	13%	11%	4%
True bug adult (Hemiptera)	18%	14%	11%
Fly adult (Diptera)	0%	2%	31%
Other	4%	2%	2%
Aquatic Winged Adult			
Caddisfly adult (Trichoptera)	13%	20%	9%
Mayfly adult (Ephemeroptera)	19%	36%	12%
Stonefly adult (Plecoptera)	0%	0%	26%
Fly adult (Diptera)	68%	40%	53%
Other	0%	4%	0%

The contribution of aquatic winged adult invertebrate prey to juvenile salmon diet was 5%, 9%, and 15% for BC, PC, and RR respectively (Figure 3.5 and Tables 3.3a,b) which was statistically different among study reaches ($F_{2, 234.7}$= 4.431, P=0.013). Pair-wise comparison of BC and RR showed significant differences for aquatic winged adult prey contributions (P=0.013). Adult Diptera of unknown origin contributed 17%, 12%, and 26% respectively to total invertebrate prey consumed by juvenile salmon in BC, PC, and RR which was statistically significant among study reaches ($F_{2, 260.8}$= 6.079, P=0.003). Pair-wise comparison between PC and RR showed significant difference for adult Diptera of unknown origin (P=0.002). The proportion of juvenile salmon diet represented by aquatic invertebrates was significantly

different among study reaches ($F_{2, 260.4}$= 13.707, P<0.001) representing 62%, 55%, and 37% respectively for BC, PC, and the RR. Post-hoc comparison showed significant differences between RR and BC (P<0.001) and PC (P=0.001). Terrestrial invertebrate prey contributed 15%, 22%, and 21% for BC, PC, and RR respectively, however these differences were not significantly different ($F_{2, 252.6}$ =1.548, P=0.215).

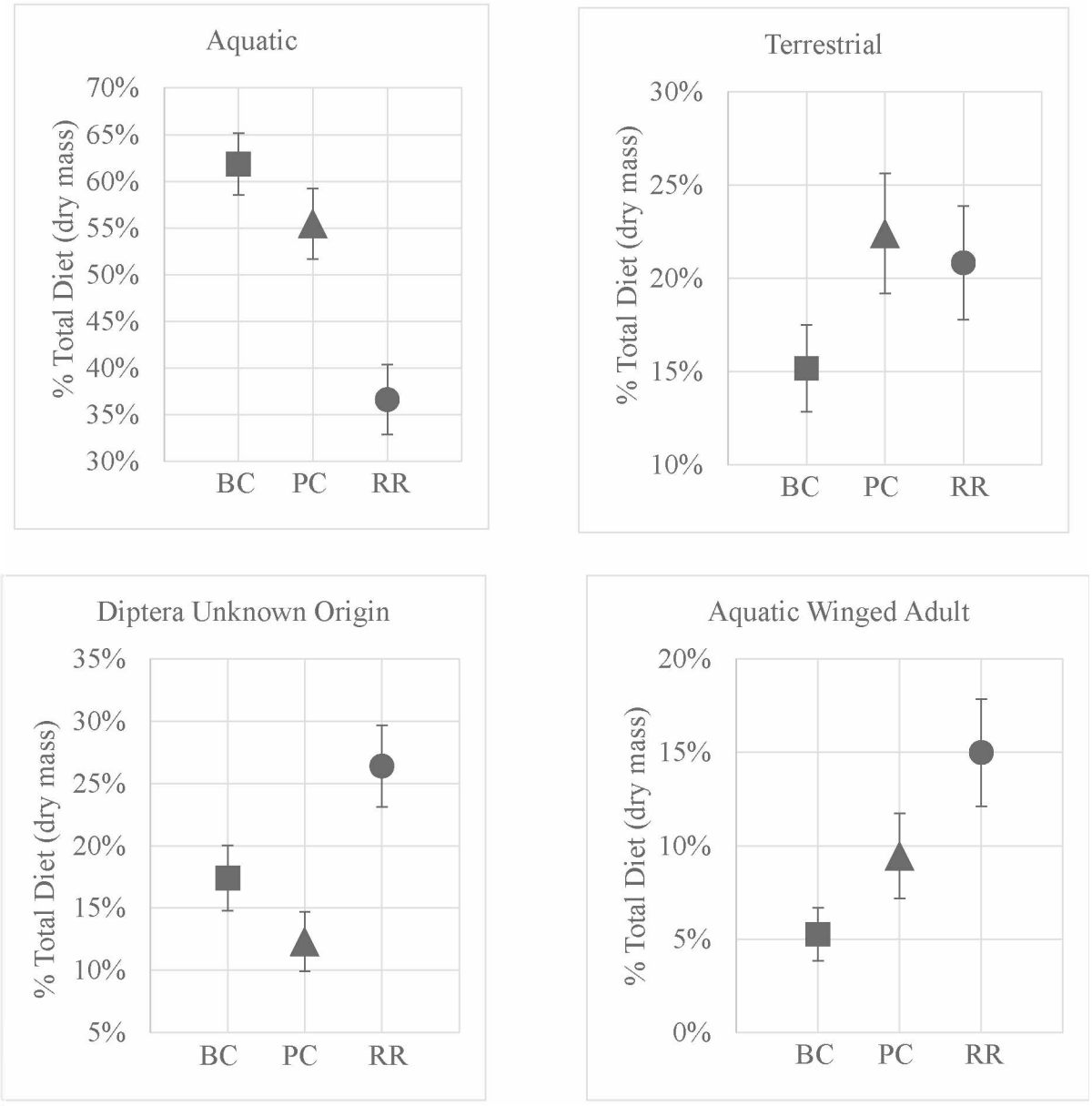


Figure 3.5: Percent of total prey dry mass (all years/dates) ingested by juvenile Coho Salmon in each study reach for each invertebrate prey category (mean ± std dev). Study reaches are: Beaver Creek (BC), Ptarmigan Creek (PC), and Russian River (RR). Note: axis differ on plots.

Table 3.3a: ANOVA results for comparison among study reaches of the percent total invertebrate prey consumed (dry mass) by each invertebrate prey category using a robust test of equality of means (Welch). Degrees of freedom, F and P statistics provided. Values were considered significant at $\alpha < 0.05$.

Invertebrate Prey Category	Fdf	F	P
Aquatic Winged Adult	$F_{2, 234}$	4.431	0.013
Diptera of Unknown Origin	$F_{2, 260.8}$	6.079	0.003
Aquatic	$F_{2, 260.4}$	13.707	<0.001
Terrestrial	$F_{2, 252.6}$	1.548	0.215
Cross-Ecosystem	$F_{2, 260.5}$	12.453	<0.001

Table 3.3b: Significance of post-hoc pair-wise comparisons (Games-Howell) of percent total invertebrate prey dry mass consumed by invertebrate prey category for study reaches. Values were considered significant at $\alpha < 0.05$.

Invertebrate Prey Category		Significance
Aquatic Winged Adult		
	BC x PC	0.307
	BC x RR	0.013
	RR x PC	0.336
Diptera of Unknown Origin		
	BC x PC	0.420
	BC x RR	0.053
	RR x PC	0.002
Aquatic		
	BC x PC	0.395
	BC x RR	0.000
	RR x PC	0.001
Terrestrial		
	BC x PC	0.264
	BC x RR	0.392
	RR x PC	0.965
Cross-Ecosystem		
	BC x PC	0.389
	BC x RR	<0.001
	RR x PC	0.003

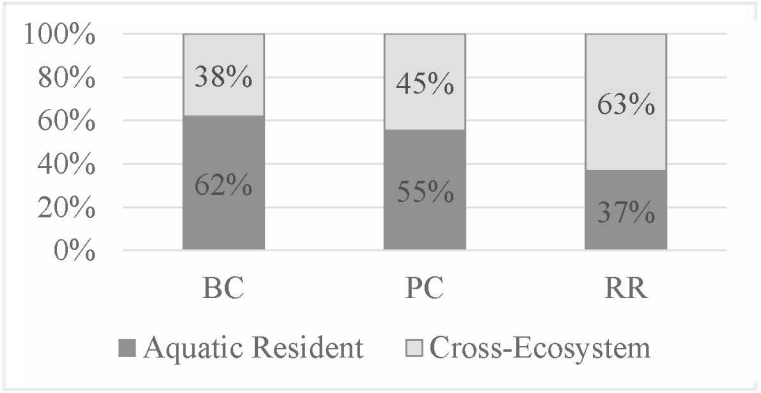


Figure 3.6: Percent of total prey dry mass ingested by juvenile Coho Salmon for cross-ecosystem and aquatic invertebrate prey categories within each study reach.

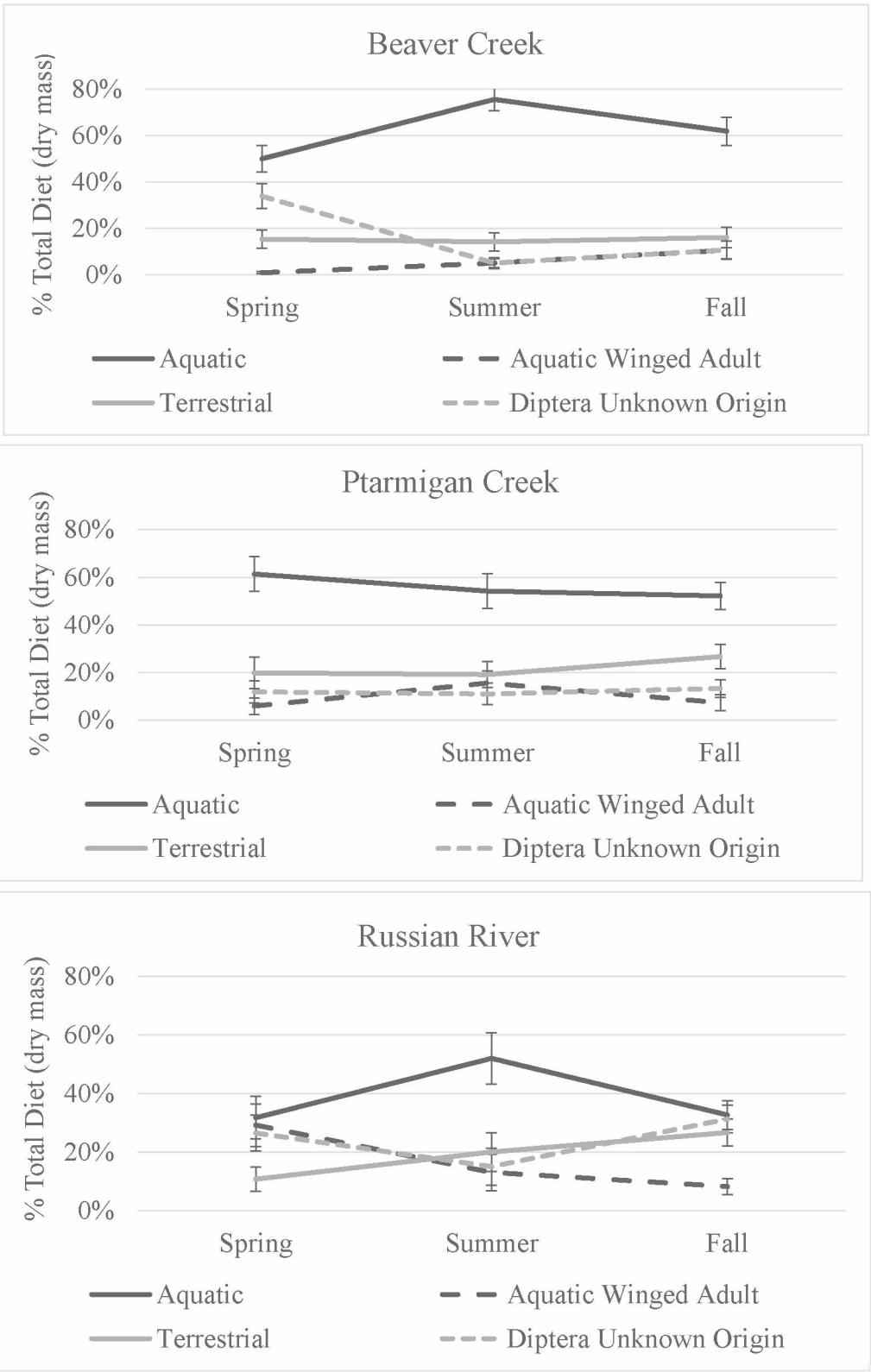


Figure 3.7: Seasonal proportion of juvenile salmon diet contributed by invertebrate prey categories within each of the study reaches.

Contributions by all cross-ecosystem sources of invertebrate prey were 38%, 45%, and 63% respectively for BC, PC, and RR (Figure 3.6) which differed significantly among study reaches ($F_{2, 260.5}$=12.453, P<0.001). Pair-wise comparison showed significant difference in cross-ecosystem invertebrate prey consumed by juvenile salmon in RR as compared to PC (P=0.003) and BC (P<0.001).

Seasonal contribution of invertebrate prey to juvenile salmon diet varied among study reaches (Figure 3.7). Aquatic invertebrates provided the majority (>50%) of prey resources to juvenile salmon in BC and PC throughout the year. In RR, aquatic invertebrate contributions decreased below 50% in Spring which was coincident with increased fractional consumption by juvenile salmon of Diptera of unknown origin and aquatic winged adult invertebrate prey and again in Fall when terrestrial and Diptera of unknown origin prey provided increased fractional contributions to diet. During Spring in BC, a reduction in the proportion of aquatic prey consumption was coincident with an increase in the proportion of Diptera of unknown origin consumed by juvenile salmon.

3.5 Discussion

Our results support the prediction that the fractional contribution to juvenile salmon diet of aquatic winged adult and cross-ecosystem invertebrates would be lower in streams with more open grass/sedge riparian habitats than those in shrub or tree riparian habitats. We found the proportion of juvenile Coho Salmon diet provided by cross-ecosystem invertebrate prey (terrestrial, aquatic winged adult, and Diptera of unknown origin) was significantly lower in grass/sedge (BC) and shrub (PC) study reaches than was observed in the tree (RR) study reach (38%, 45%, and 63% respectively). Observed differences in cross-ecosystem prey contributions among study reaches resulted in part from variation in the proportion of aquatic winged adults and Diptera of unknown origin in juvenile salmon diet. Aquatic winged adult and Diptera of unknown origin together contributed 22%, 21%, and 41% respectively to juvenile salmon diet in grass/sedge, shrub, and tree study reaches. The immature form of these taxa represented the dominant aquatic resident taxa consumed by juvenile salmon in each of the study reaches; however, the proportion of aquatic winged adult invertebrates that returned to the stream and were consumed by juvenile salmon was significantly lower in the grass/sedge (5%) vs. tree

(15%) reaches. Diptera of unknown origin provided a greater proportion of prey contributions to diet for juvenile salmon in the tree study reach (26%) as compared to the grass/sedge (17%) and shrub reaches (12%).

The observed differences between study reaches for terrestrial invertebrate contributions to juvenile salmon diet were not statistically significant. High variability in the size and frequency of terrestrial invertebrate prey observed in juvenile salmon diet contributed to the lack of significance in comparisons between study reaches. Understory vegetation within the tree reach was similar to the shrub reach and similar terrestrial invertebrate contributions were observed (21% and 22% respectively). The percent contribution of terrestrial invertebrates in the grass/sedge study reach was generally lower (15%). Prior studies have found greater terrestrial invertebrate in-fall to streams in areas of deciduous riparian shrub and tree habitat as compared to coniferous forest (Wipfli 1997; Allan et al. 2003; Inoue et al. 2013), pasture (Edwards and Huryn 1995), and grasslands (Kawaguchi and Nakano 2001). Consequently, greater observed terrestrial prey contributions from tree and shrub vegetation types as compared to grass/sedge would be expected.

Observed consumption of aquatic winged adult prey varied seasonally, and aquatic winged adults represented approximately 30% of spring invertebrate consumption in the tree study reach. Seasonal consumption of Diptera of unknown origin (~30%) was observed during spring (grass/sedge and tree study reaches) and fall (tree study reach). Increased consumption of terrestrial, aquatic winged adult, and Diptera of unknown origin was generally associated with decreases in aquatic invertebrate consumption in grass/sedge and tree study reaches and most likely were the result of emergence or hatching events. Opportunities to measure invertebrate consumption associated with emergence or hatching events were constrained by the gastric evacuation rates of juvenile salmon (Allan et al. 2003; Sweka et al. 2004; Armstrong et al. 2013) and frequency of sampling.

Our results suggest that increased dispersal of aquatic winged adult insects and Diptera of unknown origin may reduce in-fall of those taxa as prey in open riparian habitats. Abundance of aerial insects has been found to be high in areas of open riparian habitats such as grass or clear-

cut (Hetrick et al. 1998; Albertson et al. 2018); however, there is no strong correlation between aerial abundance and in-fall to streams (Hetrick et al. 1998; Inoue et al. 2013). Open areas expose insects to greater wind velocities that facilitate downwind drift and dispersal of weak-flying insects while taller riparian vegetation such as shrubs and trees can serve as habitat (Kuusela and Huusko 1996; Petersen et al. 1999; Delettre and Morvan 2000) that collects flying insects at stream margins (Helle and Muona 1985; Whitaker et al. 2000), and increases opportunities for in-fall (Cadwallder et al. 1980; Baxter et al. 2005; Saunders and Fausch 2007).

Within the Kenai watershed, late seral stage boreal forests are predicted to be replaced by persistent grasslands (Wolken et al. 2011; Hansen et al. 2016) as mean annual temperatures continue to increase, total annual precipitation decreases (Wolken et al. 2011; Bauret and Stuefer 2013; Schoen et al. 2017), and the frequency and intensity of disturbance events such as wildfire and insect outbreaks increase (Lynch et al. 2002; Klein et al. 2005; Berg et al. 2006). In addition, human development along the lower Kenai River is resulting in increased clearing within riparian areas (Schoen et al. 2017). While change in riparian vegetation from tree/shrub to grass/sedge can be expected to reduce contributions of cross-ecosystem invertebrates to juvenile salmon diet, research has shown that fish response to changing climate and habitat can be complex (Wainwright and Weitkamp 2013; Naman et al. 2018). Localized reduction of cross-ecosystem contributions to streams may result in reduced fish biomass in stream reaches due to movement of fish to more prey-rich areas (Kawaguchi and Nakano 2001; Kawaguchi et al. 2003) as well as increased predation of resident aquatic invertebrates (Nakano et al. 1999). In freshwater habitats where productivity is low, juvenile salmon are often dependent on the movement of prey resources from the terrestrial environment to streams (Allen 1951; Huryn 1996; Richardson et al. 2010). Widespread reduction in the availability of cross-ecosystem prey for resident fish may therefore result in reduced fish growth, fitness, and density when and where fish are food-limited (Sweka and Hartman 2008; Fischer et al. 2010; Inoue et al. 2013). Alternatively, a shift to more open riparian canopy could raise stream temperatures, increasing in-stream production of autotrophic aquatic invertebrate prey, and providing thermal habitats that promote fish growth and influence fish distribution (Hartman and Scrivener 1990; Armstrong and Schindler 2013; Tschaplinski and Pike 2017). In addition, increased predation risk due to

lack of cover can lead to a shift in foraging behavior and diet that can result in altered growth for stream fishes (Dill and Fraser 1984; Reinhardt 1999; Allouche and Gaudin 2001).

While riparian areas generally represent a small portion of a total watershed, they can have a large effect on stream fish (Naiman et al. 2005; Wipfli and Baxter 2010; Wipfli and Richardson 2015). Our results document decreased aquatic winged adult and cross-ecosystem prey consumption that is correlated with more open riparian canopy. These results allow us to better understand how environmental or anthropogenic caused change in riparian vegetation might affect invertebrate prey contributions to juvenile salmon diet within the Kenai watershed. Monitoring change in riparian habitat using remote sensing data such as LiDAR can help us identify the extent of those changes, and management of riparian buffers along streams is likely to help mitigate potential impacts of those changes.

3.6 Acknowledgements

This study was funded by the Alaska Experimental Program to Stimulate Competitive Research (Alaska EPSCoR) NSF award #OIA-1208927 with matching funds from the state of Alaska. The authors gratefully acknowledge review and advice provided by Dr. Barbara Adams, Dr. Anthony (Dave) McGuire and Dr. Daniel Rinella. Technicians Emily Neideigh and Christina Mielke helped with laboratory work and fieldwork throughout the project. LiDAR data were provided by the NOAA Office for Coastal Management, Kenai Watershed Forum, Kenai Peninsula Borough, University of Alaska and Alaska EPSCoR. Database of allometric juvenile salmon prey length-weight relationships is available from authors. This work was conducted under University of Alaska Fairbanks IACUC permits 720490-1 and 720490-2 and State of Alaska Department of Fish and Game fish resource permits SF2015-191 and SF2016-158. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

3.7 Literature Cited

Albertson, L. K., V. Ouellet, and M. D. Daniels. 2018. Impacts of stream riparian buffer land use on water temperature and food availability for fish. Journal of Freshwater Ecology 33(1):195–210.

Allan, J. D., M. S. Wipfli, J. P. Caouette, A. Prussian, and J. Rodgers. 2003. Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs. Canadian Journal of Fisheries and Aquatic Sciences 60(3):309–320.

Allen, K. R. 1951. The Horokiwi stream : a study of a trout population. Page 231. New Zealand Department of Fish, Bull. 10, 231pp.

Allouche, S., and P. Gaudin. 2001. Effects of avian predation threat, water flow and cover on growth and habitat use by chub, Leuciscus cephalus, in an experimental stream. Oikos 94(3):481–492.

Armstrong, J. B., and D. E. Schindler. 2013. Going with the Flow: Spatial Distributions of Juvenile Coho Salmon Track an Annually Shifting Mosaic of Water Temperature. Ecosystems 16(8):1429–1441.

Armstrong, J. B., D. E. Schindler, C. P. Ruff, G. T. Brooks, K. E. Bentley, and C. E. Torgersen. 2013. Diel horizontal migration in streams: juvenile fish exploit spatial heterogeneity in thermal and trophic resources. Ecology 94(9):2066–2075.

Bauret, S., and S. Stuefer. 2013. Kenai Peninsula Precipitation and Air Temperature Trend Analysis. Pages 35–44 19th International Northern Research Basins Symposium and Workhop. Southeast Alaska.

Baxter, C. V., K. D. Fausch, and W. Carl Saunders. 2005. Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones: Prey subsidies link stream and riparian food webs. Freshwater Biology 50(2):201–220.

Berg, E. E., J. David Henry, C. L. Fastie, A. D. De Volder, and S. M. Matsuoka. 2006. Spruce beetle outbreaks on the Kenai Peninsula, Alaska, and Kluane National Park and Reserve, Yukon Territory: Relationship to summer temperatures and regional differences in disturbance regimes. Forest Ecology and Management 227(3):219–232.

Bohonak, A. J., and D. G. Jenkins. 2003. Ecological and evolutionary significance of dispersal by freshwater invertebrates. Ecology Letters 6(8):783–796.

Briers, R. A., H. M. Cariss, and J. H. Gee. 2003. Flight activity of adult stoneflies in relation to weather. Ecological Entomology 28(1):31–40.

Briers, R. A., H. M. Cariss, R. Geoghegan, and J. H. Gee. 2005. The lateral extent of the subsidy from an upland stream to riparian lycosid spiders. Ecography 28(2):165–170.

Briers, R. A., and J. H. Gee. 2004. Riparian forestry management and adult stream insects. Hydrology and Earth System Sciences 8(3):545–549.

Cadwallder, P. L., A. K. Eden, and R. A. Hook. 1980. Role of Streamside Vegetation as a Food Source for Galaxias Olidus Günther (Pisces: Galaxiidae). Marine and Freshwater Research 31(2):257-257–262.

Collier, K. J., and B. J. Smith. 1997. Dispersal of adult caddisflies (Trichoptera) into forests alongside three New Zealand streams. Hydrobiologia 361(1–3):53–65.

Dauwalter, D. C., K. A. Fesenmyer, R. Bjork, D. R. Leasure, and S. J. Wenger. 2017. Satellite and Airborne Remote Sensing Applications for Freshwater Fisheries. Fisheries 42(10):526–537.

Delettre, Y. R., and N. Morvan. 2000. Dispersal of adult aquatic Chironomidae (Diptera) in agricultural landscapes. Freshwater Biology 44:399–411.

Dill, L. M., and A. H. G. Fraser. 1984. Risk of predation and the feeding behavior of juvenile coho salmon (Oncorhynchuskisutch). Behavioral Ecology and Sociobiology 16:65–71.

Edwards, E. D., and A. D. Huryn. 1995. Annual contribution of terrestrial invertebrates to a New Zealand trout stream. New Zealand Journal of Marine and Freshwater Research 29(4):467–477.

Fischer, J. R., M. C. Quist, S. L. Wigen, A. J. Schaefer, T. W. Stewart, and T. M. Isenhart. 2010. Assemblage and Population-Level Responses of Stream Fish to Riparian Buffers at Multiple Spatial Scales. Transactions of the American Fisheries Society 139(1):185–200.

Garman, G. C. 1991. Use of terrestrial arthropod prey by a stream-dwelling cyprinid fish. Environmental Biology of Fishes 30(3):325–331.

Greenwood, M. J. 2014. More than a barrier: The complex effects of ecotone vegetation type on terrestrial consumer consumption of an aquatic prey resource: Riparian Plants Alter Aquatic Prey Supply. Austral Ecology 39(8):941–951.

Hansen, W. D., F. S. Chapin, H. T. Naughton, T. S. Rupp, and D. Verbyla. 2016. Forest-landscape structure mediates effects of a spruce bark beetle (Dendroctonus rufipennis) outbreak on subsequent likelihood of burning in Alaskan boreal forest. Forest Ecology and Management 369:38–46.

Hartman, G. F., and J. C. Scrivener. 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin of Fisheries and Aquatic Sciences, Department of Fisheries and Oceans, Ottawa.

Helle, P., and J. Muona. 1985. Invertebrate numbers in edges between clear-fellings and mature forests in northern Finland. Silva Fennica 19(3):281–294.

Hetrick, N. J., M. A. Brusven, T. C. Bjornn, R. M. Keith, and W. R. Meehan. 1998. Effects of Canopy Removal on Invertebrates and Diet of Juvenile Coho Salmon in a Small Stream in Southeast Alaska. Transactions of the American Fisheries Society 127(6):876–888.

Hunt, R. L., and E. M. Krokhin. 1975. Food Relations and Behavior of Salmonid Fishes. Pages 137–156 in A. D. Hasler, editor. Coupling of Land and Water Systems. Springer Berlin Heidelberg, Berlin, Heidelberg.

Huryn, A. D. 1996. An appraisal of the Allen paradox in a New Zealand trout stream. Limnology and Oceanography 41(2):243–252.

Inoue, M., S. Sakamoto, and S. Kikuchi. 2013. Terrestrial prey inputs to streams bordered by deciduous broadleaved forests, conifer plantations and clear-cut sites in southwestern Japan: effects on the abundance of red-spotted masu salmon. Ecology of Freshwater Fish 22(3):335–347.

Jackson, J. K., and S. G. Fisher. 1986. Secondary Production, Emergence and Export of Aquatic Insects of a Sonoran Desert Stream. Ecology 67(3):629–638.

Kawaguchi, Y., and S. Nakano. 2001. Contribution of terrestrial invertebrates to the annual resource budget for salmonids in forest and grassland reaches of a headwater stream. Freshwater Biology 46(3):303–316.

Kawaguchi, Y., Y. Taniguchi, and S. Nakano. 2003. Terrestrial invertebrate inputs determine the local abundance of stream fishes in a forested stream. Ecology 84(3):701–708.

Klein, E., E. E. Berg, and R. Dial. 2005. Wetland drying and succession across the Kenai Peninsula Lowlands, south-central Alaska. Canadian Journal of Forest Research 35(8):1931–1941.

Kuusela, K., and A. Huusko. 1996. Post-emergence migration of stoneflies (Plecoptera) into the nearby forest. Ecological Entomology 21(2):171–177.

Lynch, J. A., J. S. Clark, N. H. Bigelow, M. E. Edwards, and B. P. Finney. 2002. Geographic and temporal variations in fire history in boreal ecosystems of Alaska. Journal of Geophysical Research 108(D1):801–817.

Mason, C. F., and S. M. Macdonald. 1982. The input of terrestrial invertebrates from tree canopies to a stream. Freshwater Biology 12:305–311.

Merritt, R. W., and K. W. Cummins, editors. 1996. An introduction to the aquatic insects of North America3rd ed. Kendall/Hunt Pub. Co, Dubuque, Iowa. pp862.

Naiman, R. J., H. Decamps, and M. E. McClain. 2005. Riparia: Ecology, Conservation and Management of Streamside Communities. Elsevier Academic Press, Burlington, MA.

Nakano, S., H. Miyasaka, and N. Kuhara. 1999. Terrestrial-Aquatic Linkages: Riparian Arthropod Inputs Alter Trophic Cascades in a Stream Food Web. Ecology 80(7):2435–2441.

Naman, S. M., J. S. Rosenfeld, P. M. Kiffney, and J. S. Richardson. 2018. The energetic consequences of habitat structure for forest stream salmonids. Journal of Animal Ecology. DOI: 10.1111/1365-2656.12845.

Parkyn, S. M., and B. J. Smith. 2011. Dispersal Constraints for Stream Invertebrates: Setting Realistic Timescales for Biodiversity Restoration. Environmental Management 48(3):602–614.

Petersen, I., J. H. Winterbottom, S. Orton, N. Friberg, A. G. Hildrew, D. C. Spiers, and others. 1999. Emergence and lateral dispersal of adult Plecoptera and Trichoptera from Broadstone Stream, UK. Freshwater Biology 42(3):401–416.

Polis, G. A., W. B. Anderson, and R. D. Holt. 1997. Toward an integration of landscape and food web ecology: the dynamics of spatially subsidized food webs. Annual Review of Ecology and Systematics 28(1):289–316.

Reinhardt, U. G. 1999. Predation risk breaks size-dependent dominance in juvenile coho salmon (Oncorhynchus kisutch) and provides growth opportunities for risk-prone individuals. Canadian Journal of Fisheries and Aquatic Sciences 56:1206–1212.

Richardson, J. S., Y. Zhang, and L. B. Marczak. 2010. Resource subsidies across the land-freshwater interface and responses in recipient communities. River Research and Applications 26(1):55–66.

Ricker, W. E. 1973. Linear Regressions in Fishery Research. Journal of the Fisheries Research Board of Canada 30(3):409–434.

Roon, D. A., M. S. Wipfli, and J. J. Kruse. 2018. Riparian defoliation by the invasive green alder sawfly influences terrestrial prey subsidies to salmon streams. Ecology of Freshwater Fish. DOI: 10.1111/eff.12407.

Roon, D. A., M. S. Wipfli, T. L. Wurtz, and A. L. Blanchard. 2016. Invasive European bird cherry (Prunus padus) reduces terrestrial prey subsidies to urban Alaskan salmon streams. Canadian Journal of Fisheries and Aquatic Sciences 73(11):1679–1690.

Saunders, W. C., and K. D. Fausch. 2007. Improved Grazing Management Increases Terrestrial Invertebrate Inputs that Feed Trout in Wyoming Rangeland Streams. Transactions of the American Fisheries Society 136(5):1216–1230.

Schoen, E. R., M. S. Wipfli, E. J. Trammell, D. J. Rinella, A. L. Floyd, J. Grunblatt, M. D. McCarthy, B. E. Meyer, J. M. Morton, J. E. Powell, A. Prakash, M. N. Reimer, S. L. Stuefer, H. Toniolo, B. M. Wells, and F. D. W. Witmer. 2017. Future of Pacific Salmon in the Face of Environmental Change: Lessons from One of the World's Remaining Productive Salmon Regions. Fisheries 42(10):538–553.

Sweka, J. A., and K. J. Hartman. 2008. Contribution of Terrestrial Invertebrates to Yearly Brook Trout Prey Consumption and Growth. Transactions of the American Fisheries Society 137(1):224–235.

Sweka, J. A., M. Keith Cox, and K. J. Hartman. 2004. Gastric Evacuation Rates of Brook Trout. Transactions of the American Fisheries Society 133(1):204–210.

Tschaplinski, P. J., and R. G. Pike. 2017. Carnation Creek watershed experiment-long-term responses of coho salmon populations to historic forest practices: Carnation Creek Watershed Experiment. Ecohydrology 10(2):e1812.

Viereck, L. A., C. T. Dyrness, A. R. Batten, and K. J. Wenzlick. 1992. The Alaska vegetation classification. Page 278 p. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR:US. 278p.

Wainwright, T. C., and L. A. Weitkamp. 2013. Effects of Climate Change on Oregon Coast Coho Salmon: Habitat and Life-Cycle Interactions. Northwest Science 87(3):219–242.

Whitaker, D. M., A. L. Carroll, and W. A. Montevecchi. 2000. Elevated numbers of flying insects and insectivorous birds in riparian buffer strips. Canadian Journal of Zoology 78(5):740–747.

Winterbourn, M. J., W. L. Chadderton, S. A. Entrekin, J. L. Tank, and J. S. Harding. 2007. Distribution and dispersal of adult stream insects in a heterogeneous montane environment. Fundamental and Applied Limnology / Archiv für Hydrobiologie 168(2):127–135.

Wipfli, M. S. 1997. Terrestrial invertebrates as salmonid prey and nitrogen sources in streams: contrasting old-growth and young-growth riparian forests in southeastern Alaska, USA. Canadian Journal of Fisheries and Aquatic Sciences 54(6):1259–1269.

Wipfli, M. S., and C. V. Baxter. 2010. Linking Ecosystems, Food Webs, and Fish Production: Subsidies in Salmonid Watersheds. Fisheries 35(8):373–387.

Wipfli, M. S., and J. S. Richardson. 2015. Management and the conservation of freshwater ecosystems. Pages 270–291. Cambridge University Press.

Wolken, J. M., T. N. Hollingsworth, T. S. Rupp, F. S. Chapin, S. F. Trainor, T. M. Barrett, P. F. Sullivan, A. D. McGuire, E. S. Euskirchen, P. E. Hennon, E. A. Beever, J. S. Conn, L. K. Crone, D. V. D'Amore, N. Fresco, T. A. Hanley, K. Kielland, J. J. Kruse, T. Patterson, E. A. G. Schuur, D. L. Verbyla, and J. Yarie. 2011. Evidence and implications of recent and projected climate change in Alaska's forest ecosystems. Ecosphere 2(11):1–35.

Chapter 4: Role of Local Media in Promoting Science Communication[3]

4.1 Abstract

News media play an important role in the communication of science to the public, and research describes a shift in public consumption of news from local to national media sources. Characterization of differences between local and national media reporting can help us better understand the significance of this shift. This analysis compared media content regarding environmental change, climate change, and global warming among national and local media sources. Results showed distinct differences in frequency of occurrence of terms, voice, and sentiment within media content. Local media can promote salience through opportunities that derive from scale for relevant framing and trusted voice. Replacing local media with national media content may shift public awareness and engagement with environmental change issues.

4.2 Introduction

News media play a role in the exchange of information between science, policy, and public spheres of society (Boykoff and Boykoff 2007; McCombs and Shaw 1972; Rice and Giles 2017). Evaluation of news media content can therefore provide insight into what information is available within a community and how that information might influence awareness of environmental change (Peeples 2015; Sampei and Aoyagi-Usui 2009; Wahlberg and Sjoberg 2000). This study compares local and national news media content regarding environmental change, climate change, and global warming to help us better understand how that information informs public perception of environmental change.

Studies of environmental news reporting generally focus on national or international media, and the importance of local reporting has received less attention (Hansen 2011; Lawhon, Pierce, and Bouwer 2018). Local media coverage can be expected to be different from national reporting as it provides content that is relevant to the everyday lives of its audience and emphasizes local voices of authority (Crawley 2007; Hester and Gibson 2007; Wakefield and Elliott 2003). Hopkins (2018) describes a nationalization of political behavior as audiences shift

[3]Grunblatt, J. (2019), Role of Local Media in Promoting Science Communication. To be submitted for publication to Science Communication, Sage Publications.

from local news media toward larger nationally oriented sources. If local environmental reporting is distinctive, then a shift towards national reporting can be expected to affect public awareness of environmental change and engagement with environmental issues. Characterization of the differences between local and national level environmental reporting is therefore important to help us recognize and better understand the significance of this shift.

This study examines differences between local and national level environmental reporting using a social identity lens. The social identity approach maintains that our concept of self is derived from both personal identity which is individual and idiosyncratic (self-characterization) as well as group identity (social identity) where one has a sense of inclusion in a larger group and a shared perspective (Fielding and Hornsey 2016; Tajfel 1974). Group identity is socially derived from in-group versus out-group orientation and group members are motivated to see their group as positive and distinct from other relevant groups (Frank et al. 2011; Fielding and Hornsey 2016; Brieger 2018). Tensions that result from discord among groups can diminish collaboration and consensus (Lopez Porras, Stringer, and Quinn 2018; Suls and Wills 1991; Tajfel et al. 1971) and adversely impact decision making and inclusive governance (Jones 2011).

4.3 Background

Language is a fundamental component of group identity that can influence a persons' assimilation of information (Fairclough 1989; Kinzler, Dupoux, and Spelke 2007; Nauroth et al. 2016). The language of science may not be familiar to non-scientists and as a result, scientists can appear outside the group with which they are trying to communicate (Gallois et al. 2017; Kinzler et al. 2007; Raman and Mohr 2014). In addition, the scientific method generally includes descriptions of uncertainty which may obscure the "straight answers" that are sought when issues are considered by public or policy audiences (Krieger and Gallois 2017). Therefore a scientist may not be an effective communicator when discussions focus on "the right thing to do" (Gallois et al. 2017). The elite cues hypothesis further suggests that individuals form opinions based on cues given by elites with whom they identify, and political elites have been shown to be effective in challenging expert opinion within groups that share their ideological orientation (Bolin and Hamilton 2018; Darmofal 2005). Mazur and Lee (1993) found that public

concern about environmental issues tended to be affected more by the amount of media attention issues received rather than the substantive content of the reporting.

More generally, the delivery of information to the public can be thought of as a marketplace in which media compete for audience and revenue (Hansen 2016). In this environment, journalistic norms of impartiality, accuracy and objectivity can shift toward concern about gaining attention, guiding understanding and defining consensus (Hansen 2016). Individuals often select information that reinforces their beliefs (selective exposure) (Brannon, Tagler, and Eagly 2007; Knobloch-Westerwick and Johnson 2014) and use information based on how it supports or conflicts with their beliefs (confirmation bias, biased assimilation and motivated reasoning) (Corner, Whitmarsh, and Xenias 2012; Kunda 1990; Lord, Ross, and Lepper 1979). Prior studies have identified the expanding use of consultants, focus groups and polls to develop media content that is intended to appeal to specific target groups through deliberate choice of language and spokespersons (Gentzkow, Shapiro, and Taddy 2016; Goffman 1974; Kinzler et al. 2007). These trends in the targeted consumption and production of information are reflected in research that identifies increasing polarization in national media coverage and public perception of climate change issues (Maibach et al. 2009; Lewandowsky et al. 2015; Pew Research 2014).

National or international environmental reporting generally contains content that is distant with regard to an individual, and coverage frequently emphasizes unfamiliar expert voices. Construal theory suggests that engagement with issues becomes associated with an individual's abstract beliefs and values as issues become more uncertain, remote in time/space or diminish in impact to ones' self or social group (cognitive distance) (Spence, Poortinga, and Pidgeon 2012). As a result, national or international reporting would be expected to be assimilated in a manner that conforms to in-group norms. Local reporting such as community newspapers remain important because they provide opportunity for framing through voice and content that is proximate and therefore engages with individuals in a manner that promotes a sense of personal involvement and agency. The social identity approach recognizes that individual preferences may not strictly adhere to shared in-group preferences or ideology and can be motivated by an individual sense of what is appropriate (Dixon, Hmielowski, and Ma 2017;

Fielding and Hornsey 2016; Goldberg et al. 2019). Local news media can potentially provide an important bridge between local perception of environmental change and a more general discussion of climate change in a manner that transcends social identity and promotes social cohesion.

This study compares media content regarding environmental change, climate change, and global warming between two large national media outlets that represent distinct, polarized perspectives and contrasts that coverage with a local media outlet. It identifies differences in news media content, voice and sentiment that are associated with these media sources to better understand the potential shift in perspective that may occur as local media coverage is replaced by national or global sources.

4.4 Methods

This analysis evaluates two major national news media sources, Fox News (FOX) and New York Times (NYT), that represent politically polarized viewpoints regarding environmental change, climate change, and global warming (Pew Research Center 2014). A local Alaska news media source, the Kenai Peninsula Clarion (KPC) was also selected for comparison. These news media sources were not intended to be broadly representative of news media. They are a purposeful sample intended to characterize the polarization of environmental/climate change reporting at the national level and allow comparison of those sources with a media source that focuses on reporting at a local level.

This study investigated frequency of occurrence of content (term frequency), voice (named entity) and sentiment within media reporting. Frequency was chosen as a primary metric as prior studies have shown that public concern about environmental issues tended to be affected more by the amount of media attention issues received rather than the substantive content of the reporting (Mazur and Lee 1993).

News articles were obtained through online queries at each media website using search tools provided at the site. News articles were selected using the following search terms: climate change, environmental change, global change, global warming, climate science, greenhouse gas,

sea level rise, climate assessment, and changing climate. Individual articles for each site were compiled, and the text associated with each article was extracted to create a corpus for analysis.

Automated content analysis was used to determine frequency of terms and named entities. Term frequency within articles was determined using the word list function of Atlas.ti (version 8) with a standard stopword list and ignoring capitalization. Frequency of occurrence for people and organizations was determined using Stanford Named Entity Recognition (NER) tools (version 3.9.2). Synonyms within results for terms and named entities were combined. The most frequently occurring terms and organizations from each media source were compared for shared occurrence. Person named entities for each media source contained few high frequency names and categories of 'Fox Correspondents' and 'Various Residents' were created within FOX and KPC respectively to group low frequency named entities that represented similar voices.

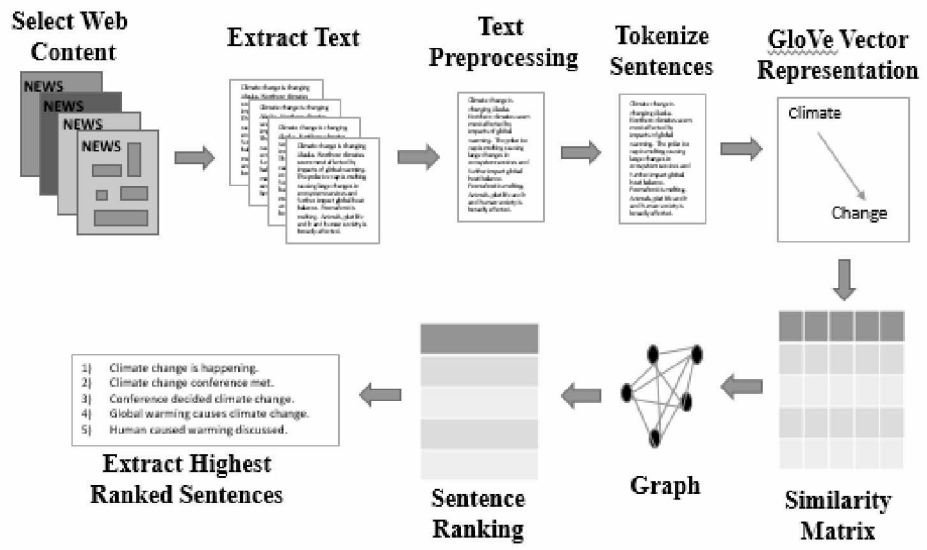


Figure 4.1: Workflow for extractive, content summary.

Article sentiment was evaluated using manual coding. This study investigated the use of an unsupervised extractive content summary technique to maintain frequency (i.e. number of articles) yet reduce the volume of material for manual coding (Figure 4.1). Content was selected from each news source using site search tools, and text was extracted and preprocessed to remove punctuation, special characters, stopwords and capitalization. Within each media article, sentences were split using the Stanford natural language processing sentence tokenizer. Similarity among pairs of sentences within an article was calculated according to a cosine-

similarity approach that used GloVe vector representation of words as a measure of similarity (Pennington, Socher, and Manning 2014). The five most similar sentences were extracted for coding along with the title for each article using a TextRank, graph-based model (Mihalcea and Tarau 2004; Poomagal and Hamsapriya 2011).

Table 4.1: Code descriptions for manual coding of media content.

Code	Description
Negative	Refutes climate change through direct negative comments or by allusion to political context (or person) that is negative. Use of irony or uncertainty to imply doubt of climate change.
Positive	Includes some assertion of climate change occurring or its effects recognized and described. Positive support for concept of climate change. Includes critical treatment of negative assertions, actions or sentiment.
Unclear	Stance not clearly represented in text. This is different from doubt as to whether climate change is real.
Not Relevant	No apparent reference or treatment of search terms in text.
Economic/Social/Health	Includes statements of economic, social or health impacts including national security that are backed up by analysis rather than personal reflection.
Lifestyle/Cultural/Anecdotal	General observation or non-technical reference including speculation or personal observation. Includes description of proposed research, religious based guidance, or an individual's political statement.
Politics	Pertains to institutions of law and governance. Statements by public official, spokesperson, or political entity meant to influence opinion or judgement. Large demonstration or gathering for the purpose of making a statement.
Science-based Assessment	Relies on natural or social science studies and includes statement of specific objectives and results. Statements by professional scientist regarding their research.
Limited Anecdotal Reference	Modifier for 'Not Relevant'. Anecdotal reference to climate/global/environmental change (or other search terms). Content does not pertain to search terms.
Limited Direct Reference	Modifier for 'Not Relevant'. Limited reference to climate/global/environmental change (or other search terms) that have direct application to rest of text.

Sentiment can be characterized using a multi-dimensional model that defines emotion along axes of valence, intensity, and dominance (Bakker et al. 2014; Russell 1980; Tian, Lai, and

Moore 2018). The use of article summaries limited the amount of information available from each article making interpretation of intensity and dominance difficult; therefore, only valence was interpreted. Valence describes the positive-negative aspects of sentiment.

Article summaries were randomly selected from the corpus during coding. Structural coding (Saldaña 2013) was initially used to identify the relevance of each article summary to the search criteria using a binary coding scheme (relevant, not relevant). Article summaries that were identified as 'not relevant' were flagged for further evaluation of relevance through coding of the full article. Article summaries that were coded as relevant were then evaluated using a three-pass manual coding approach. Initial first-pass open coding and in-vivo coding (Saldaña 2013) were used to interpret valence as well as identify the general topic and domain of the article summary. Codes from initial coding were evaluated and grouped into themes for valence and domain, and second-pass coding assigned codes to article summaries (Table 4.1). A third-pass allowed verification of consistency of coding among article summaries.

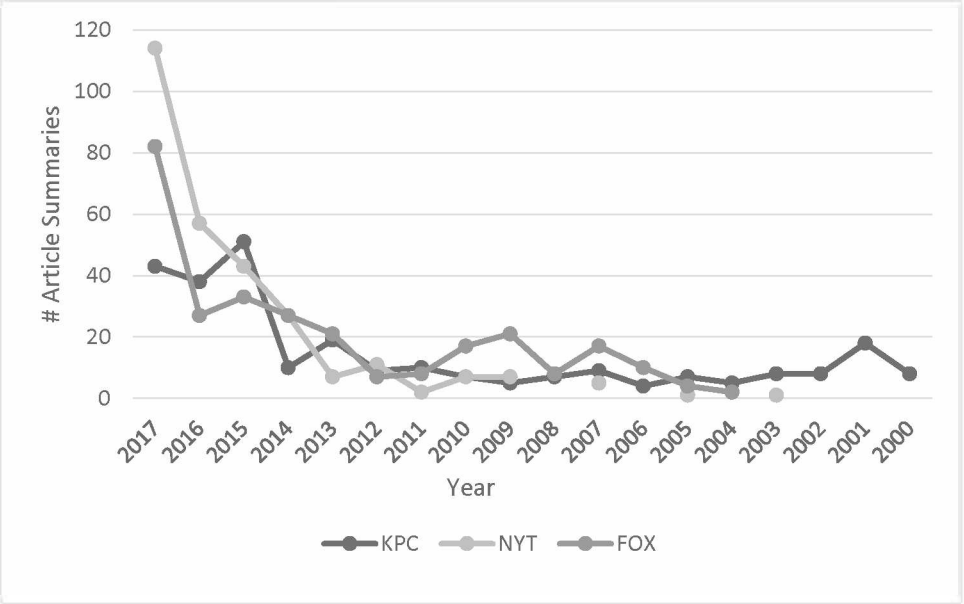


Figure 4.2: Number of corpus sample articles by year for Kenai Peninsula Clarion, New York Times, and Fox media sources.

Comparison of summary and full article coding was used to evaluate the performance of the extractive summary approach used in this analysis. A subset of full text articles was

randomly chosen from all media sources and manually coded. The results of full text coding were compared with coding of the article summaries. In addition, all article summaries that were coded as not relevant were further examined by coding the full article.

4.5 Results

Articles were obtained using search tools available at each website and a corpus of 832 articles was compiled representing 266, 285, and 281 articles from KPC, NYT, and FOX respectively (Figure 4.2 and Table 4.2). Search results were determined by website tools. Longitudinal evaluation of search results showed considerable variation in the number of articles returned in searches among sites over time. Because of this variability and lack of standardization among site search tools, analysis did not include evaluation of content over time. Rather, search results were considered to be representative of general content provided by each site during the period between the early 2000s through 2017.

Table 4.2: Corpus summary for Kenai Peninsula Clarion, New York Times, and Fox media sources.

Parameter	KPC	NYT	FOX
Number of characters (no spaces)	1,072,739	1,470,486	1,057,662
Number of words	220,876	297,465	217,456
Number of sentences	11,500	15,793	12,570
Number of Articles	266	281	285

4.5.1 Content

Comparison of term frequency for the 30 most common terms within full article content for each media source showed more shared terms (80%) between FOX and NYT than with KPC (37%) (Figure 4.3). Term frequency in articles for NYT and FOX suggested content that was descriptive of national issues for environmental change (e.g., emissions, carbon, greenhouse, world, energy). While 'climate' and 'change' rank high in term frequency as do 'state' and 'national' in each of the media sources, occurrence of more global or international terms (e.g., global, world, Paris, China) were less frequent within KPC. The local focus of KPC is reflected in the two most frequent terms which describe the geographical location of KPC as well as terms

that provide specific reference to topics relevant to the region (e.g., fish, wildlife, trees, Arctic, and salmon).

Order	KPC	NYT	FOX
1	alaska	climate	climate
2	kenai	change	change
3	climate	emissions	global
4	change	global	warming
5	peninsula	warming	president
6	people	states	emissions
7	refuge	united	people
8	state	energy	carbon
9	national	carbon	scientists
10	fish	scientists	greenhouse
11	wildlife	people	science
12	species	world	world
13	trees	president	trump
14	arctic	report	report
15	global	trump	energy
16	river	science	obama
17	ice	environmental	gas
18	spruce	paris	data
19	oil	gas	states
20	warming	research	united
21	research	power	research
22	salmon	greenhouse	sea
23	water	obama	paris
24	president	policy	temperature
25	energy	china	university
26	summer	state	ice
27	winter	water	environmental
28	forest	government	temperatures
29	north	national	national
30	anchorage	nations	state

Figure 4.3: Most frequent (30) terms (common terms in gray) for media sources.

4.5.2 Voice

Named entity recognition considered person and organization separately (Figures 4.4-5). Within all three media sources, Presidents Obama and Trump were the most frequently named entities. Local politicians and residents represented frequent person entities within KPC and they were grouped to form a general 'local resident' named entity within KPC. The names of news commentators frequently appeared in FOX article summaries and those names were grouped to

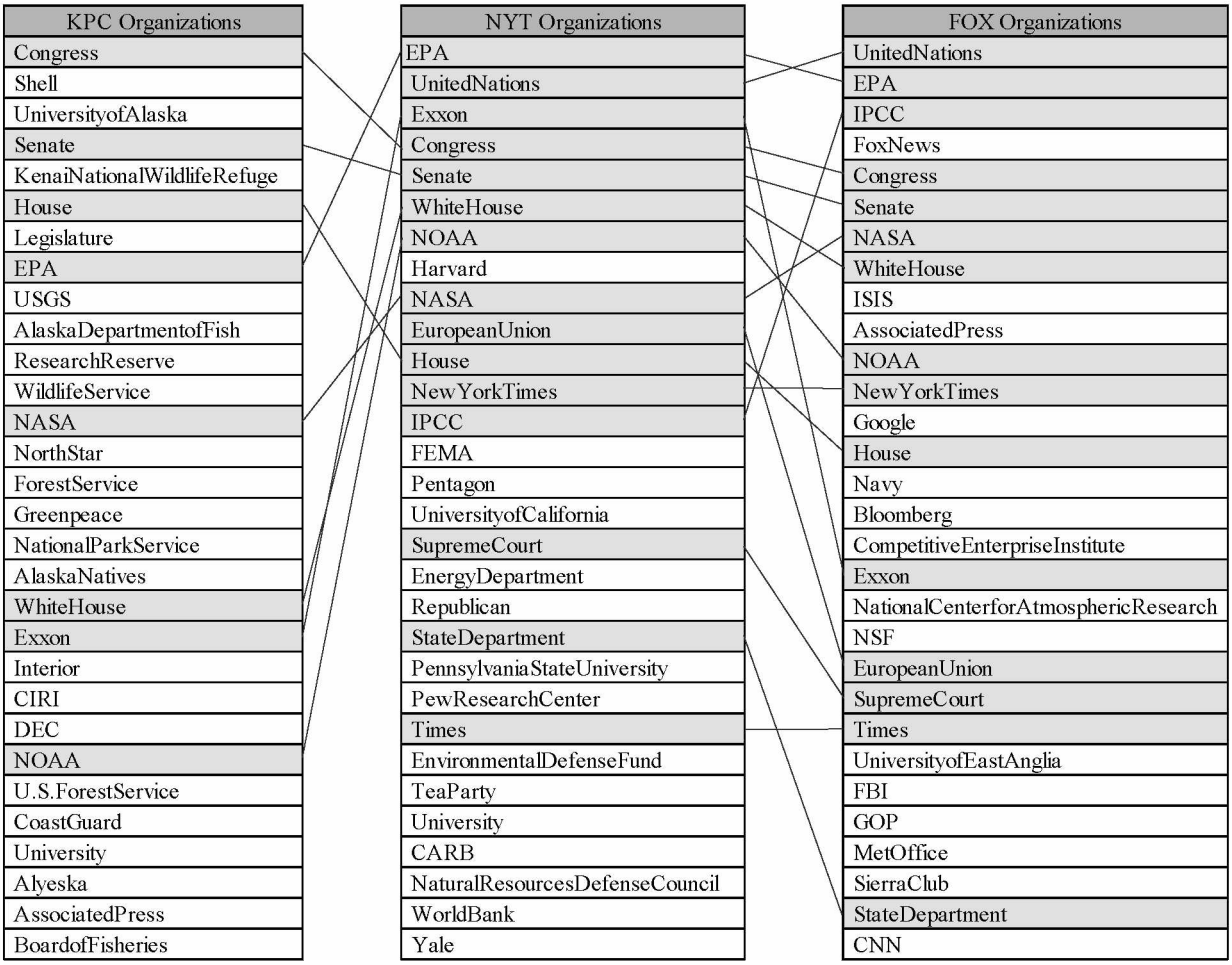


Figure 4.4: Most frequent (30) organization named entities (common entities in grey) for media sources.

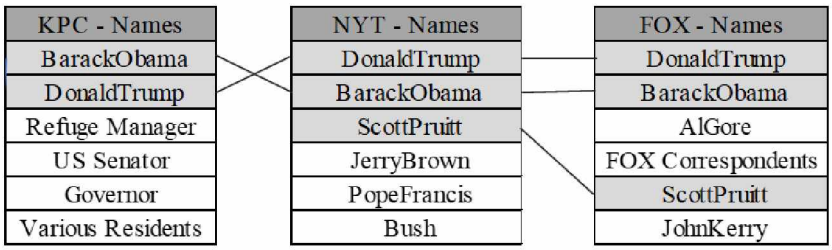


Figure 4.5: Most frequent (6) person named entities (common entities in grey) for media sources.

form a general 'FOX Commentator' named entity. NYT and FOX articles contained similar organizational entities (50%). KPC content contained fewer organizational entities that were in common with NYT and FOX (33%) and generally represented local organizations.

4.5.3 Sentiment

Coding for valence within article summaries showed polarization of content in NYT and FOX (Tables 4.3a-d). Positive coding represented 84% versus 38% and negative coding was 5% versus 49% for NYT and FOX respectively. KPC article summaries that were coded positive represented 32% of the total, and only 3% coded negative while 59% coded not relevant. All article summaries that were initially coded not relevant were further examined by coding full article content. For the majority of these articles, the search term occurred infrequently within the content and summarization based on sentence similarity failed to return content associated with search terms. Similarly, some articles contained multiple topics which were not related to environmental or climate change. In these cases, the summarization algorithm focused on different content and did not select the sentences that contained the reference to the search term. Overall 97% of articles returned by site search tools contained some content that was relevant to the search terms. Content and sentiment for all media sources was broadly distributed among thematic categories.

To evaluate the effectiveness of summarization, 32 article were randomly selected from the corpus to allow comparison of summary and full article coding. Agreement was found for 29 of 32 (90%) of the articles. Topic coding was the same for all articles however valence differed between unclear and positive. In one article, a single sentence not selected in summarization identified climate change doubt by a prominent politician while the remainder of content described examples of climate change. This introduced a suggestion of uncertainty to the entire article that was not present in the summary. In another case, the article purposefully presented both positive and negative valence for climate change; however, the summary technique focused on content that represented only positive valence. In a third case, the full article presented multiple topics and the summarization selected a non-climate change topic for summary.

Table 4.3a: Percent of article summaries coded for sentiment by media source.

Media	Negative	Positive	Unclear	Not Relevant
KPC	3%	32%	6%	59%
NYT	5%	84%	11%	1%
FOX	49%	38%	11%	2%

Table 4.3b: Percent of article summaries coded for domain by media source.

Media	Economic/Social/ Health	Lifestyle/Cultural/ Anecdotal	Politics	Science-based Assessment
KPC	14%	19%	10%	21%
NYT	57%	38%	42%	32%
FOX	29%	43%	48%	46%

Table 4.3c: Percent of article summaries coded for domain by sentiment.

Sentiment	Economic/Social/ Health	Lifestyle/Cultural/ Anecdotal	Politics	Science-based Assessment
Negative	13%	44%	21%	23%
Positive	26%	28%	24%	21%
Unclear	16%	35%	36%	12%

Table 4.3d: Number of articles summaries originally coded 'not relevant' re-coded for reference using full-articles by media source.

Media	Limited Anecdotal Reference	Limited Direct Reference	Not Relevant
KPC	24	108	26
NYT	na	2	na
FOX	na	5	1

4.6 Discussion

Results showed that frequency of terms and organization named entities were more similar between national media (NYT and FOX), than between those national sources and local content (KPC). While prominent national political entities occurred most frequently in each media source, other named entities reflected the national or local perspective of the media source. Content in FOX frequently named correspondents. This associates names with content which personalizes reporting and creates recognizable national spokespersons (elites) that reinforce in-group association. Local media (KPC) reporting provided content that reflected local issues as well as local organizations and person named entities indicating differentiation from national reporting and orientation toward a local audience. Content for all media sources was distributed among thematic domains which facilitates engagement with a broad audience through a variety of topics.

Valence was less evident in local media as compared to national media. Combined positive and negative valence for NYT, FOX and KPC was 89%, 87% and 35% respectively. Article summaries that coded not-relevant were 1%, 2% and 59% for NYT, FOX and KPC respectively. These differences in valence reflect different challenges that national and local media face in developing and maintaining an audience. National news content is distant relative to an individual consumer, consequently those sources can be expected to orient toward norms that promote brand loyalty and in-group affiliation in order to identify and maintain specific audiences. At the local level, news is more proximate and selection of news would be expected to be more personal and individually relevant. The challenge in more restricted local markets is to minimize in-group affiliation and thereby preserve broader appeal and participation by the local population.

A FOX editorial illustrates the use of in-group versus out-group orientation, uncertainty and distancing that is relevant at the national scale. In this editorial, in-group and out-group identities are defined as global warming skeptic versus scientist and IPCC (October 16, 2013):

"…climate scientists agree with the United Nations Intergovernmental Panel on Climate Change (IPCC) that most of the 0.7°C of global warming since 1951 is due to manmade greenhouse gases. Skeptics they suggest are a fringe element unworthy of media attention…. "

Later in-group vs out-groups are identified more ideologically as people vs government and experts:

"People get suspicious when government appointed experts define the science for the purpose of advancing an agenda that just happens to increase government control of energy markets."

Further discussion reinforces uncertainty with regard to out-group findings:

"The key science question for climate researchers today is not whether greenhouse gas emissions warm the planet but whether state of the art computer models are accurate enough to forecast climate change and inform policy decisions. "

The article reframes the issue from environmental risk to economic concerns shifting focus from concepts that are distant (carbon taxes, cap and trade) to one of more proximate relevance to the in-group (affordable fuel):

"…and the key issue for policymakers is not whether climate change poses risks but whether the proposed solutions carbon taxes cap and trade and other schemes to rig the market against plentiful affordable, reliable fossil fuels would do more harm than good."

The NYT provided reporting with content and voice that provide descriptions of environmental/climate change that are cognitively distant for most readers (December 5, 2017):

"Meeting in a city [Miami Beach] confronted daily with the issues of rising seas and climate change the United States Conference of Mayors approved resolutions on Monday to urge the federal government to rejoin the Paris climate agreement and to redouble their own efforts to combat climate change and commit to renewable energy."

Similarly, a NYT summary of a science-based research presents a technical discussion of uncertainty that could be expected to resonate with in-group audiences; however, it may not be persuasive to out-group readers (December 13, 2017):

"…study by an international coalition of scientists known as World Weather Attribution found that Harvey's rainfall was 15 percent higher than would be expected without climate change. … While the likelihood of a Harvey-like storm was perhaps once in every 3000 years in the past he said now its once every 1000 years or so which means that in any given year there is 0.1 percent chance of a similar storm occurring along the Gulf Coast."

Within KPC content, the mention of environmental or climate change was frequently embedded in topics of local interest. Article content contained familiar locations, experiences, and voices that engage the local audience on a personal level and mitigate in-group affiliation. For example, a science-based assessment that highlights environmental change and global warming, describes a familiar location and an observable example (October 12, 2001):

"Disappearing kettle ponds reveal a drying Kenai Peninsula…prime examples can be seen along Mackey Lake Road and along the Swanson River and Swan Lake roads on the Kenai National Wildlife Refuge. I am trying to use the small kettle holes as barometers of global warming on the Kenai."

KPC content coded not relevant for 59% of article summaries. Subsequent recoding of full content found the majority of those KPC articles to be positive for valence; however, in these articles, sentiment was presented in a limited context within a broader topic. This minimizes out-group orientation and it can increase the frequency of term use in an engaging, local and non-polarizing context. For example, from KPC reporting (December 22, 2009):

"Is it global warming when pink flamingos land in Soldotna….There were fifty-some flamingos…when we came in to work Monday and the ransom letter stated that for a donation to the Soldotna Playground the flamingos will happily fly away..."

When information is framed in a group context, information that is perceived as out-group is likely to be dismissed while information that comes from in-group is likely to be accepted (Frank et al. 2011; Fielding and Hornsey 2016; Brieger 2018). Consequently, the presence of group distinctions in information can become barriers to communication which inhibits consensus building and collaboration. Local media content in this analysis, stressed information that reflected the science-based consensus, aligned with audience experience and used framing that minimized valence and in-group or out-group context. These results support the basic premise of this study, that local news media can potentially provide an important bridge between local perception of environmental change and a more general discussion of climate change in a manner that minimizes in-group and out-group orientation and promotes social cohesion.

These results suggest that local media is not just another media source. Rather it has unique attributes that derive from scale that link audience to information in a potentially unique frame of familiarity and relevance that can mitigate ideological boundaries inherent in in-group versus out-group orientation. While the results are specific to the media sources that were investigated, they suggest that local and national media can be differentiated based on term frequency, voice and valence. Media content analysis provides insight into how environmental and climate change information is represented within a community. Replacing local media with national media content may shift public awareness and engagement with environmental change issues, promoting in-group versus out-group distinctions that adversely affect community consensus and decision making. Monitoring local news media through content analysis could be used to identify shift in editorial perspective or change in locally relevant content.

4.7 Acknowledgements

This study was partially supported by the Alaska Experimental Program to Stimulate Competitive Research (Alaska EPSCoR) NSF award #OIA-1208927 and the State of Alaska. An example of coding for the text rank extractive summarization approach is provided at: https://github.com/prateekjoshi565/textrank_text_summarization/blob/master/TestRank_Text_Summarization.ipynb.

4.8 Literature Cited

Bakker, I., T. van der Voordt, P. Vink, and J. de Boon. 2014. Pleasure, Arousal, Dominance: Mehrabian and Russell revisited. Current Psychology 33(3):405–421.

Bolin, J. L., and L. C. Hamilton. 2018. The News You Choose: news media preferences amplify views on climate change. Environmental Politics 27(3):455–476.

Boykoff, M. T., and J. M. Boykoff. 2004. Balance as bias: global warming and the US prestige press. Global Environmental Change 14(2):125–136.

Boykoff, M. T., and J. M. Boykoff. 2007. Climate change and journalistic norms: A case-study of US mass-media coverage. Geoforum 38(6):1190–1204.

Brannon, L. A., M. J. Tagler, and A. H. Eagly. 2007. The moderating role of attitude strength in selective exposure to information. Journal of Experimental Social Psychology 43(4):611–617.

Brieger, S. A. 2018. Social Identity and Environmental Concern: The Importance of Contextual Effects. Environment and Behavior:1–28.

Corner, A., L. Whitmarsh, and D. Xenias. 2012. Uncertainty, scepticism and attitudes towards climate change: biased assimilation and attitude polarisation. Climatic Change 114(3–4):463–478.

Crawley, C. E. 2007. Localized Debates of Agricultural Biotechnology in Community Newspapers: A Quantitative Content Analysis of Media Frames and Sources. Science Communication 28(3):314–346.

Darmofal, D. 2005. Elite Cues and Citizen Disagreement with Expert Opinion. Political Research Quarterly 58(3):381–395.

Dixon, G., J. Hmielowski, and Y. Ma. 2017. Improving Climate Change Acceptance Among U.S. Conservatives Through Value-Based Message Targeting. Science Communication 39(4):520–534.

Fairclough, N. 1989. Language and Power, 2nd edition. Longman, London.

Fielding, K. S., and M. J. Hornsey. 2016. A Social Identity Analysis of Climate Change and Environmental Attitudes and Behaviors: Insights and Opportunities. Frontiers in Psychology 7.

Frank, E., H. Eakin, and D. López-Carr. 2011. Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. Global Environmental Change 21(1):66–76.

Gallois, C., P. Ashworth, J. Leach, and K. Moffat. 2017. The language of science and social licence to operate. Journal of Language and Social Psychology 36(1):45–60.

Gentzkow, M., J. M. Shapiro, and M. Taddy. 2016. Measuring polarization in high-dimensional data: Method and application to congressional speech. National Bureau of Economic Research.

Goffman, E. 1974. Frame analysis: An essay on the organization of experience. Harvard University Press, Cambridge, MA.

Goldberg, M. H., S. van der Linden, M. T. Ballew, S. A. Rosenthal, A. Gustafson, and A. Leiserowitz. 2019. The Experience of Consensus: Video as an Effective Medium to Communicate Scientific Agreement on Climate Change. Science Communication 41(5):659–673.

Hansen, A. 2011. Communication, media and environment: Towards reconnecting research on the production, content and social implications of environmental communication. International Communication Gazette 73(1–2):7–25.

Hansen, A. 2016. The changing uses of accuracy in science communication. Public Understanding of Science 25(7):760–774.

Hester, J. B., and R. Gibson. 2007. The Agenda-Setting Function of National Versus Local Media: A Time-Series Analysis for the Issue of Same-Sex Marriage. Mass Communication and Society 10(3):299–317.

Hopkins, D. J. 2018. The Increasingly United States: How and Why American Political Behavior Nationalized. University of Chicago Press.

Jones, L. 2011. Towards a holistic conceptualisation of adaptive capacity at the local level: insights from the Local Adaptive Capacity framework (LAC). Overseas Development Institute (ODI).

Kinzler, K. D., E. Dupoux, and E. S. Spelke. 2007. The native language of social cognition. Proceedings of the National Academy of Sciences 104(30):12577–12580.

Knobloch-Westerwick, S., and B. K. Johnson. 2014. Selective Exposure for Better or Worse: Its Mediating Role for Online News' Impact on Political Participation. Journal of Computer-Mediated Communication 19(2):184–196.

Krieger, J. L., and C. Gallois. 2017. Translating Science: Using the Science of Language to Explicate the Language of Science. Journal of Language and Social Psychology 36(1):3–13.

Kunda, Z. 1990. The case for motivated reasoning. Psychological Bulletin 108(3):480–498.

Lawhon, M., J. Pierce, and R. Bouwer. 2018. Scale and the construction of environmental imaginaries in local news. South African Geographical Journal 100(1):1–21.

Lewandowsky, S., J. Cook, K. Oberauer, S. Brophy, E. A. Lloyd, and M. Marriott. 2015. Recurrent fury: Conspiratorial discourse in the blogosphere triggered by research on the role of conspiracist ideation in climate denial. Journal of Social and Political Psychology 3(1):142–178.

Lopez Porras, G., L. C. Stringer, and C. H. Quinn. 2018. Unravelling Stakeholder Perceptions to Enable Adaptive Water Governance in Dryland Systems. Water Resources Management 32(10):3285–3301.

Lord, C. G., L. Ross, and M. R. Lepper. 1979. Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. Journal of Personality and Social Psychology 37(11):2098–2109.

Maibach, E., C. Roser-Renouf, and A. Leiserowitz. 2009. Global Warming's Six Americas 2009: An Audience Segmentation Analysis. Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication.

Mazur, A., and J. Lee. 1993. Sounding the Global Alarm: Environmental Issues in the US National News. Social Studies of Science 23(4):681–720.

Mihalcea, R., and P. Tarau. 2004. TextRank: Bringing Order into Texts. Proceedings of the Conference on Empirical Methods in Natural Language Processing:404–411.

Nauroth, P., M. Gollwitzer, H. Kozuchowski, J. Bender, and T. Rothmund. 2016. The effects of social identity threat and social identity affirmation on laypersons' perception of scientists. Public Understanding of Science:1–17.

Peeples, J. 2015. Discourse/Rhetorical Analysis Approaches to Environment, Media and Communication:11.

Socher, and C. Manning. 2014. Glove: Global Vectors for Word Representation. Pages 1532–1543 Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing (EMNLP). Association for Computational Linguistics, Doha, Qatar.

Pew Research Center. 2014. Political-Polarization-and-Media-Habits-FINAL-REPORT-10-21-14.pdf.

Poomagal, S., and T. Hamsapriya. 2011. Cosine similarity-based PageRank calculation. International Journal of Web Science 1(1/2):142.

Raman, S., and A. Mohr. 2014. A social licence for science: capturing the public or co-constructing research? Social Epistemology 28(3–4):258–276.

Rice, R. E., and H. Giles. 2017. The Contexts and Dynamics of Science Communication and Language. Journal of Language and Social Psychology 36(1):127–139.

Russell, J. A. 1980. A circumplex model of affect. Journal of Personality and Social Psychology 39(6):1161–1178.

Saldaña, J. 2013. The coding manual for qualitative researchers2nd ed. SAGE, Los Angeles.

Sampei, Y., and M. Aoyagi-Usui. 2009. Mass-media coverage, its influence on public awareness of climate-change issues, and implications for Japan's national campaign to reduce greenhouse gas emissions. Global Environmental Change 19(2):203–212.

Spence, A., W. Poortinga, and N. Pidgeon. 2012. The Psychological Distance of Climate Change: Psychological Distance of Climate Change. Risk Analysis 32(6):957–972.

Suls, J., and T. A. (Eds.) Wills. 1991. Social comparison: Contemporary theory and research. Lawrence Erlbaum Associates, Inc, Hillsdale, NJ, US.

Tajfel, H. 1974. Social identity and intergroup behaviour. Social Science Information 13(2):65–93.

Tajfel, H., M. G. Billig, R. P. Bundy, and C. Flament. 1971. Social categorization and intergroup behaviour. European Journal of Social Psychology 1(2):149–178.

Tian, L., C. Lai, and J. Moore. 2018. Polarity and Intensity: the Two Aspects of Sentiment Analysis. Pages 40–47 Proceedings of Grand Challenge and Workshop on Human Multimodal Language (Challenge-HML). Association for Computational Linguistics, Melbourne, Australia.

Wahlberg, A. A. F., and L. Sjoberg. 2000. Risk perception and the media. Journal of Risk Research 3(1):31–50.

Wakefield, S. E. L., and S. J. Elliott. 2003. Constructing the News: The Role of Local Newspapers in Environmental Risk Communication. The Professional Geographer 55(2):216–226.

Chapter 5: Conclusions

5.1 Overview

This dissertation investigated community perception of local environmental change and considered the role that science-based information plays in informing those perceptions. An understanding of how science-based information informs local perception is important to ensure that science communication effectively supports community decision making and promotes adaptive capacity.

The term community has a broad range of definitions and in this analysis it describes a group of people with common locality, interests, and similar governance (Smit and Wandel 2006). Adaptive capacity refers to the latent ability of a system to modify its characteristics or behavior to better cope with an existing or anticipated stress (Adger 2004; Smit and Wandel 2006).

A socio-cognitive model of risk perception was proposed where cognitive distancing and cognitive processes mediate between affective, science, and identity based decision making. In this model, increasing cognitive distance reinforces abstract construal and motivates decisions based on identity whereas increasing detail and local relevance provides an opportunity to engage analytic processes that facilitate science-based decision making.

Identity promotes socially derived in-group orientation that motivates group members to see their group as positive and distinct from other groups (Frank et al. 2011; Fielding and Hornsey 2016; Brieger 2018). This may impede collaboration and consensus building. Tensions that result from discord within a community can impact decision making and inclusive governance that are associated with adaptive capacity (Jones 2011).

Discussion of local environmental change that engages with community experience can be expected to promote collaborative dialog and encourage consensus-building in decision making processes. Incorporation of detailed science-based information in community decision making can be difficult due to the technical content and format of scientific reporting. Local

news media provide a unique opportunity to promote communication of science-based information for the public by providing content that is familiar and relevant to the audience, offering a variety of topical framings for an issue, developing authoritative or trusted voices, and providing frequent exposure to content.

5.2 Discussion

Chapter 2 investigated local perception of environmental change and community attitudes regarding resource management using results from a community level survey. Community perception of environmental change was compared with science-based measurements of change to assess the utility of that comparison as a measure of adaptive capacity. The results highlight potential difficulties in comparing perceived change with science-based measurements. These results are similar to previous studies (Myers et al. 2013) and include defining the parameter of interest for comparison, discerning environmental change given the high variability associated with environmental observations, and requirements for long periods of consistent observation. Comparison of perceived and measured environmental change can help identify discrepancies between science-based assessments and community perception that are useful in developing more effective communication. However, focusing on these discrepancies may guide communication toward a deficiency model of science communication, and a focus on providing more science data to describe the phenomenon of interest. The deficiency model is frequently not an effective communication strategy for the general public as it assumes that the audience attributes similar salience, credibility and legitimacy to the science-based assessment as the scientists (Cash et al. 2002).

Shared perceptions and attitudes, as were identified in this study, can be used together with science-based assessments to frame discussion of environmental change using a collaborative context model of science communication. Strategic choice of communication framing and co-production of knowledge provide opportunities to engage in dialog that develops common language and identifies locally relevant descriptions of environmental change. This 'common ground' approach engages the public in a manner that can improve agreement and promote adaptive capacity (Grothmann et al. 2013; Pearce et al. 2015; Spence, Poortinga, and Pidgeon 2012).

The terms 'climate change' and 'global warming' have become associated with group orientation, and reference to these terms elicit responses associated with identity (Kahan 2012, 2015; Maibach, Roser-Renouf, and Leiserowitz 2009; Myers et al. 2013). This was evident in results from the community survey. A majority of the respondents who felt environmental change was unlikely, disagreed or were unsure with the cognitively distant statements that 'humans are changing the planet's climate' and 'climate is changing on the Kenai'. A majority of those same respondents agreed with the cognitively proximate statement 'I am worried about changes in land and water on the Kenai'. This supports the proposed socio-cognitive model and suggests that discussion of environmental change that is locally relevant and detailed (cognitively proximate) will be less influenced by identity and will encourage analytical, science based assessment than more cognitively distant topics such as climate change or global warming.

Chapter 3 considered riparian habitat protection areas (buffers) along Kenai streams that were implemented by controversial, local ordinances to protect riparian habitats. Results from the community-level survey identified the use of property regulation to protect the Kenai River as a divisive issue among respondents; however, there was a shared concern among respondents regarding the condition of local salmon populations. This study was intended to provide a science-based case study that linked conservation of riparian vegetation to juvenile salmon rearing habitat and reframe the importance of habitat protection areas using shared concern for salmon.

This ecological study investigated invertebrate prey contributions that move from the terrestrial environment to streams for three study reaches within the Kenai watershed and considered the importance of riparian vegetation type as a component of juvenile salmon rearing habitat. The results described significant differences in prey contributions by vegetation type and suggest that change in riparian vegetation from tree/shrub to grass/sedge will likely reduce the quantity of invertebrate prey entering streams from terrestrial habitats. Widespread change in riparian vegetation from tree/shrub to grass/sedge along Kenai streams will likely lead to lower availability of cross-ecosystem invertebrate prey for resident fish, and may potentially result in reduced fish growth and density when and where fish are food-limited (Fischer et al. 2010; Inoue, Sakamoto, and Kikuchi 2013; Sweka and Hartman 2008).

Winterfeldt (2013) proposed a framework for decision making that highlights the need for science-based information to be explicitly integrated in the decision analysis process. Detailed science-based reporting, as was produced in this ecological study, is difficult to include in decision making due to the technical content and format of scientific reporting. Interpretation of technical reports by professional staff is generally required to allow their use in policy decision making and technical reports are generally not relevant in personal decision making. Interpretation of technical reports is generally required to communicate their content to the public.

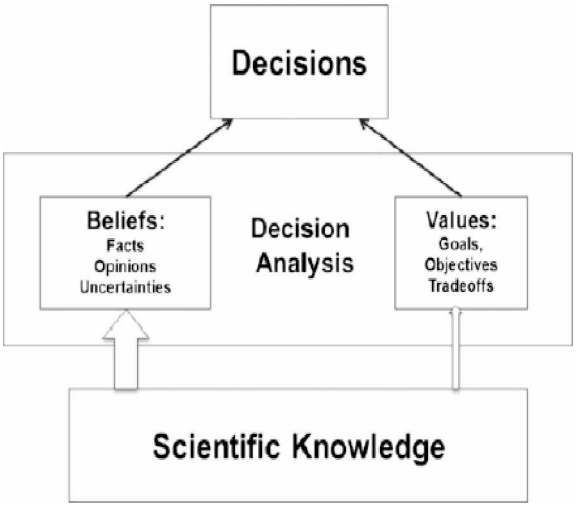


Figure 5.1: Conceptual framework for decision making.

News media play a role in the exchange of information between science, policy and public spheres of society (Boykoff and Boykoff 2007; McCombs and Shaw 1972; Rice and Giles 2017). News media interpret technical information for their audiences and promote dissemination of that information in an accessible form. Chapter 4 investigated the role of national and local media in providing content relevant to environmental change. Two major national news media sources were chosen to represent politically polarized viewpoints regarding environmental change in national media. A local Alaska news media source was also selected for comparison. These news media sources were not intended to be broadly representative of news media, rather they were a purposeful sample, intended to characterize the polarization of environmental change reporting at the national level, and allow comparison of those sources with a media source that focuses on reporting at a local level.

Results from this analysis suggest that local media are not just another media source. Rather, local media have unique attributes that derive from scale that link audience to information in a potentially unique frame of familiarity and relevance that can mitigate ideological boundaries inherent in in-group versus out-group orientation. Local reporting such

as community newspapers remain important because they provide opportunity for framing through voice and content that is proximate, and therefore engage with individuals in a manner that promotes a sense of personal involvement and agency. Results suggest that local and national media can be differentiated based on content, voice and valence. Monitoring local news media could be used to identify shifts in editorial perspective that might result from change in ownership or over time as issues evolve. Local news media provide an unique opportunity to promote effective communication of science-based information by providing a variety of inclusive framings, allowing the development of authoritative or trusted voices, and increasing frequency of exposure to content.

Alaska is experiencing unprecedented environmental change. How Alaskans perceive those changes will play a large part in determining how communities respond to the threats and opportunities that arise from those changes. An understanding of how science-based information informs local perception is important to ensure that science communication effectively supports community decision making. Institutions that generate science-based assessments of environmental change must develop effective inclusive strategies for communication that consider community perception of change and promote community adaptive capacity. The analysis provided in this dissertation provides a framework for evaluation of community perception of environmental change and suggests that local media can provide a unique opportunity for communication of that change.

5.3 Limitations of Research

This dissertation investigated community perception of local environmental change and considered the role that science-based information plays in informing those perceptions. Three interrelated studies comprise this research: 1) quantitative evaluation of perception of environmental change, 2) science-based analysis of invertebrate prey contributions to juvenile salmon diet as a function of riparian vegetation type, and 3) role of media in science communication. The approaches and methodologies used in the dissertation have limitations. For each study, the analysis area was specific to the Kenai region and extrapolation of these results to additional areas should be carefully considered. Community survey respondents in chapter 2 were not representative of the Kenai demographics and did not provide representation

of subgroups such as Indigenous peoples or Russian Old Believers; however, the diversity of responses was deemed sufficient for analysis of perceptions. In chapter 3, extended stream study reaches were selected that were relatively pure stands of the vegetation type of interest to minimize mixing of invertebrate input from adjacent areas with differing vegetation types. Sampling replicates of similar extended stream reaches was not practical. Consequently, analysis could not statistically assess effects of riparian type. In chapter 4, the news media sources were not intended to be broadly representative of news media, rather they were a purposeful sample, intended to characterize the polarization of environmental/climate change reporting at the national level and allow comparison of those sources with a media source that focuses on reporting at a local level.

The use of quantitative analysis in this dissertation provided statistical evaluation of results. The qualitative approach used in chapter 4 allowed the development of themes and evaluation of processes that provide added insight to the issues being investigated. As with any assessment, these analysis include subjectivity and bias of the investigator.

5.4 Future Research

From a methodological perspective, combining quantitative and qualitative analysis in mixed-methods design provides opportunities for innovative research. Continued development of content summarization techniques could focus on topically directed summarization.

Alaska represents the northern-most extent of the U.S. and it is experiencing environmental change in a manner that is specific to regions that are characterized by cold-climate. These environmental changes produce unique ecological, social, and economic challenges. Continued research should consider the role of the University, agencies and other science-based research organizations as authoritative voices to effectively inform Alaskans about these changes and their associated impacts. This research should be interdisciplinary in nature and require recognition of the applied aspects of scientific research. Monitoring perception of environmental change within Alaska's diverse population would provide important insight to evolving challenges presented by environmental change. Similarly, monitoring local news media content could provide perspective on how science-based information is incorporated in public dialog.

5.5 Literature Cited

Adger, W. N., N. Brooks, G. Bentham, M. Agnew, and S. Eriksen. 2004. New indicators of vulnerability and adaptive capacity. Tyndall Centre for Climate Change Research, Norwich.

Boykoff, M. T., and J. M. Boykoff. 2007. Climate change and journalistic norms: A case-study of US mass-media coverage. Geoforum 38(6):1190–1204.

Brieger, S. A. 2018. Social Identity and Environmental Concern: The Importance of Contextual Effects. Environment and Behavior:1–28.

Cash, D., W. C. Clark, F. Alcock, N. M. Dickson, N. Eckley, and J. Jäger. 2002. Salience, credibility, legitimacy and boundaries: Linking research, assessment and decision making. Faculty Research Working Papers Series. RWP02-046:1-24.

Fielding, K. S., and M. J. Hornsey. 2016. A Social Identity Analysis of Climate Change and Environmental Attitudes and Behaviors: Insights and Opportunities. Frontiers in Psychology 7.

Fischer, J. R., M. C. Quist, S. L. Wigen, A. J. Schaefer, T. W. Stewart, and T. M. Isenhart. 2010. Assemblage and Population-Level Responses of Stream Fish to Riparian Buffers at Multiple Spatial Scales. Transactions of the American Fisheries Society 139(1):185–200.

Frank, E., H. Eakin, and D. López-Carr. 2011. Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. Global Environmental Change 21(1):66–76.

Grothmann, T., K. Grecksch, M. Winges, and B. Siebenhüner. 2013. Assessing institutional capacities to adapt to climate change: integrating psychological dimensions in the Adaptive Capacity Wheel. Natural Hazards and Earth System Science 13(12):3369–3384.

Inoue, M., S. Sakamoto, and S. Kikuchi. 2013. Terrestrial prey inputs to streams bordered by deciduous broadleaved forests, conifer plantations and clear-cut sites in southwestern Japan: effects on the abundance of red-spotted masu salmon. Ecology of Freshwater Fish 22(3):335–347.

Jones, L. 2011. Towards a holistic conceptualisation of adaptive capacity at the local level: insights from the Local Adaptive Capacity framework (LAC). Overseas Development Institute (ODI).

Kahan, D. M. 2012. Ideology, motivated reasoning, and cognitive reflection: an experimental study. Judgment and Decision Making 8:407–24.

Kahan, D. M. 2015. Climate-Science Communication and the Measurement Problem. Political Psychology 36:1–43.

Maibach, E., C. Roser-Renouf, and A. Leiserowitz. 2009. Global Warming's Six Americas 2009: An Audience Segmentation Analysis. Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication.

McCombs, M. E., and D. L. Shaw. 1972. The Agenda-Setting Function of Mass Media. The Public Opinion Quarterly 36(2):176–187.

Myers, T. A., E. W. Maibach, C. Roser-Renouf, K. Akerlof, and A. A. Leiserowitz. 2013. The relationship between personal experience and belief in the reality of global warming. Nature Climate Change 3(4):343–347.

Pearce, W., B. Brown, B. Nerlich, and N. Koteyko. 2015. Communicating climate change: conduits, content, and consensus: Communicating climate change. Wiley Interdisciplinary Reviews: Climate Change 6(6):613–626.

Rice, R. E., and H. Giles. 2017. The Contexts and Dynamics of Science Communication and Language. Journal of Language and Social Psychology 36(1):127–139.

Smit, B., and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. Global Environmental Change 16(3):282–292.

Spence, A., W. Poortinga, and N. Pidgeon. 2012. The Psychological Distance of Climate Change: Psychological Distance of Climate Change. Risk Analysis 32(6):957–972.

Sweka, J. A., and K. J. Hartman. 2008. Contribution of Terrestrial Invertebrates to Yearly Brook Trout Prey Consumption and Growth. Transactions of the American Fisheries Society 137(1):224–235.

Winterfeldt, D. 2013. Bridging the gap between science and decision making. Proceedings of the National Academy of Sciences 110(Supplement_3):14055–14061.

Chapter 6: Appendix – UAA IRB

UAA Research & Graduate Studies
University of Alaska Anchorage

3211 Providence Drive
Anchorage, Alaska 99508-4614
T 907.786.1099, F 907.786.1791
www.uaa.alaska.edu/research/ric

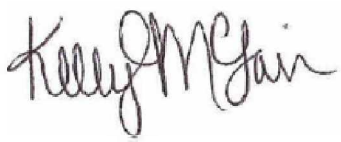
DATE:	October 10, 2013
TO:	Sarah Wandersee, Ph.D.
FROM:	University of Alaska Anchorage IRB
PROJECT TITLE:	[523254-1] Landscape and social values and links to adaptive capacity on the Kenai Peninsula
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	October 10, 2013

Your Institutional Review Board (IRB) proposal meets the U.S. Department of Health and Human Services requirements for the protection of human research subjects (45 CFR 46 as amended/revised) as being exempt from full Board review. In keeping with the usual policies and procedures of the IRB, your research project is approved with suggested revisions. Thank you for a copy of these revisions.

Therefore, you have permission to begin data collection for your study. If this study goes beyond one year from the date of this submission, you will need to submit a Progress Report for approval to continue the research and please submit a Final Report at the end of your project.

Please report promptly proposed changes in the research protocol for IRB review and approval.

On behalf of the Board, I wish to extend my best wishes for success in accomplishing the objectives of your study.



Kelly McLain, M.A.

Research Compliance Director, Institutional Review Board