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Visualizing the Range of Glaciers: Science, Art and Narrative

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ABSTRACT

Glaciers are sensitive indicators and data keepers of climatic change. The glaciers of the North Cascades, Washington, also have significant economic and cultural value as they are enmeshed in hydroelectricity generation, terrestrial and aquatic ecology, and human communities. My project approaches the current climate crisis by examining the past, present and future of the glaciers of the North Cascades through the two lenses of art and science. I review and contextualize the last century of glacier research in the North Cascades to identify patterns of glacier change and how this affects ecological and human communities. Overlaid upon my literature review, I examine the visual communication strategies of scientists. Maps, photography and innovative figures can all enhance our understanding of data and are of particular utility for communicating findings to the public. I devote the second chapter of this thesis to surveying the presence of glaciers in contemporary art and find that historically durable environmental narratives shape the creation and assimilation of glacier-focused art. Due to the swift rate of current glacier loss and the steps necessary to adaptation, the stakes of visualizing glacier loss are high. Images within both scientific and artistic contexts shape people's understanding of climate change and their ability to engage in the issue. In the final section of this project, I present my own printmaking portfolio that responds to themes and gaps within the scientific and artistic fields and tells stories from my own experience on the glaciers of the North Cascades.

ACKNOWLEDGEMENTS

A great number of people have inspired and helped me with this project. In the process they have shaped who I am as well. To all of you, I am so grateful.

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My thesis readers also provided valuable and helpful input on this project and kindled my interests in many of the topics. Chris Walker and Rory Bradley have shown me ways to think critically about art and the environment and bridge the humanities and the sciences. Professor Bess Koffman has inspired me and fostered connections to glacier research and art.

Next, I owe so much to the 2020 North Cascades Glacier Project (NCGCP) team. Mauri Pelto, Jill Pelto and Mariama Dryak have shared their incredible knowledge about glaciers and science communication, and also their friendship, with me. Jill's incredible artwork initially ignited my interest in art as a tool to communicate science. Mauri trusted my interest and initiative and allowed me to join the 2020 NCGCP field season without ever having met me. Mariama and I shared a tent, laughter, and many ideas. These three have instilled in me a passion to communicate science and to care for water resources. Additionally, the NCGCP field experience grounded my thesis with data, personal experience, and specific glaciers.

To the citizens and scientists who care for and study the North Cascades and its glaciers, thank you for your work. I extend special thanks to Stephanie Williams, Jon Riedel, Mark Carey, Jezra Beaulieu, Anna McKee and Robert Nielsen for sharing your stories with me and illuminating paths of inquiry for my project.

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INTRODUCTION

Nestled high in the peaks of the North Cascades in north central Washington state are hundreds of alpine glaciers. These bodies of ice carry great significance and contain a multitude of meanings. The ancient, layered ice, and the pace at which it melts creates a site to gather scientific information about climate change. The glaciers proximity to areas with significant human populations such as Seattle make them economically important as a source of water used for irrigation, hydroelectricity generation and recreation. They are also a natural and cultural resource. Glaciers provision ecosystem services, sustain habitat for terrestrial and aquatic species, offer spaces for recreation, locations for stories and more.

Among the many climate change impacts to the North Cascades region, glacier loss is one of the most visible and swiftly occurring. Between 1984 and 2009, cumulative North Cascades glacier loss was equivalent to 20-40% of total glacier volume. What are our strategies for understanding and responding to glacier loss? How are we communicating this rapid change? Due to the swift rate of current glacier loss and the steps necessary to adaptation, the stakes of visualizing glacier loss are high.

Much of our understanding of glaciers comes from seeing pictures of them. Because glaciers are difficult to access, most individual's perceptions of glaciers grow from visual culture. Scientific and artistic representations of glaciers transmit information about glaciers, how they are changing, and their relationship to climate. The history of depicting ice has left a legacy on research, art, and our perceptions of glaciers today. There are many lenses through which we can view glaciers. Examining the environmental narratives that color our relationships to glaciers is one way to trace this history, and to dig into the many ways that we come to understand and interact with our world. Some of the stories trickling through the glaciers of the North Cascades regard glaciers as Sublime, as a laboratory, a wilderness, an endangered species, a ruins, or a playground. Pictures from across the spectrum—from graphs to maps to abstract contemporary art—feed these narratives, enhance or obscure our understanding of the environment, and set us up to be either hopeful or hopeless about the current rapid pace of glacier loss. This thesis focuses on how we visualize glaciers, and the implications of these pictures.

This project has three parts, each with a blend of informational and visual elements. I begin with a literature review of glacier studies in the North Cascades. Integrated in this review is an analysis of visual science communication and the primary data visualization tools used. The second chapter is an artistic analysis in which I survey the field of glacier art, mostly considering contemporary pieces. Within these artworks I expose and find examples for dominant environmental narratives. My own portfolio and artist statements compose the third chapter, in which I depict how the alpine glaciers of the North Cascades are intertwined with various species, human communities and economies. Climate change is stressing all of these relationships. In the interest of finding effective ways to act upon climate change, I have undertaken this project. I strive to understand the history and impacts of climate change by bringing my inquiries “home” to the mountains and glaciers I know personally. Climate change often feels like an overwhelming but distant phenomenon, and this can be immobilizing. Since there is relatively little psychological distance between me and the changing North Cascades, these glaciers are a unique and personal site to explore the implications of climate change communication. My situatedness is of two types: knowing from a particular place and time and calling to attention the sites of knowledge that I am drawing from. Throughout this thesis I discuss how new modes of relating to glaciers and representing them will generate both a better public understanding of glacier-climate change and support environmental narratives that lead us to shape our future in the Anthropocene.

CHAPTER 1: ICE IN THE NORTH CASCADES: A REVIEW OF THE LITERATURE AND VISUAL SCIENCE COMMUNICATION ANALYSIS

Communicating Science

This chapter focuses on how changing glaciers are represented by science. This section parallels my analysis of glacier art in Chapter 2, by discussing visual communication efforts on behalf of scientists studying the North Cascades (NC). I also review fundamental NC glacial studies and approaches used to study past glacier behavior. In this chapter, I pull two sets of information from the literature. First, I review major themes within the study of NC glaciation, including glacial distribution, monitoring, past glaciation, downstream and ecological impacts, and human culture, management, and adaptation. Second, I describe figures and visual communication strategies that are enlisted in each topic. The result is that each subtopic of this chapter synthesizes papers of primary importance, then identifies one or two key figures and analyzes the scientific communication strategy of each. To that end, I attempted to identify unique figures that collectively illustrate how scientists communicate changing glaciers.

Some visuals are much stronger than others. We will find that the best scientific figures are artistic rather than purely informational. These figures do not only arrange images and numbers in strategic ways, but they are designed to complement the complexity and richness of the content. Artistic figures open new perceptive doors, highlighting pattern and connection. Within the scientific presentation, they provide relief from text and numbers. In addition, they are lovely to look at. Unalike text, information graphics can also transmit sensory details, such as by encoding temperature gradients with color. Other figures are so innovatively designed that they lead to a much richer understanding of the content than written paragraphs or the bare data can provide. The combination of information and good design can thus lead to insight.

Although the continuum of climate communication strategies may range from raw data to the abstract power of art, most scientists create figures with a slightly more specific toolbox. From visualizations with figurative to abstract qualities, the common scientific figure types are representative illustrations, illustrated diagrams, and data visualizations, as depicted in Figure 1 (Christiansen 2018). The tools and technology for each category have split apart over time, but learning techniques and problem-solving methods across the spectrum enrich all scientific visualizations. Scientific illustrators can still work across categories and multiple approaches can be used to illuminate the same data.

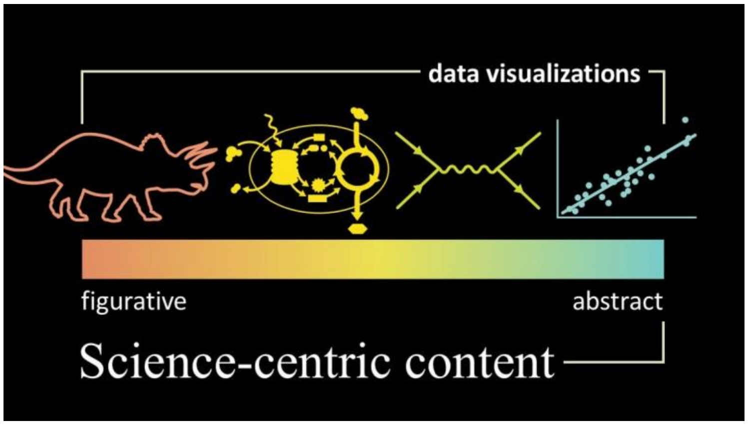

Figure 1. Jennifer Christiansen, mapping the spectrum of visual science content from illustration to infographic, 2018.

The Design of Data

Broadly considered, science communication occurs through innumerable formal and informal media including lectures, textbooks, conferences, media coverage, popular science publications, and museum exhibits (Burns et al. 2003). In this chapter I focus specifically on figures designed by scientists and published in scientific journals. An atypical focus for design critique, visual science communication "strives to "create images that speak to the viewer without additional information" (Keller and Keller 1993). Scientists must make design decisions when constructing visual science communication: this includes choices of color, texture, scale and point of view (Trumbo 2000). Likewise, a great figure is a blend of art and science.

The tactics of information design as described by Edward Tufte provide a scaffolding with which I can analyze the decisions scientists make in representing both quantitative and qualitative data. Tufte's main principles are as follows:

> "Graphical excellence is the well-designed presentation of interesting data—a matter of substance, of statistics, and of design.
> Graphical excellence consists of complex ideas communicated with clarity, precision and efficiency.
> Graphical excellence is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.
> Graphical excellence is nearly always multivariate.
> And graphical excellence requires telling the truth." (Tufte 1983, p. 51).

Tufte's call for simplicity, truth and efficiency is powerful, but challenging to achieve without remarkable creativity. However, a few key data visualization structures can effectively communicate a lot of information in the glaciology field as well as the world at large. These strategies are parallelism, confections, and mapped pictures. I define them here and will refer back to these structures throughout the chapter. Along with these structures, I will note when tools such as maps, coding with color, visual symbols, multifunctionality and composition contribute to visualizations.

Parallelism: Arranging images adjacently or with some parallel structure, allowing quick identification, contrast and review between the images.

Confection: A visual collage of information that explains, narrates, or argues a story using diverse images and words as source material.

Mapped Pictures: Representational images combined with numbers, words or scales that enhance the transmission of evidence. Scientists are well trained in concocting mapped images. Common strategies for mapping images are adding a universal scale, arrows that explicitly point out pieces of evidence, and labels. These are standardized and accepted for the publication of scientific figures.

Data visualizer David McCandless provides another concept to define good and effective data visualizations. Figure 2 communicates how a visualization succeeds based on the alignment of information, story, goal and visual form. McCandless emphasizes that the best data visualizations have doses of narrative, function, symbolism and data. Some of the visuals I discuss do not check all boxes, but they can still contribute to an understanding of science and in analyzing the lack of some elements, I provide creative critique for better visual science communication.

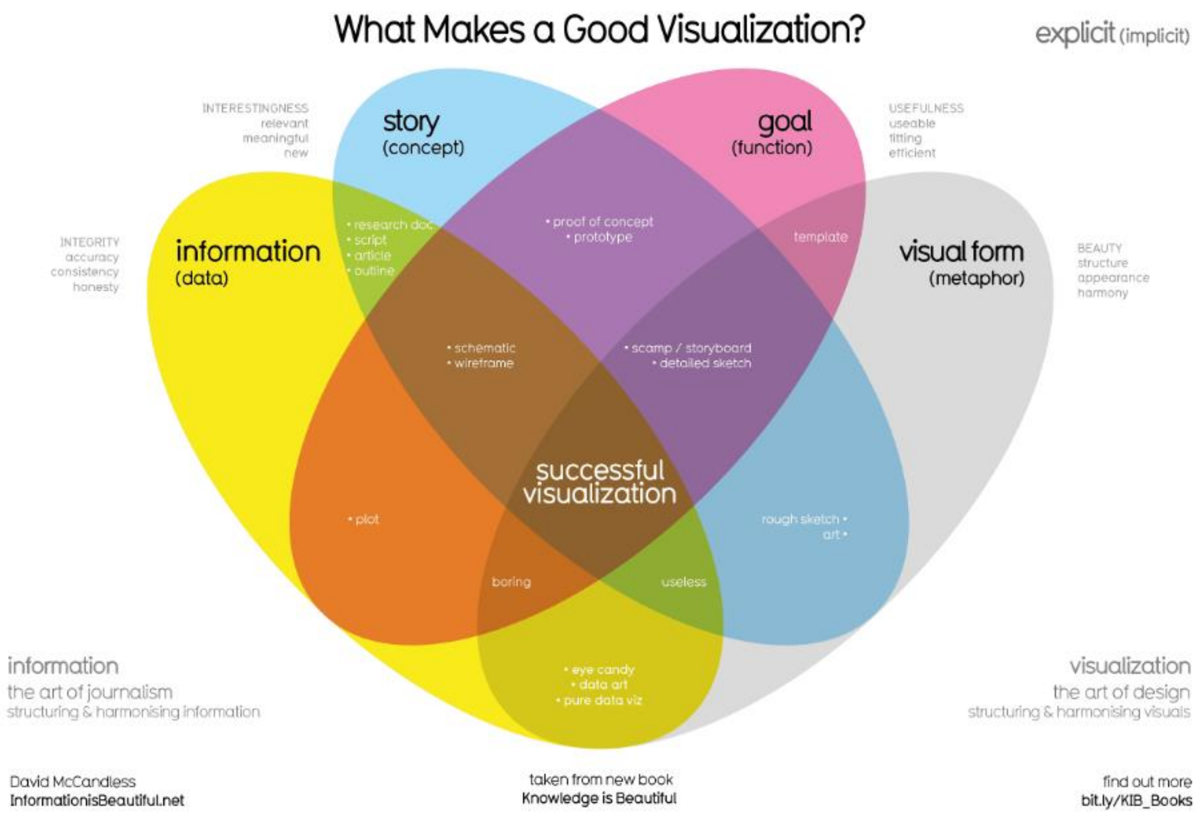

Figure 2. David McCandless, What Makes a Good Visualization? infographic.

Both the Tufte and McCandless frameworks emphasize how design is invisible in the most successful data visualizations, so that the viewer takes away the essence of the information, rather than resting on the final visual product. With too many unnecessary or distracting elements, you lose the ability to impart information. In summary, to be a powerful conduit from seeing to understanding, good visual science communication needs to center data and find a balance between too much and too little design.

Climate Science Communication

Today, climate science guides our understanding of how the world around us is changing and what measures we will have to take to meet different climate outcomes. Climate change is mostly, if not completely, anthropogenically caused, and is now threatening human and environmental systems across the globe (Solomon et al. 2007). Climate science conceptualizes the effects of climate change as interconnected phenomena, not isolated events (Dryzek et al. 2011). Although there is firm scientific consensus that climate change is driven by the activities of humans on Earth, social, political and economic systems have extremely uncertain

relationships with climate change and the future (Oreskes 2004). Scientific findings must break through scientific circles and inform decision makers and public society.

Communicating science is a critical challenge for scientists and scholars, because it is via communication that people and societies come to understand, care about, and act upon issues. Climate communication has been challenged by false assumptions in the past, namely that (1) people need more information to be moved to action; (2) visualizing catastrophe motivates action; (3) scientifically framing the issue is the most persuasive; and (4) reaching the audience is most effective with mass communication (Dryzek et al. 2011) Challenging these assumptions ire findings that meaningful engagement with the public also depends (1) values, beliefs, social systems, incentives and assistance to be moved to action; (2) an awareness of the attention cycles of issues and the importance of linking climate change to more salient problems; (3) hinging on audience and context, the most credible communicator is not always the scientist; and (4) tailoring messages to specific audience is often more effective (Dryzek et al. 2011, Downing and Ballantyne 2007). These findings emphasize that climate communication is a nuanced and evolving field of knowledge.

Scientists play a significant role in climate science communication. Although scientific writing and statistical tests have their strengths, they cannot do the work of communicating climate science problems on their own. Fortunately, data can be channeled into powerful visualizations that connect data with the public and make planetary threats visible. Tufte (1987) writes that “often the most effective way to describe, explore, and summarize a set of numbers—even a very large set—is to look at pictures of those numbers”. Unlike raw numbers, pictures may also transmit scale, emotion and urgency. Throughout Chapter 1, I discuss how photography, maps, figures and data artworks as effective ways to engage the public in climate science. I also include a smattering of data artworks that escape categorization as pure art or science, helping bridge my two chapters and illustrate the merits of art within the science world.

Table 1. List of scientific figures corresponding to topics and visualization principles.

Fig. #	Title	Topic	Data	Published	Visualization Principles
3	USGS, South Cascade Glacier	Retreat	1928-2014	1928-2014	Photography Parallelism
4	Oefner, The Rhone Glacier	Retreat	1880-2020	2020	Superimposed Parallelism
5	Porter, Topography and Isoglacihypses	Distribution	1977	1977	Mapped picture Multivariate
6	Post et al., Effect of Orientation on Glacier Size	Distribution	1971	1971	Mapped picture Topograph
7	Riedel and Larrabee, NC Mass Balance	Mass Balance	1959-2011	1959-2011	Graph
8	Pelto, Landscape of Change	Mass Balance Climate Change	1880-2015	2016	Graph Visual metaphor
9	USGS, South Cascade Glacier Area Loss	Mass Balance Glacier Retreat	1958-2015	1958-2015	Animation Coding
10	Pelto, Mt Baker Accumulation Area Ratio	Mass Balance	2009	2009	Map
11	Riedel, Cordilleran Ice Sheet	Past Glaciation	16.3 ka	2017	Landscape features
12	Anna McKee, Glacial Maximum	Past Glaciation	16.3 ka	2018	Schematic illustration Visual metaphor
13	SIGMA Peru, Impacts of Glacier Retreat	Culture			Concoction Coding
14	Frans et al., Glacier Contribution to Streamflow	Downstream Impacts	1960-2010	2018	Coding
15	Riedel and Larrabee, Fraction glacier Cover in Skagit Watershed	Downstream Impacts	2009	2016	Coding
16	Frans et al., Observed and Modeled Distribution of Glacier Area	Downstream Impacts	1915-2010	2018	Model Multivariate
17	Anesio and Laybourn-Parry, Microbial Food Webs of the Cryosphere	Ecological Impacts	2019	2012	Mapped picture
18	Anesio and Laybourn-Parry, Gray-Crowned Rosy Finch and Ice Worms	Ecological impacts	2012	2012	Figurative illustration
19	Pitman et al., Impact of Glacier Retreat upon Five Species of Pacific Salmon	Ecological Impacts		2020	Concoction Coding Multivariate
20	Morgan and Krosby, Nooksack Climate Vulnerability Assessment	Ecological Impacts	2050-2080	2017	Coding Symbolism
21	SC2, Projected Changes in Skagit River Basin Streamflow	Vulnerability and Adaptation Downstream Impacts	2038-2067	2019	Model

The North Cascades

The North Cascades are a tumultuous, vast mountain range spanning more than 300 miles between the Fraser River in British Columbia and the Columbia River as it snakes through Washington. For two million years, glaciers have sharpened and shaped this topography (Beckey 2003, p. 11). Between 21 and 11.6 thousand years ago, the Northern Cascades were capped with the southernmost lobes of the Cordilleran Ice sheet, a blanket of ice that covered all but the highest peaks (Riedel 2017). To the south, extensive valley and alpine glaciers abraded the land. After 11.6 ka, most of this ice retreated, leaving hundreds of small, isolated alpine glaciers dotting the range. Although much of the ice is now gone, the force and immensity of past glaciation is immutably evident in long U-shaped valleys, deep lakes, rock ridges worn into narrow arêtes, huge glacial erratics, and milky green rivers full of glacial flour. More than 700 alpine glaciers remain after the last global ice age (Post et al. 1971).

People have lived amidst this glacial landscape for thousands of years. Salish-speaking tribes on the western side of the mountains include the Nisqually, Cowlitz, Puyallup, Snoqualamie, Skykomish, Stillaguamish, Skagit, Nooksack, Sto:lo Halkomelem and Thomson. The eastern flank is inhabited by the Klickatat, Yakama, Kittitas, Wenatchee and Okanogan (Beckey 2003). Today, the North Cascades contain numerous human communities, hydroelectric projects, timber and mining claims, cultural sites and recreation sites. Amidst settlement and development, glaciers still provide many types of ecosystem services. In many ways, glaciers are central to the character of the North Cascades, even as they rapidly retreat under modern climate change.

Climate in the North Cascades is driven by the regional effects of the Pacific Ocean and the Pacific Crest. The western side of the Cascade Range has a cool maritime climate, with temperature and precipitation moderated by the Pacific Ocean and related climate patterns such as the Pacific Decadal Oscillation and El Niño–Southern Oscillation (Granshaw 2002, Raymond et al. 2014) The orographic effect of the Cascade mountains creates a more continental climate on the east side of the Cascades, with wider seasonal temperature ranges and less average annual precipitation (Raymond et al. 2014). Within the North Cascades, high relief creates large spatial variations in temperature over short distances (Granshaw 2002). Therefore, a winter storm can result in heavy rain at low elevations and great drifts of snow at altitude. Glaciers are most concentrated on volcanoes such as Mt. Baker and Glacier Peak, where névé fields 2700 to 4200

meters above sea level produce steep gradient valley glaciers (Hubley 1956). There are also concentrations of glaciers in mountainous pockets on the Cascade Crest like the upper Thunder Creek Watershed (Post et al. 1971).

Early Surveys and Science

Science arrived in the North Cascades on the heels of European explorers and surveyors. The first glaciers to be written about in the contiguous United States were in the Cascades. In 1833, physician and botanist William F. Tolmie journaled that "a few small glaciers were seen on the conical portion" of Tahoma, or Mt Rainier (Beckey 2003, p. 12). However, between the early 1800s and the 1950s, the North Cascades remained one of the most poorly mapped areas of the US. The efforts of early surveyors Ross, Thompson and Gibbs were complicated by thick forests, steep valleys, and the vastness of the range (Beckey 2003, p. 37). After an attempt to cross the North Cascades in 1814, Alexander Ross concluded that "A more difficult route to travel never fell to a man's lot." So even after glaciers were identified in Washington State, it was not until the mid-20th century and the advancement of technology such as cameras and planes that they were systematically catalogued.

In the 1940s, Forest Service employees J.B. Richardson and William Long photographed many glaciers throughout the North Cascades. Glaciers had been rapidly retreating for two decades, and the range-wide impact of climate on glaciers was immediately clear. Based on this documentary evidence, Long concluded that climate was best reflected in the retreating condition of local glaciers and remarked "Here the record of past climatic changes is clear and unmistakable, with the glaciers waxing and waning with broad uniformity, as the climate fluctuated from one extreme to the other." (Long, 1955). (This pattern is later expressed through synchronous patterns in annual mass balance across regional glaciers, see Figure 4.) The cataloguing of glaciers continued in the late 1950s as Post et al. (1971) identified, mapped and described all glaciers in the North Cascades with vertical and oblique aerial photography (Granshaw 2002). Also in the 1950s, Richard Hubley began studying glacier termini with aerial surveys. Advances and retreats of termini (glacier toes) is one of the best measures of glacier health (Pelto 1993). Between 1950 and 1955, 50 of 73 surveyed volcanic and non-volcanic glaciers advanced (Hubley 1956). These results are indicative that the warmer and wetter climate (producing much heavier snowfall, and therefore glacier accumulation, at high elevations) during

the 1944-1976 period in Western Washington drove glacial advance, particularly on volcanic glaciers (Hubley 1956). From 1960-1979 the United States Geological Survey (USGS) continued the annual aerial photographic surveys.

Early Visuals of Glacier Change

One of the most common tactics for visualizing glacier change over time is repeat photography, with two or more photographs arranged side by side. The adjacency and common viewpoint of the images allow for a reading of differences over time. Visual parallelism facilitates certain ways of seeing (canvassing, sorting, reviewing, contrasting and identifying) that connect to our cognitive capacity to reason and compare (Tufte 1997, p. 80). Parallelism is a simple and effective way of communicating how glaciers have changed, as the viewer is engaged in comparison from the first glance. On the scale of a single glacier, side-by-side photos are remarkably effective and accessible visual data. A comparison of historical and contemporary photography reveals patterns of glacier retreat, especially when intermediate images are included.

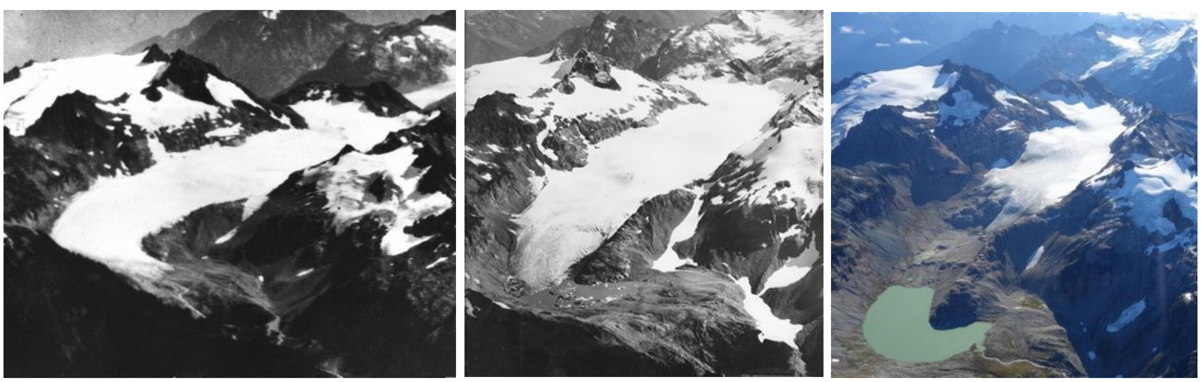

Figure 3. Aerial images from 1928 (USGS), 1955 (Post et al.) and 2014 (USGS) depict the retreat of the South Cascade Glacier.

To these early observers, photography guaranteed documentary evidence for the existence of glaciers, as well as their relatively quick responses to climate. Images could be gathered from mountaineers exploring remote regions, and they could verify the statements of old-timers. Repeat photography can help illustrate landscape change such as glacier advance and retreat and patterns of ecological succession (Byers 1987). At the turn of the century, many historic glacier images were rephotographed by the USGS (the USGS Repeat Photography Project focused on Glacier National Park was started in 1997). Other researchers contributed to

comparisons within the North Cascades. This growing library produced side-by-side comparisons that entered the popular media and raised both awareness and alarm bells. One moment that contributed to major public response was when in 2003, Hall and Fagre predicted that almost all of the namesake glaciers within Glacier National Park (GNP) could vanish by 2030 under then-current climate models (Saunders and Easley 2010). This finding was warped into the message that GNP would have no glaciers by 2020, which generated much public outcry and awareness of glacier retreat, as well as public doubt in climate scientists when glaciers did not in fact vanish by 2020. This serves as a cautionary tale to sensational science communication. Repeat glacier images are powerful and straightforward depictions of glacier change that have affected the knowledge and opinions of the public through general media.

Historical photographic records of glaciers are also valuable communication tools in other regions, with prime examples in the European Alps (Lambrecht and Kuhn 2020) and the North Cascades (through the National Park Service and studies such as Granshaw 2020). The strength of repeat glacier photography is that it can be dramatic and poetic at the same time that it imparts information.

In addition to acting as primary sources of data, photographs also capture and shape dominant narratives. Photographic evidence of climate change defied Romantic views of the North Cascades landscape, which imbued faith in the perpetuity of nature. This transition is expressed by photographer William Long in the following visually descriptive memory. The glacier he describes was located in the eastern North Cascades, where few glaciers advanced during the 1944-1976 period (unlike the advancing volcanic glaciers in Western Washington) due to drier climate.

> "The glaciers of Washington are perpetual, I thought, either stationary or advancing and always imparting a distinctive height and whiteness to the rugged hinterlands. Blinded by the dazzling icy covering, I developed a kind of mountaineer's indifference to the seemingly lasting beauty of the snowy peaks… I was dismayed to observe that the glacier was rapidly shrinking. Perhaps other Cascade Mountain glaciers also were melting. I could imagine the peaks denuded of their icy covering, standing ragged and desolate, like rows of ancient saw teeth, all rusty and stained. My observations extended north of

Mount Stuart to Lyman Glacier, in the vicinity of Lake Chelan. The melting of this glacier was of almost catastrophic proportions" (Long 1955).

Long's colorful narrative shows that over the course of just a few years, the narrative shifted from the sublime, to one of catastrophic loss. Visuals of this drastic change would also contribute to the iconography of glaciers as *the symbol* of global warming.

Photography of glaciers thus marked the onset of a public and scientific interest in glaciers, and transition in glacier narratives. The data within photography has also unleashed waves of artwork that expand upon the emotive potential of these images. One highlight is the work of Fabian Oefner, a Swiss artist who creates interactive visual storytelling. In Glacier Timelines, he analyzed the yearly termini of the Rhone Glacier from photographs, and using LED-equipped drones, mapped the glacier's behavior over the past 140 years (Figure 4). The result is a reality-based virtual world, in which the landscape and pathways can be explored. The referenced accuracy of historical data (optimized by photo-documentary techniques) merges with the interactive experience to link our emotions to this place that is not concrete in space or time. The Rhone project is one example of how data from historical photos is continually being repurposed and re-illuminated by artists.

Figure 4. Data Artwork 1. Fabian Oefner: The Rhone Glacier, photograph, 2019-2020.

Glacier Distribution

One of the first steps in understanding the relationship of glaciers and climate was understanding glacier distribution. Meier (1961) identified that over three quarters of the ice in the contiguous United States was situated in the North Cascades of Washington State. Then began a scientific effort to determine what controlled the distribution of this significant quantity of ice. Porter identified the configuration of a glaciation threshold of the North Cascades, based on latitude and elevation of existing glaciers (Figure 5). These limits parallel the Cascade Crest and generally increase in elevation to the east, although some east-west troughs such as the Skagit Valley break up this pattern, by allowing moist maritime air to penetrate eastward, thus driving the glaciation threshold up (Porter, 1977). The milestone contribution to the understanding of glacier distribution was Post and others 1971 *Inventory of North Cascades Glaciers* which established the location and extent of all glaciers in the region. A total of 756 perennial ice masses larger than 0.1 km^2 were recorded, with a total area of 267 km^2.

Visuals of Glacial Distribution

In an environment complicated by climate, topography and geology, visual representations are particularly valuable for parsing out patterns and communicating findings. These figures contribute to an understanding of where glaciers are likely to form, based on climatic and topographic factors. The isoglacihypses depicted by Porter (1977) link knowledge on individual glaciers to regional patterns of climate and topography. Portraying the shape of these driving forces is a bridge between complex patterns and understanding—ultimately a critical step in predicting climate impacts on glaciers, such as where they are likely to disappear, under what conditions they might persist, and how they are a product of larger earth systems processes. Although every glacier is a unique locality in many ways, they are broadly controlled by the same processes, as shown in this zoomed out view.

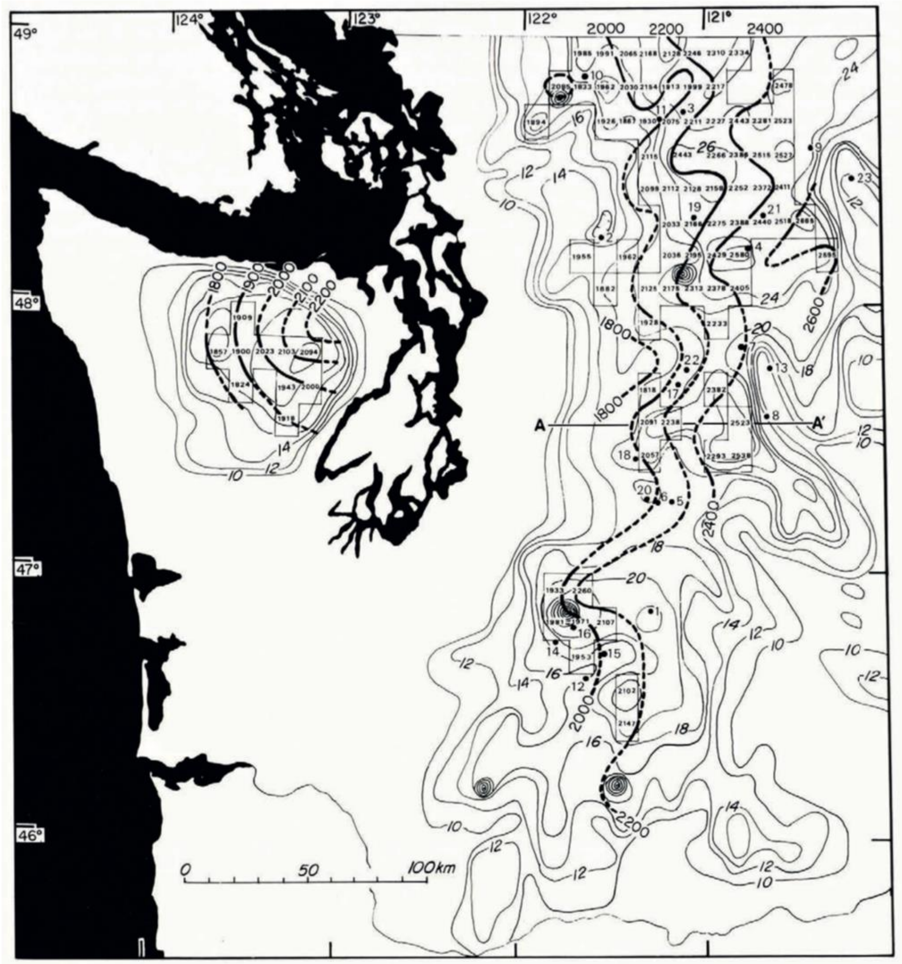

Fig. 1. Map of western Washington showing gross summit topography (contours in hundreds of meters) and isoglacihypses (heavy lines) depicting the configuration of the glaciation threshold (meters). Mean altitude of the glaciation threshold within each glacierized quadrangle is given in meters. Numbered points (1–23) are locations of meteorological stations within the Cascade Range (see Table I).

Figure 5. A map of western Washington overlaid with isoglacihypses conceptualizing how topography and climate determine the distribution of glaciers (Porter 1977).

The 1971 Post report also included illustrations about how topographic factors control glaciation, one of which shows how existing glaciers are much more extensive on north facing aspects than south facing aspects (Figure 6). As simple as this figure is, it beautifully represents the effect of orientation on glacier size to an audience just beginning to understand the glaciation of the Cascades Range. The maps in the report place glaciers within a spatial and hydrological context and the photographs portray a complex and unknown world. Each picture displays a unique peak, glacier, and pattern. The effect of combining visuals of broad scale processes such as elevation with visuals of diverse glacier types is that the patterns, beauty and variety of North Cascades glaciers are simultaneously expressed.

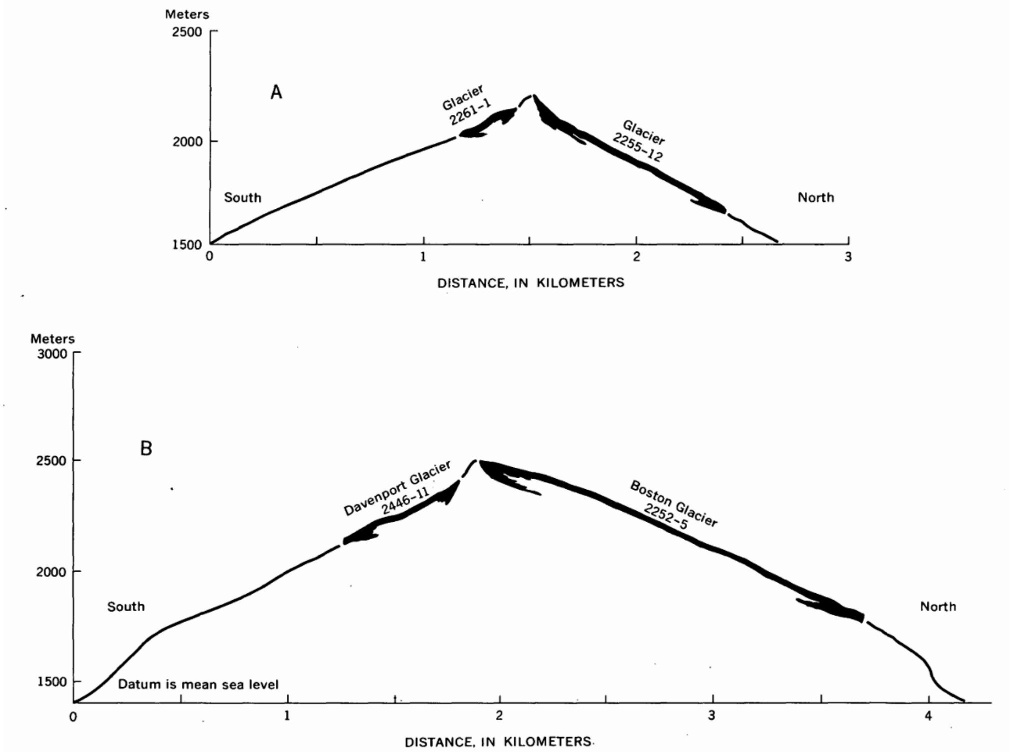

FIGURE 2.—North-south profiles between (*A*) Marble Creek and McAllister Creek and (*B*) Basin Creek and Skagit Queen Creek, showing the effect of orientation on glacier size.

Figure 6. North-south profiles showing the effect of orientation on the size of glaciers on two distinct peaks (Post et al. 1971).

A takeaway from the figures in this section is that visual depictions of glaciers are necessary to understand the patterns of both glacier distribution and change. Unlike a set of coordinates or a table of 75 conditions that can only be efficiently organized by a computer processor, a figure turns information into a structure that the human brain can process intuitively. The intersecting conditions of topography and climate that can support glaciers is complicated. Fortunately, patterns can be revealed and understood through maps and profiles. Scientists should examine their data with graphs and diagrams, both to understand the information that they collect and facilitate communicating it with the public.

Monitoring

Glacier monitoring efforts, which include mapping and measuring individual glaciers as well as creating inventories of glacier groups, aim to understand how glaciers change over time (Fountain et al. 1997). In 1959, the USGS began monitoring the mass balance of South Cascade Glacier in Washington, beginning one of North America's longest glacier mass balance records.

This project was focused on the net mass budget, or the balance between accumulation and ablation per year (Meier and Tangborn 1965). Facing the challenge of tracking glacier change across an area as remote and rugged as the North Cascades, the selection of one benchmark glacier was meant to represent general climate responses to glaciers across the North Cascades Range, and complement the monitoring of glaciers in regions such as Alaska and Montana.

However, one glacier was not fully representative, and means of accessing new glaciers became available. The North Cascades Glacier Climate Project (NCGCP) was founded in 1984 with the objective of studying 48 glaciers every year for fifty years, with detailed mass balance measurements on 10 of these (Pelto 1993). In 1993 the National Park service added 4 glaciers from within the North Cascades National Park (NCNP) complex to the benchmark monitoring program initiated by the USGS in 1958.

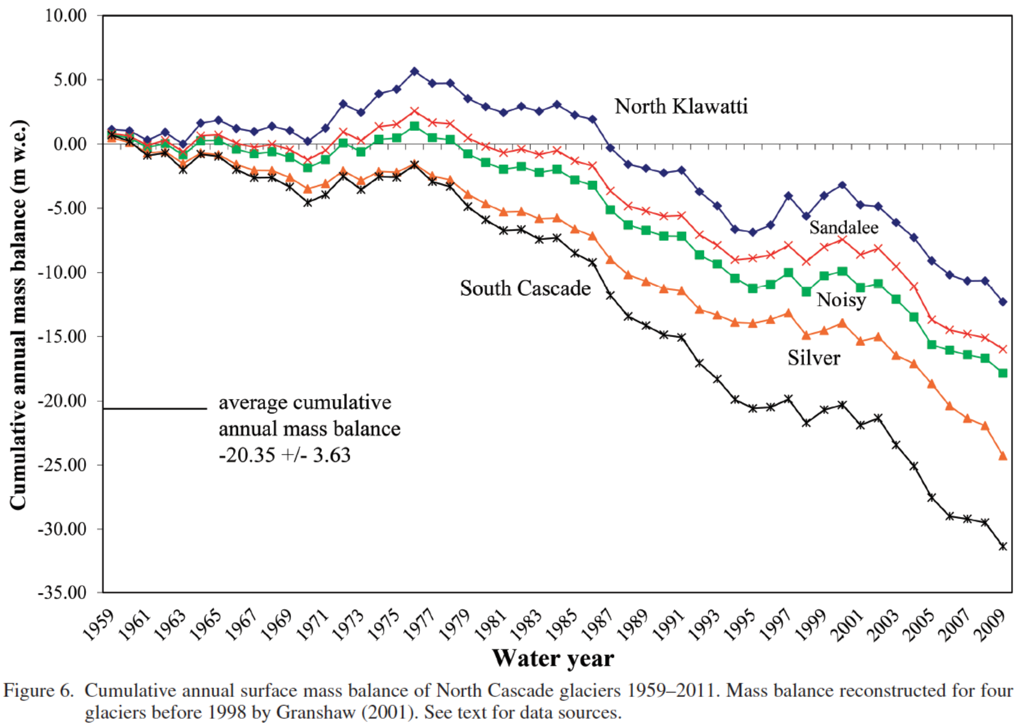

Figure 7. Annual mass balance of North Cascades National Park study glaciers 1959-2011 (Riedel and Larrabee 2016).

Most of this monitoring continues to the present day and contributes to knowledge of glacier dynamics and hydrology in response to climate change. Long term monitoring studies have enabled detailed analysis of glacier response to climate over the past 70 years. The broad trajectory since the mid 1950s has been one of cumulative mass loss—more years of negative

mass balance than positive (Riedel and Larrabee 2016). Today, the current disequilibrium of North Cascades glaciers is apparent in their "rapid and ubiquitous" retreat (Pelto 2006). Annual measurements of the NCNP glaciers reveal a steadily negative mass balance since the 1970s (Riedel and Larrabee 2016). Synchronous changes in mass balance across glaciers show that regional climate change exerts similar effects across diverse glaciers. Figure 7 is a straightforward and traditional depiction of regional glacier mass loss, leaving out details on the unique glaciers while depicting broader trends.

Figure 8. Data Artwork 2. Jill Pelto: Landscape of Change, 2016.

In *Landscape of Change,* Pelto incorporates four datasets into one watercolor. Sea level rise, increasing global temperatures, use of fossil fuels, and glacier volume decline are all represented by trendlines. By overlaying changing global climate patterns with patterns and color evocative of their sources (merging subject and object), Pelto creates a sense of rising consequences and concern for the planet and the atmosphere. The combined accuracy and emotional impact of this watercolor—the data being both alarming and beautiful—allow this piece to fit in both the art and science realms.

Between 1910 and 1940, most North Cascades glaciers were retreating rapidly (Harper 1993, Hubley 1956). There was a striking reversal in this behavior between 1944 and 1976, when around half of North Cascades glaciers began advancing (Hubley 1956 and Pelto 1993). This was especially pronounced on Mt. Baker's high elevation maritime glaciers which increased in length by 13 to 24% during the 1944 to 1976 period (Harper 1993). These remarkable changes in glacier behavior sparked questioning about glacier's relationship to climate, providing the impetus for long term monitoring. Looking back at glacier behavior and climate records, it becomes clear that increased winter precipitation and low summer temperatures during the mid-20th century drove the advance of some western Washington glaciers. In the 1980s, winter precipitation decreased and summer temperatures increased. By 1984, most North Cascades glaciers were once again retreating (Pelto 1993). Within a century, the dynamic response of glaciers to climate had been well exhibited, and annual monitoring programs provided the data.

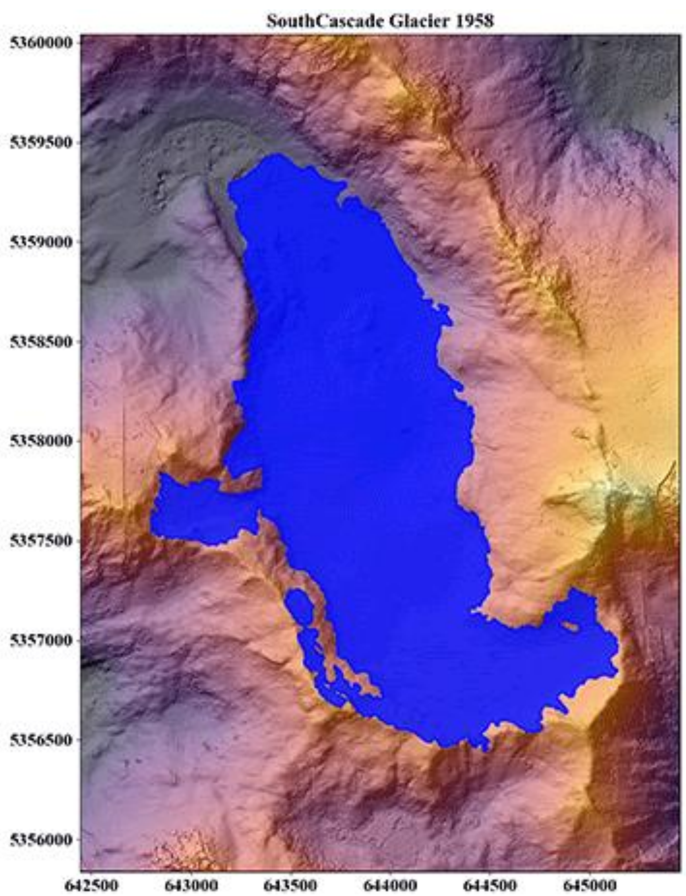

Figure 9. South Cascade Glacier area change 1958-2015 (USGS 2020).

Visuals of Long Term Monitoring

The USGS animated map (Figure 9) presents the diminishing area of the South Cascade glacier. This visualization compiles data from more than 50 years of measurements and photography, marking increased complexity compared to side-by-side photograph comparisons. Although this map succeeds at communicating changes in area over time, it lacks details on changes in glacier thickness, proglacial lake formation, erosion and ecological succession (the type of information that the photographs provide). In the Visual Display of Quantitative Information, Edward Tufte (1997) remarks that “Not a great many substantive problems, however, are exclusively two-dimensional. Indeed, the world is generally multivariate. For centuries, the profound, central issue in depicting information has been how to represent three or more dimensions of data on the two-dimensional display surfaces of walls, stone, canvas, paper, and, recently, computer screens.” (Tufte 1997). The problem of multidimensionality is present in this animation. Glaciers are a complex, substantive problem. Although many time periods can be condensed into one image, two dimensional pictures still lack essential information.

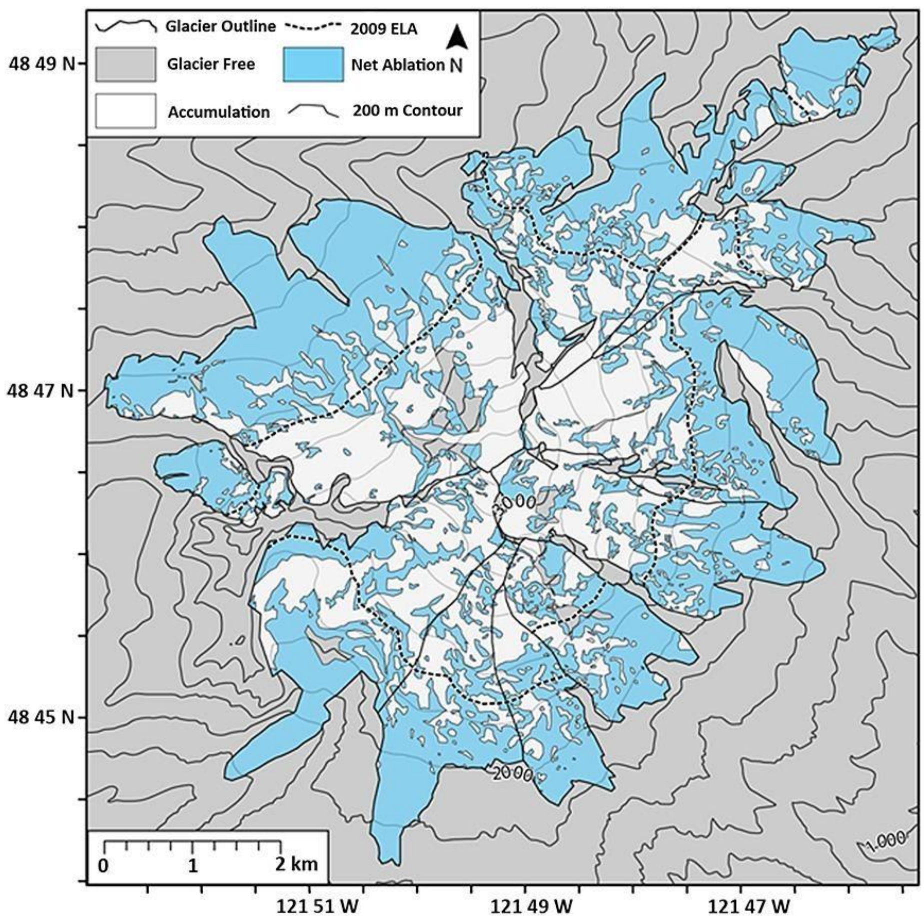

Figure 10. 2009 Accumulation area ratio based on aerial photography for Mt Baker (Pelto 2012).

Another facet of glacier monitoring programs is distinguishing areas of accumulation versus ablation. A glacier requires 65-70% of its area to remain in the accumulation zone to have equilibrium (Pelto, 1993). As seen in Figure 10, the accumulation area was far below 65% on Mt Baker during the summer of 2009. Blue depicts the net ablation areas, or the symbolic blue ice of unsheltered, rapidly melting glaciers. White designates areas of accumulation, or those that retain snow throughout the year. Layered on a topographic map, this information successfully conveys elevation, hydrologic divides, glacier area and accumulation and ablation zones. Tufte (1997) claims that "Maps express quantities visually by location (two-dimensional addresses of latitude and longitude) and by areal extent (surface coverage) …Despite their quantifying scales and grids, maps resemble miniature pictorial representations of the physical world." This map is a pictorial representation of the physical world, containing multiple layers of information. It succeeds in conveying as much information, or more, than most figures of the accumulation area ratio.

Past Glaciation

Reconstructing the behavior of glaciers thousands of years before the present yields important data for understanding the earth-climate system and poses an incredible scenario in which much of Northern Washington was covered in ice. This section asks, "What does understanding past glaciation lend to our current relationship to climate change?" Although this topic rarely travels outside of scientist's circles, the information and visualization of past glaciation thresholds in the NC could prepare us for significant changes in the glacial landscape today.

History shows that the glaciers of the North Cascades are highly sensitive to changes in climate. Approximately 21 ka, the North Cascades emerged from the Last Glacial Maximum (LGM). During this period, paleo-environmental reconstructions indicate a decrease in temperature of 5 to 7 degrees and a 40% reduction in precipitation compared to today (Riedel 2017, Porter 1977). The LGM was followed by millenia of complex glaciation and deglaciation, until the end of the Pleistocene at 11.6 ka (Riedel 2017). During this period, the Cordilleran Ice Sheet (CIS) repeatedly advanced and retreated across the Northern Cascades (Figure 7) (Riedel 2017). Around 17 ka, the Puget Lobe of the CIS flowed over the area of Seattle for over a thousand years, with a thickness of around 1000 meters (Porter and Swanson 1998). Mountain

valleys vanished under thick rivers of ice, leaving only peaks taller than 2,000 m above the ice surface in northern Washington (Kovanen and Easterbrook 2001). Millennial-scale perturbations of climate including Bond Cycles drove these advances and retreats (Riedel 2017).

These substantial changes in the reach of ice reveal that even small variations in past climate have been powerful enough to completely alter the pattern and shape of the landscape such as by turning on continental glaciation, eliminating solid rock divides and reversing the flow of rivers (Riedel, personal communication). Usually, we consider glaciers to be features formed by their surroundings, bounded by the walls of a north-facing, high elevation cirque, for example. But in the not-too distant past of the North Cascades, glaciers made a significant impact on the morphology and height of the range itself over long-term erosional processes (Mitchell and Montgomery 2006). Within the past 300 years, there have been two other periods of advance: The Little Ice Age, which ended in the late 1800s, was one, after which glaciers have notably retreated (Riedel 1987). Mid-20th century advance (as recorded by Hubble 1956) was the second.

Visuals of Past Glaciation

The ultimate visual of past glaciation is the landscape itself, with the topographic imprints of Pleistocene glaciation still evident. To a trained eye, U-shaped valleys, moraines and chatter marks on bedrock all reveal the power of glaciers over millennia. However, on paper, maps are the finest visual. Riedel (2017) synthesized regional studies and mapped glacial patterns since the LGM. This map also benefits from rough ice surface contour intervals, revealing the depth of the ice sheet across its spread. By combining modern day landscape features with the phenomenal extent of the Cordilleran ice sheet, the viewer is both oriented and awed by the scale of past glaciation.

Although climate and glaciation from 17,000 years ago may not seem like the most urgent climate science to share and understand, this topic holds unique power. When we see that small variations of past climate drove huge icy swings, our relationship to present climate may change. Suddenly the power of climate change to trigger huge landscape changes is possible. Our climate imagination has been sparked. Effective visualizations of past glaciation should prepare us to read significant changes upon the land that glaciers occupy, and open space in our minds to

visualize drastic changes and a range of possibilities for ice, habitats, and societies amidst the contemporary climate crisis.

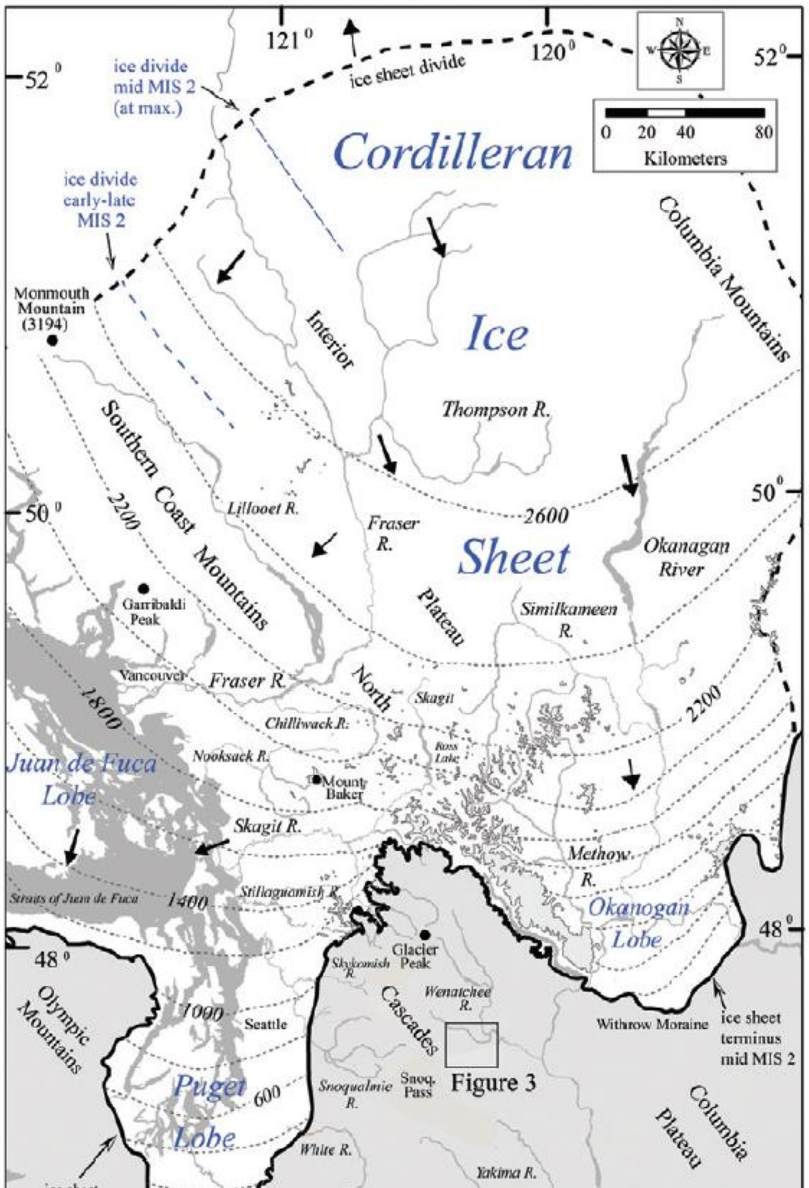

Figure 1. Maximum extent of the southwestern sector of the CIS at 16.3 ka reconstructed with data from Wilson et al. *(1958), Prest* et al. *(1968), Waitt (1972, 1977, 1979), Waitt and Thorson (1983), Booth (1986), Clague* et al. *(1980, 1983, 1989), Ryder (1989), Kovanen and Slaymaker (2004), Riedel (2015), and Evans (written communication). Ice surface contour interval is 200 m.*

Figure 11. Map showing the maximum extent of the Cordilleran Ice Sheet in Washington (Riedel 2017).

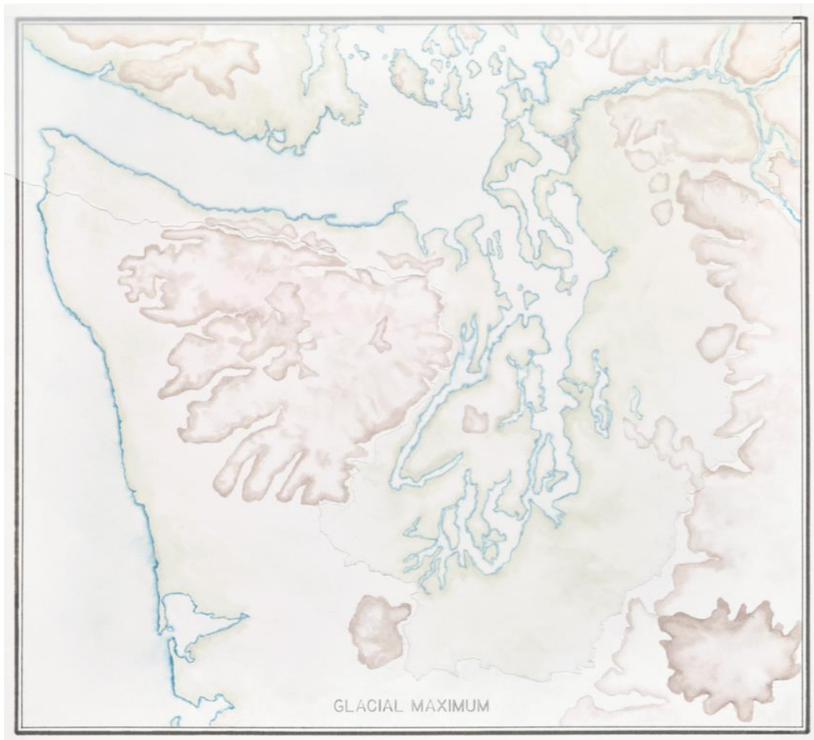

Figure 12: Data Artwork 3. Anna McKee: Glacial Maximum, 2018.

Brushing up on the same glacial maximum subject as Riedel, but from an artistic approach, Anna McKee allows data to shape her watercolor *Glacial Maximum* (Figure 12). McKee relied on a schematic illustration of past glaciation to create this subtle portrait of Western Washington under ice. In the watercolor, blue and green lines meet where modern land and sea converge. Brown shapes designate the sites of mountain ranges and alpine patterns of glaciation. A subtle grey line outline near the Puget Sound lightly marks where the Puget Lobe of the CIS would have been. This painting provides an array of clues instead of explicitly stating evidence for past glaciation. This technique engages the viewer in tracing clues and subtle lines, gathering evidence for the title of the piece just as a scientist looks for clues across the landscape in the form of moraines and glacial outwash plains. The subdued colors reflect standard mapping techniques, initially appearing as a modern map to the viewer. However, unlike a typical map, this one ranges over vast timescales. A painting of western Washington 17,000 years would make this area completely unrecognizable. *Glacial Maximum* is not only a map and a landscape, but it is also a portrait with lines and color lending Washington unique character. This painting succeeds in hinting that glacial forces have already overwrought this landscape, and therefore other realities in this space are possible, linking past and future.

Flowing Streams, Downstream Impacts

Mountain ranges are effectively huge water towers, due to their great capacity to store water in the form of snow and ice, and therefore provision human and environmental needs downstream. The North Cascades glaciers once stored as much water as all of the states' lakes, rivers and reservoirs combined (Meier 1969). The Fraser and Columbia River basins (the major watersheds that frame the North Cascades) are North America's most critical water towers units (Immerzeel 2019). In Washington, water availability impacts energy generation, water supply, agriculture, fisheries, recreation and ecosystems (Adelsman and Ekrem 2012). The North Cascades' vast stores of snow and ice, in combination with melt water's economic importance and natural demand, make these mountains significant local resources.

Climate change has a variety of hydrological implications for the North Cascades, each with myriad effects upon ecosystems and people. Across the range, glacier area and their contribution to surface melt are decreasing (Frans et al. 2018, Pelto 1993). For example, within the Skagit River watershed, between 1959 and 2016 glacier area shrank by 19% with a resulting -24% reduction in the surface melt component (Riedel and Larrabee 2016). Two major effects of melting glaciers are changes to streamflow timing and changes in stream temperature, which in turn can affect fish habitat and stress fish.

In comparison to snow or rain, ice is a more durable form of water storage. Ice prolongs the volume and timing of peak flows. Glaciers are particularly vital water resources during the summer, when their melt may comprise double the contribution fraction of other times of the year (Fountain and Tangborn 1985, Riedel and Larrabee 2016, Stahl and Moore 2006). They can provide 25% of the North Cascade region's total summer water supply (Pelto 1993). Paradoxically, the hotter and drier the summer, the more downstream communities downstream utilize glacier melt, but the more endangered the ice becomes. The tipping point has already been reached in some glacierized basins (Huss and Hock 2018). For example, glacier melt contributions to August runoff have already peaked in many catchments of the Canadian headwaters of the Columbia River (Moore et al. 2020). In the future, earlier snowmelt and higher evaporation will reduce streamflow in summer and early fall, prolonging the period of low flows in most watersheds (Hamlet et al. 2005, Raymond et al. 2014). Basins with higher ice cover, such as the Thunder Creek watershed, will have late peak runoff dates for the longest, while low ice cover basins will shift to earlier peak water sooner (Huss and Hock 2018). Although

streamflows will decrease in summers, increasingly warm and wet winters will raise winter, fall and spring streamflow (Raymond et al. 2014).

Visuals of Downstream Impacts

Although glacier contributions to rivers and streams are one of the most direct connections between ice and society, this connection is weakly illustrated. Generally, the scientific literature lacks images that visualize melting glaciers hydrological impacts on ecosystems and societies. In the following section I analyze a few of the innovative (and not-so innovative) depictions of glacier cover and contributions to streamflow from scientific literature.

Figure 13. Data Artwork 4. Cultural and environmental impacts of glacier melt (SIGMA Peru).

Figure 13 depicts the specific climatic, cultural and economic downstream impacts of glacier retreat on communities in the form of an illustrated confection. Societal Impacts of Glacier Melt in the Andes (SIGMA) Peru is a research group studying the impacts of melting glaciers upon Andean societies. This graphic is from a webpage designed to educate English school children on this topic. The designer uses color, perspective and cultural references to make this an effective infographic. Saturated colors attract the eye, specifically to ice, water and agriculture. Several layers of dramatic landscape features show that these impacts are present on a very large scale, while the sides slope in, retaining the importance of locality. Traditional

Peruvian dress and cultural activities stress the site-specificity of glacier retreat and the impacts on local livelihoods. Finally, overlaid symbols point to impacts that can be further explored through text blurbs on the webpage.

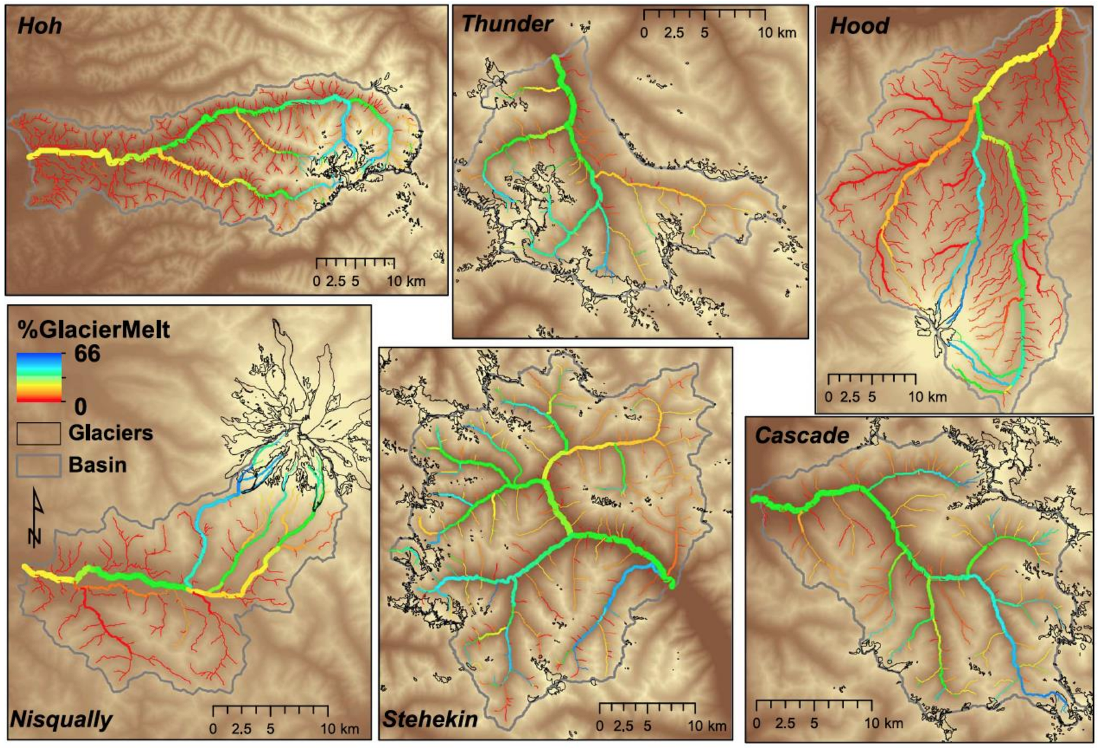

Figure 5. Mean percent glacier contribution to streamflow in September along the stream network of each study basin for the 1960–2010 period. The stream networks were defined based on local contributing area and routing of the digital elevation model surface and are used in the model for routing stream discharge. Network segment width is scaled by its discharge volume relative to discharge at the outlet.

Figure 14. Glacier melt contribution to streamflow (Frans et al. 2018).

Turning over to the literature, glacier contribution to streamflow is one key metric for understanding the impacts that glacier loss will have upon downstream areas. In Figure 14, Frans et al. (2018) color code streams by proportion of glacier melt to streamflow, which allows for several variables to be expressed in a single image. The colored ribbons invite the viewer to explore the data. The text of the study explains that the mean glacier ice contribution to streamflow in the Thunder Creek Basin from July-September is 12%, and during September the mean is 28%. In upstream tributaries, this contribution may fall in the 50-66% range. Figure 14 successfully depicts late summer glacier contributions to streamflow by (1) enlisting a map, since the location and relationship between tributaries is important, (2) using a fine grain size, to afford observations across the complex catchment area, and (3) choosing a scale with enough variety to capture a range around the mean of 28%, and the extreme of 66% (a rainbow that starts at zero

and ends at 66, rather than 100%). A clever choice in matching the metric (streamflow contribution) to the map feature (waterways) while keeping it visible (thickening the lines) benefits the figure. The six basins are shown on nearly the same scale, which aids in quick comparison. The color scale even evokes sensations of hot and cold, which correspond to “no ice” and “lots of ice”. The dominating blues and purples of the Thunder Creek map add sensorial understanding that it is the iciest basin in the North Cascades. This visual code helps us contrast Thunder Creek from Hood and Nisqually which are volcanic watersheds that do not have glaciers present along all tributaries.

Rainbow stream pathways are a more intuitive and explorative method for representing glacier streamflow contribution than the swatch technique employed in Figure 15. Here, percent glaciation is designated by an array of stippled, striped or solid patterns, having nothing to do with the actual visual appearance or feeling of glacier cover, or local characteristics of tributaries. This figure contains chartjunk, or distracting design that does not contribute information value (Tufte 1983). A better approach would be to recode the bins along a grayscale, with white designating 10-16% glacier coverage, greys taking the mid, and black remaining with the “No Glaciers” category. But alas, we are left with a figure that reminds us of a stray cat, covered in mysterious scabs.

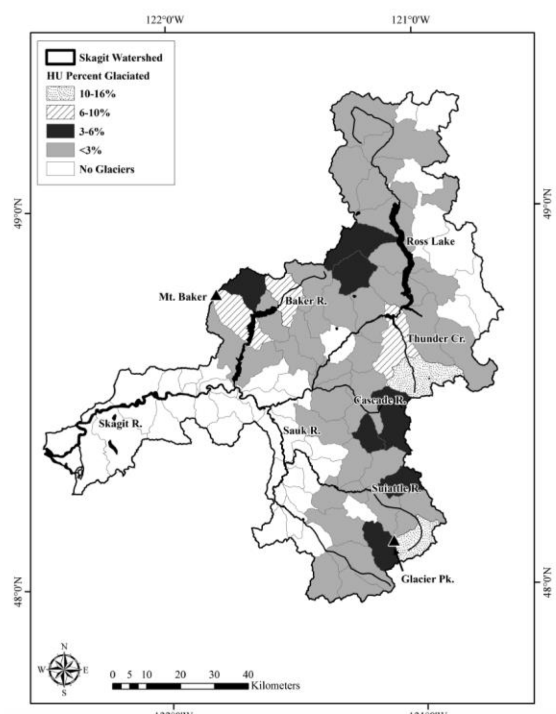

Figure 8. Fraction of glacial cover in Hydrologic Unit Code 6 scale sub-basins of the Skagit watershed in 2009.

Figure 15. Fraction glacier cover in the Skagit watershed (Riedel and Larrabee 2016).

Another approach to visualizing watersheds and the distribution of glaciers is taken with Figure 16, also from Frans et al. (2018). Each of the study's watersheds fills one column. The observed and modeled distribution of glacier area across elevation is shown by the y-axis. The intervals on the x-axis vary, but show the total glacier area. The thickness of the hourglass shapes is spatially meaningful in two different dimensions, providing a sculptural and physical connection to the ice under discussion. Another way of looking at this figure is to think that each watershed has its glaciers pooled and pinned up on a wall, with a cloud (dashed lines) hanging around them where the glaciers used to be. Figure 16 imparts multivariate information (historical and recent times, observed and modeled data, elevation shifts, six different river basins) elegantly and intuitively. The hourglass shape draws our attention to data in a novel way, allowing us to perceive new patterns and place modeled glacier area right next to observed glacier area. This modeling and visualization style here open new horizons for depicting glacier change.

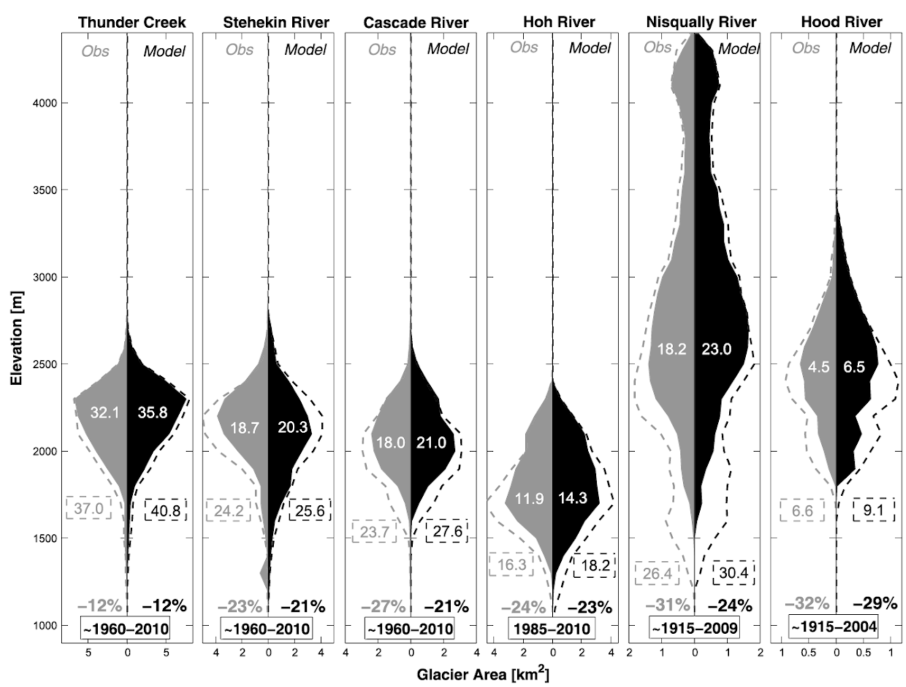

Figure 3. Observed and modeled distributions of glacier area according to elevation for historical (dashed) and recent (filled) periods of time. The period of analysis varies between basins and is reported at the bottom of each plot. For reference, the historical and recent total glacier area (km^2) is reported in the dashed boxes and filled areas, respectively. The relative change in glacier area is reported as a % over the period of analysis at the bottom of each plot. Note that the *x* axis (glacier area) intervals vary between basins.

Figure 16. Historical/recent and observed/modeled distributions of glacier area according to elevation for six watersheds in the Pacific Northwest (Frans et al. 2018).

Ecological Impacts

Although cold and quiet on the surface, glaciers are home to diverse assemblages of plants and animals and are particularly rich in algae and bacteria. Anesio and Laybourn-Parry (2012) argue for the acceptance of glaciers and the cryosphere as a unique biome dominated by microorganisms and important biogeochemical processes. These hidden organisms contribute to iron cycling and carbon respiration and sequestration at local and global scales. Glaciers are also enmeshed with the functioning of downstream ecosystems and species. In this section I review evidence and visualizations for ecological communities inhabiting the surface, interior and snow cover of glaciers, as well as those aquatic and terrestrial ecosystems dependent on glacial melt.

Cryoconite holes at the ice surface are one micro-environment inhabited by microorganisms (Anesio and Laybourn-Parry 2012). Cryoconite holes are found in the ablation zone, and are associated with sediments and surprisingly high nutrient concentrations. The primary production activity that occurs in these cryoconite holes and other areas of the glacier surface contribute organic matter and nutrients to nearby environments (Hood et al. 2009).

An even more visible form of life on North Cascades glaciers are ice worms (*Mesenchytraeus solifugus*), small annelids similar to earthworms. They are one species that lives permanently on glaciers, and nowhere else. In the North Cascades they may occur at astonishingly high densities and have been observed as high as 2600 ice worms per square meter (NCGCP observation on the Suiattle Glacier in 2002). The glacier "biome" subsidizes terrestrial food webs, as shown in the case of alpine glaciers, ice worms, and Rosy Finches (Figure 15). The consistent presence of ice worms provides a high elevation food source that enables Rosy Finches (*Leucosticte tephrocotis*) to nest high above treeline (Hotaling et al. 2020). Ice worms and their predators will be affected by climate change in several ways: first, ice worms die at temperatures much more than 10°C (NCGCP). And as glaciers vanish, so do genetically distinct populations of ice worms—reducing overall genetic diversity of this species. Climate change is also anticipated to reduce biodiversity in cold-adapted microbes, and subsequently their contribution to biogeochemical processes within ecosystems (Anesio and Laybourn-Parry 2012).

Visual conceptualizations of glacial food webs are rudimentary and speculative. As in the early days of North Cascades glacier exploration, there is not enough data to warrant discerning data visualizations, but mapped images can at least illustrate general connections amidst this food web (Figures 17 and 18).

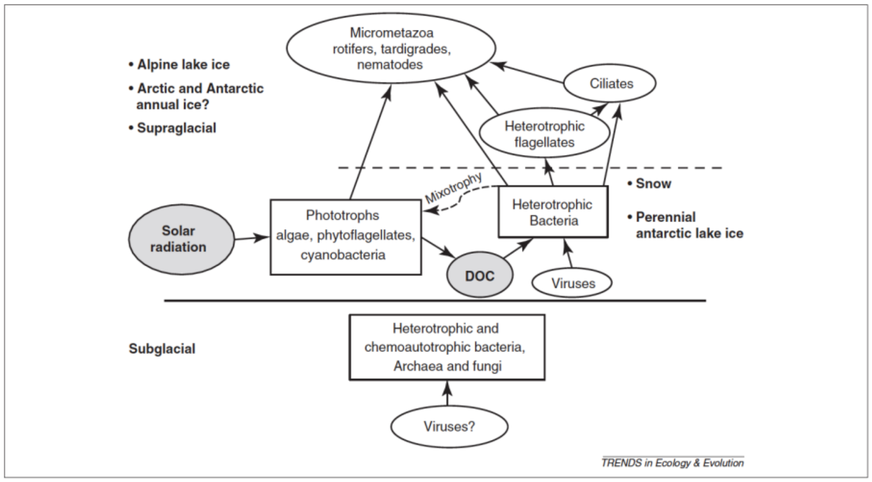

Figure 2. Microbial food webs in different cryospheric environments. Bold text indicates the different habitats. Phototrophs exude part of their photosynthate as dissolved organic carbon (DOC) that provides an energy source to heterotrophic bacteria. Some autotrophs are mixotrophic feeding on bacteria and DOC as well as undertaking photosynthesis. Viral infection and lysis of bacteria short-circuits the transfer of carbon up the food web, recycling carbon and other nutrients to the pool.

Figure 17. Microbial food webs of the cryosphere (Anesio and Laybourn-Parry 2012).

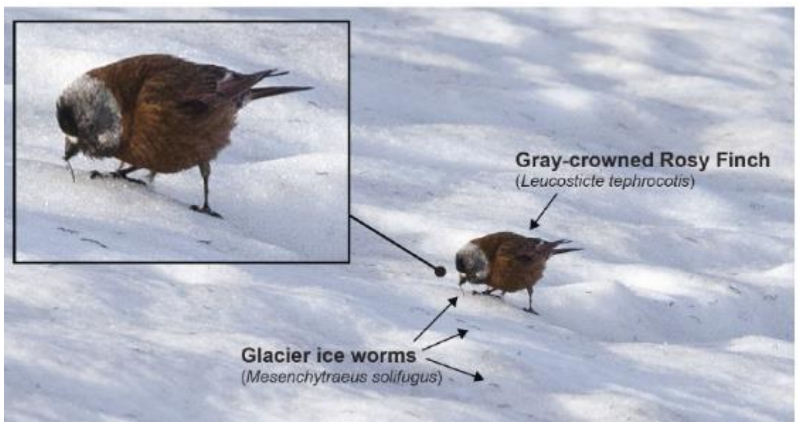

Figure 18. Gray-crowned Rosy Finch (Leucosticte tephrocotis) feeding upon ice worms on the Paradise Glacier in Washington, with both species identified by arrows (Anesio and Laybourn-Parry 2012).

Along with the organisms that dwell on glaciers, aquatic and terrestrial communities near or downstream of glaciers are affected by climate change (Huss et al. 2017). Glacial meltwater is cold, carries fine sediment, and can be rich in nutrients such as phosphorus and iron (Schroth et al. 2011). Primary productivity in glacially fed aquatic ecosystems may also subsidize organic carbon to downstream ecosystems (Caraco et al. 2010). In Washington’s Skagit Valley, these characteristics ripple throughout the river and Puget Sound (Riedel and Larabee 2016). Climate change-driven reductions in glacial meltwater thus have significant bottom-up effects on ecology in glacial lakes, in and around rivers, lakes, streams and nearshore marine areas. Aquatic macroinvertebrate communities must adapt to shifting environmental conditions: initially to the heightened cold of peak glacial water contribution to streamflow, and later to warmer water as

glacial melt contributions decrease (Finn et al. 2010). Diversity of local aquatic macrofauna may peak at intermediate levels of glacial runoff (Jacobsen et al. 2012). In summary, temperature and nutrient regime shifts in glacially-sourced streams are likely to affect macroinvertebrate species assemblages.

Fish, particularly the iconic salmonids of the North Cascades, will also be affected by hydrological changes. First, projected increases in stream temperature will stress salmonid populations by making them more susceptible to disease, eliminating cold water refugia, and introducing thermal migration barriers (Raymond 2014). Changes in peak streamflow will also govern available habitat, with some streams in the Western Cascades shifting from "favorable" to "stressful" salmon rearing habitat (Beechie et al. 2006, Rand et al. 2006).

For terrestrial communities, rising air temperatures and shorter duration of snow cover have a slew of ecological impacts, including changing the duration of the growing season which can lead to increased productivity, increased frost exposure which may kill wildflowers (Inouye 2008), reduced mortality to some conifers (Oberhuber 2004) and increased risk of bark beetle infestations to other conifers (Coops et al. 2010). Although the high alpine is heating up, and specialized high alpine species lose their space (Dirnböck et al. 2011), receding glaciers reveal terrain at their feet. This space is quickly colonized by early-successional plants, often followed by trees. In a worldwide tree line meta-analysis, Harsch et al. (2009) found that tree line was advancing in 52% of sites and receding at only 1%. Climate change will probably not cause species richness loss in the terrestrial mountain ecosystems, but instead cause an upward migration of species and communities (Lenoir et al. 2008, Chen et al. 2011).

Visuals of Ecological Impacts

Most of the studies cited above lack interesting or informative figures on alpine ecology. One possible reason that these studies tend to be missing helpful figures is that these systems are remarkably complex. Basic or standard visualization methods are not adapted to such complexity, and scientists concerned with explaining new connections don't have energy left to make figures. Pitman et al. (2020) illuminate how the species response is the product of many factors: the phase of glacial retreat or climate change, subsequent environmental changes, and the life stages of the particular species. Several visual communication strategies make this

information visible in Figure 19. Symbols denote life stages, text specifies which of the five Pacific salmon species are impacted, and color codes for habitat quality or quantity.

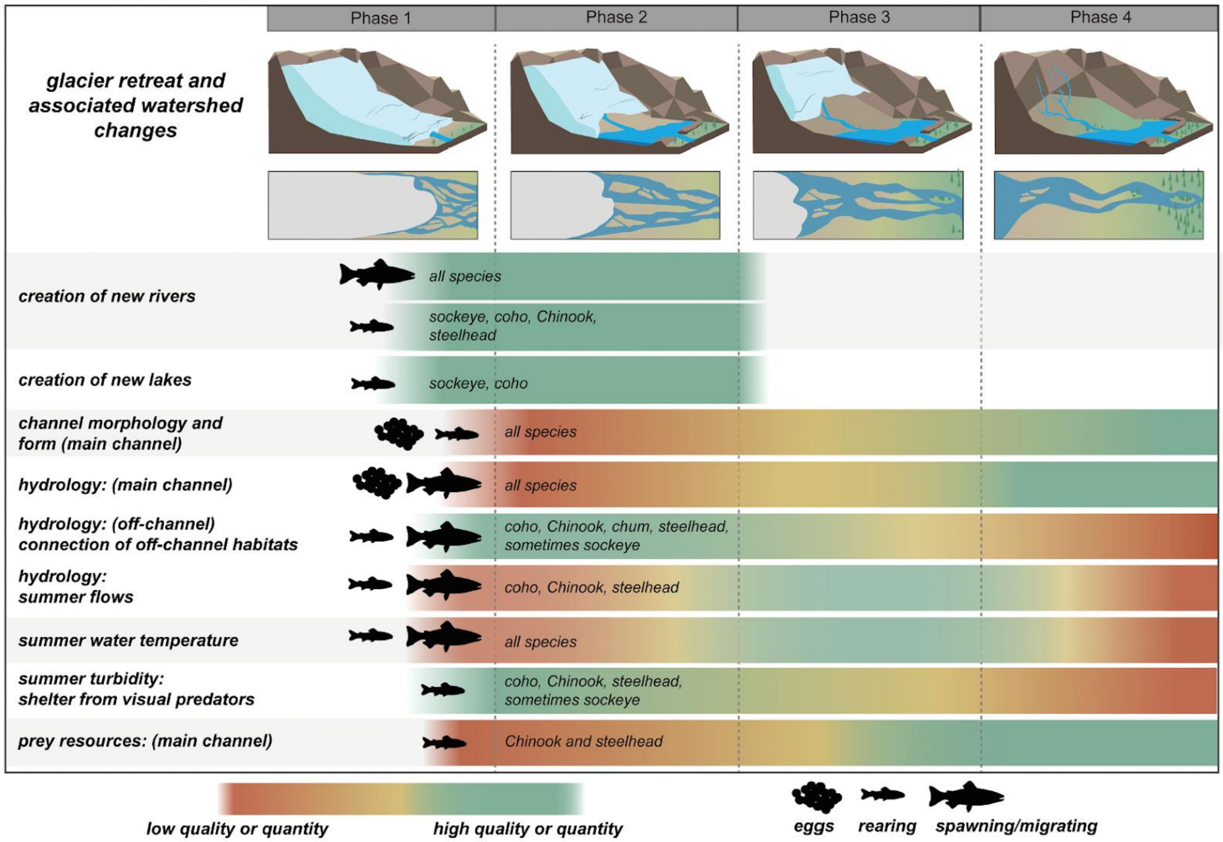

Figure 3. Predictions of how glacier retreat and its associated watershed changes can affect salmon species across life phases during the different phases of glacier retreat.

Figure 19. Impact of glacier retreat upon five species of Pacific salmon (Pitman et al. 2020).

A second visualization of ecological changes is contained in the Nooksack Climate Vulnerability Assessment (Morgan and Krosby 2017). The vulnerability of culturally important species and habitats is calculated under two time horizons (2050 and 2080) and two climate scenarios (RCP 4.5 and RCP 8.5). This menu of possible futures inspires current action, to put us on a track towards the less alarming outcomes. As we have seen several times, red encodes warm, drastically altered environments and cooler colors such as green encode cooler, more stable ones. The pictorial representation of the data, as opposed to the table, groups the species according to vulnerability (Figure 20). This is a concern-inducing hierarchy of what will go missing. The simple colors and stenciled species make this report an accessible resource for the public. However, it could be taken further. This figure is overdesigned by two indicators of vulnerability: both the bins, and the colors. The bins could be eradicated and the species instead

placed in secondary categories (importance as a cultural resource) or on a map (locations within the study area) that would dish up some more multivariate information and possible new connections.

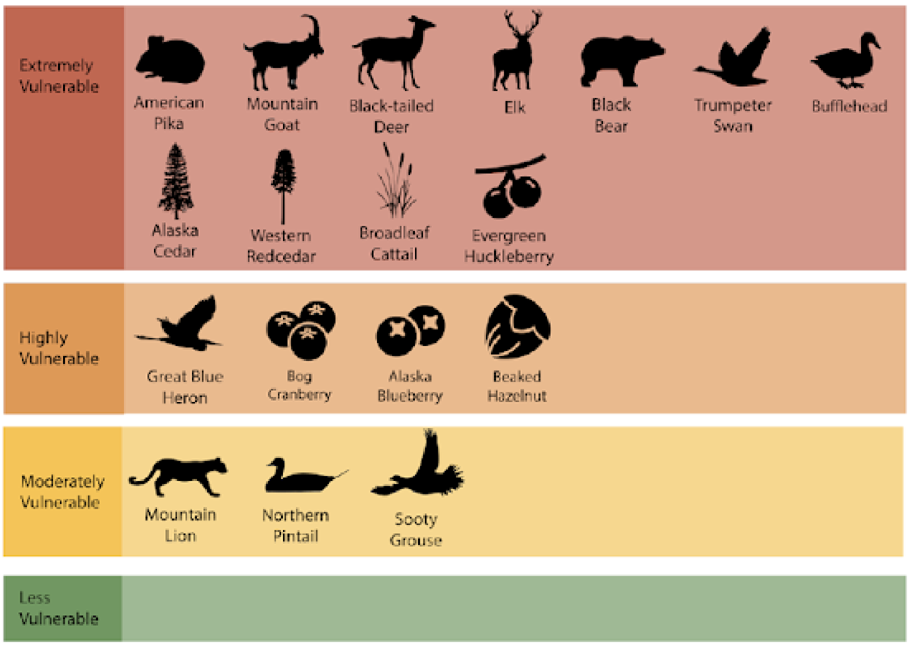

Figure 11. CCVI rankings for the 2050s under a high greenhouse gas scenario (RCP 8.5) and the 2080s under a low greenhouse gas scenario (RCP 4.5). CCVI results are identical for the 2050s under a high greenhouse gas scenario and the 2080s under a low greenhouse gas scenario. Species fell into one of four categories: Less Vulnerable (green), Moderately Vulnerable (yellow), Highly Vulnerable (orange), Extremely Vulnerable (red). Image credit for species silhouettes available on page 34 of report.

Figure 20. Climate change vulnerability inventory for culturally important species under 2050 High RCP or 2080 Low RCP scenarios (Morgan and Krosby 2017).

Effective visualizations of ecological responses to glacier retreat and climate change employ (1) color gradations that encode species vulnerability, and (2) basic symbols to identify species or life stages within intricate ecological change. Taking information graphics on this subject to the next level to the next level may include mapping and visualizing species abundances in future climate scenarios or local distributions—even utilizing something like the hourglass shapes in Figure 16 to stand in for abundance.

Vulnerability and Adaptation

Climate change impacts environments and societies around the North Cascades. The average rise in temperature in the Pacific Northwest over the next 40 years is expected to be around 0.3°C (0.5°F) per decade (Mote et al. 2008). Most models project decreases in summer precipitation and increases in winter precipitation (Mote et al. 2008). These climatic shifts will

further reduce salmon habitat as stream temperatures rise over critical thresholds (Raymond et al. 2014), challenge the ability of water supply to keep up with demand in summer (Vano et al. 2010), pose problems for public health (Doubleday et al. 2020), affect forest biodiversity (Carroll 2010, Spies et al. 2010), and alter habitat for many animal species (Raymond et al. 2014), among other affects.

Vulnerability assessments examine climate change impacts on cultural and natural resources, with the goal of identifying valuable species and habitats at risk. In this field, indigenous groups are ahead of many other groups at mapping the futures of natural resources. Across the world, indigenous and local peoples have noted recent climatic shifts and the effects upon species life cycles and interrelationships (Turner and Clifton 2009). These observations have led to concern for traditional livelihoods and environmental relationships. In Washington, the Stillaguamish and Nooksack Tribe's Natural Resources Departments have partnered with the University of Washington Climate Impacts Group to assess the vulnerability of species and habitats important to their tribes. Often, vulnerability assessments segway into adaptation plans in which goals, conservation targets or management actions are put forward to reduce those vulnerabilities (Raymond et al. 2014). For instance, the Stillaguamish plan identifies 59 strategies and 190 actions to buffer the resilience of species and habitats facing climate change impacts.

Another organization in western Washington, the Skagit Climate Science Consortium (SC2), strives to identify the consequences of melting glaciers upon forests, dams, farms, recreation and water supply. This project connects projections such as "a doubling of the area that receives rain instead of snow from 1999 to 2080" with stakeholder conversations and adaptation plans. SC2 aims to reduce vulnerability and prepare communities for climate change by sharing science via interactive maps and models. Generally, these tools are created with collaboration between multiple stakeholders such as Seattle City Light, Indian Tribes, and research groups. Figure 21 shows a downloaded image from one tool that models projected changes in streamflow based on climate change modeling in the Skagit River Basin. The intended audience for this data is people with some background in hydrology and climate change, yet the tools are online with open access and guidance for exploring the visualizations so they are open to many users. Finally, an image download feature allows users to show the information in their own presentations and papers. As a visual communication strategy, models

bring additional interactivity and usability to climate data. The "ensemble" feature in this model enhances usability by distilling the overwhelming tangle of climate models into a smoothed line, while the background data is still visible. However, it can be difficult to interpret the impacts of projected changes, so more work is needed to link these technical models to other studies on impacts and groups working on the policies and programs that can address these matters.

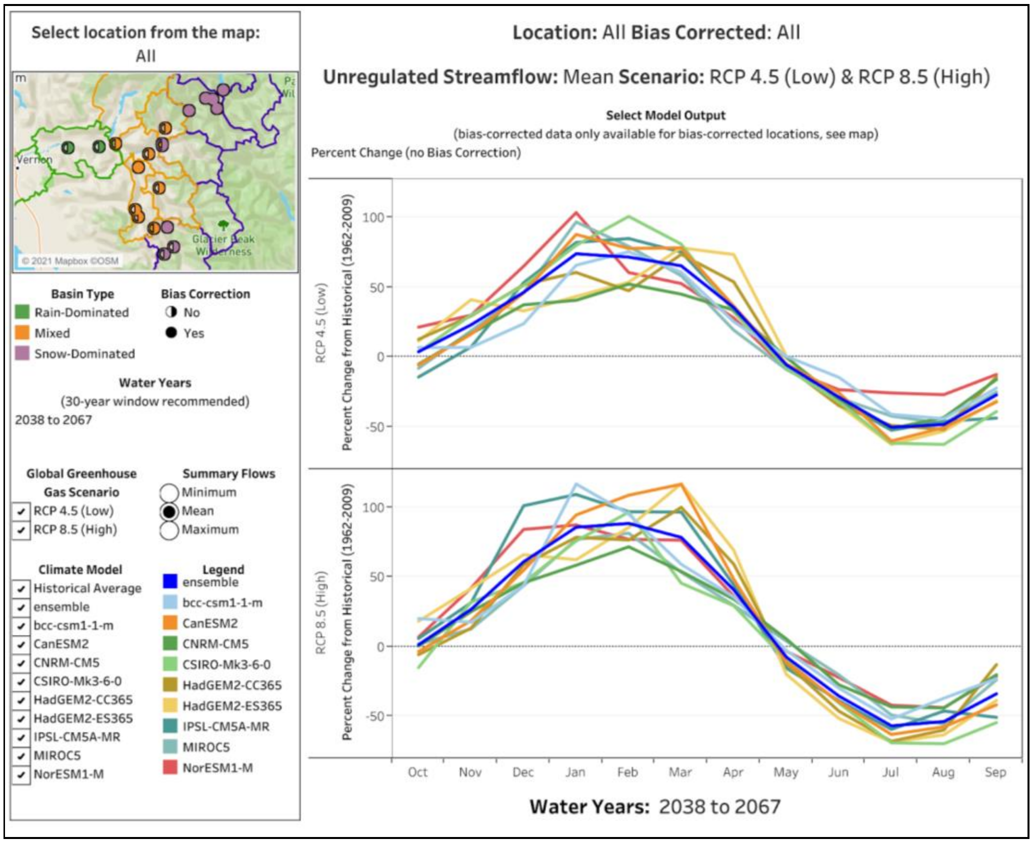

Figure 21. Projected Changes in Streamflow based on Climate Change Modeling in the Skagit River Basin, an interactive online tool to view projected changes in monthly streamflow averages and streamflow extremes across 20 sites in the Skagit River drainage (SC2).

Adaptation plans and climate models are a raw site to study visual science communication because scientists are working quickly to inform the public. In order to bring about policy change and conservation action, vulnerability assessments and adaptation plans must be communicated in an effective and timely manner. These tools and reports should be accessible public-facing resources.

Conclusion

This chapter has reviewed the basics of North Cascades glacier studies and the visual methods and styles that communicate this data. Visual science communication is an essential element of scientists' work, as it is the best tool to help the public understand data. Pictures can transmit scale, emotion and urgency that words cannot. I lean heavily on the framework put forth by Edward Tufte to analyze the clarity, quality and method of data visualizations. Although the techniques for glacier monitoring and visualizing data are not exclusive to the North Cascades, studying a small geographic subset of the fields reveals strengths and weaknesses in both efforts. Scientists engaged with glaciology of this region are influenced by one other, by the landscape, and by larger trends in glaciology and science visualization.

The timeline of North Cascades glacier studies presented in this chapter reveals how technology, research and visualization strategies have evolved in parallel. Whereas the North Cascades were thought to be terrible and unruly by early explorers, eventually planes and roads enabled comprehensive and repeatable glacier studies. Early and enduring methods such as repeat photography and mapping glacier area over time have built the foundation for understanding glacier changes. Sites such as the South Cascade Glacier, monitored since 1959 by the US Geological Survey, or the 48 glaciers under the North Cascade Glacier Climate Project's watch, track annual changes to ice, generating specific data about glaciers responses to climate change. Mapping and photography, being the main visual tools for these kinds of monitoring studies, have their advantages and disadvantages. Although seeing is believing, photography is static. Therefore, our first sight of glaciers as captured in aerial or other photographs establish a baseline expectation for what glacial landscapes should be. Glaciers' dynamic responses to climate, especially in the 1950s and the 2000s, have challenged the notions that the North Cascades glaciers are still or steadfast, and other media such as animation and data artwork have filled in some of photography's gaps. The latter chapters delve into more detail about how certain images of glaciers stick in the public memory and can sustain environmental narratives for a very long time.

Today, glacier research includes studying downstream impacts, vulnerability and adaptation. Although there is still much to untangle about how glaciers and their melt are connected to ecologies and communities, bold research has started to illuminate connections, although the visualizations must be more creative and novel. Public facing tools that forecast the

changes to landscapes and resources is one exciting contemporary way that data is being mobilized visually. Stakeholders from farmers to electrical utility companies to fishermen can benefit from the information and tools. New types of visualization, research and technology are building a new narrative that is inclusive of more people and species, and peers towards the future, forecasting what life could look like around these deglaciating landscapes.

Visual science communication can be mobilized in many different styles and may support many different narratives. Although climate and technology exert a powerful influence on research, it is the ways that we tell the data's story through pictures that resound most powerfully with the public and in turn sustain environmental narratives, guiding our relationship to climate change and our homes.

CHAPTER 2: ENVIRONMENTAL NARRATIVES WITHIN THE FIELD OF GLACIER ART

Introduction

Critique and Creativity

> "The climate crisis is also a crisis of culture, and thus of the imagination."
> Amitav Ghosh, The Great Derangement (p. 8).

Adapting to environmental change *and* analyzing art demand that we wield two essential tools: critique and creativity. We must consider what structures have and will continue to serve us, do justice, and make us think, and which structures are worn out, unproductive and unfair. In this chapter I explore how some artwork feeds specific glacier-environmental narratives, reinforcing historical environmental narratives. I ask how constructive this is, and how it may affect our environmental relationships. I also examine artists that believe in the future, and work through emerging future-facing narratives. By necessity, these artists sculpt us new worlds, show the public new perspectives, and spark new trains of thought. This chapter reveals a spectrum of art from elegiac to speculative. The biggest questions facing these artists, and this chapter, are: What do we do in the face of massive, monumental loss? What environmental narratives are broken, and which can we hold to help us face the future? These are essential questions for artists and society to consider, because as art demands interpretation, it also shapes how we think. By examining the way glaciers are performed through the work of these artists, I navigate dead ends and open doors within our thought and the stories we tell about the environment.

Environmental Narratives

What is narrative? Essentially a story, or how we understand our lives. We can think of science as a tool for building a rational understanding of the world, and art as a tool to feel the world. Stories move between these two (Fisher, 1984). Narrative is essentially how we navigate between art and science. Since narratives are how we make sense of our world, and will shape history, they should be used with consciousness and care (Cronon, 1992). As artists work to raise awareness of environmental problems related to the Anthropocene, they can produce destructive narratives. Anderson (2015) points out that the "Anthropocene narratives coming from the art

world seem to be most potentially destructive when they propose to do something, further reinforcing an attitude of human dominance over the planet. Paradoxically, art initiatives that stimulate critical thinking rather than simulate action have the potential to be most constructive." In this chapter I explore how art aligns with and advances different environmental narratives. I identify both constructive and destructive elements of these narratives.

Historian Mark Carey's article The History of Ice: How Glaciers Became an Endangered Species (2007), was foundational for informing how I have come to understand representations of glaciers and the social, cultural and political contexts they occupy. I trace several of Carey's narrative categorizations in this chapter. My contribution is connecting the narratives with works of art and occasionally through personal experiences in the North Cascades.

I start with the concept of the Sublime that arose in the European Alps. Then I turn to the idea of glaciers as laboratories, followed by their characterization as endangered species and symbols of climate change. Then I examine the narratives of glaciers as ruins and as playgrounds. Finally, I look beyond these solidified narratives to ideas of glaciers as community and speculative glacier art which opens possibilities for future glacier-landscape-human relations. Through this chapter I show how durable historical glacier narratives are. I simultaneously show how there have been enough depictions of ruin and doom and follow the gaze of forward looking artists and theorists to show how we need critical, conceptual and speculative art to tend an open, optimistic, and sustainable relationship with the environment.

Glaciers as Sublime

> "I remembered the effect that the view of the tremendous and ever-moving glacier had produced upon my mind when I first saw it. It had then filled me with a sublime ecstasy that gave wings to the soul, and allowed it to soar from the obscure world to light and joy. The sight of the awful and majestic in nature had indeed always had the effect of solemnizing my mind, and causing me to forget the passing cares of life" Mary Shelley, Frankenstein (p. 116).

Erase your glacial expectations, and imagine encountering a huge, dynamic body of ice splintering off of a craggy mountain. Without a rational scientific explanation, a warning or a marker of any kind, what would you feel during this encounter? Perhaps inspiration, puzzlement,

or terror. Throughout history, artists, poets and scientists have grappled with the changing nature of unpredictable ice-landforms (Carey, 2007). Humanity's awe of glacial landscapes is recorded in art spanning back to 1601, when Abraham Jäger painted the first known depiction of an alpine glacier: a topographical watercolor of the Rofener Glacier in the Ötztal Alps (Strasser et al. 2018).

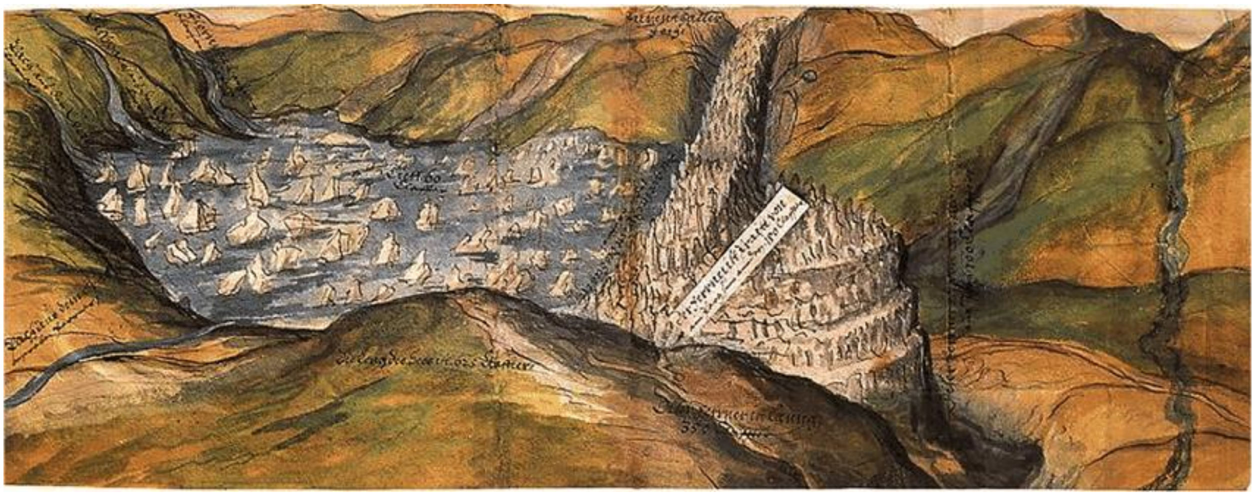

Figure 22. Abraham Jäger: The "Rofentaler Eissee" produced in 1601, depicting the Rofental glacier in the Ötztal Alps, Austria (Strasser et al. 2018).

Until the end of the 19th century, glaciers were not studied extensively by scientists, and retained characterization as terrible and overwhelming (Vanishing Ice.org). Artists of the Romantic movement such as Caspar David Friedrich exemplify how in the nineteenth century, glaciers represented "romance, mystery and unassailable majesty" (Knight, 2014). Combined with the Little Ice Age, a cold spell during which many European glaciers advanced, glaciers were perceived as immensely powerful. Today, even as glaciers remain inaccessible to many people on Earth, sublime glacial encounters are embedded in the public memory due to passages like the one at the start of this section, from Frankenstein written by Mary Shelley in 1818.

Even as glaciers came to be systematically studied during the Enlightenment, they retained elements of their overwhelming nature. Throughout time, the expansion and shrinkage of glaciers has been a source of their Sublime power. Emmanuel Kant's theory of the Sublime posits that sublime feeling is the cycle between the feeling of being overwhelmed and the pleasure of seeing the overwhelming overwhelmed (Ginsborg 2019). Glaciers, forever in turbulence and transition, achieve this. The "uncontrollable" advance of glaciers in the 19th century in Europe, or the phenomenon of surging glaciers in coastal British Columbia and

Denali, Alaska (Cruikshank 2005, Patel and Fountain 2021), qualify as the dynamic sublime. Current rates of retreat are another manifestation of the overwhelming. As all of these events are out of the control of humans, they can be sublime whether or not they are well understood.

Today, glaciated alpine landscapes remain assuredly sublime, even as they fracture and vanish. Personal experiences amidst ice provoke visceral artworks that emphasize sensation, scale, and certainly awe. Many contemporary artists blend immersion in the field with a powerful artistic practice. Zaria Forman is one example. As a large-format pastel artist, her depictions of icebergs make the fragility of Antarctica's dwindling icebergs visible, "emulating the overpowering experience of being beside a glacier," according to Forman's website. Viewing these works is a brush with the Sublime—there is the feeling of wonderment at seeing the saturated blues and swoops of glacial ice, and the feeling of reverence for Forman's ability to recreate these textures on such a scale, with simple pastels. The human hand and the natural forces simultaneously overwhelm. The dynamic, shifting ice is magnificent, ephemeral and visceral. Glaciers are fundamentally sublime, and fine art borrows their beauty easily. In return, glaciers are seen as purposeful because of the concepts transmitted by artists such as Friedrich or Forman.

Figure 23. Zaria Forman: Whale Bay, Antarctica No. 4. 88x144 inches, soft pastel on paper, 2016.

Glaciers as Laboratories

> "If La Pérouse [a French naval officer who explored of Alaska and British Columbia in 1786] imagined glaciers as manifestations of the Sublime — great yet terrible, wondrous yet fearsome — he took comfort in the technology he transported to measure nature's dimension, tame its uncertainties, and ascertain its physical attributes." Julie Cruikshank, Do Glaciers Listen? (p. 243)

The scientific process may transform encounters with glaciers from moments of terror into a process of claiming spaces and deriving information. Since the Enlightenment, glaciers have been mined for data by Western science (Carey, 2007). They produce knowledge in other ways, such as sentient myth and stories as Julie Cruikshank details in *Do Glaciers Listen?* Yet the narrative of glaciers as laboratories, places where scientific measurements can be gathered, is one of the most enduring glacier narratives, and heavily influences other perspectives such as the endangered glaciers narrative (Carey 2007). In this section I describe how artists react to three types of data that are pulled from the ice: scale, sound, and time.

Scale in the Laboratory

Since global warming has emerged as a prominent social and environmental issue, the climatic records stored in ice have captivated the attention of artists. The longest ice cores records are 800,000 to 2.7 million years old. These incredible resources are opportune and important records not only because they keep such extensive records (Kennedy and Hanson 2006), but because they are vanishing, a second key narrative to be built off later in this chapter. Accordingly, they act in the public sphere as libraries, time capsules, and storytellers. The power to share ice's stories is vested in the hands of those who can travel to the poles or high elevations and extract monumental ice cores. Throughout the laboratory narrative, it is important to remember that social, economic and cultural forces affect who has the power to reproduce the knowledge of glaciers (Carey et al. 2016).

The textures of ice cores energize the work of Peggy Weil and Anna McKee. Both artists depict textures of these ice cylinders, complete with bubbles, crystals and dust layers that once analyzed, reveal atmospheric conditions of the time. *88 Cores* by Weil is a video that descends through 110,000 years of banded ice from the Greenland Ice Sheet. Skimming these luminous

blue cylinders, the extensive memory of glaciers is emphasized. Weil says that the "pace and scale of the work is a gesture towards deep time and the gravity of climate change." Such gravity and time can be challenging to witness—yet Weil opens a window into the long memories of glaciers. By giving the public a chance to view the 'specimen' that typically only scientists would interact with, Weil builds a bridge between the laboratory and the outside world.

Depicting glaciers at different scales is another form of bridge building. Using a variety of printmaking techniques in combination, McKee animates state shifts from snow to ice. Between 2008 and 2014, Anna McKee created the *Ice Series* as part of the Deep Ice, Deep Time project (Anna McKee's website). Her work illuminates the textural signatures of ice ranging from microscopic structures of firn ice to aerial views of colossal ice sheets. The shifts between scales spark an important shift from seeing to doing. Physicist and theorist Karen Barad attests that "Seeing things across different scales is more than an attempt to represent the universe: it actively produces entities and relations. It is in this sense that seeing is already a "doing" (From Minimal Ethics for the Anthropocene, Barad 51). Such an active approach, working to connect both incomprehensible ends of space and size, transforms art viewing into "an embodied practice, rather than a spectator sport of matching linguistic representations to pre-existing things" (Barad 54). There is also feedback within the sciences: Understanding geological phenomena on a small scale contributes to our understanding of glaciology on a large scale, and vice versa. McKee's practice of engaging with data also verges on embodying loss, as "creating and organizing the structure and colors of icy worlds is a means of mourning and acceptance" (Anna McKee's website). Standing witness to loss is key to the glacier ruins narrative later in this chapter.

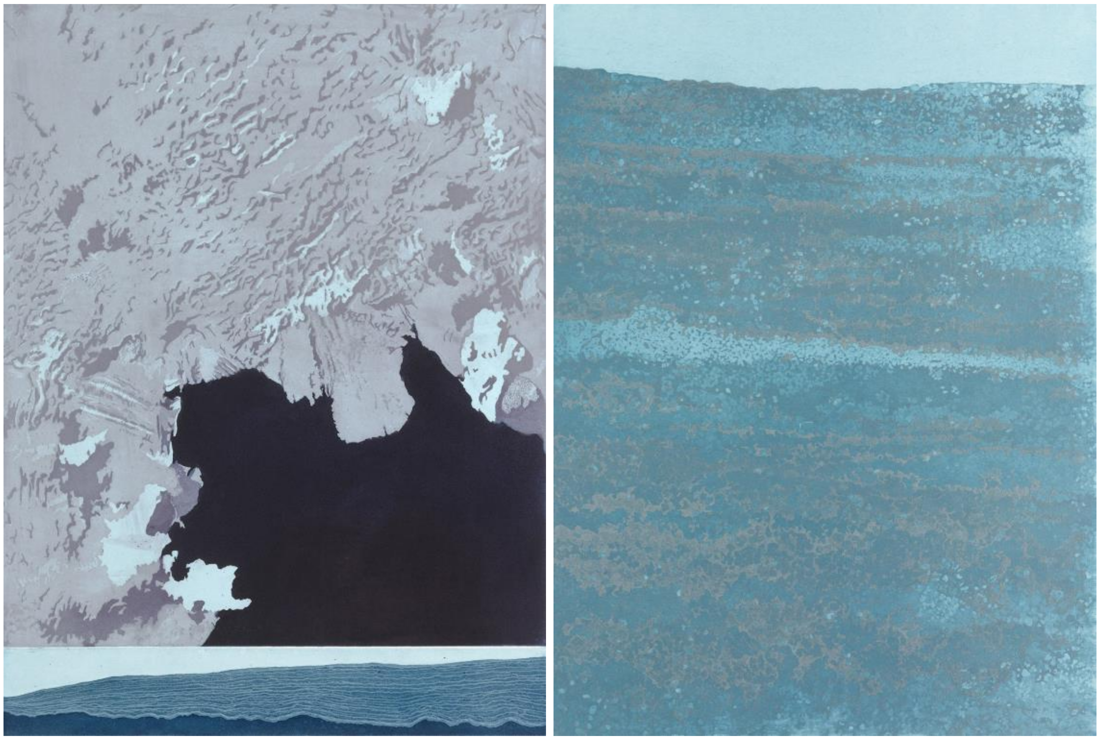

Figure 24. Anna McKee: Pine Island Basin, etching w/chine collé, 24x18 inches, 2012 (left) and Melt Layers (Silver), etching w/chine collé, 24x18 inches, 2012 (right).

To those who care about the data contained by the cryosphere, mourning is a rising theme. In the novel *The Lamentations of Zeno,* Iliana Trojanow tells the story of Zeno, a disillusioned and misanthropic scientist lost at sea in the misery of his own glacial loss. Reflecting on his chosen alpine glacier of study, Zeno says "I've been watching it my entire life, with passionate care and precise instruments." By visiting the glacier alone, "I could abandon myself to my senses, undisturbed, and feel the glacier's full emotional force before we captured its data. It was my doctoral advisor who placed this particular glacier in my care, an arranged marriage that in time became a union of love, as if every measurement were an acknowledgment of its singularity" (Trojanow 2016: 78). The aliveness of glaciers pulls at the hearts, not only the minds, of scientists and artists alike. Their mangled, broken bodies, especially visible in the smaller disappearing alpine glaciers, have the power to turn attention from science to mourning. What remains provokes lamentation of humanities planetary neglect, rather than glaciers' power and endurance, sentiments which may have peaked in the bygone era of the Sublime.

Sound in the Laboratory

Recently, the capacity of sounds to contain data about melting glaciers has been explored by scientists and artists alike. Glacier's voices can be understood as statistics, music and climate changes alarms. In a study on the underwater noise of melting icebergs, Glowacki et al. (2018) trace pulses of underwater noise to the release of bubbles from ancient ice. Bubbles generate delightful and musical qualities when formed or released. Recordings from Glowacki et al.'s acoustic array were analyzed for the directionality, intensity and statistics of sound. The growing field of ambient noise cryology allows sound to play a role as a remote sensing tool and distinguish different sources and rates of melt.

The creaks, pops and trickles of glaciers inspire a blending of data and music. Matthew Burtner conducts the Rivanna String Quartet in *Glacier Music*, an electroacoustic collection featuring the Alaskan natural landscape as the central instrument. Another piece is the auditory installation *Herald/Harbinger*, by Jeffery Kavanaugh, Shah Selbe, Jer Thorp and Ben Rubin, 2018. The subtle bubbling and breaking of the Bow Glacier is piped 135 miles from mountains to Calgary, the city that relies upon its melt. Both pieces serve to bring the sounds of remote and quickly changing environments to the public.

For humans, sound is a critical sense to engage in environmental problems and loss. It connects us to the environment and each other. Brandon LaBelle says that sound is "intrinsically and unignorably relational: it emanates, propagates, communicates, vibrates and agitates; it leaves a body and enters others; it binds and unhinges, harmonizes and traumatizes; it sends the body moving, the mind dreaming, the air oscillating" (LaBelle 2012, p. 468). In other words, it rouses within us what stale pictures of dwindling glaciers cannot. Often the first and last sense that we carry in our lives, sound is a critical sense. Ethnographer Gustavo Valdivia explains: "People, in general, are more accessible when you present them with sound than when you present them with graphs and visual information. Everyone can listen to things. You don't need to have a PhD degree to listen to recordings. For me, sound is a more accessible sense to say something about climate change." (Liang 2019). Valdivia records the voices of the Quelccaya glacier in Peru, weaving his soundscapes into both musical compositions and environmental outreach. Sound is emerging as a scientific tool for remote sensing and understanding complex glacier dynamics, as well as a means of connecting with the public in a way that visual art cannot.

Time in the Laboratory

Many passionate artist-glaciologists blur disciplinary distinctions where they share their work. One example is photographer James Balog, who in 2007 founded the Extreme Ice Survey (EIS) devoted to giving a "visual voice" to changing glacial ecosystems (Extreme Ice Survey website). Under the Earth Vision Institute, Balog's team has installed dozens of cameras over glacial ranges in Antarctica, Greenland, Iceland, Alaska, Austria, and the Rocky Mountains. The cameras have taken photos every hour, year-round, revealing the contemporary transformation of glacial landscapes. These images have been shared in media ranging from Balog's fine art ice portraits that celebrate "the art and architecture of ice" to popular documentaries such as Chasing Ice which enliven dry scientific data for the public (Volpe 2018). Balog believes that "the creative integration of art and science can shape public perception and inspire action more effectively than either art or science can do alone" (2017) which drives the transition to the classroom. EIS exemplifies how the glacier laboratory narrative can bring glaciology to the classroom via interdisciplinary channels.

Glaciers as Endangered Species and Symbols of Climate Change

Glaciers are one of the most powerful, widely used images used to visualize global warming (Carey 2007, Bronniman 2013). By melting, glaciers are showing us that the earth is vulnerable to human actions (Orlove et al. 2008). Their visual disintegration and ties to climate science have cemented their social status as measuring sticks of climate change. The risk of inaction is dire—sea level rise and warming will disrupt hundreds of ecosystems and millions of human lives. Climate change media capitalizes on the symbolism of glaciers (Carey 2007).

Satellite and aerial imagery have made the disappearance of glaciers accessible, and most importantly, predominantly visual. Not too long ago, glaciers could be considered eternal, distant, and inert by much of the world (Cruikshank, 2005: 6). Yet anyone with an internet connection today may track the changes in satellite imagery and find ice blinking out over time. This can foster knowledge about the loss of ice and inspire a sense of urgency to enact policy to protect glaciers. More effective than a graph of historical carbon dioxide levels or temperature, glaciers compel and convince the public that global warming is happening (Carey 2007).

Just as we feel driven to witness and protect endangered species when we see images of animals such as giant pandas, observing the dwindling population of glaciers around the world

rouses endangered species reactions in people: the desire to witness, protect and create policies around them. Carey (2007) identifies some of the complex ways in which the recent emergence of the endangered glacier narrative arises from a multitude of historical perspectives, including glaciers as menace, wilderness, laboratories, and places to explore or conquer. The idea of endangerment can be established through a variety of perceptions: most often, the tracking of their disappearance, and their capacity to archive climate data lead to taking steps to guard against their extinction. As with other environmental narratives, this one is embedded in social, cultural and political systems. Cruikshank describes glaciers as "a cryospheric weather vane for potential natural and social upheaval," (2005: 6) referring to the emergence of the endangered species narrative and the diverse interpretations it produces.

The endangered glacier narrative also drives trends in tourism. Sites such as Glacier National Park or Jökulsárlón lagoon in Southern Iceland attract throes of tourists to see ice breaking apart and melting (Jackson 2015). Like a critically endangered species, the dwindling number of glaciers can inspire "last-chance" tourism where people are driven to witness the ice before it is gone. Some last-ditch efforts cover tourism-heavy glacier destinations in the Alps with massive white tarps or fleeces during summers to enhance albedo and slow the melt of ice. In summary, the endangered glacier narrative grows from broader social and environmental crises, and inspires people to "save" glaciers however they can. Personal connection and urgency are the desired outcomes of the artworks I will describe in this section. This trend appears in the urban installation *Icewatch* by Olafur Elliason, and *The Last Glacier* project by printmakers Bruce Crownover and Todd Anderson.

Figure 25. Olafur Eliasson: Ice Watch, 2014. Bankside, outside Tate Modern, London, 2018. Photo: Justin Sutcliffe.

Olafur Eliasson engages the public sphere through his artworks and interventions in public spaces. Following the IPCC report in 2014, Eliasson installed icebergs in public squares in Copenhagen, Paris, and then London. *Ice Watch* was composed of blocks fished out of a fjord near Nuuk Greenland, “already ‘lost’ from the Greenland ice sheet” and transported to the cities via refrigerated shipping containers and trucks (Bottrill 2015). The goal of the work was to generate public conversations and action about climate change. By bringing blocks of ice to public spaces, where people can feel, see and hear them melting, Eliasson forges a connection between the public and the endangered ice, catalyzing a shift from thinking of climate change as an abstract phenomenon to being touched by the presence of subsiding ice. Timelapse videos record the gradual attrition of the ice as well as the many visits by passerby. Eliason situated *Ice Watch* in city squares in proximity to where climate policies are formed and enforced, allowing the installations to push for systemic change. Several were arranged in a clock formation in Paris and melted away during the COP21 conference (Bottrill 2015). This work does an exceptional job facilitating two of the endangerment steps that Carey identifies: lamenting the symbolic loss of ice, and pushing for public policy to prevent their disappearance.

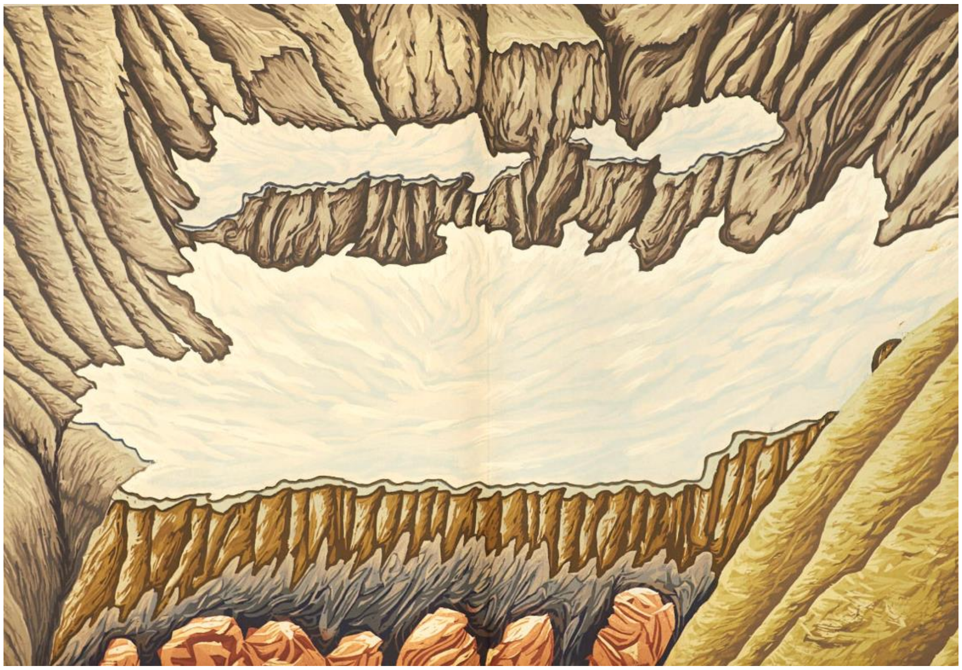

Figure 26. Bruce Crownover: Salamander Glacier, 2015. Reductive woodcut on Okawara Washi, 24 x 36 inches

A second example of the endangered glacier narrative emerging within art is the Last Glacier Project. Printmakers Bruce Crownover and Todd Anderson along with photographer Ian van Coller document the iconic ice of Glacier National Park, which went from hosting 150 glaciers in 1910 to only 25 glaciers today. As this popular tourist destination loses its namesake, this project puts forth powerful tributes to the remaining shards. Crownover makes detailed reduction woodcuts of up to 20 layers that evoke the textures, antiquity and fading light of the glacial environment. Anderson's methods are similarly painstaking and ambitious. Their sweeping, large format prints testify to the individuality of each remaining glacier, as well as the poignant risk of losing the individuals. Compiled together, these prints recreate a park of threatened, distinct and fragile glaciers. Each one is susceptible to human impacts, and each one is expected to die. This concept of mortality is key to the Last Glacier Project and the endangered species narrative. Glaciers are a vessel to tell stories about mortality and resiliency in the 21st century.

Glaciers as Ruins

"The terminology to describe glacier melting—retreat, loss, vanish, death, ruin, disappear, waste, extinct, endangered—evokes important messages about these

ice masses, spurring people to lament them rather than simply chronicling their change over time.” Mark Carey, The History of Ice (2007).

Exactly what is a ruin? It’s something wasted away and destroyed. Often the ruin is a remnant of something once great. Glaciologist Dr. M Jackson (2015) says “Ruins are what people are left with to make sense of and describe.” Throughout artistic representations of glacier ruins, these relics are fundamentally paired with a sadness and a melancholy for what once existed. Indeed, whilst dwelling in the climate crisis, it appears that the dominant environmental narrative framing our planet is that it is a ruin, or something soon to be ruined.

A crystalizing moment for this narrative may have come at the turn of the 21st century. Eric Wilson (2003) points to an apex in appearances of catastrophic ice loss imagery rising while fears about apocalypse linked to the clocks turning to the year 2000 also rose. Wilson speculates that “ice, in its striking, extreme forms— deathly bergs and crushing floes, crevasses and calving glaciers— shares the same paradoxes as Western visions of apocalypse” that were so popular at the turn of the 21st century. The concurrent fears of apocalypse and consciousness about ice loss and melting poles may have solidified the glaciers as ruins narrative.

Increasingly severe droughts, storms and wildfires, the loss of biodiversity, and all kinds of social crises contribute to the current glaciers as ruins characterization. Glacier loss has been marked by memorials and elegies all over the world, from Iceland, where glaciers are a symbol of national identity (Magnason 2019) to Switzerland where a performative funeral acts as a “warning sign” to global policy makers (Falconer 2019) to Oregon where the loss of a glacier is mourned by scientists (Gormley 2020). Deeper indigenous traditions such as the Quechua Qoyllur Rit’i ceremony, have been disrupted by glacier disappearance. Once, “Ukukus (men dressed as mythical half-man, half-bear creatures) used to cut blocks of ice from the glacier to share with the community, believing the melted water had healing powers, but have now stopped, noting a decline in the size of the glaciers because of warming trends.” (Taylor 2016). In the absence of a sacred body of ice, is there any hope for enduring myths? The impression of glaciers as ruins has permanently halted some traditions and started a wave of contemporary performative memorials.

Is there merit in thinking of glaciers as ruins? Jackson finds that the ruins perspective “tends to overlook the existing state of a glacier and/or glacier systems and speaks instead to

imagined states of loss" (Jackson 2015). Key to this definition is the "imagined" element of loss: the glaciers as ruins narrative is zeroed in on disappearance, leaving us unprepared to imagine futures or possibilities in their wake. This can be one of the potentially destructive narratives that Anderson (2015) calls to our attention. If doom-laden narratives can be unhelpful or even harmful, why are they so dominant? It may be due to the ease at which one can be struck by the immense scale and beauty of ice. Falling in love with ice and then losing it generates powerful, enduring emotion. That is what these artists experience, or fear experiencing. Emotion colors the artists relationship to the subject and stories they are poised to tell.

To show how the glaciers as ruins narrative plays into art, I will focus on just a few artworks from among the countless memorials and elegies to ice: the large landscape paintings of Diane Burko, the austere sculpture *Disappearing Ice* by Maya Lin, and the print *Nowhere To Be Found* by Mike Marks.

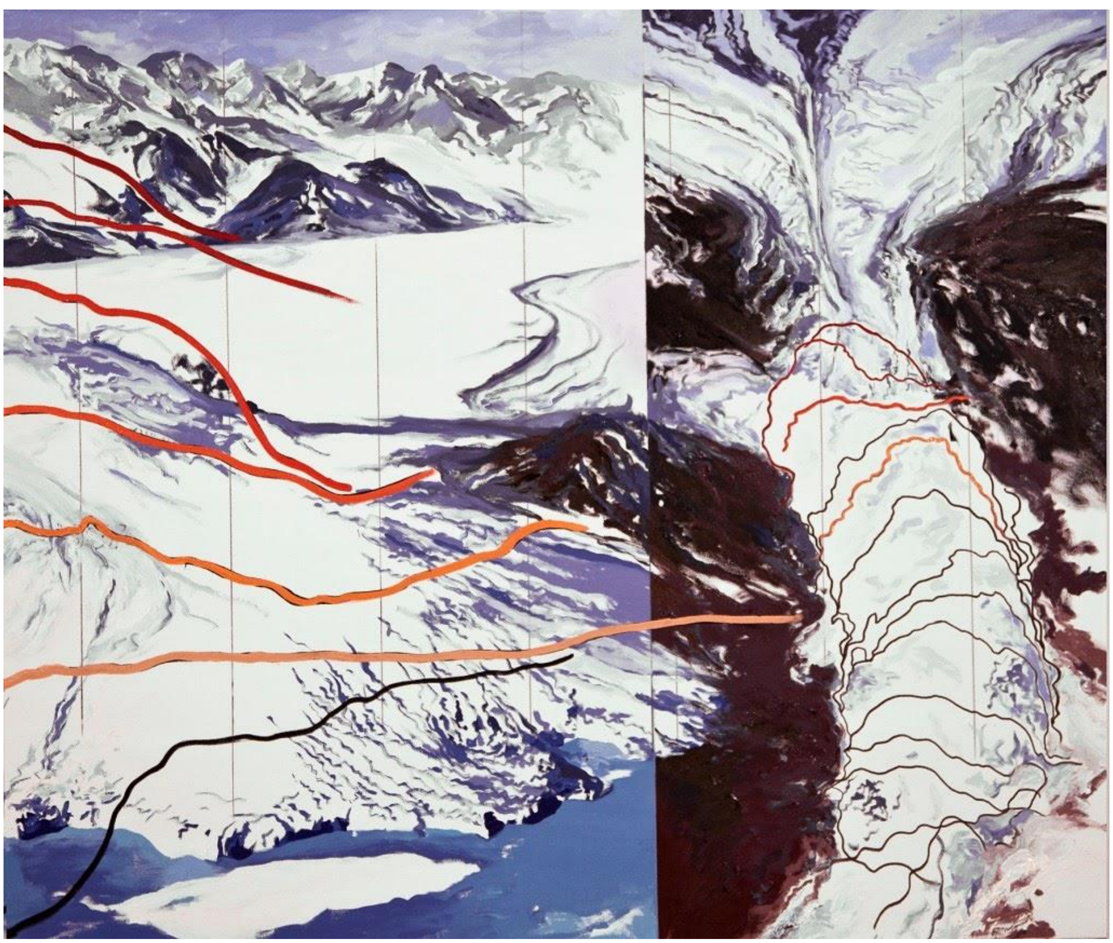

Figure 27. Diane Burko: Columbia Glacier Lines of Recession, 1980-2005, oil on canvas, 51x60 inches, 2011.

Diane Burko's large-scale landscape paintings and photographs emphasize the beauty and despair in changing glacial landscapes. Burko also collaborates with scientists, incorporates data and borrows from the idea of glaciers as laboratories. For the show Vast and Vanishing, she says "The work in this show summarizes my exploration of how data about melting glaciers can be used to explain climate change visually. Repeat photography, recessional lines, and Landsat imagery are sources I draw from to this end. By borrowing from scientific research, I am translating and transforming such devices into my visual lexicon." Her choice to use scientific data that documents glacier retreat and thinning (rather than adaptation or range shifts, for example) fuels the glacier ruin narrative. She identifies with scientific markers of diminishment rather than what fills that space. One unique aspect of glacial ruin that Burko gives voice to is what author Thom van Dooren calls the 'dull edge' of extinction—the prolonged processes "of change and loss that occurs across multiple registers and in multiple forms both long before and well after this final death" (van Dooren 2014, p. 58). Burko's regression lines show dimensions of change over a period of many years by superimposing the glacier's shifting edge.

Another series by Burko, *Elegies,* abstracts glacial patterns using white and black or blue cracked paint. Her intention with these pieces is "to provoke an uneasy visual tension where the viewer struggles to make sense of the material" (Diane Burko's website). The crackling texture reflects physical breakup with ice as well as our inherent despair with ruin. It is fascinating how an accomplished landscape artist is so comfortable processing ruin from the many polar expeditions that she has taken that she can create "elegies" from her imagination. Visually, Burko's work is distinct and beautiful. But are the themes getting tired? We could ask of glacier art as a whole: At what point does lingering around loss and ruin for so long stop being fruitful? In the book *Environmental Melancholia,* Renee Lertzman (2015) warns that despite warnings about ecological degradation threatening all life on earth, "a lack of engagement commensurate with the threats we face remains." Lertzman explains that the ecological anxiety that grows from rampant conceptualizations of loss causes paralysis. She then suggests that we shift the discourse "from a lack of something to a presence of something perhaps not well understood" which will change our "how we position ourselves in relationship to the communities in which we work from one of motivating to one based on listening and collaborating (Lertzman 2015, p. 8). These transformative ideas counter the ruins narrative, and I will explore them more in the conclusion.

Figure 28. Maya Lin: Disappearing Bodies of Water: Arctic Ice, Vermont Danby marble on a granite base, 48 x 46 x 52 inches, 2013.

Maya Lin's sculpture *Disappearing Bodies of Water: Arctic Ice* is a marble memorial to the Arctic Ice sheet. This sculpture emphasizes the reduction in size of the ice sheet over a period of years. Lin evokes stark, white, unpeopled loss with her choice of material and display. Lin's work has a clear message: This is how much we have ruined, and this is what remains to be lost. Countering the idea that ruins aren't productive, DeLaure (2020) proposes that ruins are worth lingering over but require public spaces for mourning that presently are lacking. Maya Lin's installations, by providing a physical grounding to contemplate loss, may be productive for moving beyond the paralysis of loss and into open mourning. It is even possible that ruins aren't the problem, but our practices of mourning are, and we could develop ways to mourn extinction around monuments like *Arctic Ice*. DeLaure also asserts that performing (rather than simply informing) loss is critical to understand human-planet entanglements. Instead of spitting out data, *Arctic Ice* shows, confrontationally and precariously, the loss of ice. This work is both a tomb in progress and a place to gather to consider the ruins narrative and our emotional response to loss.

Printmaker Mike Marks also interrogates processes of environmental change and loss. Marks uses the physical process of printmaking to echo environmental change by employing fragile matrices that break down or vanish during the printing process. Through printmaking Marks shows how history of human presence is written into the environment, as well as how nature comes to be represented by humans. These landscapes are ruins in the sense that nature has been destroyed or completely redefined by human actions. Marks says "It's my intent to draw parallels to the way nature/wilderness is being constantly re-constructed by forces ranging from the geological to man-made, and how these shifting boundaries makes us re-define what exactly wilderness is. The land around us is as curated a surface as any, and I hope that in making my work I can draw out the beauty I find, even in the marks that mar the places around us. The images in my work vary from the representational to the suggestive, but are always rooted in movement and place. In shifting the representation of landscape from one material to another, the act of printmaking becomes a tool for me to navigate the way in which wilderness meanings and values are socially constructed and contested." (Mike Marks' website). Marks constructs and destructs the receding Alaskan Exit and Athabasca glaciers in the piece *Nowhere To Be Found*. Marks approaches these places through the process of paper lithography, which entails using xeroxes as a printing plate. In the printing process, these xeroxes are destroyed. Due to the paper lithography process, the objects capable of documenting the glaciers retreat are as absent as the glacier itself. *Nowhere To Be Found* adapts a contemporary printmaking technique to the glacier ruins narrative, alighting a commentary on how these landscapes are curated and then perceived as destroyed once the ice vanishes. What lies beneath the glacier is de-emphasized or forgotten by this story—highlighting both the magnetism of ice, and the gaps that hyper-focusing on ice will cast.

Figure 29. Mike Marks: Nowhere To Be Found. 62x62 inches, paper-lithography on 99 panels/rag mat, 2019.

As these four artists exhibit thoughtfully and beautifully, there are many ways to depict the glacier ruins narrative. Countering some of the doom and gloom stunts or funerals that continue to occur in the mainstream media, these artists reveal nuances in glacier loss and acceptance. Lin's work raises the idea that perhaps mourning these ruins is essential, but we need new places and techniques for mourning. Ruins are that which is wasting away—and there are many ways to make sense of this through art.

Glaciers as Playgrounds

Glaciers as playgrounds, or spaces for recreation, is a narrative that is abundantly embodied by inhabitants of regions where glaciers and societies exist in proximity. It may be under-represented artistically because the focus is usually not visual or intellectual but physical. However, I include this section because it has strong historical roots and interesting climate change implications. It is also one I engage with frequently within the North Cascades. To explore this narrative, I skim over the roots of recreating on glaciers, and describe some visual and personal examples of glacier recreation in the North Cascades.

Beginning in 1786, a mountaineering craze struck Mt. Blanc. Mountains and glaciers were seen as worthy of not only scenic appreciation but also exploration (Carey 2007). The appetite for attaining summits and exploring glaciers has since spread across the globe. A side effect of exploration and mountaineering has commonly been to commodify mountains and make space for colonization (Carey 2007). One example of this is how the mountains of the Pacific Northwest bear the names of US presidents, are mined for minerals and timber, and are managed for tourism, burying many of their indigenous histories and use values. The perception of glaciers as beautiful but empty spaces has allowed for territory claiming and imperialist or racist claims (Carey 2007). As Ernest Shackleton once said about Antarctica, “By endurance we conquer,” pitting human hardiness against the environment as a means of controlling it.

Since the dawn of mountaineering in the North Cascades, visitors have carried a variety of mindsets, from dominance to awe. Warner, a photographer and part of an 1888 expedition to the summit of Mt Rainier recalled “I hardly know whether I had better try to describe the view but will say that for the first time I could see that the world was round, and I was up on a very high place. The air was very light.” In this Sublime experience, the visitor’s mind was nearly incapable of comprehending the view, yet full of appreciation for the huge powers and “round-earth” picture revealed. This awe is paired with the attainment of a summit and taking the first photographs from the glaciated peak.

Today, the fragility of alpine landscapes is at the front of mountaineers’ minds. Lowell Skoog, editor of the Northwest Mountaineering Journal, suggests that “Mountaineers can play an important role in recording and sharing with the greater community the evidence we see of climate change” (Skoog 2007). Photographer Jason Hummel’s mission to photograph, document and ski all 258 glaciers in Washington state embodies the mountaineer’s mission to document changing places.

Figure 30. Jason Hummel: Photograph of ski tourers setting a skin track from the Washington Glacier Ski Project

Hummel's project stems from a desire for adventure and exploration. Hummel describes how "ultimately, the Glacier Project has grown into something more than a personal goal. I've been able to see our glaciers, many of which have disappeared since I first skied onto a glacier, and document their health with photographs and on-site observations." The mountaineer cultivates skills of observation and awareness that lend themselves to scientific data collection, as well as an intuition for photography. Hummel continues "My hope is to inspire the adventurous spirit in each of us, even among those that will never see these places. Every one of us can appreciate and value natural wonders we may never see. It's nice to know that they are still there, or exist at all." supporting the American wilderness narrative that capitalizes on the value of pristine spaces, such as empty glaciers.

While doing glacier research in the summer of 2020 on the Easton Glacier which lies adjacent to a popular summer mountaineering route up Mt. Baker, we encountered an experienced North Cascades mountaineering guide. He expressed appreciation for our research and divulged that some of his clients do not believe in climate change. Given the obvious signatures of glacier retreat visible along the entire climbing route, this was shocking to me. This encounter highlighted the fact that not all people recreating on glaciers are open to seeing the stories that the ice tells. This glaciers narrative may be less intersectional than the other

narratives I discuss, as it stems from different sources and motivations than knowledge or beauty. Instead, glaciers are a challenge within a quest to a personal and physical accomplishment.

However, this should be an interesting area to watch for change and new visuals. There is no other community that spends so much time on ice. Mountaineers are a sizable stakeholder group and climate change is rapidly affecting the way they recreate in the mountains. Thinning glaciers restrict access to popular routes and in some cases the period of time when the mountains are climbable is shrinking. The question "should we be talking about last ascents instead of first ones?" has been posed regarding mountaineering in the North Cascades and American West (Hansman 2019). Glaciologist and climber Alison Criscitiello attests that "Many of these places that hold soon-to-be-lost climate archives are the same places that have drawn climbers for centuries and may too become unclimbable, or at least unrecognizable, in our lifetime or within a few generations." Although climate change is already dictating the hazards and logistics that mountaineers face, my research overturned surprisingly little evidence within the realm of art, but I believe this may change as the implications of climate change are felt more strongly and by more mountaineers.

Glaciers as Community

Glaciers are embedded in culture, shaping and shaped by human communities. They have become historical figures, given lives meaning, and taught people lessons. Glaciers as community is not a straightforward or linear narrative, but an expansive space for researching past, present and future relations between people and ice. In Julie Cruikshank's research on indigenous traditions in the Yukon and Alaska, glaciers emerge as actors who "make moral judgements and they punish infractions. Some elders who know them well describe them as both animate (endowed with life) and as animating (giving life to) the landscapes they inhabit" (Cruikshank 2005, p. 3). Cruikshank demonstrates how local knowledge is produced through interactions among colonists bringing western science, the oral traditions of indigenous people and the ice. There are collisions between the idea of ice as a static force, or a cold repository of scientific data, and the idea that ice can be a dynamic member of human communities. Geophysicist Henry Pollack's assertion that "Ice asks no questions, presents no arguments, reads no newspapers, listens to no debates. It is not burdened by ideology and carries no political baggage as it crosses the threshold from solid to liquid. It just melts" (Pollack 2009, p. 114)

reveals this separation of ice and agency that western science ascribes to the environment. Looking to communities in Southern Iceland, M Jackson (2017) finds that glaciers have power upon communities, are perceived as alive and self-aware, and can affirm multiple conflicting environmental narratives at the same time. Jackson also warns that "glaciers are contested, controversial, and that what is widely assumed does not match what is happening on the ground," precautioning us against generalizing glacier-people interactions. Although glaciers are a source of story, memory, and knowledge within glacier-proximate communities around the world, every community lends their own nuance to this idea.

One way to exhibit and explore the presence of glaciers within communities of people is through participatory styles of art. Hannah Perrine Mode is an artist working at the intersection of art, community storytelling and polar science. In the multi-faceted project *Collective Memory*, Mode collected memories of local change from the community of Akureyri Iceland. These people reflected upon their local environment and the effects of climate change then wrote down a memory. Each participant also chose a color, which Mode incorporated into frozen ice cores. She allowed the colored ice cores to melt onto paper in the exhibition, the ice becoming an agent of the work as well. The collection of colored ice cores and stories was exhibited in the community and reproduced on free postcards. Mode also led workshops about picturing memories. The compilation of individualized memories in *Collective Memory* celebrates the agency of ice through the lives of community members.

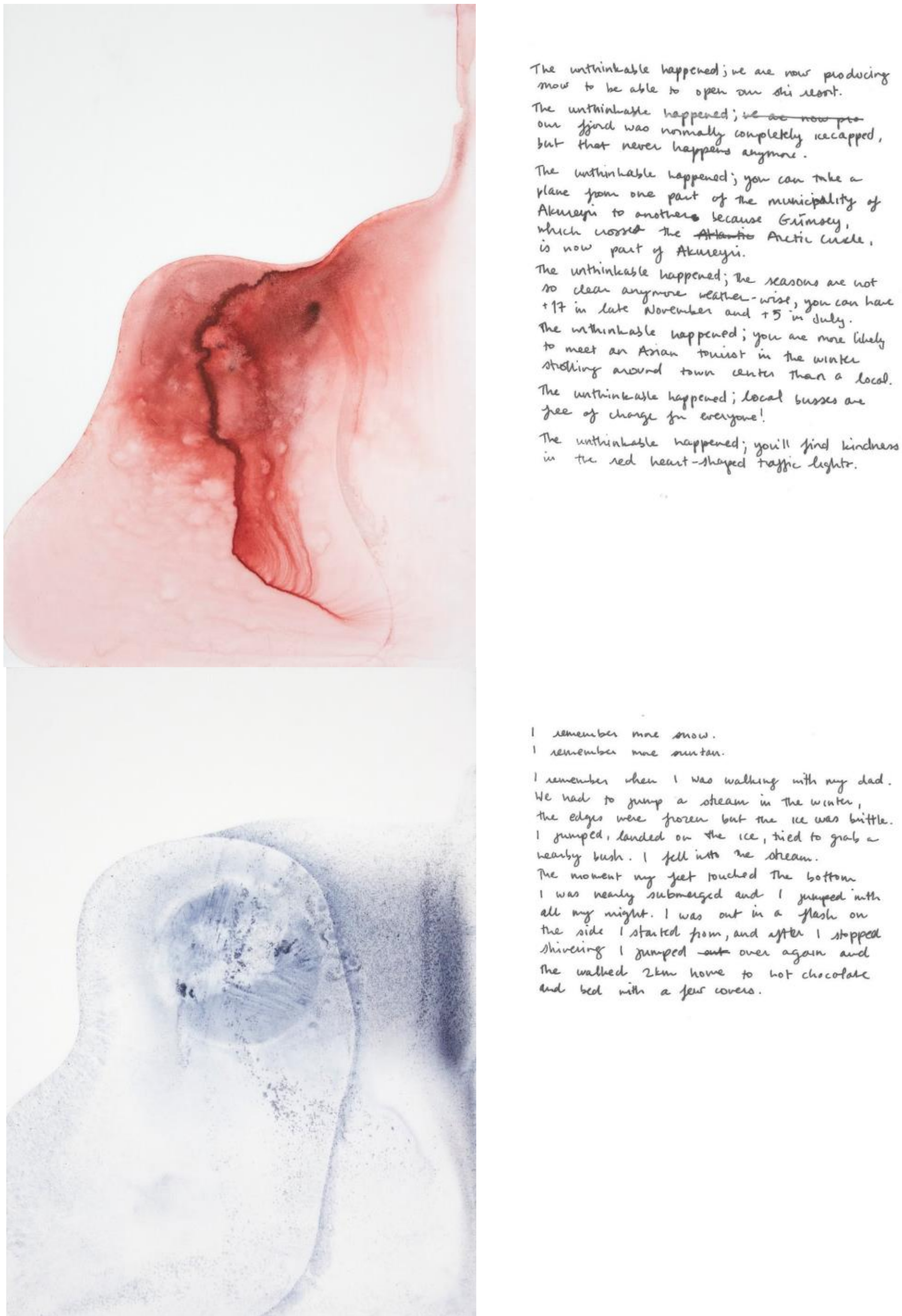

Figure 31. Hannah Perrine Mode: Excerpts from Collective Memory, 2018.

Landscape photographer Camille Seaman approaches the loss of Arctic Ice through a critical indigenous perspective. Having spent two decades photographing endangered polar regions, she believes that humans are not separate from nature. Her photography blends the endangered species narrative of glaciers with the idea of ice as community. First, her portraits of isolated icebergs adrift in wildly colored sea emphasize the Eremocene-loneliness of modern life.

The individuality of each photograph and block of ice shape them as relics of a passing age, each one its own endangered character. As Seaman rushes to photograph them before they disappear, she also celebrates them as kin. Seaman says "I approach photographing these icebergs as if I am making portraits of my ancestors, knowing that in these individual moments they exist in that way and will never exist in that way again. It is not a death when they melt, it is not an end, but it is a continuation of their path through the cycle of life." This indigenous perspective of seeing ice among "All My Relations" within a cyclical temporality is unique among iceberg people. Seaman's photographs reveal the vulnerability and isolation of modern life, with a unique blending of environmental narratives.

Figure 32. Camille Seaman: Iceberg in the Evening - Greenland, August 11, 2009 from Last Iceberg Series III, 2009.

The photographer Spencer Tunick questions the relationship between art and public space by unclothing hundreds of people in site-related installations. His 2007 piece *Switzerland, Aletsch Glacier 1 (Greenpeace*) (Pigment print. h: 48 x w: 60 in / h: 121.92 x w: 152.4 cm. Edition of 6) reacts to global warming and glaciers. The vulnerability of people without clothing echoes the precarious position of the earth without glaciers. Tunick explains "I want my images

to go more than skin-deep. I want the viewers to feel the vulnerability of their existence and how it relates closely to the sensitivity of the world's glaciers." Tunick conceptualizes how glaciers are a new part of the social imagination. They are a peopled site, where social ties and collective vulnerability to climate change can be explored. By bringing together hundreds of strangers, he not only pulls together an installation, but he also assembles a community of people, sharing vulnerabilities and adapting together. *Switzerland, Aletsch Glacier 1* bares and blends human nature with the glacier.

Figure 33. Spencer Tunick: Switzerland, Aletsch Glacier 1 (Greenpeace), 2007.

Within the glaciers as community narrative, there is room to build upon the study of glaciers and environmental change, and explore the social imagination of communities. Cruikshank and Jackson study specific cases where glaciers are entangled with human communities, showing that ice is multifaceted with a multitude of physical as well as social dimensions (Jackson, 2017). As glaciers melt, and people find ways to mobilize and adapt at different scales, complex interactions between people occur at glaciers (Gagne et al. 2014). Exactly what defines "community" when national and global actors share the stakes of glacier

loss with local people is a site for continued investigation. The artists in this section tap into various communities' relationships with glacier change. Perinne Mode shows us that we should continue to make, support and share participatory art practices that engage with communities and personal experiences to understand the individual and local impacts of climate change. Across the globe, indigenous and local people are struggling for the right to make their own places and communities—differential geographies than those that colonial powers have imposed (Castree 2004). Art is a powerful means of envisioning and sharing these differential geographies.

In summary, the idea of glaciers as communities considers glaciers to be alive, animate, and entangled with human communities. As a place-based relationship, this connection emerges through many voices and modes of creativity. Scientists Gagné et al. (2014) hold that "place-based research is fundamental to discuss a global environmental phenomenon such as glacier recession." I would expand this idea so that it not only calls for place-based scientific research, but also through creative interventions and interactions with cultures and communities surrounding glaciers. Preserving and sharing ancient knowledge of these spaces is critical as well. When we share agency with glaciers and realize that people and glaciers co-create relational spaces, we support environmental justice and approach a fuller understanding of place (Castree 2004). As glaciers shrink, communities are adapting their lives and stories to environmental change, making this an area that will continue to generate interesting art and stories.

Conclusion: Speculation and the Future

Art is a necessary and powerful way to engage with environmental problems that not everyone can see. By sparking emotion and drawing in the senses, art does what science alone cannot to communicate environmental problems and the climate crisis. Art is also created within and contextualized by environmental narratives. The power of art to shape cultural stories and the social imagination can be harnessed to productive and non-productive ends as we work to address our climate predicament. Some of the glacier narratives that I have traced in contemporary artwork are entrenched within historical frameworks, even as they attempt to navigate the present. Environmental narratives have the power to influence the questions that are asked, the knowledge that is produced, and the actions or policies that are taken (Forsyth 2003, O'Brien et al. 2007). We must be wary that some narratives can restrict our imagination and limit

our chances of responding to glacier loss in productive ways. Jackson (2017) attests that glacier narratives “significantly influence our capacity to imagine tomorrow, next year, the future.” In suggesting that glacial landscapes are or will be destroyed, the glaciers as ruins narrative blacks out potential futures and lingers with something we have very little chance at changing. Striving away from this bleak and motionless end point, this final section explores a speculative glacier futurism narrative that keeps possibilities alive and open. Artists working in this vein offer us new ways to engage with Anthropogenic climate change. Within this imaginative and limitless field, there are moments of uncanniness, acts of care, and an overwhelming sense of malleability if we engage in the creative process.

Figure 34. Pinar Yoldas: Ecosystem of Excess installation view showing “organs of the Plastisphere,” 2014.

Why speculate? In *Speculative Everything* (2013), Anthony Dunne and Fiona Raby contend that the more we speculate (and the more things we speculate about), the higher our odds of achieving desirable futures becomes. This is because speculative thinking frees ideas from fixed reality. An exceptional example of speculative ecological artwork is *An Ecosystem of Excess* by Pinar Yoldas (2014). Yoldas designs “a new Linnean order of post-human life forms,” inspiring wonderment at the possibilities of life beyond humans, yet enmeshed within the plastics we have produced and spread across the planet. Elements of the work include newly designed “organs of the Plastisphere,” such as Stomaximus that metabolizes plastics, and “species of the

Plastisphere" like the Plastic Balloon Turtle that has evolved an inflatable elastomer back after eating balloons for eons. The futuristic freakishness of these organs and organisms provokes critical thought about the impact of plastics upon other species and the human place in this ecosystem. Ecological art like this addresses the "web of interrelationships between the physical, biological, cultural, political and historical aspects of ecosystems" and can put forth new metaphors and visions for the future (Wallen 2012). In doing so, ecological art can deepen care and respect for the world and spark new dialogue. Bringing the issue of plastics back to the public eye in a fashion that doesn't shame or immobilize people (who isn't exhausted by the blame cast upon plastic straw users?) is the first major accomplishment of Yoldas' work. The second is the incredibly imaginative world building that results from turning toxic surplus into new life forms. Although this piece does not center upon glaciers, it is the type of work that exemplifies how to turn an environmentally wearisome subject into an engaging speculation upon the future. As critical ecological art, it holds potential to change how we think about environmental change.

Care can also be at the center of future speculation. One of our most available climate solutions is simply cultivating care. This is the act of caring for each other, for the elderly, for our gardens and streams and non-human neighbors. Caring about the future. This isn't merely emotion, it is needed work that needs workers. It needs artists and scientists to collaborate on observing and storytelling our interrelationships. Collaborative survival might even require us to retire the harsh divisions between the humanities and the sciences. Enriching our relationship with our localities by caring for them—stewardship for plants, animals and place. We might find that "all organisms, including humans, are tangled up with each other"—a realization that comes with both wonder and terror (Tsing et al. 2017). Although realizing our attachment to every living thing around us may be uncanny and uncomfortable, there is also the powerful potential that building symbiosis through the act of caring within human communities will increase community resilience in the face of climate problems.

CHAPTER 3: PORTFOLIO AND ARTIST STATEMENTS

Creative Process

In this chapter, I describe my personal creative process and my portfolio of printmaking work. Through linked artist statements, I explore five of the main themes in the work I generated: water bodies, wildlife, glacial history, entanglements and futures. Multimedia dimensions of my project do not fit within this paper but have been exhibited through installations and my website. Therefore, the pieces represented here are my most polished two-dimensional works. To provide a grounding for the reader, I include some photographs from the field that show elements of the glacial landscape I abstracted through my printmaking.

Journey throughout this year - Immersion and Intuition

My artwork is motivated by submergence in the North Cascades. Glaciers have captured my imagination and sent me hiking into the high hills, to comb my backyard in Washington State for ice. These trips and landscapes have challenged me, educated me, and opened me to new understandings of my place in the environment. The tools most essential to building my connection and understanding of the environment have not been measurement devices, or scientific articles, but rather *immersion and intuition***.**

Figure 35. Lingering and drawing near the Wyman and Columbia Glaciers. Photograph by Mariama Dryak, August 2020.

To me, immersion means a long wallow someplace. Long enough for the textures of that place to imprint upon the skin, to feel both fire and freeze, for thoughts to fester and develop as one works through time and space. Immersion eventually leads to a sense of attunement with that place where one wallows—and as that attunement grows, intuition gains power. Over the summer I built my attunement to the North Cascades with 3 to 14 day backpacking trips. Sometimes I was alone and sometimes I was in the company of people similarly passionate about mountaineering or environmental science. The expedition objectives were to document the retreat of a glacier, to connect watersheds, or to summit a new peak. Ultimately, the most valuable outcomes were far less objective oriented. Over long days, we found our rhythm in the mountains. Confidence in our hiking boots grew, swimming in an ice-cold stream became a familiar pleasure, and human clocks adapted not to watches but to the circling of the sun and the songs of clouds, birds, and melt water. This escape from living under the clock allowed new ideas to take root and grow. These wildly immersive moments were measured not by minutes, but by footsteps and encounters with wild life.

Progression of Work

Like the watercourses I had walked along, ideas for artworks flowed through my trips in the mountains. With a rich store of mountain moments in my heart, sketches in tattered notebooks, and a heap of photographs, videos, sound recordings in my computer, I was very eager to enter the studio in September. I never exhausted my store of summer inspiration. Executing some ideas took all year, while others were never touched. There were many twists as concepts were transformed by feedback, available materials, new research, and the ebbs and tides of a huge project while in senior year of college. Initially I was drawn to the idea of communicating concrete data with art, as artists such as Jill Pelto have done. As I delved deep into my practice, however, I realized that my approach would be different. Although I spent days and nights researching science communication and visualization methodologies, my art would veer away from didacticism into intuitiveness. Data informs what I find interesting and powerful but it no longer guides what I make.

An example of my work pulling directly from data is the project Andeorama. Early in my summer 2020 research, I produced this ink drawing that depicts varied and iconic glaciers of the Andes Cordillera. It was my attempt to depict the effects that melting glaciers are having in

South America based on the study Two Decades of Glacier Loss along the Andes (2019) led by Inés Dussaillant and published in Nature Geoscience. This research investigates the glacier mass changes in the Andes during the period 2000-2018 and includes differentiation of regional changes and downstream impacts.

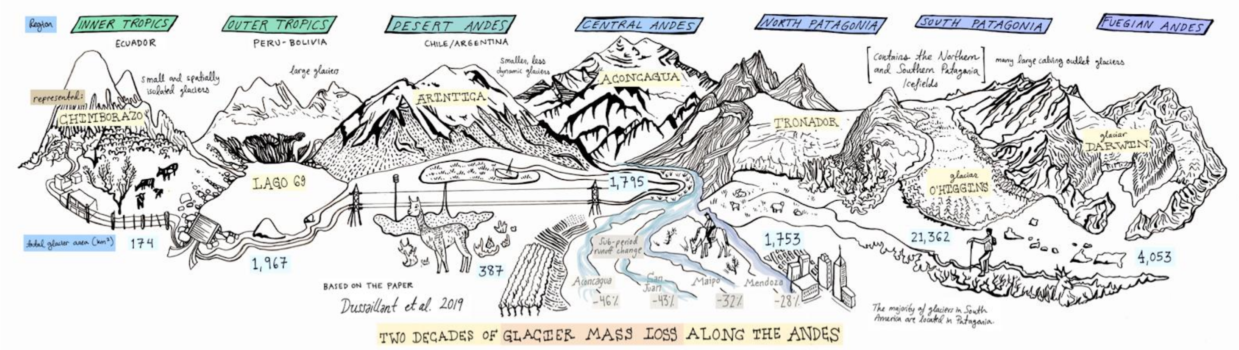

Figure 36. Andeorama. Ink and digital drawing, 2020.

After reading the Dussaillant paper, I set out to represent the extent and variety of effects that climate change has upon glacial systems in the Andes with a lengthy illustration of the Cordillera, in the style of Alexander von Humboldt's 1807 illustration of Chimborazo and Cotopaxi. The iconic profile of Chimborazo would anchor the north end of the range and then the ridgeline would take on the shape of the Dry Andes and finally the Patagonian Andes. Under this ridgeline, little titles and illustrations would depict the regional changes that Dussaillant et al identify. This illustration would combine an ode to the scientist-humanist Humboldt, who believed in the integration of art and science, with the scope of the change happening in the Andes under modern climate change. I worked on this project for two months and found that it required a lot of deliberation and exactitude to stay true to the data I was trying to depict. Andeorama challenged me to create a representative scientific illustration appropriate to the big-picture findings of an extensive study. Although I did not continue in this direction with the rest of my thesis work, this project did help me understand some of the techniques of scientific illustration that can be used to broaden the audience of scientific literature.

Another progression in my creative glacier work was a shifting focus on different glacier narratives. During my first major introduction to glaciers on a mountaineering course in 2017, a feeling of loss struck me. The Patagonian landscapes I had landed upon were starkly devoid of the glaciers that our maps outlined. This unexpected disappearance inspired me to look at the

problem of glacier retreat from many creative angles. However, as I came to understand more about glacier change, the narrow focus on disappearance grew stale. During the summer and fall I began to imagine other stories about the glacial environment, where there is room for futures and speculation. What emerges when ice retreats? Will this work provoke different thoughts than the ice as loss narrative will? Throughout the fall I was concurrently researching ecological characteristics of glaciers and their downstream environs. Learning about snow obligate species and the complex bio-geo-chemical characteristics of glaciers sparked compassion for life across all scales.

The defining pieces of my thesis are a series of scrolls that I conceptualized early in the fall but took all year to complete. The scrolls are essentially a journey through time, with Scroll I addressing the history of glaciology in the North Cascades, Scroll II depicting my own experiences in the summer of 2020, and Scroll III speculating upon a deglaciating future. The scrolls are addressed under their respective themes inside this chapter, yet the three are also meant to be viewed adjacently, ideas both carried through and challenged by contrasting scrolls.

Theme: Water Bodies

Life relies upon clean, accessible water. "Water is life" is a culturally important truth around the world, but what exactly does this truth look like within the North Cascades? How does it feel? What connects us with water? When we pause to trace our sources, what do we find? Also, how do we experience and imagine the ways that water sustains life? My experiences in the North Cascades have shaped the idea that we all function as watery organs within systems larger than ourselves.

Figure 37. Overlooking the Deming Glacier. Photograph, August 10 2020.

Company Glacier Path

The Company Glacier path was carved into birch plywood in the vicinity of Stehekin, Washington in June 2020. I spent a week in this small town at the head of Lake Chelan, which is isolated from other communities by a 50 mile trip on a boat, or a long hike over mountain passes in North Cascades National Park. The town is also isolated from any major electric grid, making it a unique place to learn about sustainability and self-sufficiency. While I was in Stehekin, I explored the connections between glaciers and the community. I hiked up long valleys and tall mountains to find sites of ice, sources of the raging runoff that would be pouring into town later that summer. I listened to the river, noticed its shapes and colors and visitors. Snow and ice melt sustain the vigorous summer flows of the Stehekin River, which is used for recreation, agriculture, and sustenance. It's also teeming with birds and wildlife. I also had the opportunity to follow public utility employee and hydroelectric wizard Robert Nielsen around. Touring the turbine facility that sustains Stehekin with electricity drew an explicit connection between glacier melt and the needs of the human community. With these actors and sounds in mind, I created the Company Creek Glacier Path print and an accompanying soundscape (Appendix A). Woven into the three-minute soundscape are the voices of people speaking about their connection to glacial melt water.

Figure 38. Robert Nielsen making the rounds at the hydroelectricity intake along Company Creek in Stehekin, WA. Photograph, June 16 2020.

Figure 39. Company Glacier Path. 8x10 inches, woodcut embossment, 2020.

The process of embossing entails pressing damp paper into a carved block to take on its sculptural qualities. Without color, this print traces a water body of which we, flowers, lightbulbs and orchards are the downstream organs. A three-minute cascade of sounds accompanies the image. The eye and ear can simultaneously trace the trees and wires bleeding from the current. The print embodies the belief that water is the common medium for all—orchardist, phytoplankton, marmot, mountaineer and tardigrade. Meltwater springs, sings and sloshes from the glacier to the lake, enlivening everything along its path.

When we think about lakes, glaciers or rivers as water *bodies,* we relate to them more intimately and sensibly than when we think of them as *resources.* Bodies have kin, possess agency, and are imbued with generosity and life. The Company Glacier Path connects many characters (alternatively, we can think of them as organs) within one sinuous path. This signifies the unifying power that water has. Portal is my second piece that contemplates water bodies.

Portal

Portal is a four-layer reduction woodcut ranging from airy white to glacial blue. This print evolved from an image taken within a crevasse in the Rainbow Glacier on Mt. Baker, Washington. The crevasse was folding over itself, curling into a small window of glossy ice through which the August sun shone. In my print, depth emerges from the wooden matrix as it is repeatedly carved and printed, echoing the process of crevasse formation. Like ice as it meets the summer sun, the wood is whittled away to a final layer, just a memory of the full body it used to have.

Figure 40. Portal. 8x10 inches, reduction woodcut, 2020.

Portal holds various meanings. First, it pictures where we come from, our freshwater source. This origin, buried in snow, high on a volcano, is suddenly illuminated by a fissure and a photograph. Portal makes a new connection between water, the source of life; and the viewer. The portal also offers a new perspective on glaciers, as seeing them from the inside lends them a new body in our imagination. Many people who view this print see bodies, organs and muscles—some in the style of Georgia O'Keefe, others with diverging stories. When I showed this print to friends I received comments like "I see an angry man," "this reminds me of organs, blood vessels, and muscles. I see the pectoral in the top left" and "this looks like a people to me, connected by a shared energy orb." This feedback aligns with my goal of encouraging the audience to be "embodied" by the glacier. Perceiving human bodies within ice is a powerful way of relating to water bodies. The connections I forged with the glacier as I explored its surface and crevasses are transferred to people across the country, who have never experienced anything like it. Portal teaches us that water is universal and we are intimately connected to it. The print also shows that the stories we pull from images are personal, yet influenced by the information and context we receive them in.

Figure 41. Personal acquaintance with the Rainbow Glacier. Photograph by Mariama Dryak, August 2020.

In addition to Company Glacier Path and Portal, I experimented with the idea of water bodies in small scrolls. Creating the following two pieces allowed me to experiment with combinations of blocks, papers, scales and themes, preparing me to generate larger scrolls.

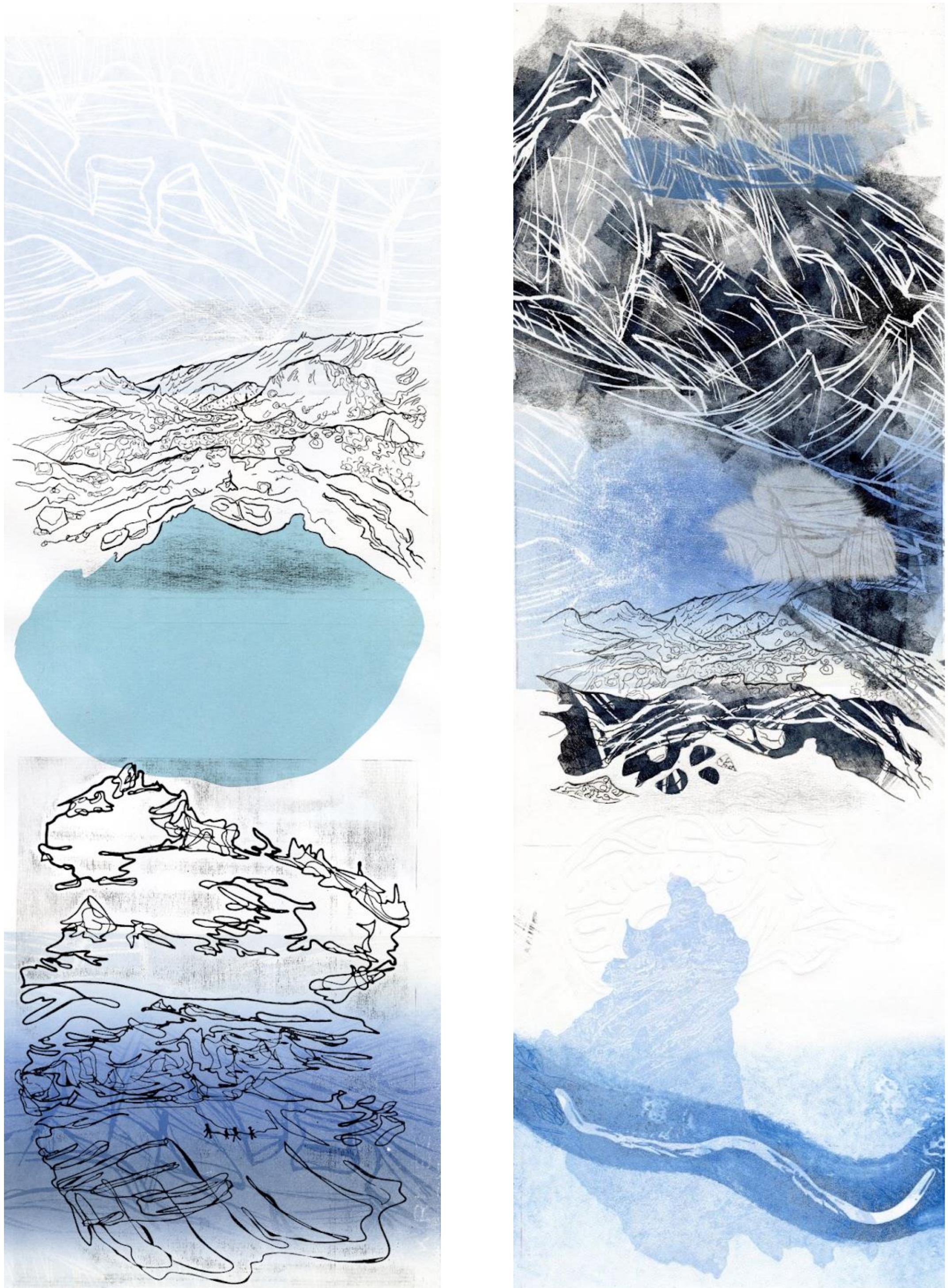

Figure 42. Experimental Water Bodies Scrolls. 10x30 inches, relief woodcut, relief acrylic, embossment and chine-collé on paper, 2020.

Theme: Wildlife

The silver splash of a salmon—the gaze of an eagle—the frequent squeak of pika: Spend any time near the mountains and the lives of animals will quickly chirp, swoop, slap and wriggle their way into your awareness. Wildlife lend character, motion and sound to alpine landscapes. It is difficult to imagine what the mountains of the North Cascades would be like without mountain goats, marmots and ravens. These alpine wildlife have unique stories to share about living in mountainous environments and adapting to climate change. Creating prints about wildlife is my practice of seeing the environment through new, nonhuman perspectives. Here I describe three of my works that fall under the wildlife theme: Animals (a series of woodcut animals narrating many of my pieces, including Sholes Ghosts), Pika Story, and Wolverine Scroll.

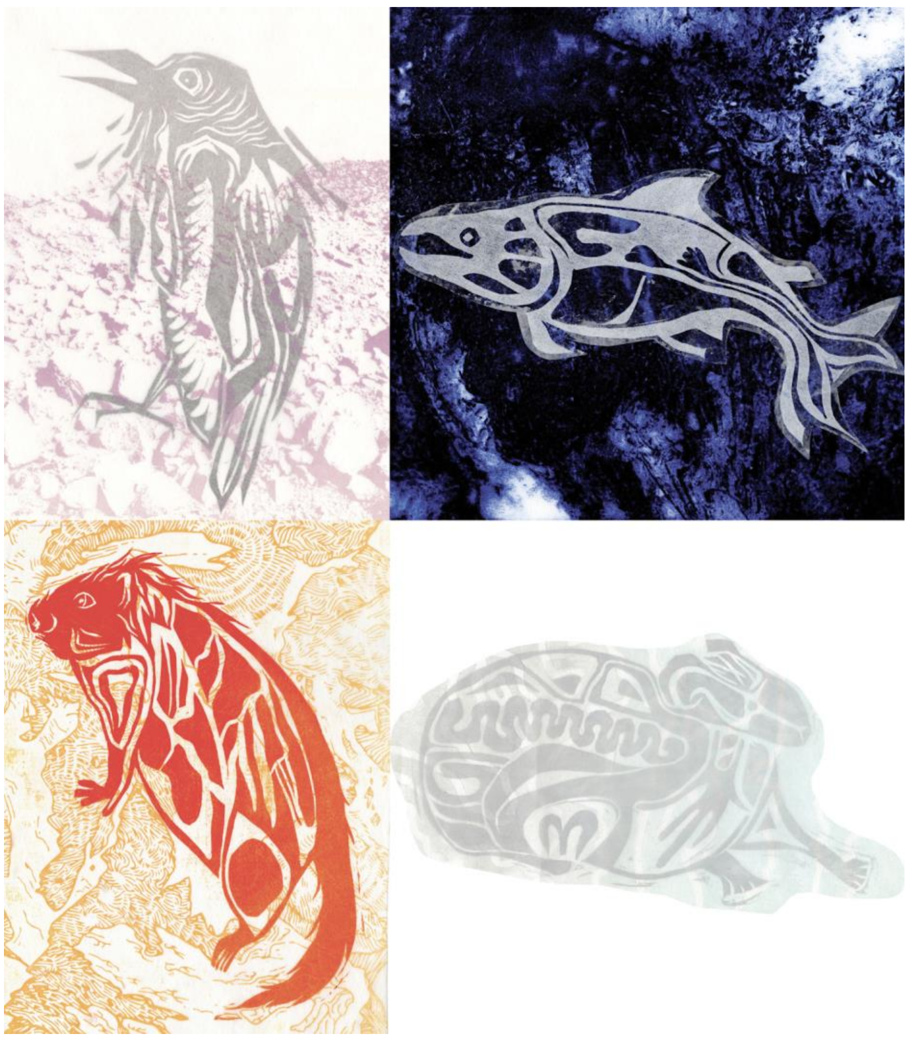

Figure 43. Animals. Clockwise from upper left: raven, salmon, pika and marmot. 6x7 to 8x10 inches, relief woodcut, 2020-2021.

Sholes Ghosts

These animals were born from an observation at the Sholes Glacier, which lies on the northeast side of Mt. Baker (Koma Kulshan), in Washington State. Sholes is a wide slope glacier, meaning that it easily changes shape as it loses mass. The glacier has retreated over 100 meters since 1984 (Pelto 2015). The Sholes drains into the North Fork of the Nooksack River, which flows into the Puget Sound at Bellingham Bay. The Nooksack tribe calls this land home. So do many furry, scaly and feathered beings. Due to the glacier's important contributions to streamflow, the Nooksack Indian Tribe Water Resources group closely monitors the behavior of the Sholes glacier.

Figure 44. The Sholes Glacier in front of Mt. Baker. Photograph, August 2020.

When we visited the Sholes in August 2020, I was thinking about these cultural and ecological relationships. Most of the glacier was covered in a few meters of snow, but there were bare patches of ice in a few places. This exposed and fractured ice held blue-grey hues, and snow filled the spaces between cracks, leading to fantastic geometric patterns. Tramping across the Sholes during a day of mass balance measurements, one of these ice patches wriggled to life as a salmon in my mind. The ice's unique shapes also reflected Northwest Coast art styles, in which geometric elements compose figures of animals. After seeing the fish, I could not help but see a

mammal and a bird within the shapes of blue ice as well. These animals appeared from a place-specific blend of environment and consciousness, and I knew that the creatures would be important storytellers for this glacier, and the North Cascades as a whole. Their embeddedness in a threatened glacier reflects alpine wildlife's overall vulnerability to climate change.

I designed my animals with the shapes of blue ice and melting streams in mind. These creatures are water bodies too. Each one is intuitively drawn and carved, rather than striving for realistic representation. Through intuitive mark making with the character of these animals in mind, I humbly follow indigenous Northwest Coast art's tradition of telling stories and passing along wisdom through painted and carved animal figures.

After carving, I embossed each animal into thick paper. These prints show the sculptural beauty of their symbolic bodies. Embossment builds form and texture from an empty page, but the figures remain ghostly and invoke contemplation of an absence. Implanting the bodies of animals within the empty white page emphasizes the fragile dependence on snow and ice. The paper also becomes a space to think about our assumptions of glaciers. To some, the animals may import the idea that glaciers are *not* empty spaces.

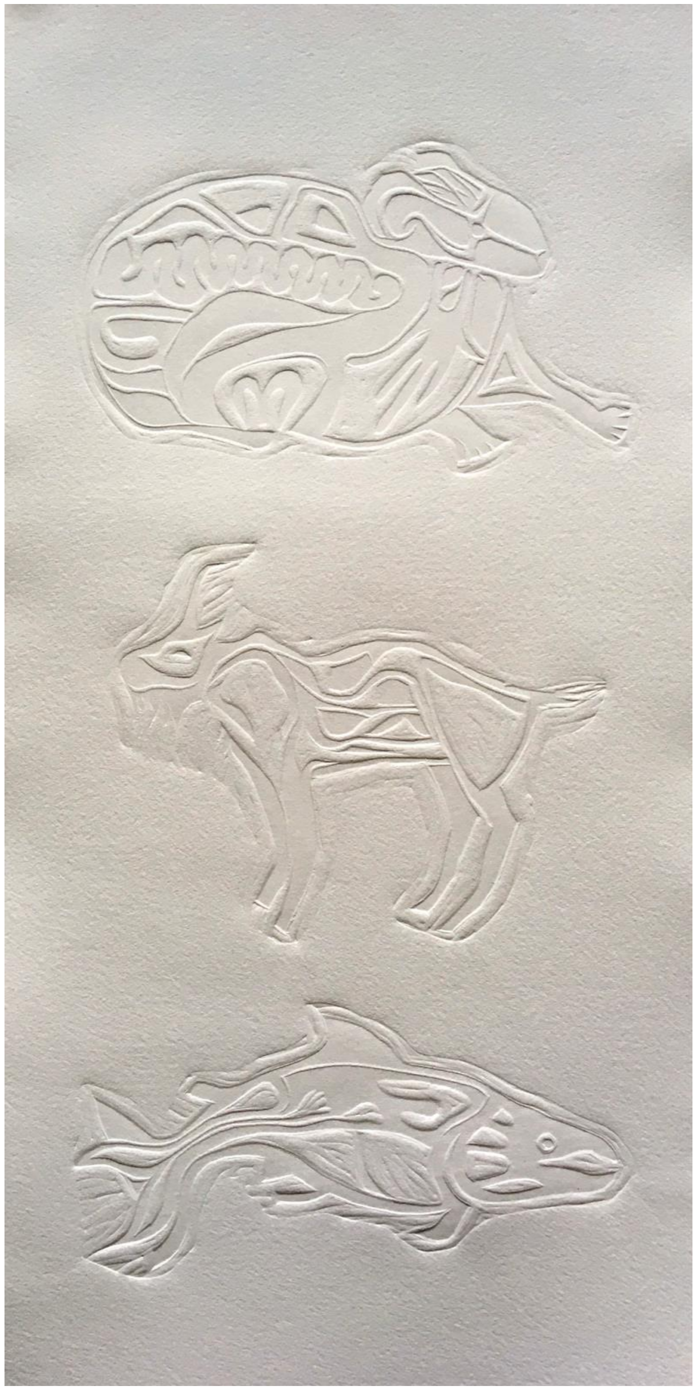

Figure 45. Animals from Sholes Ghosts collection. 10x30 inches, embossment, 2020.

Sholes Ghosts is a series of embossments and light grey prints of these blocks. As I created this work I thought about fragility, transience and resilience in addition to vulnerability. I printed these animals by themselves, or under the strong and enduring outline of Mt. Baker. In the present, these animals characterize this place. Their bodies are linked to water bodies. They

populate the Nooksack watershed and fill ecosystem niches. However, we wonder: In fifty years, will they still be there? How will they adapt? What would this place be without them? The future of fur, guts and feathers are entangled in frozen bodies of water. In the process of seeking out the undulating ghosts of the animals in these prints, the viewer reckons with the enlivened and endangered nature of ice.

After *Sholes Ghosts*, I printed the animals in many colors, and they entered new conversations with each other and the environment, especially within the Scrolls.

Pika Story

I also worked through the wildlife theme with a written and illustrated piece called Pika Story (Appendix B). Rooted in studies of pika ecology, my story gestures at the impacts of temperature rise and snowpack upon the pika's viable range and food sources from the pikas perspective. Drawn and digital illustration enhances the appeal and content of this story. Artistically, I was challenged to create a series of pictures to carry the narrative. On the creative writing side, I had to decenter my human perspective and create a story that could appeal to all ages, incorporate data, and still resonate. Although creative writing is not a strategy that I employ often, dabbling in diverse storytelling media bolsters one's own voice, technique, and artistry.

Wolverine Scroll

My final and most elaborate wildlife print is *Wolverine Scroll.* A series of two layer reduction woodcut prints with pencil overlay tell the story of a denning wolverine (Gulo-gulo) mother and her two kits. This collaged print pictures the impacts of human disturbance and climate change upon wolverine biology. The characters track across the page, moving through the habitat. Layered lines coupled with cool blues and greys carry the sensation of deep snow, emphasizing the wolverine's need for deep snowpack. Serpentine pathways suggest the burrows that wolverines dig for their dens, and the rivers that result from snow melting in springtime.

Figure 46. Wolverine Scroll. 30x22 inches, relief woodcut, relief acrylic, colored pencil, collage and chine-collé on paper, 2021.

Climate change is a pressing aspect of the wolverine story. As climate warms and winter precipitation shifts from snow to rain, their habitat shrinks. By the end of the century, their viable habitat in the Cascades may disappear. The denning stage of the wolverine life cycle is the most vulnerable time. Mother wolverines build dens in drifts of snow at least a meter deep, often in proximity to gullies or fallen trees. With a lack of snow as driven by spring melting, or added stress from human disturbance, wolverines might get on the move in search of new habitat.

With the wolverine print, I experimented with narrative structure to show different paragraphs of activity. Initially relying upon one print, I soon realized that to tell the story I would need multiple panes and backstory on the different players. I animated the reduction cuts by layering on light pencil drawings of a denning wolverine family. Although the pencil drawings show a different hand at work, this approach allowed me to storyboard the comings and goings of wildlife. Then I sliced apart my prints and surrounded the wolverines with rocks, trees and tracks—the other shapers of their habitat. Creating a narrative relies on the size and shape of the panels, how they are linked, and peripheral information to paint a fuller picture of the environment.

Theme: Entanglements

Entanglements and entwinings are a theme that has characterized my thinking about scale ecological patterns. The two works that I created under this theme, *Scroll II* and *Tangle*, share my observations on the repeating patterns in nature, and pull the viewer into the practice of relating the minute with the massive—from ice worms to watersheds. In the introduction to The Arts of Living on A Damaged Planet, authors Heather Swanson, Anna Twsing, Nils Bubandt and Elaine Gan ask “What if all organisms, including humans, are tangled up with each other?” They suggest exploring this question with numerous practices of knowing, from the scientific to the vernacular. The foundation of knowing is simply observing, which I relate to my roots in the North Cascades. Those days of weeks and walking gave me the observational knowledge to begin seeing entanglements. Swanson et al. attest that “Living in a time of planetary catastrophe thus begins with a practice at once humble and difficult: noticing the worlds around us.” I hope that the intricacies of *Tangle* and *Scroll II* provoke attention and curiosity within the viewer, who

is not afraid to dive in and examine the work closely. The act of noticing is transferred well between the art and the environment.

Working across scales and configuring objects in new spaces is one other commonality of these pieces. The word "scale" comes from the Latin scala, means "ladder." We climb up and down the device of scale to see our environment from different viewpoints (Zylinksa 2014). With *Scroll II* and *Tangle*., I blend scales within and between images and pay close attention to physical arrangements. Through these works I manipulate a variety of blocks, inks and papers to incorporate repeated textures and patterns while still retaining elements of uniqueness for each object. This is inspired by the patterns that appear across scales when attuned to the mountain surroundings. Fractals appear within ice crystals and larch branches. The color of a minute wildflower can match the cast of alpenglow on high peaks. The ideas of theorist Karen Barad seep into this work of entangling scale. Barad says "Seeing things across different scales is more than an attempt to represent the universe: it actively produces entities and relations. It is in this sense that seeing is already a 'doing.'" (Barad quoted from Zylinksa 2014, p. 51). Through *Scroll II* and *Tangle*, I create spaces and overlaps for the viewer to actively seek ecological relations diffused across scales.

Scroll II

Figure 47. Scroll II. 22x76 inches, relief woodcut, relief acrylic, embossment, collage and chine-collé on paper, 2020.

Scroll II is a cascade of many elements: mineral, animal, vegetable, topographic, aquatic and plastic, all braided together. Within the stream, I include mineral signatures of sediment, stones, and mountain sides, working across scales. I paste in prints of cryoconite holes, which are pocks in the ice formed by the radiative power of dark sediment, and within which microbes flourish. There are even small prints of plastic and trash that we picked off the Easton Glacier. To highlight specific elements, I sometimes presented explanatory text on the margins of Scroll II. These five descriptions and close up photographs are contained in Appendix C.

Tangle

Figure 48. Views of Tangle. Variable dimensions: suspended collage, relief woodcut on paper, with wax and string, 2021.

Tangle is a collection of wax-coated prints collaged on sekishu, washi and cardstock that fills three dimensional space. The piece situates the berries of the North Cascades as the heart of a vibrant ecological network. Ripe salmonberries and huckleberries interact with other plant forms and topography. Overlapping imagery and the aerial, shifting relationship of the pieces emphasize the abundance of relations across ecological scales.

This piece is inspired by setting foot in the North Cascades and encountering vibrant communities of plants and animals. These ecologies are shifting by the seasons and adapting to climate change, offering us many lessons if we pay attention. From rhizome to pithy orange fruit, salmonberry are connectors of water, soil, animals, plants, and people. This one plant can be food, medicine, shelter and shade. Ecological complexity manifests in this adaptable, relational salmonberry.

I floated these prints into a mobile because I was seeking a new way to visualize the idea of food webs. Our conceptualization of food webs usually fits a super-simplified 2D model, which is a good way to begin mapping connections. However, in order to more fully consider interconnectivity, we need more than bubbles and arrows. The tangle allows suspended shapes to rotate around each other. Brightly colored elements overlap in many configurations. Transparent elements open and complicate our fields of view. I am inspired by Anna Tsing's multispecies ethnography in her pursuit of wild matsutake mushrooms. She prods the soil, revealing ecological stories in the ruins of capitalism. With curiosity, Tsing (2015) finds that "the knots and pulses of patchiness are there to explore." This quote emphasizes that matsutake mushrooms are found within variations in energy and space. Their resilience, and relationships, can be unexpected. Tsing also shows how the matsutake exemplify collaborative survival. Living in the ruins is an ongoing, non-deterministic practice. In Tangle, I highlight the salmonberries' energetic connections to others—animal, geological and biological. As the pieces float like planets, they occasionally bump into each other, making a network that is not permanent, and therefore capable of change. *Tangle* asks for active engagement. The planetary attributes of the mobile components also highlights the worlding that occurs amidst these assemblages. Donna Haraway describes the enfolding of critters as sympoesis, or "making-with", whose actors may also be called holobionts. Haraway (2017) describes how "in polytemporal, polyspatial knottings, holobionts hold together contingently and dynamically, engaging other holobionts in complex patternings." Tangle is a dynamic assemblage of "holobionts" that demand engagement from the viewer, not only to peer at both sides of each patterned object, but also to consider the meaning of changing species assemblages represented by the mobile. To continue with Haraway's concepts, Tangle embodies the process of "staying with the trouble," acting out multi-species assemblages' responses to a changing environment.

To accompany the suspended piece, I assembled background information on the salmonberry that connects it to climate change, culture, and other species. This information supports the idea of cultural and climate change resilience, or the emergence of possible futures within a changing world (Appendix D).

Theme: Glacial History

"Storytelling becomes a space where we can escape the gaze of the cage of Empire, even if it is just for a few minutes… Storytelling is an important process for visioning, imagining, and critiquing the social space around us, and ultimately challenging the colonial norms fraught in our daily lives." Leanne Betasamosake Simpson, Dancing On Our Turtle's Back (p. 34-35).

To understand the history of glaciers and how people have understood them in the North Cascades, I look to the archives. Ice is an archive itself. It holds information about past climates and is thus understood as a laboratory for Western scientists. A collection of historical documents and pictures form another archive, telling us about the past from the perspectives of explorers, scientists and mountaineers. *Scroll I* renders these archives with traditional woodcuts printed in blacks and bright blues. A cascade of evidence flows down the paper. The scientific dimensions unfold through "loss books", bathymetric profiles and topographic maps. Histories of subsistence, climate science, recreation and territorial claims abut and overlap one another, all framed by the unique North Cascades landscape.

My investigation of the North Cascades led me to many interesting accounts, photographs and renderings of glacial history in the North Cascades. This archive inspired the print *Scroll I* and the "remnants" composing it, including *Glacier Women.* Like my other scrolls, the individual elements that make up the tall composition carry stories of their own. For some pieces of the prints, I replicated quotes from explorer's diaries and figures from published scientific articles. Acknowledging the biases in what information is retained in the archive, I also leaned on my imagination to image the histories and experiences of people besides the white men in the roles of explorers, politicians and scientists that appear in the history books. Although depicting history was very different from depicting the future, I found myself speculating a surprising amount within both themes.

Figure 49. Scroll I: Mountain Evidence. 22x80 inches, relief woodcut, relief acrylic, pen, collage and chine-collé on paper, 2021.

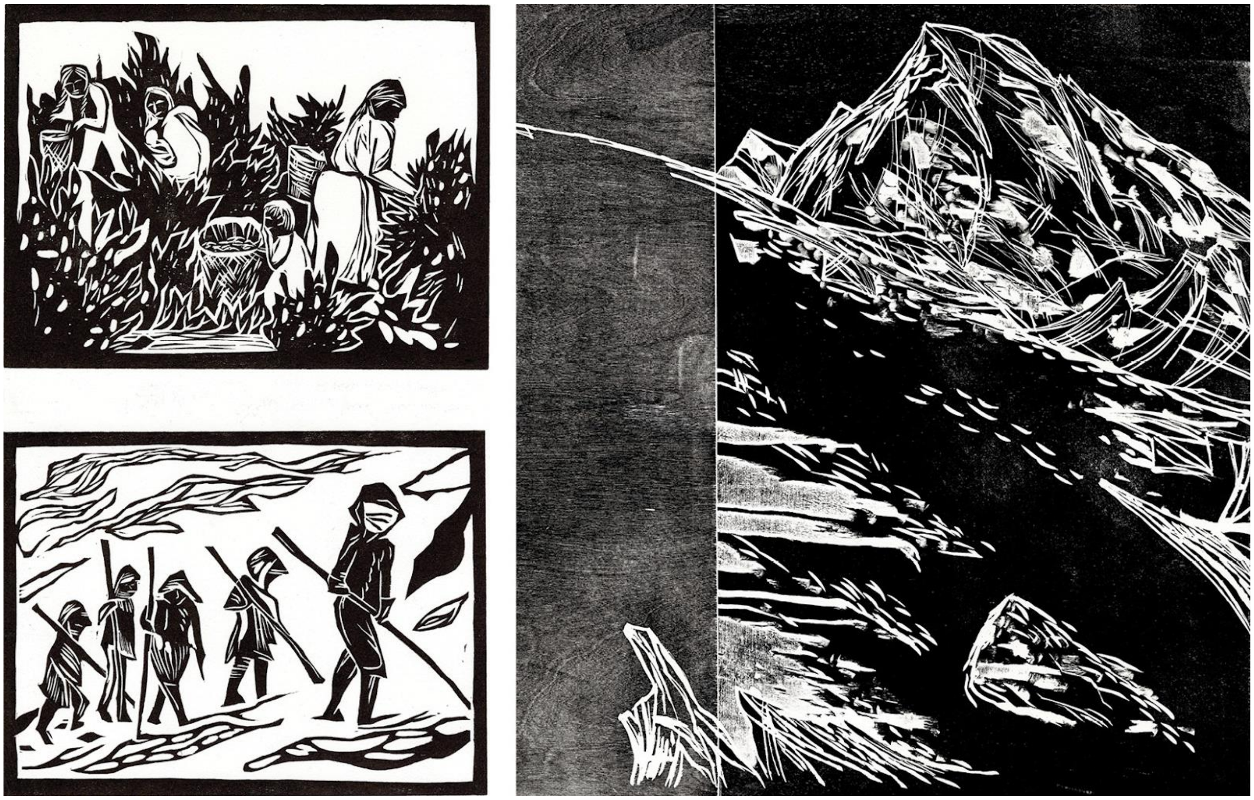

Figure 50. Glacier Women. Relief woodcuts, 6x8 inches, 2021 (left) and an untitled print of Mt. Baker, relief woodcut, 20x20 inches, 2021 (right).

Two of the unique printmaking elements nestled within *Scroll I* are “loss books” and handwritten quotes. The loss books are stacks of paper pinned through the larger print at their top edge. Each page has a cut out of the glacier’s perimeter for a given year, adapted from maps and aerial images from USGS and NCGCP. Inspired by Maya Lin’s *Disappearing Bodies of Water: Arctic Ice,* these two-and-a-half dimensional flipbooks show the diminishing glacier bodies of the Lyman Glacier and the South Cascade Glacier over time.

The handwritten quotes were transcribed from Fred Beckey’s book *Range of Glaciers* (2003) and represent early settlers’ and explorers’ impressions of the North Cascades. I also draw from Østrem’s (1966) handbook for glacier measurements and *The North Cascades: Finding Beauty and Renewal in the Wild Nearby* (Dietrich and Snyder 2014). While these quotes illuminate interesting points of view, many others have traversed this landscape. The voices of women are not well represented in the archive, so I fabulated perspectives with the pair of *Glacier Women* prints. One is based on an image taken in 1910 of a women’s mountaineering

expedition to Glacier Peak. The other is an imagined scene of women and children harvesting berries. History may be written by the victors, but it can also be reimagined and re-depicted. Storytelling may serve as a venue for challenging colonial norms and history (Simpson 2011). *Scroll I* highlights the need for this kind of storytelling and the possibilities that lie within printmaking.

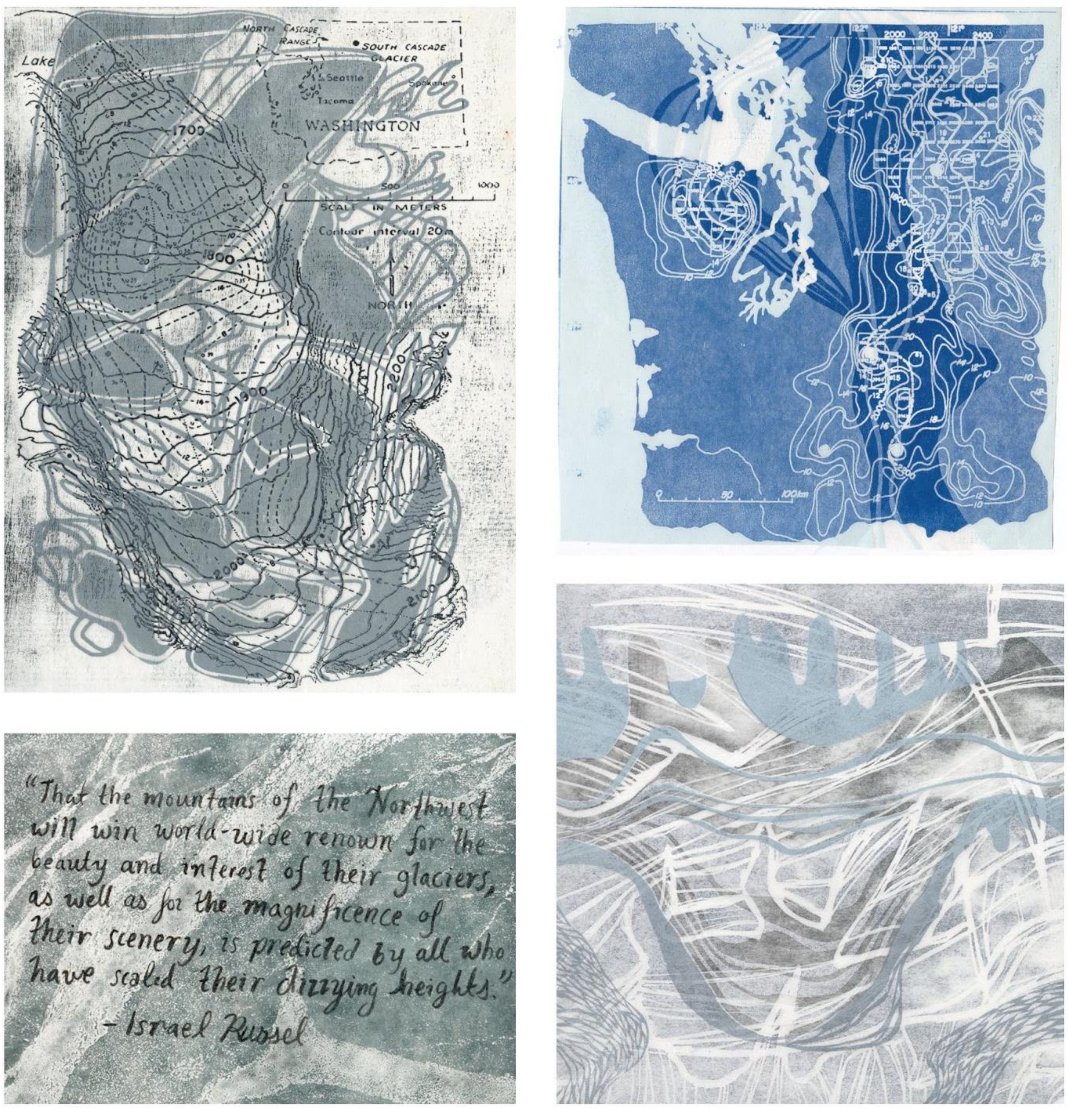

Figure 51. Remnants related to *Scroll I: Mountain Evidence*. Woodcut relief and handwritten script, 2021.

Theme: Futures

"Imagination is the key to pre-experiencing alternative futures." Gyorgy Kepes

Figure 52. Scroll III. 22x80 inches: relief woodcut, acrylic intaglio, collage and chine-collé on paper, 2021.

Scroll III is the unfinished, uncertain act of worlding a future North Cascades. This print arises from the world that I can imagine: detritus peeks through the delicate body of a planet sculpted by glaciers, watersheds of glacial blue burst into jumbles of light, a mangle of plastics is home to microbes. People pick up the ragged edges of the watersheds, finding solutions to the changing climate within their communities. Families gather ripe berries. In glacier-free valleys, there are no vacancies. Lichens explode over the rocks, and plants braid roots and sow seeds to the rhythms of an upward march. The world changes, cracks, burns, floods and goes on healing. Toxified ice crystals feed rumbling streams, feeding dying trees. Water in all forms is companion to life, to emergence, to death, and to decay. The pieces of the planet continue jostling because the act of becoming a world is constantly transformative.

Scroll III emerges from a soup of speculative thinking about the future of the North Cascades. Cast in jewel tones, with chaotic contrasts and novel combinations of imagery, this piece is not settled, or even sure what it is. This is fitting in that it speculates on the future impacts and possibilities of climate change. *Scroll III* is inspired by speculative work such as *Ecosystem of Excess* by Pinar Yoldas. Within visual culture, there is a need to use less familiar images to prompt new stories about climate change. ‘Classic’ images such as a pelican drenched in oil, or a shrunken glacier, sustain cynicism and climate fatigue. I linger with Yoldas’s work because she invents a completely new set of possibilities with her plastic species and organisms, enabling us to respond anew to our current predicament.

Worlding, as a verb, refers to a generative and active process. When an individual engages with a pile of interrelated happenings, a ‘world’ emerges for them (Palmer and Hunter 2018). Anderson and Harrison (2010) suggest that the world in “worlding” is “a mobile but more or less stable ensemble of practices, involvements, relations, capacities, tendencies and affordances." The process of worlding reflects individual engagement with entangled human-nature relationships. *Scroll III* shows my imagination acting upon the “ensemble” in the future.

Speculating *Scroll III* was quite challenging. I spent months trying to imagine what a “futures” glacier print would look like and I just barely made the noodly chaotic mess that is *Scroll III* in time for my exhibition. I found surprisingly few representations of what adaptation to climate change might look and feel like, giving me little existing material to play with, as I had with my other scrolls. I rested on my own thoughts for these speculations and returned to hopeful ideas about the “ensemble” such as: so many organisms will suck up the glacial melt

water. Trees will grow thick bark, tall trunks and deep roots as they drink the runoff. Generations upon generations of people will derive meaning and sustenance and power from deglaciating landscapes. Families can harvest salmonberries, go hiking, and tend crops enriched by glacial sediment. Ecosystems and cultures are resilient and will grow around warm rivers, abundant berries and even the proliferation of microplastics. I channel these hopeful thoughts through new and old woodblocks, using vibrant color and intense compositions to highlight imminent change and possibility. *Whitebark,* a futures side project to *Scroll III,* utilizes uncanny colors and contrasting images of live and dead trees to evoke the flicker of the future: difficult to pin down, but important to imagine.

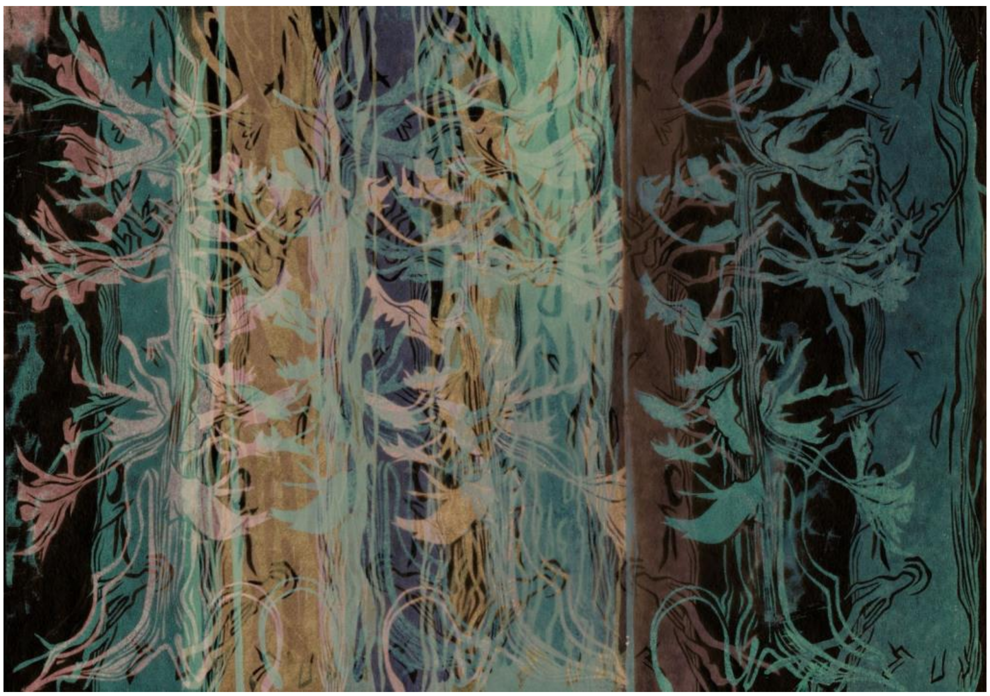

Figure 53. Whitebark. Relief woodcut and digital image, 2021.

Scroll III is my retaliation to the loss-centered story, the narrative that makes us lose our ability to imagine a future. It rises from my love of glaciers, and my frustration with how we tell their stories. Even though it is painful and fascinating to watch the glaciers that I love vanish, what agitates me is that we are stuck in seeing only the diminishment of ice, and not what is past it. If we are blind to emergence, we cannot orient ourselves to plan or act for the future. Scroll III embraces change. I believe change is an extremely exciting opportunity to care for each other and our world in better ways, and to listen and collaborate with one another. We won’t achieve the future we want to have if we don’t believe it is possible. And we won’t believe in possibility

if we only see diminishment. So, it is necessary for artists, science communicators, and scientists, to interpret data with optimism and imagination. "Artists believe in the future" was my motto in creating this work. In the absence of knowing exactly what monsters and gifts the Anthropocene will bear, art is necessary to think through, feel, and picture the possibilities.

CONCLUSION

"You cannot always stay on the summits. You have to come down again. So what's the point? Only this: what is above knows what is below, what is below does not know what is above. While climbing, take note of all the difficulties along your path. During the descent, you will no longer see them, but you will know that they are there if you observe carefully. There is an art to finding your way in the lower regions by the memory of what you have seen when you were higher up. When you can no longer see, you can at least still know." René Daumal, Mount Analogue

I learned a great deal throughout my year long printmaking explosion, especially about creating exhibition work, interdisciplinarity, and how I connect to the North Cascades. This conclusion summarizes my learning from the project, serving as a record of my growth and a collection of takeaways.

Lessons from an Exhibition

As my portfolio grew to include several significant pieces, I planned an exhibition to share my work in the atrium of the Diamond building at Colby College with assistance and funding from the Colby ES program. Conversations with peers and printmakers throughout the year shaped my decisions on the presentation. I included my four original scrolls, and four prints enlarged, digitally printed and mounted onto foam board, with small placards identifying each piece. The original scrolls were hung on tracks in the airy alcove at the base of the stairwell. I pulled elements from my narrative scrolls for the foam board prints and hung these in the hallway where they could lead the audience to the larger scrolls.

Figure 54. Exhibition View with Scrolls I-III, Diamond Atrium.

This was my first experience making pieces for an exhibition, and it pushed me to create new work with heightened consideration of audience and space. I hoped that viewers would be drawn into the space, inspect some details, and link ideas between prints. Arranging and executing an independent exhibition in this space was a great culmination of my work, and a learning process of its own. The show and the formalized presentation opportunity deepened my belief in myself as an artist, and I can certainly carry this experience to future exhibition work.

Growth as an Artist

In the studio, I took many different approaches to making art. Some of my printmaking projects such as *Scroll II* were deep, intentional dives into concepts and media that took months to execute. Other projects, especially three-dimensional ones, ended at the quick, loose and unpredictable stage. I am keen to continue working on bringing sculptural elements to my printmaking so that the pieces can interact with space in new ways. Works like *Tangle* represent this new conceptual and structural challenge for me as an artist. I built off previous knowledge and experience with materials, composition, combining print techniques, and audience interactions to develop them. Working with the laser cutter was an additional area of technical learning and finding multimedia possibilities. The invaluable input of my professor Amanda

Lilleston and the printmaking cohort nourished my leaps to using space, narrative and perspective in new ways.

My approach to describing my work has also evolved. I have thought a lot about how I describe the data, or the scientific basis of my work, within the prints and after the fact of making them. Throughout the year, I grew very mindful of how much data I brought to the printmaking studio and what I aspired to do with it. I learned that my most engaging and exciting work does not limit itself to regurgitating scientific information. Instead, my strongest works allow experience and knowledge to seep into them intuitively. This manifests also in the process of labeling my artwork for the exhibition and generating artist statements for individual pieces. On one hand, I trust that my pieces speak better than a layer of words over them can. Art is a beautiful place to express things without totally spelling them out. However, some textual explanation can enrich understanding or provide a new access point to the artwork. I typically end up writing long winded descriptions of my work, but only presenting the essentials in contexts such as labels. For instance, I sometimes included explanatory text alongside *Scroll II* to identify specific stories, but generally I shifted away from including explanatory text in most presentation settings and funneling my effort into creating art instead. My feelings about my art shift over time, so keeping the artist statements simple allows them to be relevant as my relationship with the work continues to evolve.

Experimental printmaking opened many creative and critical doorways, and now I feel like I could run with this project for several lifetimes. There are so many opportunities for collaboration and presentation with multimedia and installation. There are also so many stories waiting to be told, and my enthusiasm for telling them grows with every conversation I have with other artists and scientists.

Reflections on Interdisciplinarity

When I was planning this thesis, I described it as “vigorously interdisciplinary.” The challenge of bending and blending disciplines has certainly been a huge effort. Understanding the scientific literature and adapting this information to art requires thinking in multiple directions and using both critique and creativity. Although “science,” “art” and “narrative” contribute to the title of my thesis, the range of disciplines and thought styles I encountered and worked through is much broader. Some of the threads I have tied in include geography,

environmental history, environmental humanities, philosophy, speculation, education and visual culture studies. Each has unique approaches and perspectives, but the elements of critique and creativity surface throughout. I am emerging from the cumulative reading of them all with the understanding that they can all show us something about how to make pictures, and in turn shape how we think.

One of the ways that this research has revealed gaps and patterns in how we *think*, is through the practice of binning aspects of the world into dualisms, such as Enlightenment categories of nature versus culture. This dualism has been imported to wild places through empire and exploration and the ideological divide between nature and culture remains sedimented there. The paradigm of Western rationality, "the idea that a measurable natural world might be pried from its cultural moorings" persists among colonized landscapes (Cruikshank 2005). It also cascades through current debates about environmentalism and climate change. And finally, it is translated, reproduced and remembered via images. Glaciers are a fascinating site to consider the nature-culture debate because although they are rarely inhabited by humans, they are still culturally significant and interwoven.

An even more relevant construct to unpack with this thesis is the conflict or agreement between science and art. When I began conceptualizing this project, I expected that the field of natural science and the field of art would have very different things to say about communicating climate change. I was defining arts and sciences are separate disciplines that were both necessary to address climate change, but I wasn't sure what kind of common ground would be found. Subjective art values abstraction and obscurity. Objective science favors precision and facts. Following C. P. Snow (1964), one could indeed conclude that the natural sciences and the humanities have a fundamental, polar opposition, a problem that results in a gulf of misunderstanding between groups. In the context of communicating North Cascades glacier change, this would mean that scientists and artists, although both concerned with climate change, would not understand one another's work, and therefore not collaborate and contribute to a collective understanding of the problem. Opposition, or separation, is a missed chance to build understanding and creative solutions.

However, what I feel and understand standing at the end of this project shows another side: there is much commonality between art and science, they are in fact inseparable. A holistic understanding of the world is formed by a constant conversation between the two. Art inspires

science, science inspires art. Artists inspire scientists, and scientists inspire artists. When you strive to deeply understand something, there is no need to bin types of knowledge, because they are so constantly merging and building upon each other. The common ground between art and science is not a place, but a constant conversation. In place of thinking about the tensions between art and science, I now sense elements of both enriching everything I see. Sometimes they are subtly or invisibly collaborative, as when a fact spurs an artist to create an abstract piece. At other times the two can power and sustain a year-long or life-long interest in the environment—such as when the beauty of a glacier pushes one to study and communicate their changes. So combined, the art-science dualism fades in relevance. Instead of worrying about this dualism, we can move forward and begin thinking about integrating these tools (creativity and science) into public engagement with climate change.

Within my practice, following rich seams of creative potential took me away from the hard details of science—and I believe that is okay, even though it is not where I expected to go. Working alongside environmental themes, while not necessarily bringing beauty to hard data, is valuable. In my CLAS presentation, I was asked how I incorporated the data that I collected on the glaciers in the summer of 2020 into my artwork. In fact, I had initially been inspired to weave actual measurements into my art, but once in the studio I stepped away from this idea. For art that beautifully picks numerical data and depicts it directly, I look to artists Jill Pelto or Chris Jordan. They are incredibly effective at weaving specific measurements into art. However, I moved towards themes that scientists are uncovering but not telling as effectively as a story. For example, the Johnston et al. (2019) paper is charged with data about how pikas are impacted by climate change, yet within the study the response of the pika is primarily a metric to measure ecological change. I thought that by digging deeply into how the pika would struggle to adapt to local conditions, visualizing their behaviors, and thinking about what the absence and migration of pika would mean, art could round out this side of the story. I took a similar approach in depicting a scientific story with *Wolverine Scroll.*

Environmental history research seeped into all elements of my thesis. As I went about my creative work, I constantly made connections to the archives and articles I had encountered in research. For example, upon completing an abstract print I would compare it to a photograph of the early mountaineering craze in the Alps and find that it mirrored a photograph taken in the summer of 2020 perfectly. The narrative of glaciers as a playground has many iterations, often

visually resonant. The repetition of perspectives throughout time became very tangible as I reworked ideas with my hands. Looking across the archives, scientific articles, and my own photography and printmaking, I realized that views, pictures and opinions are reproduced through all types of media. Understanding historical context pushed my work forward. It was at times befuddling or comforting to realize that whatever I made would embody some historical environmental narrative, and the longer I investigated the past, the more values I would see reflected in my own work. However, researching through scientific papers, texts and photographs has limits—notably the presence of preservation bias and the imbalance between whose stories are reproduced, and whose are latent or unwritten. Aware of this imbalance and keen on poking around all glacier perspectives, I had to ask questions of myself such as, what did I want to highlight from the past? Where were the voices of indigenous people and women? I found some in the archives, I fabricated some, I imagined hundreds more. I also had to consider which narratives are shining into the future offering constructive ideas that will help us navigate the Anthropocene, and which narratives are dimming, outdated or unhelpful.

Output

This project has most obviously generated a text and a body of printmaking work. Yet the less visible outputs are perhaps even more valuable. The ultimate thesis output is also me. If you're reading this, you probably have some stake in taking on big Environmental Studies projects yourself (as a student or an advisor), so I would love to acknowledge the ways that this thesis has changed me, a query initiated by my peers Sophie and Ingrid. The realization that the most valuable output of my time at Colby is not a pile of projects, but rather myself, happened in the spring of my senior year. This realization allowed me to frame my thesis in a healthy way and to consider how critical thinking and interdisciplinary work will carry me into the next stage of my life. The benefits of taking on this massive project unfold at unexpected moments, and I assume they will continue to do so.

This work has strengthened the bonds between me and the North Cascades. Parts of my identity are defined by traversing, researching and appreciating these mountains. Since artists have started depicting glaciers, their white, high-albedo surfaces have served as a reflection site. In my own experience, as I understand this place, I also understand myself. Even though I didn't spend any time *in* the North Cascades once my senior year began, this place still inspired more

work than I could generate or even articulate. When I think about my evolving relationship to place, I return to the Daumal quote at the beginning of this section. The memory of what I saw when I was higher up, living amongst glaciers, has sustained my interest and enriched my appreciation for this place. I trust in the process of knowing, even when things cannot be seen.

Through this topophilia, I have learned to see the range in so many new ways. I have tried to be a voice for scientists, artists, natural resource managers, trees, pikas and glaciers through my stories and prints. I am eager to find more ways of looking out, and to develop new ways of telling these stories.

I have also learned about my capabilities and limits as an artist, a mountaineer, and a student. Artistically, I have found that my interests lie in connecting the stories underfoot, overhead, and dispersed throughout time. Although I spent many hours trying to put words to my artwork, in the end I am happiest letting it speak for itself. My relationship to my work—written and visual—is constantly evolving, and the more I can let my artwork breathe free of my interpretation at one static moment, the more open it becomes. As a mountaineer, I have appreciation anew for the rock, ice and snow that I travel upon. Within the context of past glaciation and current climate change, my time in the mountains is enriched and even more precious. I hope that I can articulate information and ideas from this project to those that I travel with and contribute to the collective environmental ethic of the North Cascades. As a student, I have realized that nearly every discipline has something to contribute to this work. This thesis is by no means perfect, but it does mark my progress in tying together concepts from many disciplines and thinking in necessarily new ways. In summary, I am proud and ready to set this document behind me, yet carry forward this growing part of my identity, many ideas for continued inquiry, and a strengthened bond with the place I call home.

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APPENDICES

Appendix A. Company Glacier Soundscape

Description:

The soundscape is complementary to the Company Glacier Path print. It includes the voices of water and people from Stehekin and the Company Creek drainage and hydroelectric facility.

Filename:

Company Sound.mp4

Appendix B. Pika Story

Description:

This "chapter" was written for the Vivid Glacier climate change glacier storytelling project organized by Mauri Pelto in 2020. Additional chapters from the perspectives of various organisms were created by other glaciologists and science communicators. I chose to write from the perspective of the American Pika (*Ochotona princeps*), one of my favorite animals in the North Cascades and one that is uniquely vulnerable to snow drought and warming temperatures.

Hawk circles the sky, and I sound the alarm. The other pikas hear my shriek and we all dart beneath rocks. Summer sun bares down on the talus slope where I have lived my entire life. It's the start of an August day, the hottest time of the year.

Figure B.1 Pikas foraging amidst mountain landscape and wildflowers.

To avoid overheating I rest in the cool shadows during the day and forage diurnally. At this time of year, I don't have to look far to find nourishing shrubs and flowers. The alpine meadows scattered across the slope are at the peak of summer abundance. Meltwater trickles down from Vivid glacier throughout the summer, and this cold water feeds the alpine vegetation. I gather mouthfuls of thistles, fireweed and alpine grasses. Once the stems are dry, I scuttle them to

caches in the rock, deep piles of collected plants called haypiles. These will feed me throughout the winter.

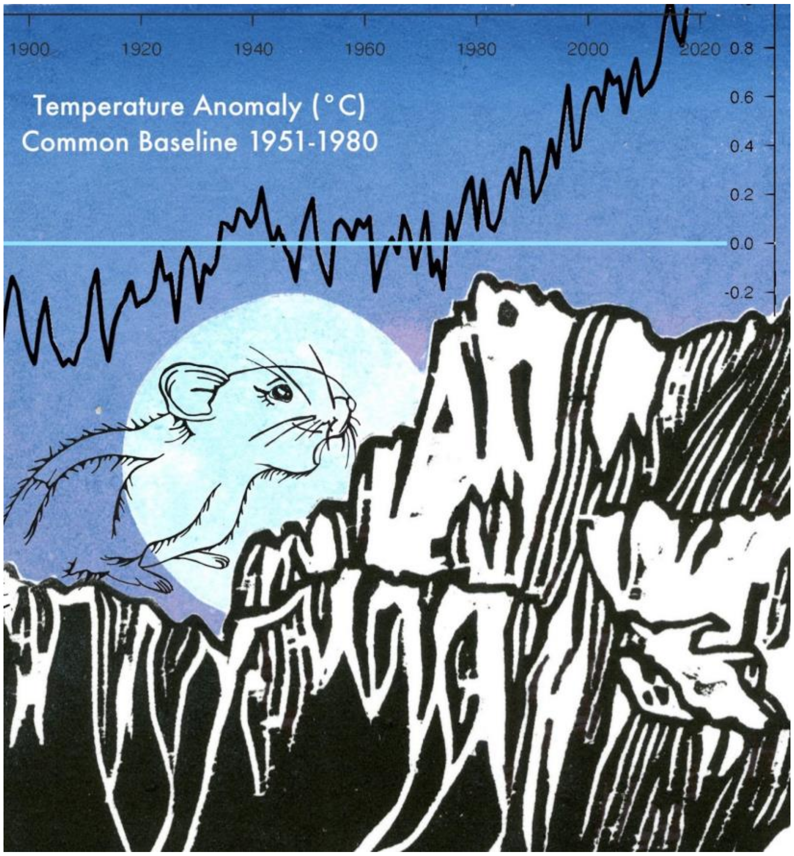

Figure B.2. The pika sounds the alarm for rising temperatures.

EEE!

I shriek again, unsure if my fellow critters can hear or understand. This is not an alarm for the presence of owl or weasel or snake. It is something more dangerous than a predator—it is a temperature warning. Of any of the inhabitants of Vivid Glacier, we know the dangers of rising temperatures the best. We pikas die if exposed to temperatures of over 78°F for too long, temperatures that the lower rock fields now reach regularly in the summer. Generations ago, my family lived at the base of this slope—but even in the shelter of the rocks, the heat became deadly. So we have climbed to cooler, higher places. Pika by pika, we are forced to establish new homes higher on the mountain.

Temperature is forcing everyone to move up—the glacier, the forest, our predators and our forage. Sometimes we move at different paces, so each season contains unpredictable risks and possibilities. Forests take root in scree slopes that once were open snow and sun. Not long ago, the talus pile where I live was covered by the cold weight of Vivid Glacier. Currently, the rocks are dry four to six months of the year and crammed with a mosaic of alpine vegetation. It's a good home for now, but I will nose my kids up the slope when they are born. Summer temperatures keep rising, and we must too. Between here and the remnant of Vivid Glacier and the mountain top, there isn't that much room to move. What will happen when all of the alpine life is restricted to a mountaintop? Will it become a summit of sun-bleached bones?

This is looking to be a really hot summer. What can we do? I shriek for my neighbors, but my voice feels unusually small. I hear no chirps from downslope—and I worry that my lower relatives are dying. We are powerless in the heat.

Figure B.3. Pikas move up in elevation. Linocut.

Months pass, and the air cools. I've survived the heat of summer and stashed away many twigs and wildflowers. Now it begins to snow, light flurries at first, and then a huge storm bring deeper drifts. Within the rocks, I sit upon my favorite haypile and the slope grows very quiet.

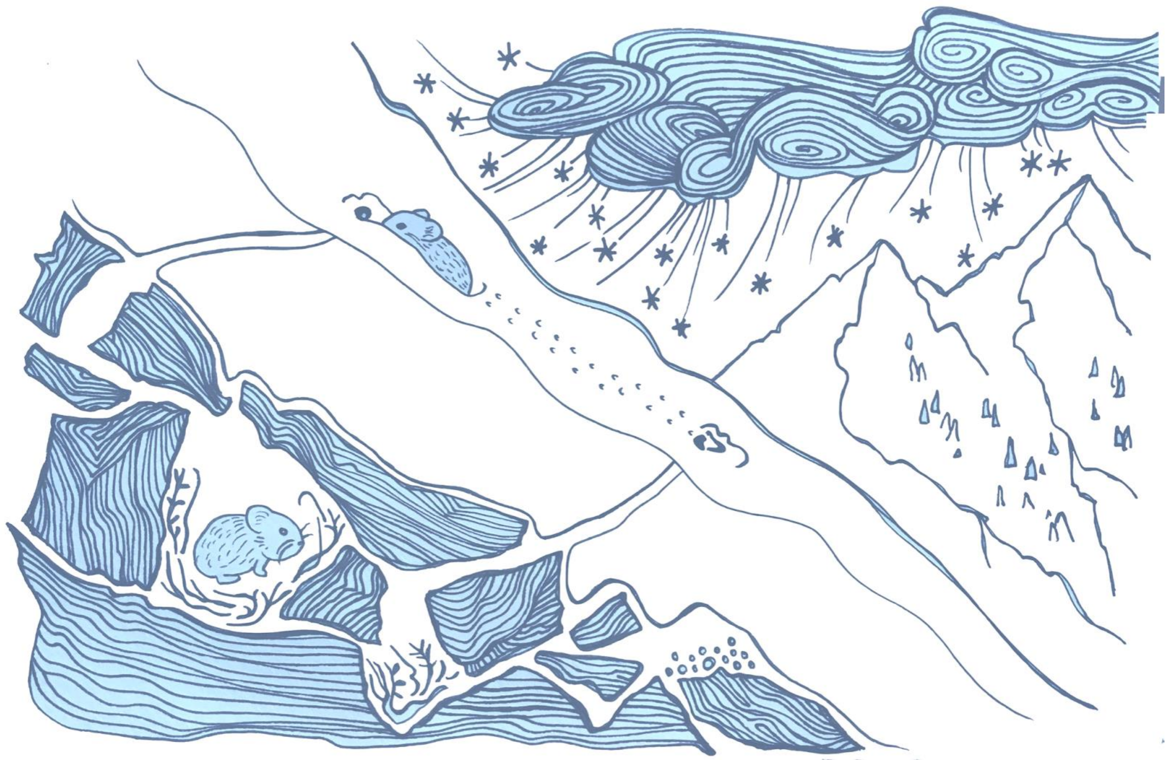

Figure B.4. Scene with a snow insulated pika den.

Unlike bears, I don't hibernate, and unlike many birds, I cannot migrate. I need a thick snow blanket to insulate my home. When there is enough snow, the ground temperature is stable at 32°F, and I can survive. Without snow, winter cold can be deadly. I know that we pikas often fail to reproduce when there is not an insulative snowpack. Additionally, our favorite plants suffer frost damage and we have less to eat when melt-off begins. The talus slope is better with baby pikas and abundant forage. In solitude, I hope for plenty of snowfall, especially if this winter is a cold one. Then I scurry out to excavate an air shaft and build a tunnel to access my haypiles. Even in winter, I don't sit still for long.

Winter passes. Under the changing surface of the snow, I have survived another season. The only place I have ever known is the alpine, where blazing summer days contrast chilly nights and even more frigid winters. In the climate of the past, we pikas were well equipped. But every year is different now. Despite our adaptations for living in the extreme reaches of the alpine, this stochasticity challenges our biological strategies. Although this winter brought plenty of snow to envelope my territory, at the bottom of the slope where my ancestors once lived, things were

different. There was little snow, exposing the plants and animals to bitter cold and low moisture. The alpine meadows withered, and shrubs took their place. It seems there is no way to survive down there now.

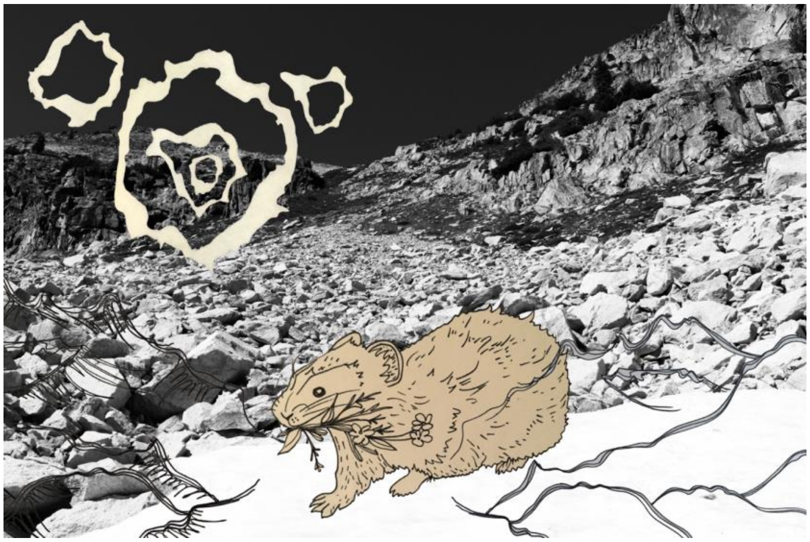

Figure B.5 A pika poised in a talus field.

Another change this year is the quick arrival of spring. I get moving and foraging a month earlier than my ancestors did. Springtime seems as lush as ever, yet when I look for my favorite tufts of forget-me-nots, they're no longer there. My favorite plants migrate upslope, or disappear, and new ones march into their rootwells. All I can do is change my diet.

Over the summer, less and less water trickles down from Vivid glacier, leaving the foliage thirsty and skimpy. I stockpile what I can, preparing for the uncertain months ahead. August feels much hotter, and I get close to overheating many days. The stress and solitude fatigue me.

Below, the talus slopes in the valley are ghostly quiet. No more EEE's! rise on the mountain thermals. There are a few more pikas above me, at the upper limit of the rock below Vivid glacier. Our population struggles to find the spot where we can survive both summer and winter temperatures and find enough to eat. We are quickly running out of space. But the temperature marches constantly upward, past where we can go.

We will climb until the heat bleaches our bones. Heed the warning of the Pika, sentinel of Vivid Glacier.

Appendix C. Scroll II Explanatory Text

Description:

Five descriptions are placed on the margins of *Scroll II* and illuminate some of the backstories contained within the large print. From the top to bottom of the scroll, these are:

Raven surveys the watershed from the high reaches of the volcano. The Deming Icefall splinters below. Each of the five animals in this print are made up of shapes that were inspired by the patterns of snow melting off of the glacier's blue ice. Although they rise from a common source, each animal has their own character and story.

Figure C.1. Raven (left) and two scientists (right).

Two scientists "go fishing". They lower a weighted and metered rope into a deep crevasse on the Easton Glacier. By collecting data on snow depth, the team can calculate the mass balance of the glacier. In a good year, thick snow insulates the glacier from melt and there isn't much bare ice to be seen. The rope sinks 3, 4, 5, meters down into the crevasse before reaching the glacier ice. To stay healthy, the glacier needs to retain snow over 65-70% of its area. Unfortunately, there are a lot of bad years when snow vanishes from much more of the glacier. During their

annual field work, the team also keeps tabs on other glacier responses to climate change, such as streamflow, crevasse depth, and the location of the glacier terminus.

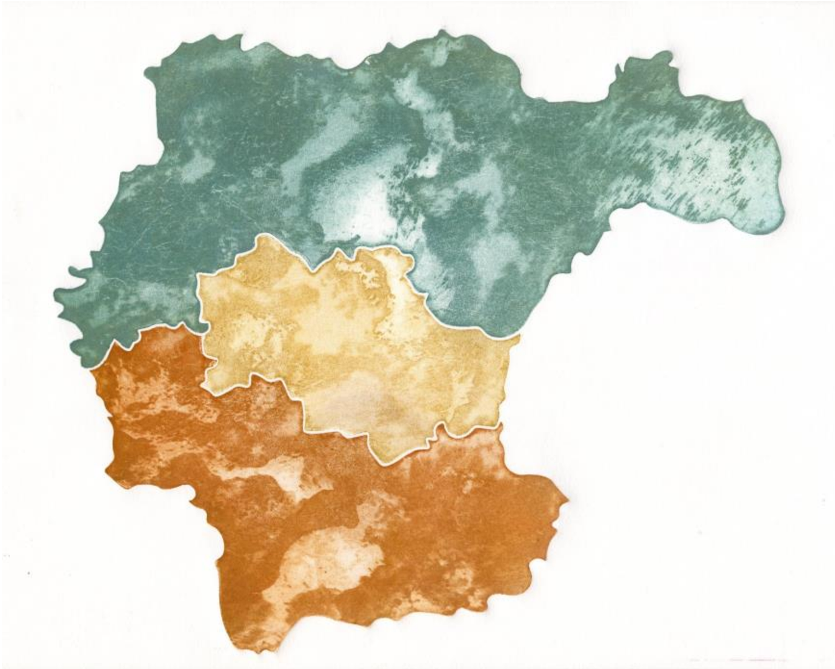

Figure C.2. Three Nooksacks.

This tricolored puzzle has the texture of a frothing glacial creek. But the shapes show something much more macro: watersheds. These are the three forks of the Nooksack River. The three forks encircle Mt. Baker. Of the forks, the North is fed by many glaciers, the Middle by a few, and the South no longer receives any glacial melt. Anadromous fish, including the five species of Pacific salmon, thrive in habitat created and maintained by glaciers and glacial melt. Will the salmon of the South Fork of the Nooksack soon be ghosts? Dam removals and stream restoration (including planting hundreds of trees and engineering dozens of new log jams) are giving the fish places to go in a warming world. What happens in 20 or 50 years when one piece of the puzzle is removed?

The stream rips downhill, across vacant moraines, through meadows and into the lush forest. The cold water carries nutrients and organic carbon that sustain ecosystems. It can be rich in glacial flour, the fine sediment that diffracts light in such a way that lakes and streams appear milky green or brown. I envision the stream and its sediment nourishing trees, fish, marmots and flowers on its journey to the sea.

Figure C.3. Pika

Meadow, Pika, Ellipsis. The active American Pika collects mouthfuls of alpine grasses and flowers. Pika live in talus fields, using rocks as a pantry and a shelter. The pika is temperature sensitive, and can die when exposed to much more than 70° F. Pika considers her next move: Move up into the empty moraine? Will there be flowers?

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Appendix D. Tangle Supplementary Information

Description: To accompany *Tangle,* a suspended collection of wax-coated prints, I assembled background information on the salmonberry. These ideas relate to the berries' cultural importance and climate change resilience.

Salmonberry (*Rubus spectabilis*) is a spiky understory shrub native to the Pacific Northwest, where it most often grows in moist forests at elevations from sea level to 1,200 meters. Salmonberry can also grow in dry or disturbed areas, such as fencerows, roadsides, and logged areas.

Salmonberries are resilient.

Due to climate change, more winter precipitation is falling as rain instead of snow. This reduces the frequency of snow avalanches, and salmonberry bushes spread into heather meadows in Alaskan coastal forests. Salmonberry is one of the characters of sub-alpine landscapes that will fill the shoes of some species that retreat upward. In some contexts salmonberry is considered a weed, as its hardy root network makes it difficult to eradicate. Yet these strong rhizomatic systems also protect slopes from erosion, and salmonberries are popular in stream restoration projects.

Salmonberries are habitat.

Salmonberry shrubs provide food and shelter for many wildlife species. The bushes shade streams, cooling water for aquatic species. Birds browse the shrubs for berries, and may build their nests in the thorny branches. As Rufous Hummingbirds zip north in the spring, they draw nectar from the salmonberries showy flowers. Large ungulates such as elk, deer, moose and mountain goats may browse salmonberry shoots in burnt areas or early spring.

Salmonberries are cultural.

Salmonberries are so named perhaps because indigenous people of the Pacific Northwest favored eating the berries with salmon roe. The storytellers of the Chinook First Nation have a story that the coyote was "instructed to place these berries in the mouth of each salmon he caught in order to ensure continued good fishing" and so the Salmonberry became known. Various parts of the

salmonberry plant bear significance. In the springtime, young salmonberry shoots are an important food. The bushes shoots and bark are used as medicine, often to treat wounds and burns. And of course, their berries are a welcome burst of summer flavor, sometimes made into preserves. The ripening of the berries in May or June coincides with the song of the Swainson's thrush, often called the "salmonberry bird". The song of breeding males is a fluting upward-spiraling melody. Finally, an abundance of salmonberries signal that pink salmon will be plentiful, and that winter will be snowy.

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