

APPLYING CUMULATIVE EFFECTS PERSPECTIVE TO WILDLIFE HEALTH:
ADAPTING A DETERMINANTS OF HEALTH APPROACH TO WILDLIFE
POPULATIONS

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By

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ABSTRACT

This thesis explores the feasibility and utility of adapting a determinants of health (DOH) approach to wildlife populations in order to develop a cumulative effects perspective of health in those populations. The first objective was to investigate the theoretical feasibility of adapting the DOH framework from human population health to wildlife. This was accomplished using a combination of methods including a scoping literature review, expert knowledge elicitation, and network analysis. We found that a ***theoretical foundation*** does exist for a DOH approach in wildlife and that it is consistent both with how wildlife is discussed in the literature and how management professionals perceive health.

The second objective was to determine if the DOH conceptual model could be used to facilitate identification of shared goals or priorities for wildlife management across different stakeholder groups. Using network analysis of the expert opinion of two key Pacific salmon (*Oncorhynchus spp.*) stakeholder groups, we evaluated whether the DOH model could be used to identify shared perceptions of health. The DOH network was ***useful*** for visualizations of perceptions of health and was effective for identification of commonalities between disparate groups.

The third objective was to identify if the DOH model could meet a need within existing policy to determine if this approach could be feasible within the existing system. We conducted a review of policy pertaining to Pacific salmon within Fisheries and Oceans Canada. A ***policy need*** was identified for a DOH approach that would provide a cohesive vision of salmon health across different government sectors.

The fourth objective was to investigate whether there is an existing foundation of practice for applying a DOH perspective to support a healthy policy approach for wildlife. We reviewed data from already existing sources for Chilko Lake sockeye salmon (*O. nerka*) to determine if there were resources available to implement a DOH perspective. A DOH approach to measuring and monitoring salmon health within DFO was feasible and a ***foundation of practice*** exists, with measures or indicators of many of the expert-identified drivers of health already being collected.

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LIST OF ABBREVIATIONS

Cohen Commission: The Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River

DFO: Fisheries and Oceans Canada

DOH: determinants of health

FNFC: First Nations Fisheries Council

Wild Salmon Policy: Policy for Conservation of Wild Pacific Salmon

CHAPTER 1: LITERATURE REVIEW AND RESEARCH GOALS

1.1 HISTORY OF HOW WILDLIFE HEALTH IS DISCUSSED AND MANAGED

Health has long been a management goal for wildlife populations (Hanisch et al. 2012; Stephen 2013). The health of wildlife is also a goal of many pieces of legislation and government agency strategic plans (Hanisch, Riley, & Nelson, 2012; Stephen, 2014). Health has historically been ill-defined in veterinary medicine or has focused on the disease-centric approach (Gunnarsson, 2006; Nordenfelt, 2011). This statement is particularly true for wildlife populations, where health research has focused on infectious disease-causing agents and pollutants (Stephen 2013, 2014). A systematic review of wildlife health literature (458 peer-reviewed papers) identified that 56% of the literature conferred health from an absence of disease perspective and 40% considered health in an unclear context (Sinclair et al., 2016). Another review of recent wildlife health literature found 35% of the 469 reviewed papers focused on pathogens or parasite detection or surveillance, 20% were concerned with identifying outbreaks, morbidity or mortality, or determining disease risk factors, 10% investigated disease ecology and host-agent interactions (Stephen, Wittrock, & Wade, 2018). This disease-centric approach is reflected in Canadian federal and provincial fish and wildlife¹ legislation, policies, and regulations which either do not provide parameters defining health or use the absence of specific, regulated diseases as the defining feature. An example is Canada's Health of Animals Act, where the context of animal health is a risk to human populations or economic endeavours from regulated infectious diseases (Minister of Justice, 1990).

Wildlife disease management is important for conservation. Disease can be a regulating factor for populations and has played a leading role in species extinctions, with declining populations at greater risk of a disease-related extinction (Heard et al., 2013). Common pollutants, such as mercury, polychlorinated biphenyls, and persistent organic pollutants, continue to have negative consequences on the fitness and survival of populations (Elie Goutte et al., 2015; Jepson & Law, 2016). The abundance and distribution of species can be adversely impacted by population-level traumas, including vehicle collisions (Frair, Merrill, Beyer, & Morales, 2008), predation by house cats (Moseby, Peacock, & Read, 2015), and bird-window collisions (Hager et al., 2017).

¹ In this thesis, I use the term "wildlife" to refer to all free-ranging species, including aquatic and terrestrial animals encompassing mammals, birds, fish, reptiles and amphibians.

Past attitudes largely do not view disease as an important issue for wildlife. Rather, disease was often considered as a self-correcting population regulating effect. In recent years, however, there has been increased incidence of wildlife disease, largely due to other pressures on wildlife that make them more vulnerable (Acevedo-Whitehouse & Duffus, 2009). Concern about diseases in wildlife populations is a growing concern as there is increasing documentation of the role of wildlife as sources of diseases that affect economic activities and public health (Daszak, Cunningham, & Hyatt, 2001; Decker et al., 2010). In recent years, the issue of emerging diseases has been a driving force behind much of the investment in wildlife disease research and management (Daszak et al., 2001; Judson et al., 2017). The requirement of two branches of the World Health Organization (OIE – World Organization for Animal Health and IHR – International Health Regulations) for countries to have wildlife disease surveillance systems (OIE, 2019; World Health Organization, 2005), further engrains the perspective of wildlife as a potential threat to human health.

Current Canadian management goals are also interested in the positive contributions of wildlife health to ecosystem function and to the public and economic health of the country. For instance, an objective of the Pan-Canadian Approach to Wildlife Health is “... to protect and sustain wild animal health and the values they bring to Canadians...”. Wildlife play a critical role in their ecosystems, and their health is an integral factor for ecosystem health (Heard et al., 2013). Because wildlife species play different roles within their ecosystems, if a species is impacted by some health-altering factor and populations decline or distributions shift, there can be unexpected repercussions. For instance, as caribou populations decline, wolves, who primarily feed on caribou, may be forced to switch to a different diet such as moose (Merkle, Polfus, Derbridge, & Heinemeyer, 2017). This change may impact vegetation or alter predator-prey dynamics, ultimately shifting the balance of the ecosystem.

Wildlife health is important for public health and well-being in a number of different ways. As humans and wildlife exist in a shared environment, wildlife can be used as sentinels of potential public health threats, such as those from pathogens and pollutants (Kuiken et al., 2005; Reif, 2011). Wildlife are also culturally and economically important to humans. There is also increasing evidence on the importance of nature in supporting people’s mental health and sense of community (Berto, 2014). Various communities, including First Nations, derive an enormous cultural meaning from wildlife (Bhattacharyya & Slocombe, 2017). Many rural and remote

Canadians rely on wildlife for sustenance and food security (Gurney, Caniglia, Mix, & Baum, 2015; Wesche & Chan, 2010), making the health of wildlife imperative for supporting healthy human populations. Wildlife are also important economically. Fishing, hunting, guiding, and tourism, both recreationally and commercially, are huge industries upon which many people rely (House of Commons Canada, 2015; Wilderness Tourism Association British Columbia, 2013). Additionally, wildlife can serve to provide ecosystem services with health and economic implications to humans, such as in the case of bats whose massive consumption of insect pests saves the agriculture industry billions of dollars in pesticides (Boyles, Cryan, Mccracken, & Kunz, 2011) Wildlife health is a resource that influences conservation, public health, and economies.

1.2 THE NEED TO MODERNIZE CONCEPTS OF WILDLIFE HEALTH

Hanisch et al (2012, p. 478) stated that “a clear vision of wildlife health [has not] been articulated”. Although disease and pathogens play a role in the health of a wildlife population, there is more to being healthy than not being sick. A disease-centric approach to health can be useful if the sole goal of the management program is disease control. However, using disease or pathogens as the only measures of health is inadequate for three reasons (Deem, Parker, & Miller, 2008; Hanisch et al., 2012; Lerner, 2008; Stephen, 2014). Firstly, it is not consistent with modern concepts of health in other realms that define health by what is present (capacities) rather than by what is absent (disease). Secondly, it does not account for the various ways in which health can be negatively affected, apart from pollutants or pathogens. And finally, it limits investigation and management to single causes of disease rather than seeing health as interacting positive and negative determinants that need co-management to achieve optimal health. Another major flaw with the absence of disease definition of health is that anyone could develop a list of diseases “and if none of these [diseases] are observed in the animal, the animal is regarded as healthy”, even if it is not (Lerner, 2008, p. 80).

Around the globe, there have been massive die-offs of wildlife species, with a decline in abundance of 58% between 1970 and 2012 in monitored species populations (World Wildlife Fund for Nature, 2016). Some of these mortality events have been attributed to specific pathogens, such as in the case of *Batrachochytrium dendrobatidis* (Chytrid Disease), a fungal infection responsible for declining amphibian populations worldwide (Guilherme Becker, Roberto Fonseca, Fernando Baptista Haddad, Fernandes Batista, & Inácio Prado, 2007), or

Pseudogymnoascus destructans (White-Nose Syndrome), the fungus implicated in the deaths of over 6 million bats in eastern North America (Reeder, Field, & Slater, 2016). Most population declines, however, cannot be assigned only to a disease, but rather are due to a suite of complex and cumulative factors that put wildlife populations at risk (Cohen, 2012b; Vors & Boyce, 2009). Even in cases where a particular disease has been identified as the proximate cause of mortality, other extenuating factors such as habitat degradation, predispose the population to diseases or reduce their capacity to cope with their effects (Deem, Karesh, & Weisman, 2008). For instance, the global declines of amphibians in part due to the outbreak of Chytrid Disease was exacerbated by translocation of the pathogen globally, a changing climate that dries out critical amphibian habitat that put added stress on the animals (Daszak et al., 2001). Similarly, the North American outbreak of White-Nose Syndrome, a fungus originating from Europe, was incredibly deadly (over 6 million bats succumbing to the fungus) due to globalization and the introduction of a disease to a continent of naïve populations, changing land-use, and warming temperatures (Flory, Kumar, Stohlgren, & Cryan, 2012). Stephen (2014, p. 427) posits that “a disease-centered approach to wildlife health is inadequate for... the principal health challenges imposed by the unprecedented environmental changes that characterize the 21st century”. These challenges being factors such as climate change, habitat loss, and over-exploitation, which can limit the capacity for populations to thrive and sustain themselves in times of unprecedented social and ecological changes (Stephen, 2014).

The current disease-centric approach to wildlife health lags more than 70 years behind modern concepts of human health (Stephen, 2014). The prevailing wildlife health paradigm also has not developed alongside other concepts related to wildlife, such as vulnerability, resilience, and sustainability (Deem, Parker, et al., 2008; Stephen, 2014). There is a need for a modern definition of wildlife health that both reflects the evolution of health-understanding in other sectors and enables fields, such as natural resource conservation, ecosystem restoration, and public health, to integrate wildlife health into their programs in a relevant and meaningful way.

As effective management depends on specific and measurable objectives (Clemen & Reilly, 2001), since the ambiguity surrounding definitions of wildlife health can hinder the efficacy of management efforts (Hanisch et al., 2012). When investigating how wildlife health professionals perceived health, Hanisch et al (2012) found that the experts conceptualized wildlife health as multifaceted and as more than the absence of disease. Integration of a new

definition of wildlife health that reflects these perspectives into policies and management programs would make wildlife health a “meaningful, measurable concept” and would “increase the probability of achieving objectives for wildlife health” (Hanisch et al., 2012, p. 481).

The scholars calling for a new approach to wildlife health provide some guidance on concepts that could be used to inform the paradigm shift. Deem et al (2008) and Hanisch et al (2012), for example, recommend implementing Leopold’s (1933) perspective to wildlife health, namely that environmental and population factors are far more important in promoting health than focusing on disease. To promote the shift towards a more Leopoldian approach to wildlife health, Hanisch et al (2012) highlighted the importance of integrating both descriptive and normative elements, and human dimensions and societal values into how wildlife health is conceived. Similar to Hanisch et al (2012), Deem et al (2008) advocated for bridging the divide between the wildlife health and conservation fields, identifying the intrinsic connection between conservation goals and wildlife health concerns. The similarities in perspectives between the two fields, namely the focus on the capacity to “restore and sustain a ‘state of balance’”, was the foundation for Deem et al (2008) recommending more collaboration and integration within wildlife professions. Stephen (2014) echoed this position, advising the incorporation of resilience and sustainability of populations into the wildlife health perspective to help merge the divide between wildlife health and ecology. The primary counsel provided by Stephen (2014), however, was to adapt a human population health approach to wildlife populations. The recommendations made by these authors are helpful in identifying different concepts that may be useful in inspiring a shift towards a more holistic approach to wildlife health. However, the suggestions in these papers do not provide guidance on how to implement or operationalize these ideas for wildlife health. None addressed how to operationalize a holistic, multifactorial, cumulative effects approach to wildlife health that addresses the environmental, biological, and societal pressures on wildlife populations. This thesis will investigate whether a definition of wildlife health can be developed that addresses the different needs and expectations for health while providing a consistent and adaptable framework to promote active planning and priority setting.

1.3 BACKGROUND

1.3.1 Cumulative Effects

A cumulative effects approach to wildlife health may better reflect current thinking in population health and in wildlife management and lead to new approaches for assessing wildlife

health. Cumulative effects are interacting changes to the biophysical, social, economic, and social environments over the past, present, and future (Hegmann et al., 1999; Smit & Spaling, 1995). There is a focus in cumulative effects thinking on how the many external factors in a system may impact the outcome, phenomenon, or population of interest (Canter & Atkinson, 2011; deFur et al., 2007). Cumulative effects assessments are regularly carried out in environmental assessments to determine whether actions or events will have an overall positive or negative effect on the resilience of the system (Hegmann et al., 1999). They differ from environmental assessments in the more broad spatial and temporal boundaries and attention paid to mitigating adverse effects and consideration of other projects in the region (Smit & Spaling, 1995). Cumulative effects assessments are used, essentially, to explain the health of an ecosystem (Wells, 2003).

There is a shift in ecosystem and wildlife management towards a cumulative effects perspective (Krausman & Harris, 2011; Schultz, 2010). By considering all of the activities and components within an ecosystem, a management focus on resilience is more achievable and desirable (Krausman & Harris, 2011). Historically, assessments and management strategies have considered single projects in time (Biggs et al., 2012; Krausman & Harris, 2011; Schultz, 2010). A cumulative approach, however, allows managers and decision makers to develop longer term plans that favour the capacity of a system or population to be resilient (Biggs et al., 2012; Krausman & Harris, 2011).

In this thesis, I hypothesize that a cumulative effects approach to wildlife health could be a strategy that provides insight into the current health status and future population resilience, based on assessment of past and present health determinants.

1.3.2 Existing Concepts of Health as a Cumulative Effect

1.3.2.1 Herd health

Herd health is a practice where individual, environmental, and management data for various metrics are regularly collected and analyzed to inform management decisions to optimize health, welfare, and production of poultry or livestock (Radostitis, Leslie, & Fetrow, 1994). Herd health acknowledges the importance of external factors on health capacity. Herd health extends beyond only measuring the presence of disease or disease-causing agents to include the external factors that influence health outcomes, such as environmental and social characteristics (Radostitis et al., 1994). For instance, in dairy cattle herds in developed countries, herd health is

standard practice and includes regular monitoring of individual level health indicators, such as body condition score, milk and blood composition, and lameness scores along with environmental measures, like adequate nutrition and housing parameters, which impact a herd's capacity to cope with metabolic stress and prevent disease (Mulligan, O'Grady, Rice, & Doherty, 2006). Herd health measures are typically robust and extensive, as there is the capacity to sample and track from each individual within the population, a luxury that would not be possible in wildlife populations.

1.3.2.2. Life course epidemiology

The life course perspective recognizes the cumulative nature of health, over a lifetime (Ben-shlomo & Kuh, 2002; Kuh, Lynch, Hallqvist, & Power, 2003). Life course epidemiology considers the impact over time of various biological, behavioural, social, and environmental exposures on specific health outcomes for an individual or population (Ben-shlomo & Kuh, 2002; Kuh et al., 2003). This concept of a population's capacity to be healthy being a cumulative outcome of various risk or protective factors over a lifetime has many commonalities with the cumulative effects approach used in environmental assessment for natural resource or industrial development. For instance, both life course epidemiology and cumulative effects assessments consider how the positive or negative factors experienced in the past will impact the current capacity of a population to be resilient. The development of both the life course perspective of health and the cumulative effects assessments of the environment signify an evolution towards considering complexity in the way health is understood. Life course epidemiology is used to understand the changing contexts, and associated risks, to a population as it ages (Kuh et al., 2003). The life course approach to health is often used to better understand the complex interplay of cumulative factors in the development of chronic disease and aging (Ben-Shlomo, Cooper, & Kuh, 2016). Because of the long-term time element of this approach, it allows researchers to investigate how exposures and stresses earlier in life can impact health capacity decades later (Ben-Shlomo et al., 2016; Ben-shlomo & Kuh, 2002). Using this type of approach would pose some logistical challenges for a free-ranging population, as it may be difficult to know or track all the pressures over a life time or to follow the same individual for its life course without modifying how that animal lives.

1.3.2.3 Population health

The health of a population, as defined by Frankish et al (1996, p. 28), is “the capacity of people to adapt to, respond to, or control life’s challenges and changes”. This conception of health as a “resource rather than a state” acknowledges the wide range of external factors that impact health (Public Health Agency of Canada, 2004). Population health is not focused on a single definitive measure of health, but rather on a spectrum of determinants (Kindig & Stoddart, 2003). Population health outcomes are influenced by the actions and actors from various sectors including “legislators, managers, providers, and individuals” (Kindig & Stoddart, 2003, p. 381). Population health is “the indivisible health experience of a collective of individuals, where this collective is taken to be distinguishable from a mere collection or summation of individuals” (Arah, 2009, p. 239). Although population health is dependent on the health of the individuals within the group, population health is greater-than-the-sum-of-the-parts (Arah, 2009).

How population health is measured, perceived, understood, and evaluated is contingent on the context in which the population exists and the evaluator’s perspectives (Arah, 2009).

One level of population health context is performance expectation. The performance expectations of stake and right holders are one of the key differences between individual and population health (Arah, 2009; Butler-Jones, 1999; Jayasinghe, 2011). Where a population can be objectively healthy on an individual level by biometric and physiological definitions of health, the collective could be considered unhealthy if as a population it fails to meet performance expectations. For example, take a population of dairy cows where the individuals of a herd all test in the “healthy” range for a variety of infectious and metabolic parameters, but the herd could still be considered unhealthy. This unhealthy status of the population may be determined by the failure of the herd to meet performance (milk production) expectations. In the case of the dairy cows, their failure to meet population health standards could be due to various factors outside of the realm of individuals. The same types of human expectations for performance are imposed on wildlife; usually the value society places on the desire to either harvest or view the animals (Hanisch et al., 2012).

External factors also cause health to vary within and between populations. The external factors that influence population health include things such as abiotic environment and social dynamics (Kindig & Stoddart, 2003; Public Health Agency of Canada, 2001). While these external factors can impact the health of individuals directly, there is often large variability in the

weight of that impact. The distribution of external factors can vary greatly across a population, not impacting individuals equally (Kindig & Stoddart, 2003; Pampalon et al., 2005). This model of health establishes that there are multiple factors, in both the social and ecological realms, that influence an individual or population's capacity to be healthy (Berkes, Doubleday, & Cumming, 2012; Cumming et al., 2015; Kindig & Stoddart, 2003). Not only are there multiple influencing factors, but there are multiple levels of influence on health or resilience identified in the socio-ecological model, ranging from individual lifestyle factors to environmental, cultural, and socio-economic conditions (Whitehead, 2007). The socio-ecological approach recognizes the complex and context specific nature of health that is the foundation of the population health model (Berkes et al., 2012; Cumming et al., 2015). The socio-ecological model for health promotion is informed by systems thinking (McLeroy, 2006), acknowledging the complex set of processes involved in changing health-related behaviours (Naaldenberg et al., 2009; Norman, 2009).

Population health models have been useful for informing development of public health programs, surveillance, and research (Hennessy et al., 2015). Population health models have been used for developing containment of emerging infectious diseases in humans, such as different types of influenza, an infection with complex disease ecology and numerous potential outcomes (Yaesoubi & Cohen, 2011). By applying a population health model to influenza, researchers have been able to project changes in the prevalence of risk factors, particularly in movements and financial costs, and these predictions can then be used to inform policy makers (Yaesoubi & Cohen, 2011). Additionally, the population health model has been used to identify ways in which to support populations to be more resilient and healthier, for instance, by encouraging and fostering collaboration and community engagement during disaster preparations (O'Sullivan, Kuziemy, Toal-Sullivan, & Corneil, 2013); planning for systemically reduced vulnerability in the face of public pressures like climate change (Keim, 2008); and promoting healthy lifestyles (Breslow, 1996; Kegler, Swan, Alcantara, Feldman, & Glanz, 2014). Population health has been foundational in the transition from the focus on individual health to a public health model in humans through its cumulative consideration of multiple factors and levels of influence.

1.3.2.4 Determinants of health model

The determinants of health concept is fundamental to the population health model. It articulates specific categories of factors that cumulatively impact the capacity of a human

population to be healthy (Figure 1-1). The Public Health Agency of Canada (2018) defines determinants of health as “the broad range of personal, social, economic, and environmental factors that determine individual and population health”. Determinants of health are well studied in humans and are often the focus and foundation of public health programs (Association of Faculties of Medicine of Canada, 2017). It is also the prevailing public health model in developed western nations (Diez Roux, 2008). The eleven main determinants of health are: income and social status, employment and working conditions, education and literacy, childhood experiences, physical environments, social supports and coping skills, healthy behaviours, access to health services, biological and genetic endowment, gender, and culture (Public Health Agency of Canada, 2018). The determinants of health framework provide thematic categories which can guide development of indicators and measures for a health program (Hancock, Labonte, & Edwards, 1999; Kindig & Stoddart, 2003). The determinants of health do not define what health is, but rather identify the factors and circumstances required for a population to be healthy (AFMC, 2007). This framework provides a model for evidence-based health programs that incorporate the multiple and cross-sectorial factors that impact health.

A determinants of health approach has several strengths. The first is the ability to adapt the framework to different contexts. Diverse governments, programs, and policy makers use the determinants of health to identify priorities for various populations. Depending on the context, more or less emphasis can be placed on any of the determinant of health categories, with selection of context-specific indicators that are meaningful for the program (Butler-Jones, 1999). The second strength of the determinants of health approach is the ability to target different aspects of health at the individual or community level, or both (Association of Faculties of Medicine of Canada, 2017). The goals, interests, or concerns of the program will guide the level of the population on which to concentrate. The third advantage of the determinants of health model is the capacity to identify opportunities for intervention, prior to development of adverse health effects (Butler-Jones, 1999; Public Health Agency of Canada, 2013). By taking a more cumulative perspective to health, not only are more intervention options available than a traditional disease control approach, but it may also be possible to ascertain which factors may be more pertinent for health (Association of Faculties of Medicine of Canada, 2017; Butler-Jones, 1999).

The determinants of health are often used to guide management strategies and develop policy (Public Health Agency of Canada, 2001). It is not used to create a summative measure of health, but rather to guide a collective view of health by looking at the contributing factors. Due to the interdisciplinary nature of the determinants of health and its contextual flexibility, it is a useful tool for helping to identify management and policy priorities and a framework for making evidence-based decisions (Frankish et al., 1996; Hennessy et al., 2015). A determinants of health approach is frequently used for developing population or community-level interventions on broad-scale policies, such as for disaster preparedness, healthy lifestyles (Breslow, 1996; Kegler et al., 2014), and climate change (Keim, 2008)

I hypothesize that a determinants of health model can be applied to wildlife populations to serve as a cumulative multifactorial approach to positively influence the health of populations. The contextual flexibility, the focus on cross-disciplinary cooperation, and the proactive nature of the approach aligns with the challenges faced within wildlife management, both in terms of the historical disease-focus of wildlife health and the growing expectations to look at population health and resilience as cumulative effects (Acevedo-Whitehouse & Duffus, 2009; Deem, Karesh, et al., 2008; Hanisch et al., 2012; Stephen, 2014). The determinants of health approach was developed to create policy for the public good of public health and therefore may be transferable to wildlife which is also a public good, impacted by government policy (Organ, Decker, Stevens, Lama, & Doyle-Capitman, 2014).

1.4 THE OVERARCHING QUESTION FOR THIS THESIS

My guiding research question for this thesis is, can a determinants of health approach be adapted to wildlife populations?

I have five main lines of reasoning to support this hypothesis:

- 1) The approach addresses calls to manage wildlife more holistically and from a cumulative effects perspective to build resilient populations.
- 2) It is a direct response to recommendations from other authors looking to modernize definitions of wildlife health.
- 3) The context for using the determinants of health approach in the public health sector has parallels with the management context for wildlife health.
- 4) The determinants of health approach does not suffer from limitations seen in other cumulative views of health like herd health and a life-course perspective

- 5) The approach is flexible and should be adaptable to different species and populations

1.5 CONTEXT FOR THIS RESEARCH

1.5.1 Introduction to the Study Populations

I use two case study species to investigate various aspects of the feasibility of adapting a determinants of health approach to wildlife populations. The first species is barren ground caribou (*Rangifer tarandus groenlandicus*) in the Northwest Territories, Canada. The second is Pacific salmon (*Oncorhynchus spp.*) in British Columbia, Canada, with a focus in places on sockeye salmon (*O. nerka*) originating from the Fraser River watershed. Both caribou and Pacific salmon are culturally, recreationally, and financially important animals. Because of the importance of these animals to a wide range of people, they are also closely monitored and managed by government.

Caribou and salmon were selected for three main reasons. First, both animals are charismatic populations subject to intense management and research in recent years because of precipitous population declines with no single causal explanation as to why (caribou: Vors and Boyce 2009; salmon: Price et al. 2017). Management goals and objectives strive to support healthy populations and both groups have been subject to a variety of forms of health research.

Second, both populations are well studied, with significant information available. Caribou populations have semi-regular population censuses and there is also information available on possible determinants and drivers of health such as weather, fires, and human development over the years (Greig, Wedeles, & Beukema, 2013). For Pacific salmon, population surveys and escapement counts are conducted most years, and there are also environmental and migration timing data available (Fisheries and Oceans Canada, 2015b).

Third, cumulative effects have been identified to be at play in both cases (Cohen, 2012b; Greig et al., 2013), but experts have not explicitly considered these cumulative effects under the umbrella of health. For both case populations, similar to most other wildlife, health continues to be disease focused, often creating a wedge between biologists and health managers, when it would be better to be working together (Deem, Parker, et al., 2008).

1.5.2 Overview of the General Methodological Approach

1.5.2.1 Principles of health policy research

“Health policy and systems research is an emerging field that seeks to understand and improve how societies organize themselves in achieving collective health goals, and how

different actors interact in the policy and implementation processes to contribute to outcomes” (World Health Organization, 2007). Health policy research uses an interdisciplinary approach in order to address the complex nature of the issues in health policy (Mabry, Marcus, Clark, Leischow, & Mendez, 2010; Mabry, Olster, Morgan, & Abrams, 2008). Health policy research is helpful for identifying problems, evaluating the strengths and weaknesses with the different solutions, estimating budgets, and how to implement the legislation or develop other supporting policies (Clancy, Glied, & Lurie, 2012).

Health policy is a major area of research in human health (de Leeuw, Clavier, & Breton, 2014). There are even a number of theories dedicated to the analysis of health policies that have been developing since the 1980s (de Leeuw et al., 2014). Healthy policy is a consideration at most government levels, from international (World Health Organization, 1986) to provincial (Public Health Ontario, 2013). There is little done in Canadian governments regarding health policy research in animal populations beyond how disease might impact agriculture economics. Health policy research, however, is largely overlooked in wildlife health.

Using a systems approach, health policy research “addresses... policy questions that are not disease-specific but concern systems problems that have repercussions on the performance of the health system as a whole” (Remme et al., 2010, p. 5). Health policy and systems research can be applied at various points in the policy making process, from conception of policies to reviews of policy impacts (World Health Organization, 2007). It is also used for answering a wide range of questions (World Health Organization, 2007). Using an approach that incorporates a wide range of methods is advantageous for exploring different types of questions on a complex topic (Mabry et al., 2010). The interdisciplinary approach of health policy research lends itself well to understanding wildlife health, with the multiple sectors, stakeholders, and ecosystem factors at play.

Health policy research for wildlife populations would require consideration of human dimensions, such as how priorities are determined, political issues, and how governments and stakeholders perceive and value wildlife. These human dimensions have an impact on the types of policy that are developed for wildlife populations (Organ et al., 2014). The priorities that are reflected in the developed policy will directly impact how the various factors that effect a population’s capacity to be healthy are managed. For wildlife health policy research, it would be necessary to consider the direct biological factors that influence health, but also how human

priorities and decisions will dictate how those biological factors are managed. With the warming climate, globalization, and shrinking natural areas (World Wildlife Fund for Nature, 2016), research that addresses the human dimensions of wildlife conservation is both critical and urgent. Researching health policy for wildlife requires a reliance on qualitative methods which are interdisciplinary and systems focused. Therefore, my thesis will make use of well-established methods familiar to veterinary medicine (scoping literature review), emerging methods in veterinary methods (network analysis), and methods new to veterinary medicine (health policy review).

1.5.2.2 Using Stage Theory of Organizational Change as a guiding concept

This research intends to change how wildlife health is conceived, assessed, and measured in practice by developing and assessing the determinants of health approach. Others have studied how organizations change or how they adopt and implement innovation. Wildlife health professionals, including people such as academics and managers, can be considered an informal organization (“a group of people intentionally organized to accomplish an overall, common goal or set of goals” (Butterfoss, Kegler, & Francisco, 2008, p. 336)). These professionals are an organization of people who research and implement interventions in an effort to better understand and conserve wildlife health. The Stage Theory of Organizational Change describes how organizations transition through several steps as they change (Butterfoss et al., 2008) and is used as an organizing framework for the research in this thesis.

By defining and recognizing each stage of change, specific strategies can be used to promote the change (Butterfoss et al., 2008). There are four stages in Stage Theory: (1) definition of the problem; (2) initiation of the innovation; (3) implementation of the change; and (4) institutionalization of the innovation (Kaluzny & Hernandez, 1988). Stage one includes both describing the problem and identifying and evaluating potential solutions (Butterfoss et al., 2008). Stage two consists of consultation with stakeholders and development of policy and resources for implementation (Butterfoss et al., 2008). Implementation of the change, stage three, allows the organization to adjust to the changes and for role changes to occur (Butterfoss et al., 2008). Institutionalization is the final stage when the innovation, whether it be a policy or program, has become well established within the organization and the new priorities and values have been internalized (Butterfoss et al., 2008).

Stage Theory is used to better understand how change and innovation are being embraced by organizations as a whole (Batras, Duff, & Smith, 2016). Understanding how change happens at an organizational level is important as individuals rarely adopt innovations unless the concepts are already in practice by the organization (Steckler, Goodman, & Kegler, 2002). Conversely, it is also important that the social environment of the organization be supportive of the proposed innovation, or it is unlikely to succeed (Smith, Steckler, McCormick, & McLeroy, 1995). I used the Stage Theory of Organizational Change as a framework for investigating aspects of the feasibility of a wildlife health paradigm shift towards a determinants of health model. It is my hope that using this framework may inspire and support the adoption and operationalization of the holistic wildlife health vision for which previous authors have advocated.

1.6 CHAPTER RESEARCH QUESTIONS

1.6.1 Chapter 2

The question for my first research chapter was: Can the determinants of health model be adapted from human population health to wildlife health? This first chapter addresses stage 1 of the Stage Theory of Organizational Change, specifically identifying and evaluating possible solutions to the problem. Based on commentary from previous authors, it is apparent that a new, multifactorial approach to wildlife health is needed. The first challenge was to ascertain if the determinants of health approach could be adapted to wildlife. Using the human model for the determinants of health, I used a combination of scoping literature review, expert knowledge elicitation, and network analysis to evaluate if a) the determinants of health model can be translated for wildlife populations and b) if a determinants of health model reflects how wildlife health professionals perceive and understand health.

1.6.2 Chapter 3

My second research chapter answers the question: Can a determinants of health conceptual model facilitate the identification of shared goals or priorities for wildlife health management across different stakeholder groups? One of the benefits of a determinants of health approach is its adaptability to different contexts and for prioritization. This chapter also addresses stage 1 of the Stage Theory of Organizational Change, further investigating the possible solution of the problem. After establishing if a determinants of health model can be applied to and is appropriate for wildlife populations, I evaluated if the model could be adapted

to different stakeholder contexts. Using the Pacific salmon case study, I worked with two key stakeholder groups to evaluate if the model could be used to identify shared perceptions of health.

1.6.3 Chapter 4

For my third research chapter, I focused on the question: Is there a need to change policy to a determinants of health approach to Pacific salmon within Fisheries and Oceans Canada? This is an important question due to the role that policy plays in determining wildlife management actions. Evaluating whether there is a foundation for a determinants of health approach within policy addresses components of stages 1 and 2 of the Stage Theory of Organizational Change. This question continues the investigation of the feasibility of the solution, i.e. whether or not there is a foundation for a determinants of health approach within the policy that guides governmental actions that impact wildlife health. It also begins to consider stage 2, development of resources and policy for implementation. This step will help to identify the capacity of current policy implementation of the change. I reviewed policies as they relate to the determinants of health identified in Chapter 2, using a standard framework to assess readiness to change policy.

1.6.4 Chapter 5

The final research chapter in my thesis answers the question: Is there a foundation in practice for using a determinants of health perspective to support a healthy public policy approach to salmon population health? This chapter will contribute to step 2 of the Stage Theory of Organizational Change, evaluating the already existing resources available for implementing the determinants of health approach. To establish if a determinants of health approach is feasible for wildlife populations, we looked in detail at Chilko sockeye salmon and adapted a public health framework for assessing readiness to use a healthy public policy approach.

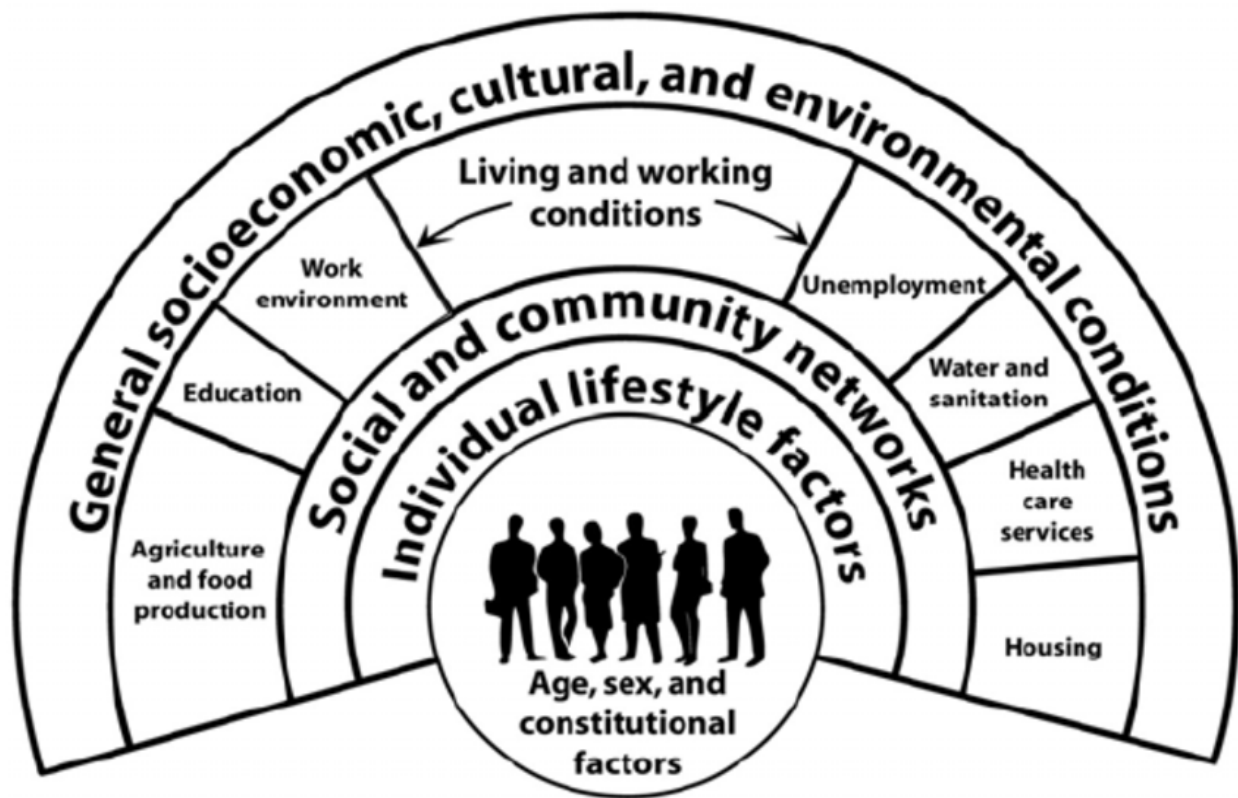


Figure 1-1. A model of the determinants of health for human populations. Pictured are the various biotic, abiotic, and social factors that influence the health capacity of a population. The multiple levels of influence from the socio-ecological model are also captured by the concentric circles, from the inside to the outside. This figure from Dahlgren and Whitehead (1991), presented here with permission from the original publisher, is used widely in the public health and health promotion fields to depict the determinants of health model.

CHAPTER 2: A DETERMINANTS OF HEALTH CONCEPTUAL MODEL FOR FISH AND WILDLIFE HEALTH

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2.1 INTRODUCTION

Health is a common but vaguely defined management goal for wildlife populations (Hanisch et al. 2012; Stephen 2013). Health in veterinary medicine, particularly as it concerns wildlife, historically focused on adverse pathophysiologic or productivity outcomes or used a disease-centric approach (Gunnarsson 2006; Nordenfelt 2011; Stephen 2013, 2014). Perspectives on health are changing and there is consensus in other fields, such as human public health and herd health, that health is more than the absence of disease (Eriksson and Lindstrom 2008; Jayasinghe 2011; Nordenfelt 2011). These fields acknowledge that health is not a dichotomous state where an individual or population can be classified as healthy or unhealthy but is rather an aspirational capacity (Arah 2009; Nordenfelt 2011). Being healthy is the ability or capacity to realize full function, satisfy daily needs, and adapt to or cope with changing environments (Frankish et al. 1996; Eriksson and Lindstrom 2008).

The determinants of health (DOH) approach is the prevailing public health perspective for understanding what makes a population healthy or not (Eyles and Furgal 2002; Cieza et al. 2016). The DOH model includes 12 key determinants of health (Table 2-1) signifying the interacting and varying contributions that abiotic, biotic, and social elements make to health outcomes (McDowell, 2017; Public Health Agency of Canada [PHAC] 2018). Advantages of using a DOH approach in public health are: The inclusion of interactions among the many contributing factors that influence resilience, rather than a focus on a physiologic state (Frankish et al. 1996; Nordenfelt 2011); the expansion of the scope of interventions, information, and

expertise that can be employed to influence health by considering these multiple factors (Frankish et al. 1996; Stephen 2013); and recognition of factors in addition to adverse outcomes, such as death and disease, which allow for a proactive approach that can be implemented prior to adverse outcomes (Frankish et al. 1996; Stephen 2014). The DOH approach focuses on building and reinforcing the capacity to remain healthy rather than on delaying actions until harms are detected (Stephen 2014).

Some authors advocate for a multifactorial approach that integrates diverse drivers as the next step toward a modern understanding of wildlife health (Deem et al. 2008; Hanisch et al. 2012; Stephen and Duncan 2017). Despite their arguments, those authors did not provide an operational definition of health and therefore a gap exists on how a multifactorial approach to health might be applied in practice. We hypothesized that a DOH model for wildlife populations could be a way to address this gap. We focused on two well-studied, socially important species for which the management of health and resilience is a priority in Canada: barren ground caribou (*Rangifer tarandus groenlandicus*) and Pacific salmon (*Oncorhynchus spp.*). The purpose of our study was to determine if: 1) a DOH model for wildlife health could be derived from an analysis of literature on wildlife health and resilience; 2) the model could be applied to more than one species; and 3) the model reflected how fish and wildlife health managers and investigators conceptualized health.

2.2 METHODS

2.2.1 Adapting the Determinants of Health Model to Wildlife Health

Thematic analysis can identify patterns and themes within and across qualitative data (Clarke and Braun 2017). Thematic analysis is useful for applied health research, particularly when research questions involve analysis of policy (Braun and Clarke 2014). We followed the six-phase thematic analysis structure described by Braun and Clarke (2006) where themes were based on the functional attributes of each DOH in the public health model (Table 2-1; PHAC 2013).

We selected two case studies, barren ground caribou and Pacific salmon, to investigate if the DOH model could be adapted to wildlife. A scoping literature review was conducted and summarized according to standard methods (Levac et al. 2010) as outlined in Table 2-2. We used the definitions and attributes of DOH used in public health to categorize features characterizing health or resilience in the literature that we reviewed. In socioecologic systems, resilience is

defined as “. . .the ability to cope with shocks and keep functioning in much the same kind of way” (Walker and Salt 2012), and therefore overlaps modern perspectives of wildlife health as described in Stephen 2014. If no equivalent to a specific human DOH was found, that DOH was dropped from further consideration whereas if a paper used features to define health differently from the human DOH, a new wildlife DOH theme was created. From this process, candidate DOH themes were created for barren ground caribou and Pacific salmon health. The DOH we identified for the two types of animals were combined to develop our initial wildlife health DOH model.

2.2.2 Consistency of the Model with Operational Perceptions of Wildlife Health Experts

We conducted two separate expert opinion processes, one focused on caribou and the other on Pacific salmon, specifically sockeye salmon, to test whether the candidate DOH were consistent with how experts perceived wildlife health. We identified experts using peer-referential techniques (Penrod et al. 2003; Christopoulos 2009). The Environment and Natural Resources Department (ENRD; Government of the Northwest Territories) provided an initial list of caribou experts. Each expert was contacted by email with a follow-up phone call and given an opportunity to provide names of additional experts. Because this was a small group of experts, only three levels of referrals were required using snowball sampling (Christopoulos 2009). A total of 34 experts were identified by their peers. Contact information was secured for 31 and 11 participated.

A similar process was used for the sockeye salmon study with an initial list of experts in Pacific salmon biology derived from the staff scientist directory for the Department of Fisheries and Oceans (DFO), Pacific Science Branch, Pacific Biological Station. This list was evaluated by an independent fisheries biologist familiar with the science employees at the Pacific Biological Station to further refine the list to those with background knowledge on salmon health or resilience. Experts were contacted through email to request their participation and to nominate up to three colleagues. A total of 38 DFO staff or contractors in salmon research were contacted to request their participation and 12 completed the exercise.

A diagrammatic approach to network analysis was used to identify the type and interrelationships of determinants of caribou and salmon health deemed important by the experts based on their personal and professional judgement and experience. This approach can provide insight into the opinions of experts on complex issues, specifically as to how different factors

interrelate (Campbell and Muncer 2005; White 2008). Caribou experts all participated remotely via email. A face-to-face meeting was offered to the salmon experts, with nine of the 11 completing their assignments at that meeting and two of the 11 communicating only via email.

The participants were each asked to draw a diagram of the direction, interrelationships, and relative impacts of the various factors they believed to determine caribou or salmon health, depending on their expertise. Before beginning the diagram component of the exercise, participants were given a brief description of our perspective of health as the ability, or capacity, to realize full function, satisfy daily needs, and adapt to or cope with changing environments. We also drew their attention to the similarity of this perspective with the concept of resilience. Caribou experts were asked to consider a population of barren ground caribou in the Northwest Territories. Salmon experts were to consider a population of marine adult Fraser River sockeye salmon (*Oncorhynchus nerka*). For the salmon, a geographic boundary, the Strait of Georgia, was collectively agreed upon by the experts during the in-person session and was shared with the remote participants.

Participants were given a list of factors identified during the thematic analysis for the literature-based model. Experts could include any, all, or none of the provided factors in their diagrams and had the option to add additional factors as they saw fit. With 'health' written in the center of the page, the experts wrote down the factors in the surrounding space. The experts were then instructed to draw an arrow between their chosen factors and health in the center to represent the causal relationships they believed to exist. For each relationship, a plus or minus (+, -) was added to denote whether the factor had a positive or negative impact on the outcome. Finally, experts provided an impact score between 1 and 10 for each relationship to denote the size of the impact that the factor had on the outcome (1 = small or negligible impact, 10 = very large impact). Participants were informed that the impact scores would be used to identify which relationships within the networks were likely to have the largest impact on health. The salmon experts requested the ability to note differences in relationships in the network for juvenile freshwater Fraser River sockeye salmon, if they existed, using an alternate color on the diagram. Finally, the experts were asked on what source of knowledge their answers were based, using the categories of experience in the field, traditional knowledge, scientific literature, intuition, common sense, anecdotal evidence, and not sure. For this question, the experts could select up to three sources.

Data from the two case studies were evaluated independently, using the same technique. If three or more experts mentioned the same relationship, it was included in the network analysis along with the mean impact score. As necessary, some factors were consolidated to account for inconsistencies in terminology. The Fruchterman Reingold algorithm in the open-source network visualization and analysis software Gephi 0.9.2 (Gephi 2018) was used to visualize the relationships between the nodes. The Eigenvector centrality statistic was used to determine which nodes had the most connections. Single-sided t-tests were used to compare the weights of positive vs. negative relationships in the aggregate networks using Stata 15.2 (StatCorp LLC, College Station, Texas, USA). We also used a paired, two-sided t-test to compare the mean impact scores of the salmon adults and juveniles, where experts included juvenile differences.

2.3 RESULTS

2.3.1 Determinants of Wildlife Health

Six DOH themes were identified in the literature for salmon and caribou health: abiotic environment, needs for daily living, social environment, biologic endowment, direct mortality pressures, and human expectations (Tables 2-3 and 2-4). Abiotic environment, analogous to physical environment in humans, relates to the health of the natural environment in which the populations exist and includes different factors related to climate and anthropogenic pressures on the environment (Smit and Spaling 1995; Canter and Atkinson 2011; Raby et al. 2015). The needs for daily living, comparable to socioeconomics in humans, included factors related to the equitable distribution of resources which would allow an individual control and discretion over their decisions. Factors connected to habitat, food, and the ability to express natural behaviors in the environment fell into the needs for daily living category (Stephen 2014). Social environment reflects how the community at large can impact an individual's capacity to cope by influencing access to various resources. Population demographics, interspecific competition, and intraspecific competition were aspects pertinent to social environment. Biologic endowment, a fundamental determinant of health that is the inherited or predisposed capacity to cope based on biology made up of factors such as genetics, disease, and stress, is the same in both wildlife and humans. One DOH that impacts wildlife but is not a recognized DOH for human health is direct mortality pressures. Direct mortality pressures are the factors that pose an immediate threat to wildlife survival and include predation and hunting or fishing by people (Munns 2006). The final DOH identified for wildlife was human expectations, which is comparable to health services in

humans. Health services are defined as “services. . . designed to maintain and promote health, to prevent disease, and to restore health and function. . . to population health” (PHAC 2013). In wildlife, analogous service functions are provided by various policies, management actions, education programs, and their performance levels established by stakeholder expectations. Although the specific components or attributes of each DOH may vary between contexts, such as in different ecosystems, these six categories represented the general themes extracted from the literature regarding caribou and salmon resilience and health. Based on the similarities found in the caribou and salmon literature regarding DOH themes and the types of factors that drive health and resilience, we were able to integrate these two species-specific models into a single model (Fig. 2-1).

2.3.2 Expert Opinion

The resulting network model (Fig. 2-2) of factors influencing caribou health and their interrelationships based on our experts’ opinions included all six DOH themes identified in Figure 2-1. There was no statistical difference in the mean impact scores of the positive and negative relationships (depicted by arrow weight; $P=0.663$). Recruitment (a social environment factor) and forage quality and quantity (a needs factor for daily living) had the largest perceived positive direct impacts on caribou health. Although disease and stress were included, 87% of the expert-identified drivers of health were represented by other DOH (Table 2-5). The abiotic DOH were believed to impact caribou health in the most ways, representing 40% of the nodes in the network (Table 2-5). Experience in the field and common sense were the most-commonly mentioned sources of knowledge specified by the caribou experts (six mentions each). Scientific literature and intuition were mentioned five and four times, respectively. Traditional knowledge and anecdotal evidence were mentioned once each. No caribou expert selected being “not sure” of their knowledge sources while completing the network exercise.

For salmon, five of the six DOH themes were identified collectively in the expert network (Fig. 2-3). Human expectations did not feature in the network analysis. Pathogens, disease, stress, and genetics were featured in the expert network analysis; however, there was also a large emphasis on habitat quality, including water and food quality. Thirty percent of the nominated DOH themes in the salmon network involved biologic endowment, which included pathogens, disease, stress, and genetics (Table 2-5). The impact score of the positive relationships was not statistically different from those of the negative ones ($P=0.781$). The

salmon network had fewer positive relationships (six) than negative relationships (nine). The salmon experts had an opportunity to include different relationships or impact scores for juvenile sockeye salmon if they believed them to be different than those for adult salmon. The mean impact scores for the adults and juveniles were not statistically different ($P=0.247$); therefore, we only modeled the adult group. Experience in the field and scientific literature were the most commonly mentioned sources of knowledge specified by the experts (12 mentions each). Common sense (five) and anecdotal evidence (three) featured less frequently as knowledge sources. No experts selected traditional knowledge, intuition, or not being sure.

In both the salmon and caribou cases, experts reported that they had sufficient information and expertise to complete the assignments and assess a wide suite of DOH. The experts did not identify any additional DOH beyond those found in Figure 1.

2.4 DISCUSSION

A DOH model for wildlife health was adapted from the model commonly described in human population and public health. This model accommodated the suite of drivers described in literature on the health and resilience of barren ground caribou and Pacific salmon and was compatible with how experts perceived the drivers and determinants of health for these species. Expert opinion and the collective health and resilience literature for both barren ground caribou and Pacific salmon supported a cumulative effects health model involving multiple factors. The numerous factors influencing health were seen to extend far beyond the disease or pathogen focus common in wildlife health studies and legislation (Stephen 2013, 2014). The caribou and salmon DOH themes were the same, allowing them to be combined into a single wildlife DOH model. Although human drivers and expectations were included in the final model, both the literature and experts emphasized biotic and abiotic factors.

Resilience in ecology is a complex concept that acknowledges the impacts that diverse factors can have on an ecosystem's capacity to cope with change (Biggs et al. 2012; Walker and Salt 2012). The resilience of an ecosystem is dependent on the functionality and structure of its components (Gunderson 2000; Walker and Salt 2012), the nature, severity, and duration of impacts on the system (Rapport 1998; Biggs et al. 2012), the potential cumulative impact of multiple stressors (Gunderson 2000), and the effectiveness of management measures or interventions (Biggs et al. 2012). These components of ecosystem resilience are congruous with many of the drivers of health identified by the expert participants in our study.

The range of interventions available to wildlife managers, particularly when it comes to health (or more traditionally, to disease), is limited (Stephen et al. 2018). A DOH approach may be a method to identify potential issues that reduce a population's resilience in advance of a harm, or reduces their ability to cope with harms, without needing to rely on the standard disease control approaches used in domestic species. For instance, in public health, factors in the social and physical environments are modified to reduce human exposure to hazards in advance of disease (Cole et al. 1998). Various policy and regulatory measures, for example, aim at exposure as a primary public health target (Cole et al. 1998). The DOH approach may be useful to target not only factors that increase susceptibility to disease (Frankish et al. 1996) but also to direct action on the major drivers of population declines and extinctions such as habitat loss, climate change, unsustainable hunting, poaching, and harvesting, pollution, and invasive species and disease (World Wildlife Fund 2016).

Not only is a multifactorial and proactive approach to health needed for wildlife, but also there is a need for an operational definition of health. Health is a management goal for both caribou (DENR 2011) and Pacific salmon (DFO 2005), but health is rarely defined in management documents. Without a definition of health for wildlife, it remains an amorphous concept (Nordenfelt 2011; Stephen 2013) making planning, management, and measurement toward health goals very challenging. Based on experience in public health, a DOH approach could help to provide a mode for attaining the goals advocated for by Stephen (2014) and Hanisch et al. (2012). The DOH model helps to identify the external drivers of health, recognizing the complex and interrelated nature of health (Jayasinghe 2011). A multifactorial model of health, like a DOH model, could help make explicit some of the external drivers of health which could in turn help to identify a wider suite of stakeholders, interventions, and policy options to prevent harm and to promote health (Pourbohloul and Kiény 2011; Rapport and Hilden 2013).

Using qualitative methods to adapt the DOH model to two types of wildlife may have affected the structure and content of the model. The literature component of our study, which was conducted following established methods used for thematic analysis (Braun and Clarke 2006; Clarke and Braun 2017), and scoping of literature reviews (Levac et al. 2010), constrained the concepts that could be explored in constructing our model. Selection of additional search terms in relation to our selected species, such as "survival" or "population dynamics," may

have increased the number of returned journal articles and, therefore, possibly more potential factors impacting the species. However, there is information to suggest that this was not a significant bias. The indicators for caribou identified in our scoping review were compared with those found in a comprehensive review of caribou literature (Greig et al. 2013), and their review did not identify any additional factors. Furthermore, the expert opinion networks did not result in added DOH. Our study showed the generic model could be applied to two different species and shared core determinants that were applicable across populations and life stages.

Network analysis is an established method commonly used to investigate opinions on the relationships between various interconnected elements (Campbell and Muncer 2005; Hecker et al. 2013). We elected to use the diagrammatic approach to network analysis (Green and McManus 1995) instead of the more common matrix approach (White 2008), as there are a number of criticisms of the matrix approach including: the production of larger networks with more causal connections than are perceived by any one participant (Muncer and Gillen 1997); an overly complex representation as participants are asked to consider relationships that may not exist (Campbell and Muncer 2005); and there is no opportunity for free choice of factors (Green and McManus 1995). The diagrammatic approach aims to address these issues by providing the opportunity for participants to spontaneously identify the most important relationships and by analyzing the results in a way that represents the average network (Campbell and Muncer 2005).

We concluded that the network exercise was acceptable and understandable because all but one expert who participated in the in-person salmon workshop submitted data. One expert, who contributed data remotely to the salmon network and therefore did not participate in the priming presentation or group discussion, submitted data but not in the network format. The submission by this expert, as well as the low response rate from the caribou experts for the digital survey, may signify that these methods are best implemented in person. There were a few salmon experts who noted that they could not separate in their minds the impacts of factors on adult and juvenile Fraser River sockeye salmon. This perspective may reflect a life course epidemiology perspective, where the accumulation of events over a lifetime impact an individual or population's capacity to be healthy at any given point (Ben-Shlomo and Kuh 2002). The in-person session allowed for the group to clarify the parameters of the network exercise, but our study did not assess the strengths and weaknesses of in-person or email responses. This mixed

approach to engaging experts was selected as the most feasible way to facilitate participation of experts living across a large geographic area.

In humans, the DOH model is not typically used as a measurement tool (Diez Roux 2008) but as a framework for planning, policy development, and guiding research (Pourbohloul and Kieny 2011). A hallmark of the DOH model is its adaptability to different contexts, populations, and challenges (Pourbohloul and Kieny 2011; Mayhew and Hanefeld 2014). Health is context specific—for wildlife as well as for people (Arah 2009; Jayasinghe 2011). What may be a critical DOH for one population may be less significant for another. Figure 2-1 should be a starting point for those wishing to conduct an analysis such as the one we did with the caribou and salmon. For a general health model to be useful, it is important that it be adaptable to nuances while still operating within the general framework. The network analysis was useful for capturing the opinions of experts and was adaptable to different species in different ecosystems, demonstrating the generality of the DOH model. The DOH model that we produced may be the foundation of a wildlife health planning tool that conceives health as a cumulative effect and helps to strategize and prioritize a suite of actions in a world of interacting determinants of health.

Table 2-1. Human determinants of health and their functional attributes (based on PHAC 2013) that guided a six-phase thematic analysis of a scoping review of literature on barren ground caribou (*Rangifer tarandus groenlandicus*) and Pacific salmon (*Oncorhynchus* spp.) health and resilience.

Human Determinant of Health	Functional Attribute of the Determinant
Income and Social Status	Equitable distribution of prosperity would allow for more individual control and discretion to make life decisions
Social Support Networks	Close relationships with peers may impact sense of satisfaction and wellbeing
Social Environments	The community at large can impact an individual's repertoire of strategies to cope by influencing access to various resources
Physical Environments	The health of the natural and built environments; typically, levels of various contaminants in the air, water, food, soil, etc.
Employment and Working Conditions	Risky or stressful work, or unemployment
Education and Literacy	Education and literacy in humans are closely tied to socioeconomic status, it provides an opportunity for more control over one's lifestyle
Personal Health Practices and Coping Skills	Actions taken by individuals to improve their health, closely linked to socioeconomics
Healthy Child Development	Early experiences impact other determinants of health
Biology and Genetic Endowment	The inherited or predisposition/capacity to cope, based on biology, is a fundamental determinant of health
Health Services	Health services are designed to prevent disease, maintain, promote, and restore health and function in a population
Gender	Aspects of social status and roles can impact health differently based on gender
Culture	Culture and socioeconomics may impact various aspects of lifestyle and access to health care

Table 2-2. Scoping literature review criteria used to identify and select literature concerning health and resilience of barren ground caribou (*Rangifer tarandus groenlandicus*) and Pacific salmon (*Oncorhynchus spp.*) to develop a conceptual model of wildlife health.

	Caribou	Salmon
Search Terms	“caribou AND health”; “caribou AND resilience”	“Pacific AND salmon AND health”; “Pacific AND salmon AND resilience”
Years	1996-2016	1996-2016
Languages	English	English
Databases Searched	Scopus, Zoological Record, CABI, Biosis Previews	Scopus, Zoological Record, CABI, Biosis Previews
Number of Papers	314	531
Inclusion Criteria	Peer review journal article; contains the search terms; presents data on caribou (i.e., not just mentioned in introduction or discussion)	Peer review journal article; contains the search terms; presents data on salmon (i.e., not just mentioned in introduction or discussion, or a review); <i>Oncorhynchus</i> spp. native to, and study took place in, the North-Eastern Pacific Ocean
Exclusion Criteria	Woodland or mountain caribou focus; domesticated or semi-domesticated; if only the summary was in English; caribou was only mentioned as a meat source for humans with no data on the animals or hunting; caribou is in the name of a place or plant	Atlantic salmon focus; salmon was only mentioned as a consumed species with no data on the animals or fishing; studies on captive raising of Pacific salmon with no apparent application or relevance to wild salmon (ex., survival comparison between two holding tank set-ups); feral populations of Pacific salmon; studies focused on assessment of methods
Final Number of Papers	107	242

Table 2-3. Categorization of features influencing the health and resilience of barren ground caribou (*Rangifer tarandus groelandicus*) and Pacific Salmon (*Oncorhynchus* spp) derived from a scoping literature review, using the human determinants of health (based on PHAC, 2013) as thematic categories.

Health Determinant		Human	Examples of caribou Indicators	Examples of salmon indicators
Wildlife				
Needs for Daily Living	Socio-economics		Nutrition; habitat quality; forage availability and quality; habitat or range use; migration paths	Habitat availability and quality; prey abundance and quality; food web productivity; water temperature; migration timing; survival; escapement; habitat use; ecological resilience
Abiotic Environment	Physical Environment		Heavy metal and radiation contamination; climate change; weather; insect harassment; human disturbance; severe winter conditions; snow pack; human development; forest fire	Climate change; human encroachment and development; heavy metal, pesticide, and radiation contamination; water temperature; salinity; stream flows; ocean ice cover
Social Environment	Social Environment		Demography; sex ratio; calf survival; population dynamics; abundance; herd structure	Competition; abundance; demographics; population density; run size;
Biological Endowment	Biological Endowment		Age; lactation; pathogens; body weight; parasites; growth; disease; body condition; physiological stress; reproductive success	Parasites; disease lesions; pathogens; reproductive success; aging; physiological stress; immune function; body condition; growth;
Direct Mortality Pressures	n/a		Consumption of caribou; hunting pressure; predation	Predation; fishing
Human Expectations	Health Services		Consumption of caribou; expectation of herd performance; education programs; local and traditional knowledge; management strategies	Harvest expectations; hatchery contributions; opinion on salmon recovery; economics of salmon fisheries; management practices and priorities; importance to First Nations; policy implications; habitat recovery funding; co-management

Table 2-4. Accounting of the determinant of health themes extracted from a scoping review of health and resilience literature for barren ground caribou (*Rangifer tarandus groenlandicus*) and Pacific salmon (*Oncorhynchus* spp.). A reference could include more than one determinant of health theme. The number of references including the theme (n) indicates the frequency a theme was found, showing within group relative importance. The percentage = (n/N) where N is the total number of references assessed. N was 107 for caribou and 242 for salmon.

Health Determinant	Caribou literature	Pacific salmon literature
Abiotic Environment	49 (46%)	112 (46%)
Biological Endowment	42 (39%)	108 (45%)
Needs for Daily Living	28 (26%)	108 (45%)
Human Expectation	17 (16%)	35 (14%)
Social Environment	16 (15%)	36 (15%)
Direct Mortality Pressures	12 (11%)	36 (15%)

Table 2-5. Frequency with which the determinants of health (DOH) were included in the barren ground caribou (*Rangifer tarandus groenlandicus*) and sockeye salmon (*Oncorhynchus nerka*) expert networks. Each driver of health identified collectively by the experts were categorized into the six DOH themes. The number of health drivers in each of the DOH themes (n) indicates the frequency with which a theme was included in the final expert networks, showing within group relative importance. The percentage = (n/N) where N is the total number of health drivers from the expert health networks. N was 15 for caribou and 15 for salmon.

DOH	Frequency (%)	
	Caribou	Pacific salmon
Abiotic Environment	6 (40)	2 (15)
Biological Endowment	2 (13)	4 (30)
Direct Mortality Pressure	2 (13)	2 (15)
Needs for Daily Living	2 (13)	2 (15)
Social Environment	2 (13)	3 (23)
Human Expectations	1 (6)	0 (0)

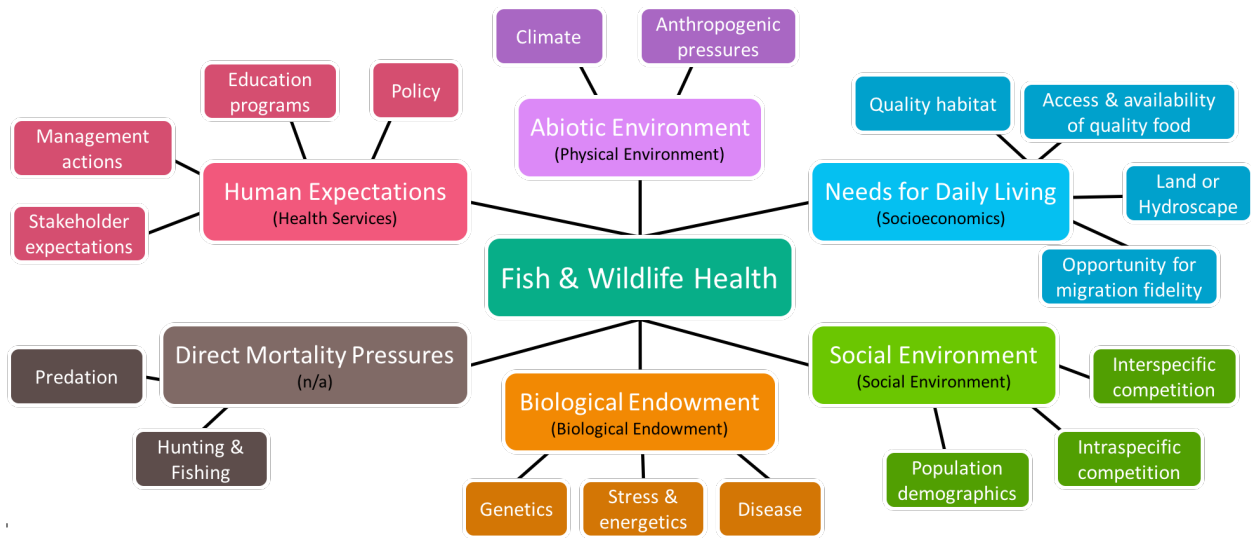


Figure 2-1. Candidate determinants of fish and wildlife health derived from a thematic analysis of a scoping review of literature on health and resilience of barren ground caribou (*Rangifer tarandus groenlandicus*) and Pacific salmon (*Oncorhynchus* spp). Six central themes are related to the determinants of human health as described in PHAC, 2013. Human determinants of health analogies are in brackets. Secondary branches are wildlife specific factors that clustered in the analysis with each central theme.

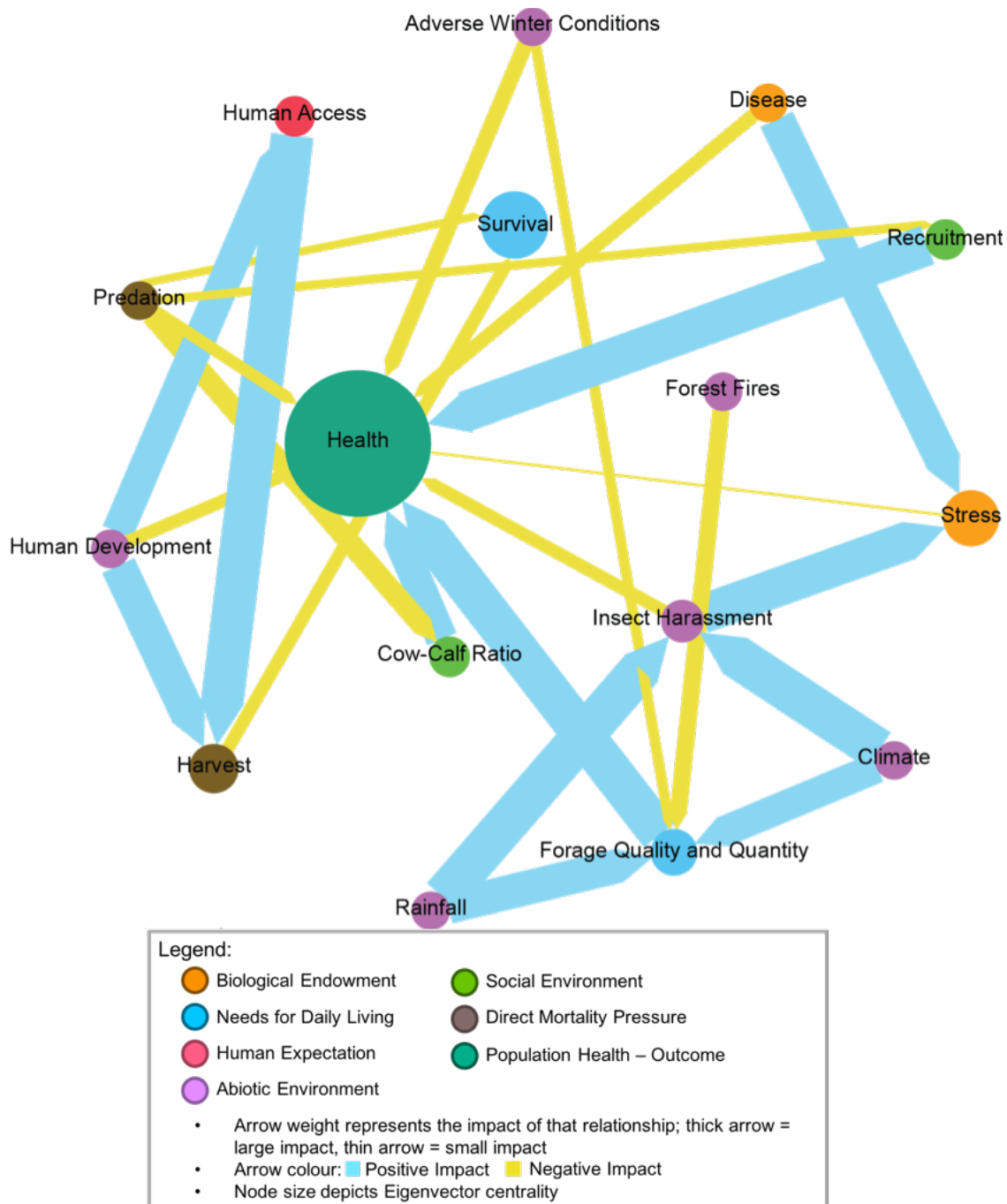


Figure 2-2. Diagrammatic network analysis of 11 expert constructed diagrams of the type, direction, interrelationships, and relative impacts of determinants of barren ground caribou (*Rangifer tarandus groenlandicus*) health based on the expert’s personal and professional judgement and experience. Arrow direction indicates direction of the interaction. Arrow color represents positive (blue) or negative (yellow) effects. Arrow size indicates the relative size of the effect of the interaction (thicker arrows equal larger effects).

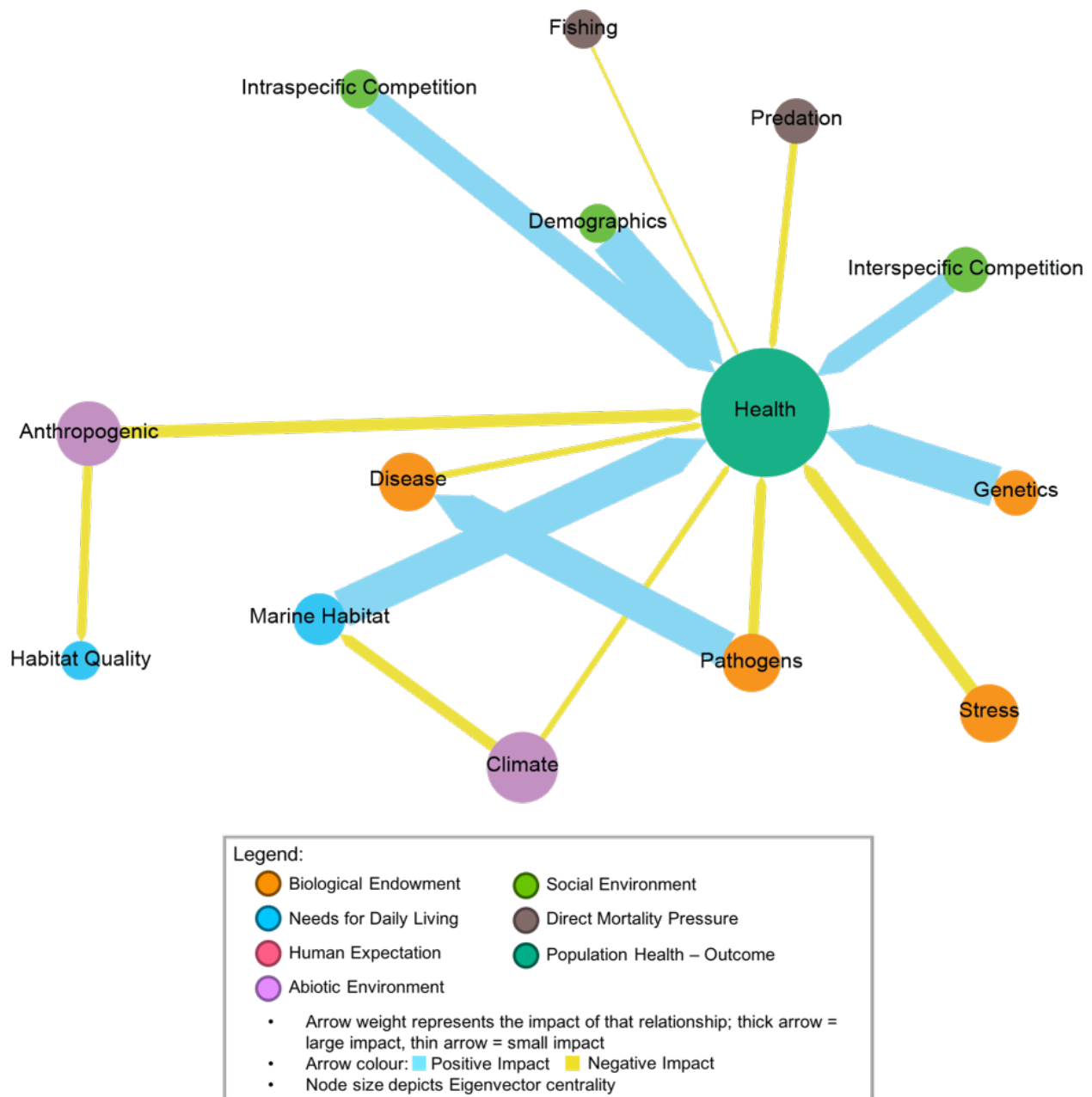


Figure 2-3. Diagrammatic network analysis of 12 expert constructed diagrams of the type, direction, interrelationships, and relative impacts of determinants of sockeye salmon (*Oncorhynchus nerka*) health based on the expert’s personal and professional judgement and experience. Arrow direction indicates direction of the interaction. Arrow color represents positive (blue) or negative (yellow) effects. Arrow size indicates the relative size of the effect of the interaction (thicker arrows equal larger effects).

CHAPTER 3: USING A DETERMINANTS OF HEALTH APPROACH MODEL TO FIND SHARED PRIORITIES FOR WILDLIFE HEALTH: A SALMON CASE STUDY

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3.1 INTRODUCTION

Wildlife health management is challenged not only by technical difficulties related to surveillance and research (Stallknecht, 2007), but also by differing views of what health means to different people. Being healthy is the ability or capacity to realize full function, satisfy daily needs, and to adapt or cope with changing environments (Eriksson & Lindström, 2008; Frankish et al., 1996; World Health Organization, 1986). How health is perceived is context specific and influenced by the species, population, stakeholder group, and performance goals involved (Arah, 2009; Butler-Jones, 1999; Jayasinghe, 2011). There is no definitive diagnosis of the healthy or unhealthy. Health, therefore, is aspirational rather than a state. The aspiration in the context of wildlife health is defined by the stakeholders as they are the ones who are selecting the goals and measures that reflect their perception of health. Because of the contextual nature of health, it is not possible to create a single health index with universal indicators or measures that are acceptable to all (Briggs, 2008; Jayasinghe, 2011). This in turn means that health policies and management strategies must be tailored to specific situations and developed on a case-by-case basis in collaboration with stake- and right-holders (Briggs, 2008; Kreuter, Rosa, Howze, & Baldwin, 2004). Collaborative wildlife health planning could, therefore, benefit from a framework based on themes or attributes of health that are adaptable to different contexts. It is to this end that we ask the question: Can a determinants of health (DOH) conceptual model facilitate the identification of shared goals or priorities for wildlife health management across different stakeholder groups?

To explore this concept, we considered the health of Fraser River sockeye salmon (*Oncorhynchus nerka*) in British Columbia, Canada with two separate groups of experts. Sockeye salmon were selected for this study as they are culturally, economically, and ecologically important, some populations are experiencing sharp declines, and because there are various groups of people with vested interest in sockeye salmon survival and health (Cohen, 2012a). There are strong and divergent views on the principal factors threatening the health of the Fraser River sockeye (Cohen, 2012c). These conflicts of opinion and stakeholder priorities are a major factor for the lack of action in the supportive management of these threatened populations (Cohen, 2012c, 2012b).

Fraser River sockeye salmon health is challenged by many influencing factors such as habitat, hydropower, harvest, hatchery activities, and ecological conditions (Ruckelshaus, Levin, Johnson, & Kareiva, 2002). The numerous management approaches related to these components can result in conflict between and among managers or stakeholder groups (Ruckelshaus et al., 2002). Management of salmon health is further complicated when considering whom to consult when defining management objectives as there can be discord between managers, affected parties, or the general public (Lackey, 2000). These differences in management priorities and approaches can result in difficult working relationships between groups with vested interest in the salmon populations (Lackey, 2000; Ruckelshaus et al., 2002).

These agencies have different roles in salmon health protection and the surveillance and management of Pacific salmon stocks falls under the purview of Fisheries and Oceans Canada (DFO), including conducting run-forecasts and determining annual fishing quotas (Fisheries and Oceans Canada, 2005). The First Nations Fisheries Council of British Columbia (FNFC) works on behalf of the First Nations of British Columbia to protect, advocate for, and support the rights and titles First Nations have to fisheries and aquatic resources (BCFNFC, n.d.). Not only are salmon culturally, socially, and economically important to First Nations, but they also have legal rights to harvest, and nations with treaties typically have habitat management rights on their lands (Jacob, Mcdaniels, & Hinch, 2010). The Canadian federal government has fiduciary obligations to ensure access to safe and sustainable wild food supplies for First Nations, including salmon. With DFO's legislative authority over Pacific salmon stocks, and First Nations rights to harvest, both groups have strong interest and roles in salmon management.

Further complicating the management of Fraser River sockeye salmon is the lack of a definition of what constitutes a healthy population. Most of the overarching legislation and regulations guiding the actions of DFO, the governmental body in charge of surveillance and management of Fraser River sockeye salmon, rarely mentions health (see review in Chapter 5). In contrast, the Cohen Commission into the Disappearance of Fraser River Sockeye Salmon uses the word health prolifically, over 400 times in the 3 volumes combined, without ever providing a definition (Cohen, 2012a, 2012c, 2012b). Without a definition of salmon health, developing consistent and transparent health-related management goals or priorities is a challenge.

The purpose of this study was to determine if processes that help groups develop a mental model of health can also help to identify shared priorities for salmon health protecting action. We hypothesize that the DOH model from Chapter 2 would be an adaptable and understandable framework that would allow the construction of comparable mental models for Fraser River sockeye salmon health.

3.2 METHODS

We followed the methods set out in Chapter 2 for the expert opinion exercise. Briefly, participants presented with some background information and a list of potential drivers of Fraser River sockeye salmon health and were asked to draw the relationships between what they believed to be the most important factors, essentially a causal diagram. The experts drew arrows to represent the direction of the relationships, whether the impact was positive or negative, and to give a score between one and ten of how large of an impact the driver had on the outcome. They completed this exercise individually. We conducted the network exercise with two groups of Pacific salmon experts, the same group of DFO employees and consultants in Chapter 2 and a group of experts affiliated with the FNFC.

Instead of using peer-referential techniques to identify the experts for the FNFC group, the Strategic Development Manager for FNFC, who is familiar with the staff of the various member nations of the FNFC, personally invited representatives who had expertise in Pacific salmon biology to attend. An in-person session was conducted with the same structure as for the DFO experts. All 13 of the FNFC participants completed the same diagrammatic network exercise as the DFO participants in Chapter 2.

We used the diagrammatic approach to network analysis to document how participants perceived the relationships between various determinants of salmon health. The diagrammatic

approach to network analysis is designed to visualize and make explicit peoples' opinions and perceptions on complex concepts, such as health (Campbell & Muncer, 2005; White, 2008). This approach avoids creation of a large aggregated network that contains more causal links than those perceived by a single participant, an analysis issue that could be encountered with the matrix approach to network analysis (Muncer & Gillen, 1997). This method also avoids over complication of the networks that may occur as participants attempt to encode their opinions into a strict matrix, and provides the opportunity of free choice by allowing participants to include the factors they perceived to be relevant (Campbell & Muncer, 2005). Primed with background on the concept of health as a capacity to cope and a list of factors, the same as in Chapter 2, the experts were asked to draw the relationships they believed to be the most important drivers of health, including direction, and a positive or negative impact score. Impact scores were assigned at the participants discretion on a 10-point scale, with 1 being a low or small impact and 10 being a high or very large impact. The data collected from the FNFC exercises were entered into network visualization and analysis software (Gephi 0.9.2) and analyzed using the Fruchterman Reingold algorithm and Eigenvector centrality statistic, just as in Chapter 2 for the DFO exercises.

Using statistical software (Stata 15.2; StatCorp LLC, College Station TX, USA), we used one-sided T-tests to compare the impact scores of positive versus negative relationships in the aggregate networks. We also used a paired two-sided t-test to compare the mean impact scores of the salmon adults and juveniles, where experts included juvenile differences. Using the mean impact scores for these two expert groups, we identified the four most negative and positive drivers with direct relationships on health for both groups. The mean impact score denotes how strong of an effect the driver might have on the target. We did not use the Eigenvector centrality measure to compare between networks as forcing health into the centre of both networks would have created discrepancies between what the software identified as the "most important" nodes in the network compared to what the collective expert opinion identified as the most important using the mean impact scores.

3.3 RESULTS

Figures 3-1 and 3-2 are the resulting network models of factors perceived by DFO and FNFC experts to influence Pacific salmon health and the interrelationships of these factors. Five of the six DOH categories identified in Chapter 2 for wildlife health were represented in both

expert opinion networks. The five categories included were: abiotic environment, social environment, needs for daily living, biological endowment, direct mortality pressures. While some the salmon experts from both groups included human expectation in their individual models, the human expectation DOH was not included in either of the final collective expert networks.

The most commonly nominated DOH theme in the DFO network was biological endowment, which includes the pathogens, stress and genetics (30.8%; Table 3-1). Abiotic environmental factors were the most represented in the FNFC network (28%; Table 3-1). For both networks, the impact score of the positive relationships was not statistically different from those of the negative ones (DFO $p=0.8$; FNFC $p=0.3$). The DFO network had fewer positive relationships (6) than negative relationships (9). The FNFC network had a similar trend with fewer positive (7) than negative (21) relationships. The FNFC network (Figure 3-2) had more relationship factors and relationships than the DFO network (Figure 3-1), with 28 relationships vs. 15.

The experts had an opportunity to include different relationships or impact scores for juvenile sockeye salmon if they believed them to be different than those for adult salmon. The mean impact scores for the adults and juveniles were not statistically different for the DFO network ($p=0.2$) nor the FNFC network ($p=0.07$), therefore we only modelled the adult group for both groups.

For the DFO experts, experience in the field and scientific literature were the most commonly mentioned sources of knowledge (12 mentions each). Common sense (5) and anecdotal evidence (3) featured less frequently. No experts selected traditional knowledge, intuition, or not being sure as the basis for their assessments.

For the FNFC experts, experience in the field was the most frequently selected source of knowledge (12). Scientific literature (9), common sense (7), and anecdotal evidence (5) were the next most common knowledge sources. Traditional knowledge and intuition were mentioned by one expert each, and no experts selected “not sure”.

The DFO and FNFC networks shared positive and negative drivers of Pacific salmon health (Table 3-2). The four most highly weighted positive drivers of both groups were: fresh water quality; food quality, quantity, and availability; genetic endowment; and population demographics. These drivers fall into needs for daily living, biological endowment, and social

environment DOH categories. The four most highly weighted negative drivers for the DFO group were: fishing, climate, disease lesions, and predation. These drivers fell into direct mortality pressure, abiotic environment, or biological endowment DOH categories. The four most highly weighted negative drivers for the FNFC group were: pathogen presence, pollution, stress, and disease lesions. These drivers fell into either biological endowment or abiotic environment DOH categories. All of these shared drivers of health were identified by the experts as having a direct impact on salmon health.

3.4 DISCUSSION

The DOH network approach allowed us to visualize perceptions of the drivers of Fraser River sockeye salmon health and thus allow for explicit presentation of overlaps and commonalities across groups. These qualities may make the DOH model a useful and transparent mechanism for fostering dialogue and shared visioning for salmon health goals and priorities.

As in Chapter 2, the DOH framework provided a conceptual foundation that allowed people to develop a mental model and the network approach allowed those models to be visualized in a way that captures a group's expertise into a single model. Although the participants in our study deliberated individually, the resulting network models of salmon health were similar. By identifying the most negative and positive drivers of salmon health and providing some context, including direction of relationships and interactions, we were able to get a rich description of health that could be compared across the two groups. The comparisons of the resulting descriptions of health demonstrates the shared perceptions of important health drivers between the groups. Both the DFO and FNFC models were multifactorial with the environment (abiotic environment and needs for daily living DOH categories) playing a large role in Fraser River sockeye salmon health. Comparison of the two networks also reveals differences, which may highlight divergent priorities between the DFO and FNFC participants. For instance, the FNFC network included not only more health drivers as a whole compared to the DFO model, but it also contained proportionately more environmental and habitat health drivers than the DFO network. The comparison between the two models highlights both areas of shared goals for collaboration presently, as well as topics to foster dialogue and information sharing to determine if the divergent perceptions held by these two groups can be modified from co-learning.

In the complex realm of health, participatory processes are invaluable in the development and setting of health goals. Stakeholders and the end users are ultimately the ones who will be deciding both whether a population is healthy and what actions, if any, should be implemented (Turnhout et al. 2007; Levac et al. 2010; Lancaster et al. 2017). To be relevant to a community of stakeholders and decision makers, it is critical that they be included in the process of defining the goals and boundaries of health monitoring programs (Briggs, 2008; Hancock et al., 1999; Levac, Colquhoun, & O'Brien, 2010). When presented with the same ranking exercise on health system priorities, distinct stakeholder groups will have different results (Bowling, Jacobson, & Southgate, 1993). Although there is no straightforward way to weight stakeholder opinions and no guidance on how to select one stakeholder's priorities over another (Bowling et al., 1993), the process followed in this study suggests a simple and acceptable way to capture similarities and differences in how groups perceive health and its most important determinants.

A harm reduction approach may provide direction on how to move forward with collaborative action despite differences in stakeholder perceptions and priorities. Harm reduction concepts focus on developing pragmatic strategies for reducing the negative consequences of hazards, actively involving stakeholders to identify potential solutions at various levels (BC Ministry of Health 2005). By acknowledging that hazards, such as a pathogen, cannot always be eliminated quickly, if ever, a harm reduction approach concentrates on creating shared goals for the different stakeholder groups (BC Ministry of Health 2005). By identifying shared goals together, these stakeholders in harm reduction processes are often inspired to collective action despite differences in priorities (BC Ministry of Health 2005). For the Fraser River sockeye salmon case study, the specific weightings of health determinants for DFO and FNFC were different (i.e. biological endowment factors for DFO and abiotic environment factors for FNFC), but there was significant overlap in the top 4 important negative and positive influences, suggesting a ground for shared priorities and action. Fraser River sockeye health management has been characterized by a focus on differences (Cohen, 2012b) rather than common ground, thus stagnating collective action. This participatory approach shows the promise of helping groups discover their common goals, priorities and perceptions, facilitating a harm reduction approach. It was clear from this study that both groups identify the need to take a multi-level approach for reducing harm and protecting salmon health by working on multiple determinants

of health simultaneously and that health management requires action outside of the traditional field of salmon health which focuses largely on pathogens and disease.

The participants considered Fraser River sockeye salmon health to be complex and multifactorial, with diverse factors determining whether a population is healthy. This multifactorial thinking is contrary to most policy approaches that either leaves health undefined or focusses on defining health as the absence of disease. The results suggest that the study participants might be ready to apply the expanded definition of health developed in Chapter 2. The discordance between what is understood (health is complex) and how a system works (health is undefined), suggests there will be a need to help salmon health experts and managers become aware of the implications of retaining the current approach and the value of the DOH model to conceptualize, monitor and manage salmon health (Butterfoss et al., 2008).

Providing the opportunity for people to consider and deliberate on a topic allows participants to contemplate their positions, resulting in changed or more entrenched views (Abelson et al., 2003). While the network exercise was useful for identifying the mental models of different groups of experts, and for making comparisons in their conceptions of health, we do not know if the exercise affected participants perceptions of subsequent actions. Shared mental models of complex concepts can improve decision quality as it improves mutual understanding of others' perspectives (Kellermanns, Floyd, Pearson, & Spencer, 2008). A desk top model, such as ours, however does not take into account political, fiscal, or other realities that prevent action on priorities by one group or another. Additionally, it was beyond the scope of this study to investigate if or how the outputs of this exercise influenced people's willingness to act collectively or on common determinants.

The DOH model is not only applicable across species (Chapter 2) but also can be understood and used by different social groups. This chapter demonstrated that how salmon health professionals perceive and understand health is not reflected in the "traditional" absence of disease approach to health that is the current default. The network exercise illustrated that there is a need for fish and wildlife health programs to expand beyond looking for diseases or genetic flaws, to incorporate more environmental, habitat, and human influence factors. Finally, this study showed that application of a DOH model can help groups identify areas of common perceptions and priorities that can be the foundation for collaborative action.

Table 3-1. Summary of the determinant of health (DOH) categories included in the Fisheries and Oceans Canada (DFO) and First Nations Fisheries Council of British Columbia (FNFC) Fraser River sockeye salmon (*Oncorhynchus nerka*) expert networks. Each driver of health identified collectively by the experts were categorized into the DOH themes identified in Chapter 2

DOH Category	DFO Frequency (%)	FNFC Frequency (%)
Biological Endowment	4 (31)	4 (22)
Social Environment	3 (24)	3 (17)
Abiotic Environment	2 (15)	5 (28)
Needs for Daily Living	2 (15)	4 (22)
Direct Mortality Pressure	2 (15)	2 (11)
Human Expectations	0 (0)	0 (0)
Total	15 (100)	18 (100)

Table 3-2. The drivers of Fraser River sockeye salmon (*Oncorhynchus nerka*) health for the Fisheries and Oceans Canada (DFO) and First Nations Fisheries Council (FNFC) networks with the highest mean impact scores. Mean impact scores were calculated for all submitted relationships in the network analysis exercise and were considered in this analysis if mentioned by three or more experts. Only the top four positive and negative impact scores are included in this table. All relationships directly impacted sockeye salmon population health. Mentions are the number of times that driver was included by an expert during the network analysis exercise.

Type of Impact on Salmon Health	Highest Mean Impact Score on Salmon Health	Mean Impact Score (Mentions)	
		DFO	FNFC
Positive	Fresh Water Quality	8 (3)	5.3 (11)
	Food Quality, Quantity, and Availability	7 (4)	9 (10)
	Genetic Endowment	6.7 (7)	8.9 (10)
	Population Demographics	6.5 (4)	8 (4)
Negative	Fishing	-6.6 (6)	
	Climate	-5.5 (4)	
	Disease Lesions	-5.2 (5)	-7.3 (4)
	Pathogen Presence	-5 (7)	-8.5 (5)
	Pollution		-7.6 (5)
	Stress		-7.5 (3)

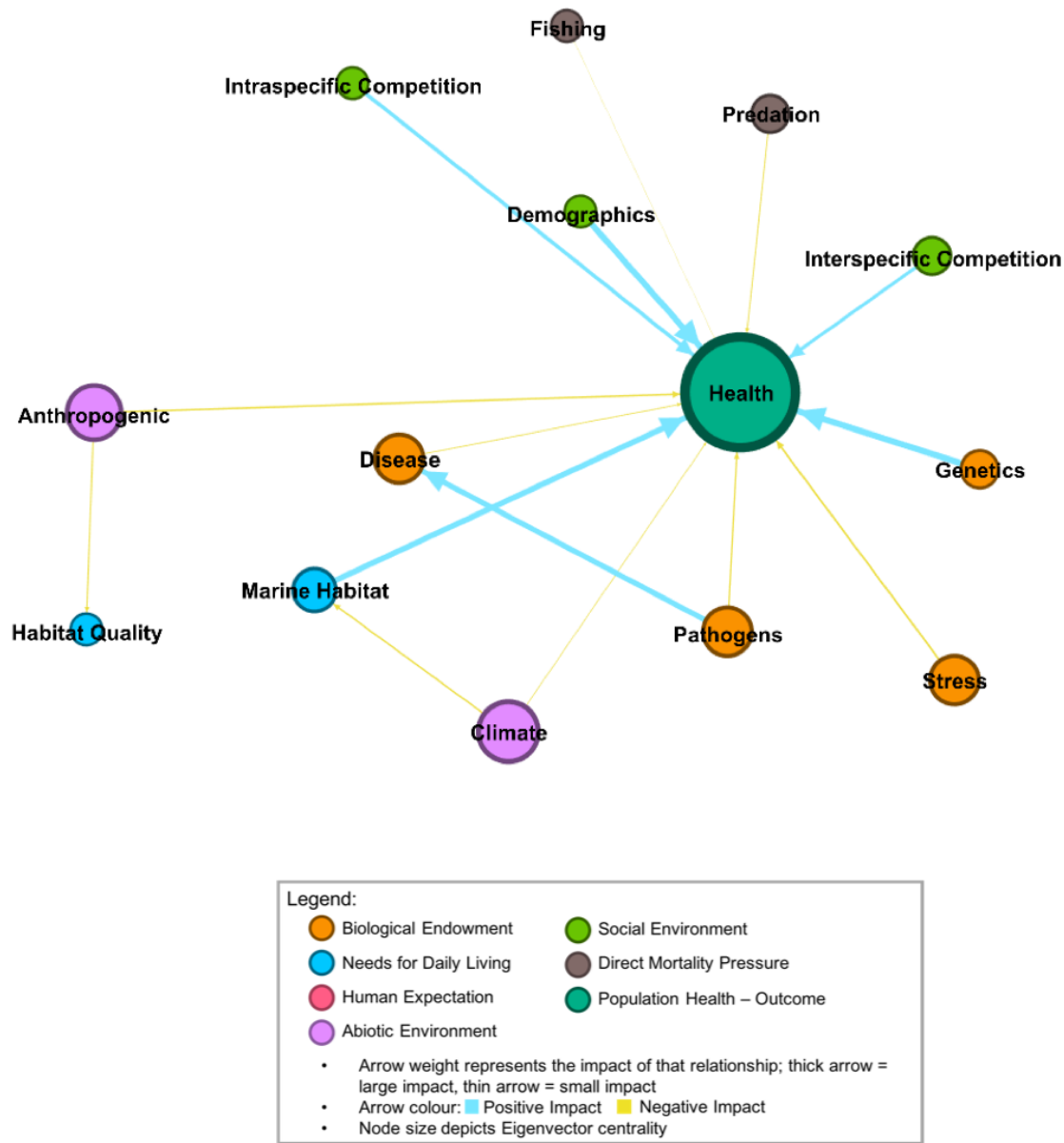


Figure 3-1. Diagrammatic network analysis of 12 Fisheries and Oceans Canada Pacific Biological Station staff and contractors constructed diagrams of the type, direction, interrelationships, and relative impacts of determinants of Fraser River sockeye salmon (*Oncorhynchus nerka*) health based on the expert’s personal and professional judgement and experience. Arrow direction indicates direction of the interaction. Arrow colour represents positive (blue) or negative (yellow) effects. Arrow size indicates the relative size of the effect of the interaction (thicker arrows equal larger effects).

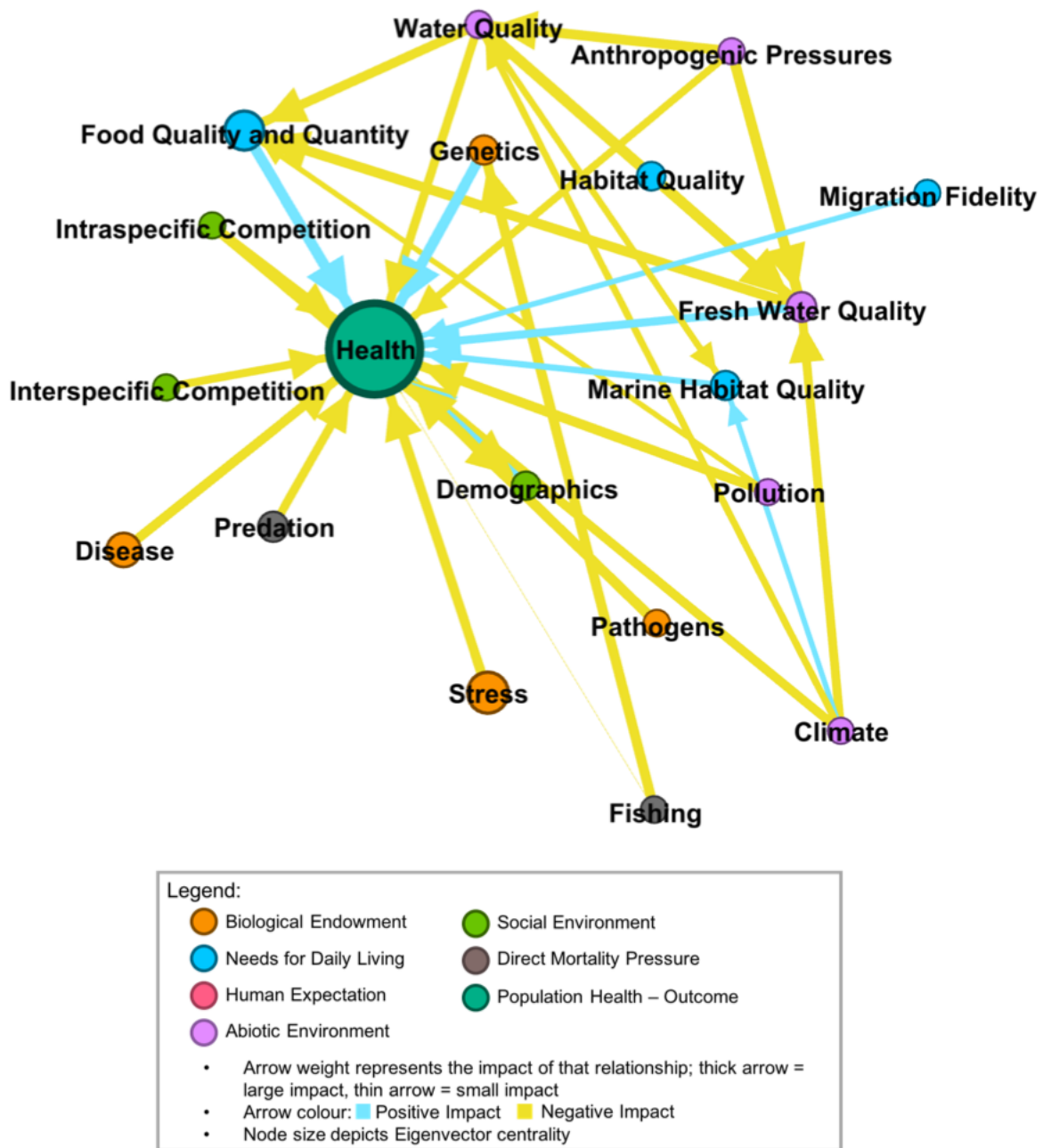


Figure 3-2. Diagrammatic network analysis of 13 First Nations Fisheries Council representatives constructed diagrams of the type, direction, interrelationships, and relative impacts of determinants of Fraser River sockeye salmon (*Oncorhynchus nerka*) health based on the expert’s personal and professional judgement and experience. Arrow direction indicates direction of the interaction. Arrow color represents positive (blue) or negative (yellow) effects. Arrow size indicates the relative size of the effect of the interaction (thicker arrows equal larger effects).

CHAPTER 4: IDENTIFYING AN OPPORTUNITY FOR A NEW SALMON HEALTH PERSPECTIVE IN CANADIAN FEDERAL POLICY

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4.1 INTRODUCTION

Risks to and responsibility for salmon health is an ongoing challenge for Fisheries and Oceans Canada (DFO), which is the federal agency with regulatory responsibility for salmon (Minister of Justice, 1985b, 1985a). Restoration and maintenance of healthy populations is featured in the Policy for Conservation of Wild Pacific Salmon (referred to as the Wild Salmon Policy; Fisheries and Oceans Canada 2005). The Wild Salmon Policy is meant to represent DFO's "commitment to maintain healthy and diverse populations of salmon that will support sustainable fisheries now, and meet the needs of future generations" (Fisheries and Oceans Canada, 2017). It includes healthy salmon as its central management goal. The issue of salmon health is a major regulatory preoccupation. For example, much of the debate around sustainable salmon aquaculture in British Columbia, Canada revolves around the effects of aquaculture on the health of free-ranging salmon (Fisheries and Oceans Canada, 2002, 2015a, 2018h). However, DFO policy lacks a definition of health that can be used to recognize when health management goals have been met. The current default reliance on how many salmon return to spawn and/or the absence of pathogens as the measures of health plus the lack of accepted thresholds to declare if a population is healthy complicate consistent and transparent declarations on policy impacts on salmon health.

There is a gap between how fish and wildlife health are perceived, measured, and managed (Stephen, 2017). In Chapters 2 and 3 we developed evidence to propose that a determinants of health (DOH) perspective based on a population health model that includes

social, biological and ecological factors would provide new opportunities for salmon health managers to strategize and prioritize a suite of collaborative actions to protect and promote salmon health. Chapter 2 also demonstrated that fish and wildlife managers perceive health in a complex, cumulative way that is consistent with the DOH model. However, "... agencies involved in managing oceans activities have been typically concerned with managing a single species or a single activity" (Fisheries and Oceans Canada, 2002, p. 3).

Canada has made an expressed commitment to an ecosystem approach, even stating in the preamble of the Oceans Act, which is a guiding document for DFO, that "Canada holds that conservation, based on an ecosystem approach, is of fundamental importance to maintaining biological diversity and productivity in the marine environment" (Minister of Justice, 1996, p. 1). The Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River (hereafter referred to as the Cohen Commission) identified that although a cumulative ecosystems approach was a stated priority to DFO, this was not reflected in their Fraser River sockeye salmon management actions (Cohen, 2012c). The Cohen Commission, which was mandated by the Canadian federal government, investigated the many contributing factors in the decline in the Fraser River sockeye salmon population. Justice Cohen recommended that DFO consider cumulative effects in order to better understand, manage, and conserve salmon populations (Cohen, 2012c). Within the fish and wildlife field, there have been calls to incorporate more cumulative effects thinking into management strategies (deFur et al., 2007; Johnson et al., 2005; Krausman & Harris, 2011). The DOH model we adapted in Chapter 2 may be a way to address the gaps between stated commitments and actions to a cumulative approach to health. Given the success of the DOH model at getting people to cooperate (Bowling et al., 1993), it may also assist DFO to apply an ecosystem approach to managing salmon health. To promote the adoption of a DOH approach to salmon health within the Ministry, DFO must first recognize a policy gap and see the DOH approach as a possible solution (Butterfoss et al., 2008; Mintrom & Norman, 2009).

Wild Pacific salmon (*Oncorhynchus spp.*) are a common good in Canada, with the responsibility for management, conservation, and stewardship delegated to DFO by the Crown (Minister of Justice, 1985b, 1985a). Pacific salmon are valuable culturally, recreationally, and economically (Fisheries and Oceans Canada, 2005; Jacob et al., 2010). The five species of wild Pacific salmon in Canada (*Oncorhynchus tshawytscha*, *O. keta*, *O. kisutch*, *O. gorbuscha*, and *O.*

nerka) are managed by DFO (Fisheries and Oceans Canada, 2018f). There are differences in the biology of these five species, each having different morphologies, migration phenology, and life cycle timing (Groot & Margolis, 1991). Along with these biological differences, there are variabilities in how the species are valued and used by society (Fisheries and Oceans Canada, 2005). Some species are highly regulated, with stocks under threat and experiencing population declines (Fisheries and Oceans Canada, 2005; Ruckelshaus et al., 2002). Certain populations are a focus of significant legal and social conflict for DFO (Nikiforuk, 2016; West Coast Environmental Law & Raincoast Research Society, 2016). Due to these biological and societal differences between the salmon species, a new health model would need to be relevant and adaptable across these social and ecological contexts. The objective of this policy study was to identify if there are policy needs or opportunities within DFO for a DOH approach for Pacific salmon, to guide DFO legislation, policy, and regulations and actions.

We hypothesized that a need exists based on three lines of evidence: (i) the outcome of Chapter 2, (ii) the prominence of Pacific salmon health issues as a DFO management need (Cohen, 2012c; Stephen et al., 2018), and (iii) the utility of the DOH approach in the public health sector (Kindig & Stoddart, 2003). Public health promotion recognizes that “health cannot be separated from other goals” and advocates for an approach to health policy that integrates social, political, economic, and environmental components (World Health Organization, 1986, p. 3). This perspective champions a cumulative DOH approach to developing policy in order to better support health (Eriksson & Lindström, 2008), and would be consistent with DFO policy, like the Ocean’s Act.

4.2 METHODS

4.2.1 Inventory and Review of the Policy

DFO legislation and regulations on record in January 2016 were found by searching Canada’s Department of Justice’s “Justice Laws Website”, the online source for Canada’s consolidated Acts and regulations (Department of Justice, 2018). We subsequently turned to the search tool on the DFO website (Fisheries and Oceans Canada, 2018d) to assemble all policies and regulations that might apply to Pacific salmon populations, using the titles of the legislation and regulations found on the Justice Laws website as search terms. We found 34 policies and regulations related to salmon based on these Acts. Using the search terms “Pacific salmon” and

“legislation” or “treaty” or “policy” or “regulation” in Google, we sought applicable international law and reports from international commissions.

Using these documents, we conducted a narrative descriptive synthesis of the DFO Pacific salmon-related policy. The narrative synthesis was carried out using guidelines from Popay et al (2006) to inform the critical appraisal, data extraction, and exploration between relationships of the documents. Our aims were to (i) identify how legislation and policy discuss health; (ii) identify themes and measures with which the legislation and policies were concerned, and (iii) determine if or how existing legislation and policy aligned with the determinants of health identified in Chapter 2. We categorized the legislation, policy, and regulations into the six main themes based on the conceptual DOH model from Chapter 2 namely: abiotic environment, social environment, needs for daily living, biological endowment, direct mortality pressure, and human expectations. A scoping review of Web of Science Core Collection, MEDLINE, Zoological Record, Ebscohost, and CAB direct was conducted using the words 'due diligence' 'fish surveillance' 'fish health surveillance' plus variations using key concepts that establish due diligence (ex., standards of practice, threshold) to further seek evidence of a policy base that established accepted health thresholds. The literature between 1995 and 2017 in English was searched. Inclusion criteria were any peer-reviewed literature that included the search terms, focusing on due diligence in surveillance of fish health or fish populations.

4.2.2 Identifying the Need for a Change in Policy

We used the Kingdon (1995; 1984) multiple streams framework to identify if there was a timely need to re-assess DFO Pacific salmon health policy. The multiple streams approach is typically used for setting public policy agendas (Béland, Howlett, & Kuan, 2016). An issue becomes a policy priority when there is convergence of the three streams: problems, policies, and politics (J. W. Kingdon, 1984). The problem stream outlines conditions that are seen by people as a problem and that require government action. The policy stream, includes the needs and expectations of policies and programs that have become the focus of a review for new initiatives. National mood, social pressure, and changes in administration priorities occur in the politics stream.

4.2.2.1 Problem stream

To delineate the “problem” with the current DFO Pacific salmon policy, we turned to sources that have been critiquing DFO policy.

The Cohen Commission was used as a guiding document for outlining the problem stream in the Pacific salmon health issue (Cohen, 2012b, 2012a, 2012c). Justice Cohen in his final report made 75 recommendations (Cohen, 2012c). We selected the Cohen Commission as it is currently guiding and driving DFO policy, actions, and programs on Fraser River sockeye. As the Cohen Commission was solely focused on Fraser River sockeye, we wanted to see if the recommendations made would be applicable to other species of Pacific salmon in Canada. In his report, Justice Cohen (2012c) outlined that there was a need for a detailed implementation plan for the Wild Salmon Policy. The Wild Salmon Policy (Fisheries and Oceans Canada, 2005), the guiding document for managing and conserving all species of Pacific salmon in Canada was released in 2005.

We also conducted an internet search using Google with the term “protecting wild salmon health”. We included news articles, blogs, and other popular grey literature. We conducted this search to gain insight into the conversation in the media and general public perceptions on the topic (Scharkow & Vogelgesang, 2011).

4.2.2.2 Policy stream

We used the results from the policy inventory and narrative review described above to fulfill the policy stream component of the Kingdon approach. While conducting the narrative review, we identified whether there were needs or opportunities for a DOH perspective within DFO legislation, policy, and regulations and pieces of international law. We identified if there was a gap between how health was perceived by the salmon scientists and managers in Chapter 2 and how health was discussed or mentioned in legislation and policy. An opportunity for a DOH existed if a guiding document advocated for, or described, an aspect of the DOH framework that either did not exist in other documents or if there was no information of implementation.

4.2.2.3 Politics stream

To assess the political need to develop a new approach into the DFO Pacific salmon perspective, we turned to the mandate letter from Canada’s Prime Minister to his Minister of Fisheries Oceans Canada in 2016 (Prime Minister of Canada, 2016). Mandate letters provide “a framework for what Ministers are expected to accomplish, including specific policy objectives and challenges to be addressed” (Prime Minister of Canada, 2015). These letters are meant to guide the approach and priorities of the ministry’s work (Prime Minister of Canada, 2015).

4.3 RESULTS

4.3.1 Policy Inventory

Six pieces of legislation that governed DFO in 2016 were: the Coastal Fisheries Protection Act, the Department of Fisheries and Oceans Act, the Species At Risk Act, the Fisheries Act, the Health of Animals Act, and the Oceans Act. Although no document defined or provided parameters or thresholds for measuring health, components of each of the DOH category could be found dispersed across numerous policies (Table 4-1). The Cohen Commission (Cohen, 2012a, 2012b, 2012c) and the DFO's Wild Salmon Policy (Fisheries and Oceans Canada, 2005) were the only documents that included references to or guidelines on all of the DOH themes. Despite using the word 'health' over 400 times in the three volumes of the Cohen Commission and over 100 times in the Wild Salmon Policy, neither document provided a definition for health (Table 4-2). The context in which salmon or health were mentioned was always for the purpose of serving or protecting anthropocentric interests.

4.3.2 Need for Policy Change

4.3.2.1 Problem stream

Health was a concept that crossed multiple spheres of DFO interest. Healthy runs, healthy sectors, healthy oceans, and healthy populations were concepts throughout six guiding pieces of DFO legislation and the related policies. The Cohen Commission final report included 13 recommendations where health was highlighted. Health is a primary focus of DFO's Wild Salmon Policy, with the primary goal, two principles, two objectives, and three strategies centring on or mentioning health. The recommendations and strategies in the Cohen Commission and the Wild Salmon Policy included: research and monitoring of the health of Fraser River sockeye from a cumulative impacts assessment, linking health information to conservation, assessing the effects of salmonid enhancement facilities on wild sockeye health, accessing and sharing fish health data, and determining if serious risks to health occur. The Strategic Salmon Health Initiative, a DFO response to some of the recommendations made in the Cohen Commission, focused primarily on finding signals of pathogen presence (Fisheries and Oceans Canada, 2016). The DFO had not publicly released a strategy for addressing the multiple stressors that may impact salmon health by 2018.

The presence of commercial salmon farms has been considered a potential threat to wild salmon health and has been the source of significant debate about salmon health. For example,

some scientists and citizens have been concerned with the increased parasite loads that may spread from farmed to wild salmon, suggesting that “salmon farms can cause parasite outbreaks that erode the capacity of a coastal ecosystem to support wild salmon populations” (Krkosek et al., 2007, p. 1). Marty et al. (2010) presented data that indicated that the wild salmon population declines were not due to the parasite but to some other health condition and other “complex issues”. Despite such debates, a recent provincial government advisory panel in British Columbia made sea lice action a critical recommendation (Minister of Agriculture’s Advisory Council on Finfish Aquaculture, 2018). Wild-farmed salmon health issues are also socially contentious. For example, DFO has been sued for prioritizing commercial salmon farming operations over wild salmon populations by allowing the transfer of domestic stock seemingly infected with piscine reovirus into open sea cages (Hume, 2013; Nikiforuk, 2016). In 2016 there was a petition to the Office of the Auditor General of Canada over “concerns about fish farming practice in British Columbia and their effect on the health of farmed fish and wild fish” (West Coast Environmental Law & Raincoast Research Society, 2016). Scientists and some vocal members of the public, including some First Nations, have expressed concern about threats to the health of wild salmon from aquaculture and that DFO are not doing enough to reduce these threats.

Our search of the grey literature found four main themes related to salmon health in British Columbia; (1) risks to wild salmon from commercial salmon aquaculture (particularly private sector aquaculture); (2) protecting the needs for daily living for salmon (with an emphasis on protection of freshwater habitats); (3) action on climate change and pollution; and (4) the role for salmonid enhancement hatcheries to supplement wild populations. These coincide with major areas of interest within the Cohen Commission and are also reflected in the Wild Salmon Policy (Fisheries and Oceans Canada 2005).

4.3.2.2 Policy stream

Many policies focused on managing salmon populations for people. This is reflected by the large number of policies concerned with salmon harvest (Table 4-1; Direct Mortality Pressures). While several DFO policies and recommendations cite healthy salmon and fish stocks as a management and conservation goal, they either do not define how to recognize a healthy state, or they use a single aspect of health to describe health status (Table 4-2).

The Fish Health Protection Regulations (Fisheries and Oceans Canada, 1984) do not define health nor do the Pacific Aquaculture Regulations (Fisheries and Oceans Canada, 2015a).

Rather, they focus exclusively on the absence of a disease or pathogen. Fish Health Management Plans, a requirement of the National Aquatic Animal Health Program for aquaculture operations, are largely focused on biosecurity measures to prevent the introduction and movement of infectious diseases, safe use of drugs and chemicals, and plans to respond to disease emergencies (Fisheries and Oceans Canada, 2018e). The objective of DFO's fish health program in British Columbia is to monitor and minimize the potential risks of disease and disease transmission from farmed fish to wild salmon (Fisheries and Oceans Canada, 2018h). We found no literature to define performance thresholds for health monitoring or surveillance to establish when they meet expectations for due diligence. Review of DFO policy also failed to identify thresholds for adequacy of surveillance or monitoring.

Some policies dealing with conservation topics include consideration of the abiotic environment, needs for daily living, biological endowment, and social environmental determinants of health themes (Table 3-1). Most of these documents, however, either do not provide much detail or only mention single variables in isolation.

The Cohen Commission reports and the Wild Salmon Policy were the only documents that addressed a wide suite of health determinants. Many of the recommendations made in the Cohen Commission focused on creating precise and measurable definitions, goals, and targets to assess how well DFO policies and regulations fulfill their intended objectives. Both the Cohen Commission reports and the Wild Salmon Policy focus on transparent procedures, each mentioning "transparent" more than 100 times.

4.3.2.3 Politics stream

In his mandate letter, the Minister responsible for DFO in 2016 was expected to; "restore funding to support federal ocean science and monitoring programs, to protect the health of fish stocks, to monitor contaminants and pollution in the oceans, and to support responsible and sustainable aquaculture industries on Canada's coast" and to act on recommendations of the Cohen Commission (Cohen, 2012c). The Minister's mandate letter emphasizes the importance of health stating the "overarching goal will be to protect our three oceans, coasts, waterways and fisheries and ensure they remain healthy for future generations" and listed "protect[ing] the health of fish stocks" as a top priority (Prime Minister of Canada, 2016). Ongoing litigation in British Columbia associated with finfish aquaculture frequently involves concerns about health

and disease (Nikiforuk, 2016; West Coast Environmental Law & Raincoast Research Society, 2016).

4.4. DISCUSSION

The interface of the policy, political and problem streams supports the recommendation to develop a new approach to salmon health within DFO. The 2016 mandate for the direction of DFO from the Prime Minister (Prime Minister of Canada, 2016), plus outstanding concerns about sustainable aquaculture, produce social and administrative pressures to define health. Political, policy and public expectations emphasize health as a target for wild salmon management. Most attention has been focused on detecting specific pathogens or estimating harvestable returns. The focus on absence of disease is a significantly out-dated definition for health, but no alternatives were provided in DFO policy or legislation. The lack of unified vision of salmon health as a cumulative effect and the political motivation to create one has produced a need for a new policy perspective on describing and identifying progress and priorities for protecting salmon health. We believe that the DOH approach outlined in Chapter 2 meets this policy need as it is designed to address the cumulative factors that impact health, including social aspects, into a single framework and perspective.

DFO's guiding principles and responsibilities for aquatic animal health are spread across multiple policies and regulations (Cohen, 2012c; Fisheries and Oceans Canada, 1984, 2005, 2013, 2018e, 2018a; Government of Canada, 2017; Minister of Justice, 2002) but there is no organizational framework to integrate information and activities derived from these various policies and programs. There is also no single policy vision for salmon health nor an adaptable, broadly acceptable definition capable of integrating various perspectives of health. The use of the word health without a definition means that DFO cannot explicitly assess if it has reached its management target. To that end, one of the potentially most challenging recommendation made in the Cohen Commission is determining if serious risks to Pacific salmon health occur. The Cohen Commission report noted that “without established fish health standards... scientists and regulators cannot properly assess these risks and take informed preventive actions to reduce risks” (Cohen, 2012c, p. 27).

The absence of an explicit framework to incorporate investigations of multiple stressors will complicate DFO's ability to demonstrate a health benefit of research or policy changes. The absence of disease, while an important DOH, is only a single dimension that does not adequately

address health as a cumulative effect, typically restricts assessment to a pre-set list of specific pathogens, and provides trigger points for action that occur after adverse effects are being or near to being realized (ex., disease; Stephen 2013, 2014; Cieza et al. 2016). The reliance on the absence of disease or infection model of health leaves DFO with an unattainable health goal as parasitic and infections pathogens and diseases are a normal part of any wild or farmed population. The focus on single, specific diseases decouples salmon health work from salmon population management and desires to protect health through a cumulative effects or ecosystem perspective. Furthermore, as noted in Technical Report 1a of the Cohen Commission, there is no “evidence-based, non-zero standard to define an acceptable frequency or amount of transfer of pathogens from enhanced fish to wild fish that could be used in a risk assessment” (Stephen, Stitt, Dawson-Coates, & McCarthy, 2011, p. 2). The current methods of stock assessment for abundance-based management have not been able to address the nuances of what is happening during the life-course of salmon (Holt & Peterman, 2008). A cumulative effects approach could provide a more complete picture.

While wild salmon health is a concern and priority for multiple levels of government, response to declines in some Pacific salmon populations has been limited (Cohen, 2012b). The British Columbia government has stated that it places the health of all wild fisheries, including salmon, as paramount (British Columbia Ministry of Agriculture, 2017). But in a follow-up to that statement, it limits its response to health issues by noting they will work with “federal counterparts and aquaculture operators to monitor for diseases and is prepared to implement a prompt, coordinated and science-based response if required” (British Columbia Ministry of Agriculture, 2017). The BC Minister of Agriculture’s Advisory Council on Finfish Aquaculture was called upon in July 2016 to advise the minister on matters related to finfish aquaculture (Minister of Agriculture’s Advisory Council on Finfish Aquaculture, 2018). Their vision is “sustaining wild salmon within a healthy ecosystem while recognizing the interdependence and importance of wild salmon to communities in BC” (Minister of Agriculture’s Advisory Council on Finfish Aquaculture, 2018, p. 4). This statement makes the issue of risks to wild salmon health clearly within their scope of consideration. In their final report to the Minister of Agriculture, the advisory committee puts major emphasis on a harm reduction approach, making recommendations that “reduc[e] known existing harms to wild salmon and the risk of future harms” (Minister of Agriculture’s Advisory Council on Finfish Aquaculture, 2018, p. 7). They

also advocate for “a new area-based management approach that considers cumulative risks” (Minister of Agriculture’s Advisory Council on Finfish Aquaculture, 2018, p. 8). Although much of the responsibility of managing Pacific salmon stocks falls under the purview of DFO, other levels of government are concerned with salmon health and are advocating for changes in the way salmon are managed.

The Technical Report 1a of the Cohen Commission concluded that, “the goal of determining the impact of a specific disease on wild fish productivity is largely unachievable due to the high variability in exposure settings, environmental conditions and biological responses; high level of uncertainty due to infrequent or inaccurate measurements; and large number of unknown interacting factors” (Stephen et al., 2011, p. 2). A DOH approach may be a way to identify potential modes to initiate action and reduce harm in the declining Pacific salmon populations under conditions of uncertainty and challenges in eliminating health hazards. Harm reduction concepts rely on a DOH approach to identify opportunities to minimize the impacts of a harm or hazard while recognizing it may not be possible to remove the hazard altogether (Health, 2005; Stephen et al., 2018). The DOH multifactorial perspective of health identifies opportunities to have an impact on health beyond minimizing exposure to pathogens, recognizing multiple avenues to potentially reduce harm. For example, farming of Atlantic salmon (*Salmo salar*) was identified in the Cohen Commission as a potential harm to Fraser River sockeye salmon (Cohen, 2012b). By using the DOH approach to identify the factors that impact Pacific salmon’s capacity to be healthy, it may be possible to identify opportunities for harm reduction beyond banning the farming of Atlantic salmon (Stephen et al., 2018).

The multiple streams approach created by Kingdon (1984), while a foundational piece of work in policy analysis (Béland et al., 2016), has faced some criticism. The primary critique of the multiple streams approach is its focus on agenda-setting and less on the later stages of the policy process (Howlett, McConnell, & Perl, 2015). Although some scholars see this as a shortcoming of the approach, others argue that agenda-setting determines the subsequent stages of the policy process (Barzelay, 2003). As our purpose in this study was to identify if there was a need within DFO policy for a DOH approach, essentially defining the problem, this critique of the multiple streams approach is not relevant at this stage.

A DOH approach may provide a framework for transitioning DFO from health policies to healthy policies perspective. DFO currently has a collection of isolated health policies that focus

on disease monitoring. Healthy public policy is the awareness of how policy that may be seemingly unrelated to health could have an impact on health (World Health Organization, 1986). This study showed how multiple DFO policies deal with determinants of health but there is a lack of mechanism or process to develop an integrated perspective. A healthy policy perspective is a coordinated approach to policy development that uses health as a unifying concept (World Health Organization 1986). The six DOH themes could be used to identify how policies beyond the current explicit salmon health policies influence health and identify opportunities to integrate multiple policy domains. By shifting towards a healthy policy perspective within DFO, using a DOH framework, it may be possible to take a more multifactorial approach to health within the organization, ultimately benefiting the animals and ecosystems DFO manages. The DOH approach could provide a framework to integrate all of the policies that exist separately into a healthy salmon policy network.

Table 4-1. Documents guiding Fisheries and Oceans Canada (DFO) Pacific salmon population management, categorized by determinant of health categories identified in Chapter 2

Determinant of Health Theme	Canadian Federal Legislation, Policy, Regulations, and International Treaties Directing DFO.	Other Documents Influencing and Informing DFO Policy
Abiotic Environment	<ul style="list-style-type: none"> • Policy for Conservation of Wild Pacific Salmon • Fish Toxicant Regulations • Canadian Environmental Protection Act • Species at Risk Act • Canadian Shipping Act • Fisheries Act • Pacific Salmon Treaty 	<ul style="list-style-type: none"> • United Nations - In Dead Water • United Nations Conference of Straddling Fish Stocks/Highly Migratory Fish Stocks Agreement • Standing Committee Report on 2004 Fraser River Salmon Fishery • Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River • United Nations Convention on Biological Diversity
Needs for Daily Living	<ul style="list-style-type: none"> • Riparian Areas Regulations • Policy for Conservation of Wild Pacific Salmon • Fisheries Act • Fish Protection Act • Canadian Environmental Protection Act • Species at Risk Act • Oceans Act • Pacific Salmon Treaty 	<ul style="list-style-type: none"> • Standing Committee Report on 2004 Fraser River Salmon Fishery • United Nations Conference of Straddling Fish Stocks/Highly Migratory Fish Stocks Agreement • Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River • United Nations Convention on Law of the Sea • United Nations Convention on Biological Diversity
Biological Endowment	<ul style="list-style-type: none"> • Fish Health Protection Regulations • Policy for Conservation of Wild Pacific Salmon • Fisheries Act 	<ul style="list-style-type: none"> • United Nations Conference of Straddling Fish Stocks/Highly Migratory Fish Stocks Agreement • Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River
Social Environment	<ul style="list-style-type: none"> • Policy for Conservation of Wild Pacific Salmon • Species at Risk Act • Pacific Salmon Treaty 	<ul style="list-style-type: none"> • Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River • United Nations Convention on Biological Diversity

Table continued on following page

Table 4-1 Continued

Determinant of Health Theme	Canadian Federal Legislation, Policy, Regulations, and International Treaties Directing DFO.	Other Documents Influencing and Informing DFO Policy
Direct Mortality Pressures	<ul style="list-style-type: none"> • Fishery Regulations • Policy for Conservation of Wild Pacific Salmon • Fisheries Act • Species at Risk Act • Pacific Salmon Treaty 	<ul style="list-style-type: none"> • British Columbia Provincial Forestry Regulations • Standing Committee Report on 2004 Fraser River Salmon Fishery • United Nations – In Dead Water • United Nations Conference of Straddling Fish Stocks/Highly Migratory Fish Stocks Agreement • Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River
Human Expectation	<ul style="list-style-type: none"> • Fishery Regulations • Policy for Conservation of Wild Pacific Salmon • Fishing and Recreational Harbours Act • Fisheries Act • Oceans Act • Fisheries Improvement Loans Act • Fisheries Development Act • Coastal Fisheries Protection Act • Pacific Salmon Treaty 	<ul style="list-style-type: none"> • British Columbia Provincial Hydroelectric Regulations • Pacific Salmon Resources in Northern British Columbia and Yukon Transboundary Rivers • United Nations Conference of Straddling Fish Stocks/Highly Migratory Fish Stocks Agreement • Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River Reports for the Minister of Fisheries and Oceans Canada (Oceans Act and/or Fisheries Act) • United Nations Convention on Law of the Sea • United Nations Convention on Biological Diversity

Table 4-2. Overview of the context in which the word “health” was used in federal policies, legislations, regulations, and other documents guiding Fisheries and Oceans Canada Pacific salmon (*Oncorhyncus spp.*) health management

Number of documents reviewed	43
Documents that do not mention health	31
Documents that only use health in reference to humans and/or livestock	9
Documents that use health without a definition	11
Documents that use health <30 times	9
Documents that use health >100 times	3

CHAPTER 5: ASSESSING THE READINESS FOR A HEALTHY SALMON POLICY APPROACH IN CANADA

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5.1 INTRODUCTION

Pacific salmon population health, as demonstrated in Chapters 2 and 3 is influenced largely by things outside of DFO's current policy that specifically mentions the word health. In Chapters 2 and 4, we showed that when DFO mentioned health in policy, it was typically focused on disease risk management. This contrasts with the salmon determinants of health (DOH) model developed and assessed in Chapters 2 and 3 where we identified six DOH categories driving salmon health and resilience namely, biological influences, the abiotic environment, social environment, direct mortality pressures, human expectations, and needs for daily living. In Chapter 4, we demonstrated that DFO has a suite of policies managing many of the DOH, but there is no mechanism to integrate or coordinate activities across policies and programs nor a shared goal to guide policy actions in a coordinated fashion. The goal of healthy public policy is for policy makers inside and out of the health sector to be aware of the consequences of their policy on the health of a population (Kemmer, 2001) and to make policy decisions that have a positive impact on health (World Health Organization, 1986). Healthy public policy considers the health implications across all policy (Kemmer, 2001). This approach is consistent with many of the policy drivers for salmon health at the federal level identified in Chapter 4. It is used to identify the influence of actors towards the shared goal of health. Our goal in this chapter is to determine if a foundation for a healthy salmon policy approach exists within DFO.

The primary steps in policy development are: initiation, adoption, implementation, evaluation, and reformulation (Milio, 1987). Building healthy public policy follows this same

general framework, but from a systems perspective (Kemmm, 2001; Milio, 1987). External influencing factors, and the relationships amongst them, are considered when developing healthy public policy (Milio, 1987). These external factors include the social climate of the organization, the participants, stakeholders, and the goals, priorities, agendas, and resources of the policy-keeper (Milio, 1987). When building healthy public policy, policy makers must consider the health implications, either benefits or costs, at a DOH level (Kemmm, 2001; Milio, 1987; World Health Organization, 1986).

There are several high-level guiding documents on healthy public policy development, including from the World Health Organization (Bowman et al., 2012; World Health Organization, 2010) and the Canadian National Collaborating Centre for Healthy Public Policy (2018). In this chapter, we opted for a framework that is used by on-the-ground public health policy makers as our foundation for assessing the readiness of DFO to adopt or adapt a healthy public policy approach to salmon health because many of DFO's salmon health protecting programs function as on-the-ground management. Specifically, we used the healthy public policy development structure employed by Public Health Ontario (2013). This framework provides an eight-step process for producing healthy policy (Table 5-1), which are: (1) describe the problem; (2) assess the readiness for policy development; (3) develop goals, objectives, and policy options; (4) identify decision-makers and influencers; (5) build support for the policy; (6) draft and/or revise the policy; (7) implement the policy; and (8) evaluate and monitor the policy. As the goal of this chapter was to assess if a foundation for healthy salmon policy exists and not apply new policy, we did not include steps 4-8 of this framework in the analysis as they focus on implementation, evaluation, and reformulation of policy. Step 1, "describe the problem" focuses on understanding the specific problem to be addressed; creating the foundation for the following steps in policy development (Public Health Ontario, 2013). This step was addressed in Chapters 2, 3, and 4 where we established the need for a new approach to salmon health and built the argument that a healthy public policy approach could address prevailing problems and challenges facing DFO salmon health management.

Readiness for policy development is based on both the readiness of stakeholders for a change in policy, as well as the capacity, opportunity, and resources in an organization to support a change (Public Health Ontario, 2013). With regard to stakeholder readiness, we demonstrated in Chapters 2 and 3 that DFO salmon biologists and salmon experts associated with First Nations

Fisheries Council perceive health in a manner consistent with the DOH model. In Chapter 2 and 3 we demonstrated that DFO staff and contract biologists who conduct salmon work perceive health from a DOH perspective. This indicates that members within the organization are ready for a healthy salmon policy approach. We also discussed previously that there has been a recommendation in the Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River, for DFO to take a cumulative effects approach to salmon health (Cohen, 2012c), and that a proactive health perspective is a priority for the Prime Minister of Canada (Prime Minister of Canada, 2016). In Chapter 4, we identified several court cases that demonstrate that some citizens are unsatisfied with DFO's current approach to salmon health management and are calling for change (Hume, 2013; Marty et al., 2010; Nikiforuk, 2016), implying that they are ready for a shift away from the current health policy approach. We also demonstrated in Chapter 4 that although some gaps exist and the policies that govern activities for each DOH category were isolated, with some effort to shift perspectives and expansion of consideration of the cumulative impacts of policies, DFO could adopt a healthy salmon policy approach.

This chapter will focus on steps 2 and 3 of the Public Health Ontario framework; assessment of readiness for policy development and development of goals, objectives, and policy options. We evaluated these steps of the framework in reference to the Chilko Lake sockeye salmon (*Oncorhynchus nerka*) population. It was not our intention to select indicator measurements or identify thresholds, but to test the general principle of applying a DOH approach and healthy policy development framework by determining the availability of components for a specific case.

The Chilko lake population was chosen as it was identified as being the population of Fraser River sockeye with the most available and diverse data, (S.C.H. Grant, Program Head of Sockeye and Pink Salmon Analytical and Fraser River Stock Assessment for Fisheries and Oceans Canada, personal communication, December 16, 2016). The Chilko lake population has the longest time-series of data starting from 1948 (S.C.H. Grant, personal communication, December 16, 2016). We chose to conduct the case study on this population because if the information was not available for this population, then it would be unlikely that sufficient information would be available for more data-deficient populations.

Chilko Lake is situated in the Pacific Ranges of the Coast Mountains and covers 182 km², being 60 km long by 3 km wide (Desloges & Gilbert, 1998). The Chilko Lake sockeye stock

utilize the Chilko River watershed for spawning and their juvenile freshwater phase (Fisheries and Oceans Canada, 1995). The Chilko River watershed is situated in the Chilcotin region of British Columbia, Canada (Fisheries and Oceans Canada, 1995). Chilko sockeye salmon contribute approximately 30% of the total abundance in of Fraser River sockeye salmon most years (Fisheries and Oceans Canada, 2015b). The Fraser River sockeye salmon were the subject of the Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River, a document that is a significant DFO policy driver.

We assessed the readiness for adopting a DOH based healthy policy approach by determining the availability and ability to describe and link data on the determinants of salmon health for the Chilko Lake sockeye salmon population. We identified if programs and policies relevant to the Chilko population have goals, objectives and options or opportunities to evolve into a healthy salmon policy approach. When combined with the results of Chapters 2-4, the results will help us determine if DFO is ready to implement an innovative healthy policy approach based on a DOH model.

5.2 METHODS

5.2.1 Framework for Healthy Salmon Policy

Steps one and two of the Public Health Ontario framework (readiness assessment, and defining goals, objectives, and policy options) are described in Table 5-1. Guided by the component or focus information provided in the Public Health Ontario framework, we identified both DFO organizational and Chilko Lake sockeye salmon information that could be used to evaluate DFOs readiness. We used data gathered in the previous three chapters as well as additional information collected, as described below, to conduct the assessment.

5.2.2 Assessing the Readiness for Policy Development

Chapter 4 established that DFO had a suite of policies that could serve as the foundation of a healthy salmon policy approach but did not establish if those policies were translated into actions that generated information that could be used to measure and manage across all DOH. In this step of the assessment, we focused on operational readiness in terms of evidence that DFO monitored, measured and or managed across all DOH for the Chilko population.

We searched for documents containing the word “sockeye” in the title on DFO’s Canadian Science Advisory Secretariat website (Fisheries and Oceans Canada, 2018b). The Canadian Science Advisory Secretariat is responsible for the schedule, policies, and directives of

the DFO, and is the body that publishes the pre-season return forecasts. Pre-season return forecasts were important documents as they represent the monitoring activities of DFO for the Chilko Lake sockeye salmon population and have been published yearly and are available online starting from 2000 (S.C.H. Grant, personal communication, December 16). We included all research documents, science advisory reports, and science responses. These documents were then searched for the word “Chilko”. A total of 43 documents were identified for further evaluation including 18 run forecasts documents from 1998-2018 and 25 other documents. We excluded papers that only presented Chilko Lake data as a comparison population (ex., Status of Cultus Lake Salmon; Bradford et al. 2010).

We also searched peer-reviewed literature to identify other public sources of data related to the Chilko lake sockeye salmon population. Using the search terms “sockeye AND Chilko”, we used the USearch search engine through the University of Saskatchewan’s library. The USearch search engine has access to a variety of data bases, including those commonly used in biology research like Web of Science, Ovid, and Scopus. We limited results to peer-reviewed journal articles published between 1997 and 2017 in English. At the time of the search, 133 results were returned. After duplicates were removed, 125 articles remained.

These 125 articles were evaluated for the following inclusion and exclusion criteria. To focus the data review on the Chilko lake population specifically, papers that only included “Chilko” in the references were excluded in the evaluation. We only included papers that presented or used data on the Chilko population. This meant that we did not include sources that only mentioned Chilko lake salmon in the introduction or discussion of the paper. To reduce repetition of the same data, we also excluded review papers and meta-analyses of already published data. Forty-five peer-reviewed journal articles met these criteria.

The content of the selected 35 DFO documents and the 45 journal articles were then assessed to determine if there was a sufficient breath of information on the DOH to support an evidence-based healthy salmon policy approach. It was not our intention to assess the biological data, but rather identify parameters around collection of the available data. Firstly, the available data on Chilko sockeye salmon was categorized into the six DOH themes: abiotic environment, social environment, needs for daily living, biological endowment, direct mortality pressure, or human expectations. Depending on what was measured and reported in the papers, it was possible for the papers to fall into more than one DOH category. Secondly, we identified the

regularity at which the study and/or data collection occurred and for how long the data were collected. Thirdly, the source of the data was identified for each journal article. A number of studies did not collect all of the data themselves, for instance many relied on information from DFO datasets. Finally, we assessed if the sampling methods used for the Chilko Lake sockeye salmon population were clear and available. To do this we identified the population sampling method, which populations were sampled, the age groups, and where the study took place.

We identified the policy goals and objectives included in the DFO documents by searching these documents for the words “goal”, “objective”, and “target”. The sentences that included these words were assessed to determine if the goal was related to the general health of salmon or to one of the drivers of salmon health established in Chapter 2. We also conducted a search on the DFO website with the terms: “health”, “salmon”, “policy”, “Pacific salmon”, AND “objective”. Results that were outdated reports, updates, or plans (for years prior to 2017) or archived documents were excluded. This was done to ensure we reviewed DFO’s most current policy objectives. Species-specific documents that did not pertain to Pacific salmon were also excluded. We searched the included DFO documents for the words: “goal”, “objective”, and “target”. The sentences that included these words were assessed to determine if they were referring to an overarching DFO goal, a health-specific objective, or a population target.

5.3 RESULTS

5.3.1 Readiness for Policy Development

Data from DFO pre-season return forecasts, other DFO documents, and peer-reviewed literature covered aspects of all six DOH themes (Table 5-2). The annual pre-season return forecasts for the Fraser River Sockeye salmon, published most years by DFO, included information on four of the six of the DOH, while the other DFO documents cumulatively contained data on all six DOH (Table 5-2). The pre-season return forecasts use historical data and information on the salmon populations from previous years to predict how many adults will be returning to their natal streams and lakes to spawn (Fisheries and Oceans Canada, 2018g). The 45 reviewed journal articles contained data on five of the six DOH, including abiotic environment, social environment, needs for daily living, biological endowment, and direct mortality pressure (Table 5-2). Human expectation was the only DOH not covered by the available peer-reviewed literature on Chilko Lake sockeye. Biological endowment was the most thoroughly covered DOH in the peer-reviewed literature, with 43 of the 45 papers including

some measure addressing this determinant. Data were available for many of the drivers of Fraser River sockeye salmon health that were identified during the expert network analysis in Chapter 2 (Table 5-3).

There were no data available in the DFO pre-run forecasts nor the 45 reviewed papers that addressed anthropogenic pressures or pollution (both abiotic DOH; Table 5-3). These were the only two expert-identified drivers of salmon health identified in Chapter 2 where no data were available for Chilko Lake sockeye salmon. For the remainder of the expert-identified drivers of salmon health, there were varying amounts of information available for each of the DOH categories (Figure 5-1). While the peer-reviewed literature provided more coverage on the biological endowment and direct mortality pressure aspects of salmon health, the DFO documents presented more data on abiotic environment, needs for daily living, social environment, and human expectations (Figure 5-1).

Table 5-4 summarizes the features of the various DOH measurements found in the pre-run forecasts, other DFO documents and peer-reviewed literature. There was no consistency across studies in terms of the spatial and temporal scale of measurements, frequency of measurement, life-stage measured, and sampling method. The studies took place across multiple life stages, geographic boundaries, and time intervals. No one study presented a cumulative perspective or an integrated summary of the data, however the pre-season run forecasts did provide information from many of the DOH categories, across age groups and geographical range, and the authors synthesize the variety of information in a discussion.

5.3.2 Goals, Objectives, and Policy Options

At the national level, DFO has general goals for health. The 2017-2018 departmental plan stated “the overarching goal of [DFO] is to protect Canada’s three oceans, coasts, waterways and fisheries and ensure they remain healthy for generations” (Fisheries and Oceans Canada, 2018c). There were no specific objectives or target thresholds associated with this goal. Another national DFO target was to protect 10% of marine and coastal areas by 2020 in Canada, in an effort to conserve sensitive marine ecosystems (Government of Canada, 2011). Although health was not explicitly stated in this goal, it is pertinent to salmon health when applying a DOH perspective. Under the Health of Animals Act (Minister of Justice, 1990), DFO and the Canadian Food Inspection Agency have implemented the National Aquatic Animal Health Program (Fisheries and Oceans Canada, 2018e). This program is designed to meet the World Organization for

Animal Health standards for preventing “the transfer of pathogens of international concern” both to and from Canada ((Fisheries and Oceans Canada, 2018e). The goals of this health program were focused on the absence of pathogens, rather than a DOH approach to health.

There were also salmon-specific DFO health objectives, which would pertain directly to the Chilko Lake sockeye. A primary goal of Canada’s Policy for Conservation of Wild Pacific Salmon (hereafter abbreviated as the Wild Salmon Policy), was “to restore and maintain healthy diverse salmon populations and their habitats for the benefit and enjoyment of the people of Canada in perpetuity” (Fisheries and Oceans Canada, 2005, p. 8). The objectives for the Wild Salmon Policy are to safeguard the genetic diversity of wild Pacific salmon, to maintain habitat and ecosystem integrity, and to manage fisheries for sustainable benefits (Fisheries and Oceans Canada, 2005). This document and other policies did not explicitly mention the Chilko Lake sockeye salmon population. None of these goals that stated health as an objective provided a definition or parameters for measuring health.

The pre-season return forecasts did mention the Chilko Lake sockeye salmon population and included some goals and targets. These goals and targets are not health-specific goals, but rather focused on production parameters such as escapements or adults returning to spawn. Some other DFO documents also report success as numbers of escapements (de Mestral Bezanson et al., 2012; Grant & Pestal, 2012). In addition to these production-focused targets, some DFO documents contained goals and measurements for water quality, water temperatures (Martins et al., 2011), and freshwater and marine survival (Fisheries and Oceans Canada, 2015b).

5.4 DISCUSSION

Although some gaps exist in bringing everything together, there is a substantial foundation of goals and perspectives within DFO from which to build a healthy public policy approach to salmon health (Table 5-5). The data from this and previous chapters demonstrate that both stakeholders and the organization are conceptually ready for a shift in policy towards a DOH perspective. Although we did not complete an exhaustive survey of stakeholder readiness for a shift towards a DOH-informed healthy salmon policy, the political motives, recommendations from a commission into Fraser River sockeye salmon declines, public expectations for broader accountability and action (Chapter 4), plus the contrast between how biologists perceive salmon health and how it is addressed in policy (Chapters 2 and 4), indicate the stakeholders are ready for a change in DFO’s approach to health policy. An exhaustive

assessment of stakeholder readiness assessment would have included further consultation directly with members of the community to determine receptivity to the DOH approach (Public Health Ontario, 2013).

In moving from fish health policy to healthy salmon policy, the emphasis shifts from the planning, funding, and delivery of disease management services to a much wider range of ecological, social, environmental, and political forces that have an impact on the health of individuals and the broader population. DFO has a suite of policies outside the formal health sector that have an impact on health, such as those influencing habitat protection and fisheries pressures (Chapter 4). A health agenda has been set in guiding policies like the Wild Salmon Policy and in directions to the Minister of Fisheries (Chapter 4). However, guidance on what constitutes health remains limited to absence of disease or sustainable returns for fisheries. Despite mentioning health as a goal in various documents, such as in the Wild Salmon Policy (Fisheries and Oceans Canada, 2005), the Healthy Coasts and Oceans Program (Natural Resources Canada, 2017), and the current DFO departmental plan (Fisheries and Oceans Canada, 2018c), the objectives for measuring health are vague and undefined. Although there are thresholds for fishable or sustainable numbers of returning Pacific salmon (Fisheries and Oceans Canada, 2014, 2015b), levels of acceptable toxins or pollutants in waterways, and measures of biodiversity (Fisheries and Oceans Canada, 2013), they are not framed as related to health. To meet the DFO objective of creating policy and subsequent management strategies that are transparent (Fisheries and Oceans Canada, 2018i, 2018c), a clear definition of health, health goals, and objectives of healthy salmon policy are necessary. It was beyond the scope of this study to outline these definitions and goals; delineating such objectives and targets must be done by the governing bodies in consultation with their stakeholders (Gagnon, Kouri, & Burtan, 2008; World Health Organization, 2010).

For a policy to have an impact, decisions have to be made after agreeing that an issue requires action and information has to be available for analysis on the range of possible responses (Fafard, 2008). Information on a wide suite of variables related to all DOH themes could be found for Chilko sockeye salmon. Between the information on Chilko Lake sockeye salmon that DFO regularly collects, and one-off scientific projects, there is a large variety in the types of variables that can be monitored or assessed. Much of the available data related to abiotic environment, needs for daily living, and social environment are measured regularly. Regular

monitoring of that information, and evaluation of the information in the health framework, could provide guidance for when interventions might be required. Although many of the reviewed sources contained information on Chilko Lake salmon's needs for daily living, the majority of those variables were water temperature related. More coverage on the availability and quality of food sources may be a useful for gauging the future health as population trends often follow the performance of food sources (Hone & Clutton-Brock, 2007), although there will be a trade-off between acquiring more knowledge and financial and resource investment. There was minimal information available for the human expectations component of health. More data should be collected here to inform decision makers on stakeholder expectations and acceptable thresholds for other indicators (Eyles & Furgal, 2002; Turnhout, Hisschemöller, & Eijssackers, 2007). Consultation of the various stakeholder groups would also help to guide which variables within each of the DOH categories are most important or valued (Eyles & Furgal, 2002; Raby et al., 2015). The available variety in potential health-monitoring data may provide DFO with the opportunity to develop healthy salmon policy objectives that are specific, measurable, acceptable, realistic, and time-bound; essential components of useful policy objectives (Public Health Ontario, 2013; Statistics, 2009). By gauging policy objectives on these criteria, development of effective and useful policy is possible (Gagnon et al., 2008; Public Health Ontario, 2013).

Measurable and actionable objectives in the other DOH categories will be important for making proactive evidence-based policy recommendations (Head, 2013; Newman, Cherney, & Head, 2017). Most of the available data collected on the Chilko Lake sockeye salmon population was focused on various survival ratios (ex., escapement, fry survival, juvenile marine survival, spawning success, recruitment, etc.). These types of data reflect cumulative health outcomes but do not provide insights into how the DOH are changing and thus possibly affecting future outcomes. Some currently measured DOH variables that may be of use are zooplankton abundance and various water quality parameters which could inform actions around habitat management and restoration.

We were unable to find many definitive thresholds for action for the available data. In the pre-season return forecasts, DFO biologists predict numbers of returning salmon and report whether it is increased, declined, or remained steady in comparison to previous years. This information is used to make management decisions about recreational and commercial fishing

quotas on a case-by-case basis (Fisheries and Oceans Canada, 2018g). We were not able to find actionable thresholds for other parameters. Although gaps do exist in how and what is measured for each of the DOH categories for Chilko Lake sockeye salmon, and how that data might be utilized for informing policy decisions, there is information available for each DOH category.

None of the identified data sources bring the information together as a cumulative assessment, although some documents, such as the pre-season return forecasts, include information from several DOH categories. The information that is gathered on Chilko Lake sockeye salmon is diverse and extensive, but various logistical issues exist that DFO would need to address if they were to attempt to consolidate the data into a single measure of health. The data covers a life-course, but with different individuals. It also is collected at varying time intervals and at different geographical locations. Uncertainty is commonplace when it comes to collecting data for free-ranging species, particularly with timescales (Lachish & Murray, 2018). Developing a comprehensive view of the state of health of a population, however, does not require that all data be collected at the same time, in the same place. Health indices are typically made up of a number of carefully selected indicators that are measured over time (Pampalon et al., 2005) and acknowledge that there is no one definitive measure of health (Kindig & Stoddart, 2003). The intention of the DOH approach is not to provide a single summative measure of health, but given the immense spatial and temporal challenges of integrating data on a large scale, the DOH model aims to identify the changes in patterns over time for the DOH indicators (Kindig & Stoddart, 2003). In developing an index for a complex issue, such as health, it is important to define the priorities, expectations, and goals for the index (Frankish et al. 1996; Hancock et al. 1999). Because of the contextual nature of health, it is not possible to create one single index of health with universal indicators or measures (Briggs, 2008; Jayasinghe, 2011).

Health indices are tremendously useful for facilitating benchmarking on complex issues (Lowndes et al., 2015), guiding assessments over time (Rapport & Hildén, 2013), and creating adaptive and responsive management strategies (Briggs, 2008). In humans, for instance, frameworks exist for measuring and tracking how populations are doing with regards to the DOH categories. The Canadian Index of Wellbeing is one example of such a framework (Canadian Index of Wellbeing, 2018). This index exists to “understanding the interconnectedness of many aspects of wellbeing and using it to fuel evidence-based and community-focused decision-making.” (Canadian Index of Wellbeing, 2018). The Canadian Index of Wellbeing was created to

measure social progress, quality of life, and overall wellbeing in a rigorous and comprehensive way (Canadian Index of Wellbeing, 2018). The index includes 64 separate indicators distributed across eight interconnected categories. Although this multi-factorial health index attempts to develop a shared vision and common standards for collecting and collating information on population well-being, there is ongoing discussion about trade-offs between single-item and multi-item scales (De Boer et al., 2004; Helliwell & Barrington-Leigh, 2010).

Due to the innate contextual complexities of health, it is important that health indices be developed on a case-by-case basis in collaboration with stakeholders (Briggs, 2008; Kreuter et al., 2004). This context-driven approach is also an innate component of cumulative effects assessments where boundaries are defined, and problems scoped as the initial step of the process (Smit and Spaling 1995; Hegmann et al. 1999). By using a DOH framework that is adaptable to the Chilko Lake sockeye salmon context, it may be possible to use existing data, hopefully with some supplementation, to develop a salmon health framework that is consistent with expert and stakeholder expectations.

The purpose of a healthy salmon policy approach could be to have the evidence and mechanisms to influence public policies of government sectors other than the fish health sector so as to produce an effective, coherent and integrated response to the various problems and issues of concern to salmon health (Gagnon et al., 2008). A significant challenge to implementing a healthy salmon policy approach would be the lack of mechanism for integrated governance across programs in DFO and across other government portfolios, and a need for dedicated leadership. We failed to find mechanisms in policy or the case study to link information, actions, and recourses across the programs impacting various salmon DOH.

Using a DOH, or multifactorial, context-adaptable approach to the population health of Chilko Lake sockeye salmon is consistent with integrated governance for health and cumulative effects assessments. Integrated governance is foundational for the development and implementation of healthy public policy (Gagnon et al., 2008). Integrated governance is “an action initiated and developed by a public agency striving to integrate the actions of other actors around the same problems” (Gagnon et al., 2008, p. 3). In public health, collaboration and cooperation between different sectors of government is critical for improving health outcomes (Fafard, 2008; Gagnon et al., 2008). This is because the goal of healthy public policy is to affect policy in other sectors (Gagnon et al., 2008). Management of cumulative effects also requires

integrated governance arrangements across sectors in order to impact the various ecological components at play (Kristensen, Noble, & Patrick, 2013; Wells, 2003). In order to successfully implement healthy public policy for Pacific salmon within DFO, it would be necessary to develop formal working relationships and agreements for integrated governance with the multiple branches of the ministry that manage the drivers of salmon health.

If DFO aspires to pursue the development of a healthy salmon policy, building on the existing foundation of practice, it would be necessary to remedy some issues and consult with stakeholders. The largest hurdle would be to develop clearly defined goals and objectives that are specific, measurable, acceptable, realistic, and time-bound. It would also be necessary to involve personnel from across the different sectors of DFO to ensure that the multiple components of DOH are integrated into DFO healthy salmon policy priorities (Kemmer, 2001).

Table 5-1. Descriptions of steps 2 and 3 from Public Health Ontario’s 8-step framework for developing a healthy public policy (Public Health Ontario, 2013).

Step	Description	Components or Focus
2) Assess the readiness for policy development	Decide whether to proceed with policy development. Determine if the stakeholders are ready for a specific policy and if the policy-making organization is ready to lead or support the process	Identify the forces that will either “drive” or “restrain” the process of implementing the policy, at both stakeholder and organizational levels
3) Develop goals, objectives, and policy options	Clear objectives and goals must be defined for the policy change	Clearly state the goals of the policy, outlining the direction and desired achievements; Establish the desired impacts and effects of the policy

Table 5-2. Coverage of determinant of health categories by Chilko Lake sockeye salmon (*Oncorhynchus nerka*) data in peer-reviewed literature, Fisheries and Oceans Canada (DFO) pre-season return forecast reports, and other DFO documents.

Determinant of Health	Peer-Reviewed Literature	Pre-Season Return Forecasts	Other DFO Documents
Abiotic Environment	√	√	√
Social Environment	√	√	√
Needs for Daily Living	√	.	√
Biological Endowment	√	.	√
Direct Mortality Pressure	√	√	√
Human Expectation	.	√	√

Table 5-3. Types of measurements available for drivers of health for Chilko Lake sockeye salmon (*Oncorhynchus nerka*) found in peer-review literature, Fisheries and Oceans Canada pre-season return forecasts, and other Fisheries and Oceans Canada documents. Determinants of health themes and expert identified drivers were identified in Chapter 2.

Determinant of Health Theme	Expert-Identified Drivers of Salmon Health	What was measured in the reviewed documents
Abiotic Environment	Anthropogenic	-
	Pollution	-
	Fresh Water Quality	Water temperatures, levels, and flows
	Climate	Air temperature and water temperatures, levels, and flows
	Temperature	Air and water temperature
Needs for Daily Living	Habitat Quality	Water temperature, levels, and flows, algal blooms
	Marine Habitat Quality	Water temperature, ocean climate and weather patterns, phytoplankton density,
	Food Quality & Quantity	Freshwater limnology: zooplankton abundance, food web productivity, photosynthetic rates
Biological Endowment	Disease	Ribonucleic acid expression and histopathology
	Pathogens	Ribonucleic acid expression and histopathology
	Stress	Physiology: ions, metabolites, steroids, glucose, fat reserves
	Genetics	Various genetic markers including those for cardiac mRNA and multiple polymorphisms

Table continued on following page

Table 5-3 Continued

Determinant of Health Theme	Expert-Identified Drivers of Salmon Health	What was measured in the reviewed documents
Social Environment	Abundance	Stock-recruitment, escapement, pre-spawn spawner success (egg retention and viability; construction and deposition of eggs, egg:fry, egg:smolt survival)
	Intraspecific Competition	Migration speed and travel times, distribution within the Strait of Georgia
	Demographics	Pre-spawn, fry, and freshwater vs. marine survival
	Interspecific Competition	Bull trout stomach contents, scale growth compared with pink salmon
Direct Mortality Pressures	Fishing	Escapement, marine survival
	Predation	Smolt behaviour, escapement, marine and freshwater survival
Human Expectation	Hatchery	Stock-recruitment, time series smolt data

Table 5-4. Summary of the characteristics of available data for Chilko Lake Fraser River sockeye salmon (*Oncorhynchus nerka*) from 45 peer-reviewed journal articles and 35 Fisheries and Oceans Canada documents.

	Category	Peer Reviewed Sources (%)	DFO Sources (%)
Study data sources	Included Fisheries and Oceans Canada Data	21 (46.7)	-
	Only Fisheries and Oceans Canada Data	11 (24.4)	35 (100%)
	Multiple Source (may include DFO data)	13 (28.9)	-
	Collected Solely by the Investigators	21 (46.7)	-
Regularity with which the data is collected	One Study	29 (64.4)	-
	Ongoing	16 (35.6)	35 (100)
Duration of the study periods	Once	16 (35.6)	1 (2.9)
	Multiple Years	11 (24.4)	18 (51.4)
	Decades	8 (17.8)	6 (22.9)
	Retrospective	10 (22.2)	10 (28.6)
Salmon capture methods stated in the study	Yes	28 (62.2)	35 (100)
	No	17 (37.8)	-
Studies included data on these populations	Chilko Lake Population	12 (26.7)	-
	Multiple Populations	33 (73.3)	35 (100)

Table continued on following page

Table 5-4 Continued

	Category	Peer Reviewed Sources (%)	DFO Sources (%)
Study locations	Ocean	5 (11.1)	-
	River	5 (11.1)	-
	Laboratory	9 (20.0)	-
	River and Laboratory	5 (11.1)	-
	Ocean and Laboratory	2 (4.4)	-
	Ocean and River	2 (4.4)	25 (71.4)
	Ocean, River, and Laboratory	1 (2.2)	10 (28.6)
	Does Not Specify	16 (35.6)	-
Age group of study population	Gamete	1 (2.2)	-
	Smolt or Juveniles	9 (20.0)	-
	Smolt or Juveniles and Returning Adult	4 (8.9)	29 (82.9)
	Smolt and Adult	2 (4.4)	-
	Adult	2 (4.4)	-
	Returning Adult	11 (24.4)	6 (17.1)
	Does Not Specify	16 (35.6)	-
	Population sample method was stated	Yes	20 (44.4)
No		25 (55.6)	-

Table 5-5. Summary of Fisheries and Oceans Canada readiness to adopt a healthy salmon policy based Public Health Ontario’s 8-step framework for developing a healthy public policy (Public Health Ontario, 2013)

Step	Component	Assessment
2) Readiness for policy development	Mechanisms to collect appropriate information	<ul style="list-style-type: none"> - Data are generated on all determinants of health but information is spread across sources and collected at different times, locations and with different methods - No system to integrate the information into a single comprehensive health perspective
	Motivation and readiness to change	<ul style="list-style-type: none"> - Political motivation for a cumulative approach to health exists (Chapter 4) - Researchers and biologists perceive health as a cumulative effect (Chapter 2 and 3)
3) Goals, objectives, and policy options	Goals and objectives	<ul style="list-style-type: none"> - High level goals prioritize health - Local and regional goals focus on salmon returns and absence of disease - No definition of health as a cumulative effect or product of DOH
	Policy options	<ul style="list-style-type: none"> - Wide suite of policies cover most DOH (Chapter 4) - No mechanisms to link policies and programs (Chapter 4)

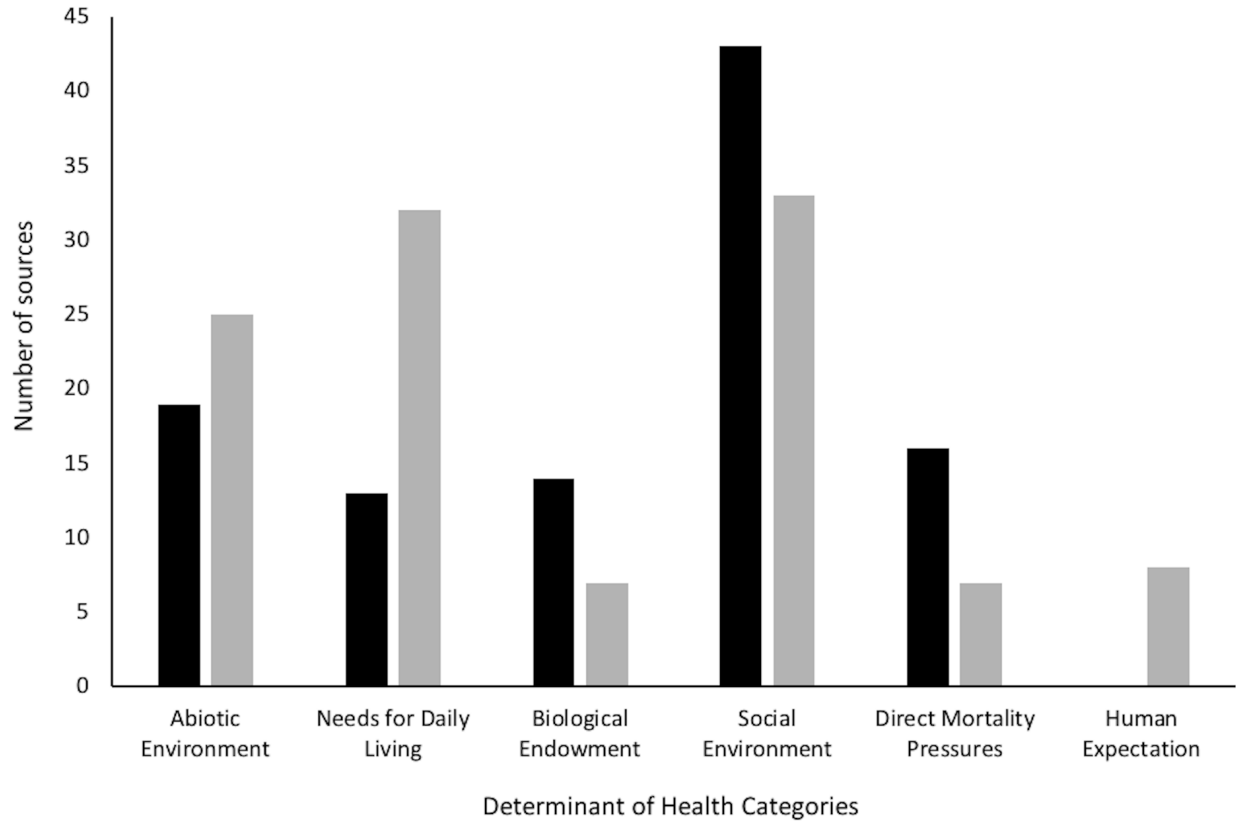


Figure 5-1. Distribution of variables measured in the 45 peer-reviewed literature (black bars) and 35 Fisheries and Oceans Canada pre-season return forecasts and other documents (grey bars) for Chilko Lake sockeye salmon (*Oncorhynchus nerka*). The assessed documents qualified for a determinant of health category if they contained one or more applicable variable, as discussed in Chapters 2 and 3.

CHAPTER 6: DISCUSSION

6.1 INTRODUCTION

The determinants of health model (DOH) has been used in humans to assess and manage health as a cumulative effect. In this thesis, I asked the question “can a DOH approach be adapted to wildlife populations?” I set out to investigate whether support existed for a theoretical and conceptual foundation for shifting towards a population health and healthy policy approach in fish and wildlife and whether it could be useful. The research in this thesis proposed and assessed the feasibility of a model that conceptually meets the need for a holistic approach to health in wildlife, called for by previous authors.

This work moves beyond outlining the historic wildlife health paradigm by being the first to identify the foundation and feasibility of using a DOH model. The flexibility both in adaptability to different populations, stakeholder, managerial priorities and political and situation contexts (Chapter 3 and 4; Butler-Jones 1999; Jayasinghe 2011; Hennessy et al. 2015), and the ability to prioritize which elements of health are most pertinent to the policy goals or population (Chapter 2, 3, and 4; (Bowman et al., 2012)) lends the DOH approach well to wildlife, where resources can be limited and species and populations diverse (Chapters 2 and 5). The DOH approach is consistent with cumulative effects thinking, including qualities that could be useful for addressing the issues and problems often confronted in wildlife health management. The DOH model was developed on the premise that health is complex and that more factors contribute to population health than only those of an individual’s biology (Jayasinghe, 2011). To deal with the complicated nature of population health, the DOH perspective aims to address the environmental and social components that impact the health capacity of a population, in addition to the biological aspects (Jayasinghe, 2011; Kindig & Stoddart, 2003). Wildlife exist in the same world as humans and, therefore, face similar abiotic, social, and biological pressures. These similarities made it plausible that a socio-ecological model for understanding health would be applicable across species. The types of questions that were asked in human population health that resulted in the development of a DOH approach are also similar to the types of questions being asked by recent authors of wildlife populations. For instance, Butler-Jones et al. (1999) highlighted the inadequacy of the disease-centric approach to health in humans, and recognized the roles that policies and programs can play in population health. Livestock health practitioners had the same revelation that a more proactive approach that addresses the external influencing

factors that impact health capacity could and should be incorporated into their practice in order to move beyond a reactive disease-focused approach (Radostitis et al., 1994). My thesis was an exploration of the adaptation and application of a well-used approach to population health to a new area of practice.

6.2 PRINCIPAL LESSONS

6.2.1 Chapter 2

In Chapter 2, I established that a *theoretical foundation* exists for the DOH model to be applied to wildlife. I found that a DOH model could be translated from human to wildlife populations. A conceptual model was developed using a scoping review on fish and wildlife health and resilience coupled with a participatory process with experts on caribou (*Rangifer tarandus*) and Pacific salmon (*Oncorhynchus* spp.) health. Both the literature and experts supported the concept of wildlife health as a cumulative effect. Six themes were associated with fish and wildlife health namely; (i) the biological endowment of the individual and population; (ii) the animal's social environment; (iii) the quality and abundance of the needs for daily living; (iv) their abiotic environment; (v) sources of direct mortality; and (vi) changing human expectations. These themes were shared between salmon and caribou and conformed with expert perceptions of health. This congruency demonstrates that the DOH model fits perspectives of health held in the field of wildlife management. The DOH conception of health may be useful for providing an operational definition of wildlife health, as current policies frequently states health as a goal but rarely define it. The DOH model produced in this study may be the foundation of a wildlife health planning tool that conceives health as a cumulative effect and helps to strategize and prioritise a suite of actions in a world of interacting DOH.

6.2.2 Chapter 3

I ascertained in Chapter 3 that a DOH network was *useful* for visualization of perceptions of health. The network approach to the DOH model was particularly effective for the identification of commonalities between disparate perspectives. I used the diagrammatic approach to network analysis to document how participants perceived the relationships between various determinants of salmon health, using two salmon health expert groups. The diagrammatic approach allowed me to visualize and make explicit peoples' opinions and perceptions of salmon health. The DOH framework provided a conceptual foundation that allowed people to develop a mental model and the network approach allowed those models to be

visualized in a way that captures a group's expertise into a single model. By weighting the most negative and positive drivers of salmon health and providing some context, including direction of relationships and interactions, we were able to get a rich description of health that could be compared across the two groups. The comparisons of the resulting descriptions of health demonstrated the shared perceptions of important health drivers between the groups. The DOH model may be a useful and transparent mechanism for fostering dialogue and shared visioning for health goals and priorities. There may be potential in using the DOH model for developing harm reduction programs or protocols. Using the DOH model for identifying areas of common perceptions and priorities could be the foundation for collaborative action.

6.2.3 Chapter 4

In Chapter 4, I identified the *policy need* for the development of a new approach to salmon health within Fisheries and Oceans Canada (DFO). The current default reliance on salmon returns and/or the absence of pathogens to declare if a population is healthy limits the scope of policy influence on assessment of salmon health. By combining a policy narrative review with Kingdon's (1984) multiple streams framework, it appeared that there is a policy need for DFO to adopt a DOH perspective of salmon health. A DOH approach may provide a framework for transitioning DFO from a fish health policy approach (which focuses on disease) to a healthy public policies perspective (that seeks strength across policy domains to secure the DOHs). The Canadian government and public are calling for a transparent and holistic approach to salmon health. The lack of a policy vision for salmon health as a cumulative effect of multiple, interacting determinants of health along with the political motivation to create one has produced the need for a new policy perspective on describing and identifying progress and priorities for protecting salmon health. The absence of an explicit framework to incorporate investigations of multiple stressors will complicate DFO's ability to demonstrate a health benefit of research or policy changes. The DOH themes could be used to identify how policies beyond the current explicit salmon health policies influence health and identify opportunities to integrate multiple policy domains.

6.2.4 Chapter 5

In Chapter 5, I established that taking a DOH approach to measuring and monitoring salmon health within DFO is *feasible* and that a foundation of practice exists. My goal in this chapter was to determine if a foundation for a healthy salmon public policy approach exists

within DFO. A healthy public policy approach involves coordinated action between all levels and sectors of policy makers to be aware of and take responsibility for how their actions effect the capacity of individuals and populations to be healthy. I used a case study approach, focussing my inquiries on the Chilko Lake sockeye salmon (*Oncorhynchus nerka*) population as they were the most data rich salmon run in BC. Although there were limitations in the integration of data and policies, and a lack of health definition for policy goal development (apart from salmon returns), we found that there was data available for the case population for all of the DOH categories along with political and organizational will for a change to a DOH perspective. In shifting from fish health policy to healthy salmon policy, the emphasis must shift from the planning, funding, and delivery of disease management services to a management of a much wider range of ecological, social, environmental, and political forces that have an impact on the health of individuals and especially of the broader population. My findings suggest that DFO has motivation and resources, to shift to a population health model for salmon.

I found a *theoretical foundation* for applying the DOH model to wildlife populations and demonstrated that it has the potential to be *useful*, to meet a *policy need*, and could *feasibly* be applied.

6.3 STAGE THEORY FOR ORGANIZATIONAL CHANGE

In this thesis I used the Stage Theory of Organizational Change (Butterfoss et al., 2008) to guide my investigation into the suitability, utility, and feasibility of a DOH perspective within the wildlife health community.

Stage one, the problem definition or awareness stage (Butterfoss et al., 2008), has been partly addressed by the previous authors, including Deem (2008), Hanisch (2012), and Stephen (2014), who have identified the constraints of a disease-focused approach to wildlife health. The second part of stage one involves identifying potential solutions for the problem (Batras et al., 2016; Butterfoss et al., 2008). While other authors have incorporated cumulative effects into assessments of wildlife populations (ex., Schultz 2010; Krausman and Harris 2011; Wilson et al. 2013) they have not explicitly used a health perspective. My research is the first to propose a potential solution, the DOH model as an innovation for shifting the paradigm within the wildlife health community towards a population health approach, thereby completing stage one. Chapter 2 demonstrated that the DOH approach was consistent with the body of literature on health and

resilience of caribou and salmon. This will help augment the acceptability of the DOH approach in the wildlife health community.

I addressed stage two of Stage Theory, the initiation or adoption phase (Butterfoss et al., 2008), by consulting with some stakeholders, reviewing policy, and inventorying DOH pertinent data. I also focused exclusively assessing the DOH model for wild Pacific salmon. Stage two is critical for identifying how the innovation could be implemented (Batras et al., 2016).

Proposed changes are more likely to be accepted and implemented if there is an existing foundation for it within the organization (Butterfoss et al., 2008). I demonstrated the potential usefulness of the DOH approach through a policy analysis and was able to identify where resources and data within DFO exist or could be developed for implementation of a population health approach, using a case study (Chapter 4). These attributes contribute to the feasibility and utility of the DOH approach to salmon health.

In addition to knowledge of how to implement an innovation, the attitudes within an organization are a critical component of whether or not an innovation is adopted, as “the decision to adopt... also requires attitude change” (Oldenburg & Glanz, 2008, p. 319). Buy-in from key players is imperative for a change within an organization to be successful and my findings suggest that many professionals within the field already support my proposed population health model. I demonstrated with the network analysis component of my research that the DOH reflects the current thinking of a set of fish health professionals. This further builds the acceptability of the DOH approach.

The third stage of Stage Theory is implementation of the innovation (Butterfoss et al., 2008). Although my thesis focused on stages one and two, the work that I have conducted may be useful for moving to stage three, which would be putting population health theory into practice for wildlife. With the information that I developed, I identified a conceptual and operational foundation for shifting towards a population health approach, including modifying current policy to fit a healthy policy framework. Innovation and change strategies are most likely to be effective and sustained when they target multiple levels within an organization (Embry, 2004). While my work has been necessary for laying the conceptual ground work for operationalizing a population health approach for wildlife, it is not sufficient to fully implement a DOH perspective.

6.4 LIMITATIONS AND FUTURE RESEARCH

There are two scholarly and three operational limitations that would need to be addressed in order to move implementation of a population health approach for wildlife forward.

The first scholarly limitation is that I was only able to apply the population health and healthy policy frameworks to barren ground caribou and salmon; and focused most of the investigation in one species (sockeye salmon). Although I chose very different species to test the adaptability of the DOH model, and my results conclude that the model was adaptable to these two species, it may not be advisable to directly apply my findings to another species. I cannot conclude that the DOH approach will work everywhere, and it should not be assumed that the model can be applied to other situations without further testing. In the future, the model should be applied and assessed with other species and social context, something that is achievable as demonstrated in Chapter 3 with the two salmon stakeholder groups, but potentially time consuming. The similarity between the salmon, caribou and human DOH models suggests a broad applicability of the DOH approach across species.

Health is a social construct. As such, it is not expected to find complete agreement nor a fully generalizable model that defines the attributes and thresholds for health. Furthermore, due to the social context of health and the overlaps in the functional definitions of the DOH themes, it is possible that a different observer may have sorted some drivers differently. This work, however, is consistent with philosophical and practical considerations encountered when developing health indices in any species, namely that despite agreement on thresholds, there is often agreement on the nature of determinants critical for population health (Xia & Tong, 2006).

There are also limitations to the peer-referred expert approach that we used. Our intention with this approach was to get a sense of how experts in the field of barren-ground caribou and Pacific salmon population biology and management perceive health for these animals. We employed peer-referential techniques to identify members of these groups as they are useful in the investigations of expert opinion in small populations when you want to ensure that a sizable proportion of the population is identified (Christopoulos, 2009). Although this approach for identifying participants was legitimate for the question that we were asking, there are some potential issues, including: overlooking the perspectives of un-involved stakeholders and the possible influence of “group think” (Shirey, 2012). As our objective was not to achieve consensus within a group, or to gain perspective into how all stakeholders perceive health, it was

appropriate to use the peer-referential methods we employed to target experts. I cannot conclude, however, that the results of the expert network analyses represent the opinions of all caribou or all salmon experts. It was clear in the comparison between the two groups of salmon experts that different groups are likely to have different perspectives on the same issue. If someone in the future wished to gain insight into how health in these populations is perceived by stakeholders at large, an alternative sampling technique would need to be used. The six primary DOH categories are unlikely to change between different species and contexts, but drivers of health within these categories and their relative importance will vary situationally.

There are many lessons to consider from the application of the DOH model in human populations. The ability to customize and adapt a framework to the needs and characteristics of a specific population is a key feature of the DOH model (Association of Faculties of Medicine of Canada, 2017). Public health programs are regularly developed based on priorities and goals identified using DOH frameworks (Arah, 2009). My thesis was the first time the DOH model was applied to wildlife populations, and while I was only able to adapt it for two species, the success of my research (and that done for people) suggests that the approach has considerable potential to be adapted for others.

The second scholarly limitation was the use of a best-case scenario when assessing available DOH data. Even with a best-case scenario, there were gaps in the available data for assessing the DOH for the Chilko sockeye salmon population. I would expect that if the DOH model were applied to a different wildlife population, there would be limited data available for the different drivers of health. Although developing a new program for measuring health-driver data may be unfeasible with the meagre time and resources often available to wildlife managers, the DOH approach may be a potential tool for dealing with uncertainty. Coping with uncertainty is an intrinsic component of wildlife management (Delahay, Smith, & Hutchings, 2009). One level of uncertainty is the issue of temporality. Over time, the DOH interact and influence each other over time (Hennessy et al., 2015; Kindig & Stoddart, 2003). The relationships in the expert network analyses were not evaluated for temporality. We assumed that the participants implicitly considered temporal complexity while completing the exercise, but we did not test this assumption. While evidence is important for making informed wildlife management decisions, there are other essential pieces of information that need to be accounted for. Context is a critical component to understanding health (Hancock et al., 1999; Public Health Agency of Canada,

2001), to evaluating cumulative effects (Baxter, Ross, & Spaling, 2001; Hegmann et al., 1999), and for making policy or management decisions (Hantrais, Lenihan, & MacGregor, 2015; Lenihan, 2015). The DOH model may have the potential to help identify both the evidence and context necessary for making informed management decisions by providing a framework for governments and stakeholders to clearly outline and define their priorities and goals.

Together, these two scholarly limitations mean that more work needs to be done to determine if the methods really are generalizable to different species. Although I have hypothesized that the DOH framework may have potential as a tool for identifying shared priorities between disparate groups of stakeholders, research needs to be conducted to evaluate how this could be implemented in other species and situations or in decision making.

I identified three operational limitations for implementing a DOH framework. The first issue is the lack of definition of health. Without a definition of health, developing achievable goals is incredibly difficult (Kindig & Stoddart, 2003; Nordenfelt, 2011; Stephen, 2014). A clear definition of health would be needed in order to develop the specific, measurable, attainable, realistic, and time-bound objectives needed for a successful healthy policy (Public Health Ontario, 2013). Creating transparent management policies and programs is also dependent on an explicit health definition (Stephen, 2014). Although health has no universal definition, it is possible to choose definitions and identify important parameters of health in order to measure progress towards a health goal. If a definition is not created for a circumstance, there is not a clear way to know if health policies or management interventions are having an impact on health. My research has developed a potentially useful tool for identifying the important drivers of health based on the concept of health as a capacity to cope.

The second operational limitation, related to the need for a definition of health, is the need to develop thresholds for success. Thresholds should be defined along with health goals and objectives to help guide policy and management actions. In relation to health objectives, a threshold might be a point at which data suggests movement from one classification to another (ex., healthy becomes unhealthy), or when an action should be taken (ex., harvest should be halted). Some thresholds already exist in relation to wildlife health and wildlife management, such as allowable air or water pollutants, or whether caribou or salmon should be hunted or fished. As seen in this research, the other definition of health used outside the wildlife health literature tends to focus on harvestability as the principle indicator. Trends or historical

information can be used to help define thresholds, however this type of information is not always available (Canter & Atkinson, 2011; Hegmann et al., 1999). When threshold selection is not obvious, there are more subjective means to define them. Hegmann et al. (1999, p. 47) suggests “consult[ing] various stakeholders, government agencies and technical experts” when there is an absence of defined thresholds. Including stakeholders may make defining thresholds more challenging, but it is important to integrate their values and expectations into the development of thresholds to improve the acceptability of the thresholds (Levac et al., 2010; Turnhout et al., 2007). Including stakeholders in the process of threshold setting was beyond the scope of my thesis. However, a DOH approach is often used in situations to help guide population health programs where thresholds do not already exist. For instance, the DOH model has been used in the Canadian Index of Wellbeing (Canadian Index of Wellbeing, 2018). In this example, the authors do not typically set definitive thresholds, but rather identify domains in which thresholds can be set. This is because setting thresholds for measures of health is a context specific endeavour (Hancock et al., 1999; Pampalon et al., 2005). For cumulative effects assessments of ecosystems, thresholds are set for indicators on a case-by-case basis (Canter & Atkinson, 2011; Canter & Ross, 2010). Setting thresholds in human assessments of wellbeing are dependent on population-specific information (Canadian Index of Wellbeing, 2018). In order to successfully implement a population health approach for wildlife, it would be important to develop thresholds for success along with a definition of health and health objectives for individual situations.

The third operational limitation to implementing a population health approach to wildlife is that there is no one designated to bring the various components of health together. Although I uncovered a few reports for both caribou and salmon that synthesize the various drivers of population health, I was unable to identify a department or position within DFO whose mandate is to advocate for wildlife healthy policy. The interdisciplinary nature of wildlife health makes it imperative that there is collaboration between historically divided departments and groups. As acceptance of an innovation within an organization is more likely to occur if the strategy targets multiple levels (Butterfoss et al., 2008), appointing someone to advocate for healthy wildlife policy may also help to accelerate the acceptance of the DOH model within organizations. In public health, entire health promotion programs exist to create, distribute, and implement programs that promote policies that benefit the health of a population to all sectors, not just those directly related to the medical field (Frankish et al., 1996). To successfully implement a

population health approach for wildlife, it would be necessary to have a liaison between the different departments or organizations who manage the various drivers of wildlife health.

6.5 MANAGEMENT IMPLICATIONS

Although it would not be possible to immediately implement a population health approach to wildlife using the methods proposed in this thesis, there is potential to use elements of the DOH framework I have developed. The main strength in my proposed approach to wildlife population health is that it represents an inclusive perspective to health that could be used to help open the dialogue about how health is perceived and managed by different groups.

The conceptual DOH framework is an opportunity to facilitate collaboration between disparate groups with vested interests in wildlife. Wildlife managers are often faced with making decisions in the face of uncertainty, and one element of that uncertainty is how their actions may be perceived by others (Delahay et al., 2009). The network exercise has the potential to be used to find shared health priorities and collaboration between different stakeholder groups. Identifying shared priorities might further be used to strategize implementation of harm reduction programs to conserve wildlife populations at risk.

The DOH model also benefits wildlife managers by reframing the health of populations as a positive construct. Health in wildlife populations has historically been focused on a reactive approach to disease and pathogens, with limited ability to take a proactive approach to enabling wildlife to cope with stress and change (Stephen et al., 2018). By using the DOH framework to shift the focus of what impacts health to include the external factors that enable a population to be healthy, a more positive perspective of what health is and how it is managed can be achieved. Viewing health in a positive light may open up more opportunities for potential management actions and how relevant policies are implemented.

Using the DOH framework to evaluate existing policy within DFO helped to identify potential areas for growth within government and targets for advocating in order to improve wildlife health. The results from the policy analysis I conducted in Chapter 4 amount to a take-home message that could be used immediately by DFO officials to guide their implementation of policy and adaptation of organizational structure in order to better serve the health of salmon. This policy work could also help address several elements and recommendations of the Cohen Commission, the largest public inquiry in Commonwealth history. Similar policy reviews could be conducted by other governments or departments to identify what actions could be taken to

support wildlife health in their already existing organizational mandates and structures. For instance, this type of approach could benefit the Pan-Canadian Approach to Wildlife Health, which was recently accepted by Canadian federal, provincial, and territorial ministers in 2018 (Canadian Wildlife Health Cooperative, 2018).

The DOH model could also be used to help describe and guide activities pertaining to wildlife populations and their health. The DOH framework has potential as a tool for identifying priorities within or between organizations. These priorities could possibly translate into how resources are distributed, programs are developed, activities are planned, and policies are implemented. More work needs to be done to test the usefulness of the DOH approach as a policy and management development tool, but given the contextual nature of health, I believe it has potential.

Application of the DOH framework in a wildlife population context represents an integrated and synthesized approach to planning. This is how the DOH model is used in people (Frankish et al., 1996). The entire premise behind health promotion and public health in human populations is that health is a positive construct that is impacted by various external factors, and can therefore be supported and managed through efforts in domains unrelated to disease care and the medical system (Frankish et al., 1996).

6.6 CONCLUSION

Wildlife health has been a reactive area of management and research, but with the massive global declines in various populations (World Wildlife Fund for Nature, 2016), there is an increasing need to take a proactive approach. The DOH model is a path forward to shifting perspectives to be more inclusive both about what health means as well as what impacts health and who can make positive changes to benefit wildlife. A cumulative effects, DOH, approach to health provides an opportunity for building resilience and the capacity for health, and also reflects the multifactorial viewpoints of experts on wildlife health (Patyk et al., 2015; Stephen et al., 2018). My thesis is a cutting edge and useful piece of work, pieces of which are already impacting how wildlife health professionals and government officials are thinking about wildlife health. As the DOH model is further tested and implemented in the context of wildlife populations, I believe more new opportunities for building health capacity will be identified.

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