Developing a baseline understanding of gill lice distribution, prevalence, and infestation intensity in the Upper Snake River Watershed

William Fetzer[1*], Robert Al-Chokhachy[2], Jeffrey Baldock[3], Clark Johnson[4], Diana Miller[4], Annika Walters[5], Chad Whaley[6]

1 Assistant Professor, Department of Zoology and Physiology, University of Wyoming, Laramie, WY
2 Research Fisheries Biologist, Northern Rocky Mountain Science Center, United States Geological Survey, Bozeman, MT
3 PhD Student, Department of Zoology and Physiology, University of Wyoming, Laramie, WY
4 Fisheries Biologist, Wyoming Game and Fish Department, Jackson, WY
5 Assistant Unit Leader, Wyoming Cooperative Research Unit, United States Geological Survey and Associate Professor, Department of Zoology and Physiology, University of Wyoming, Laramie, WY
6 Fisheries Biologist and Aquatic Invasive Species Coordinator, Grand Teton National Park, Moose, WY
* Author for correspondence: wfetzer@uwyo.edu

Abstract Climate change is altering temperature, precipitation, and snowpack dynamics, which will affect aquatic ecosystem thermal and flow regimes. Pathogens are an emerging threat that also has the potential to interact with climate change to affect fish population dynamics. Our research addresses: 1) What species of gill lice are present within the USR, 2) What is their distribution, prevalence, and infection intensity, and 3) Does gill lice infestation negatively affect metrics of fish condition? During 2020 and 2021, our team observed gill lice on 307 out of 7,255 fish inspected. Of twelve species inspected, gill lice were only observed on Snake River Cutthroat Trout and Mountain Whitefish. Our preliminary results suggest that the current distributions of gill lice within USR is primarily limited to the Snake River and immediately adjacent tributaries and infection prevalence and intensity remain low. While conditions in the USR have not reached the level of concern observed in other locations, a greater understanding of what factors could increase the extent and intensity of gill lice is needed to develop management strategies to improve the resilience of fish populations and communities to multiple stressors, including climate change, non-native species, and emerging pathogens.

Introduction

Multiple stressors are threatening freshwater ecosystem structure and function across the globe, negatively affecting ecologically, economically, and culturally important fish populations and communities. Despite a growing understanding of the effects of individual stressors on fish populations and communities, there is limited knowledge about the interaction of multiple stressors and the potential for synergistic or antagonistic effects. This knowledge gap complicates our ability to develop effective management actions to achieve desired outcomes when faced with multiple threats. Stressors of high concern in the Intermountain West include climate change, non-native species introductions, and pathogens. Climate change is altering temperature, precipitation, and snowpack dynamics, which will affect aquatic ecosystem thermal and flow regimes. Aquatic species' life history traits are adapted to their local and regional thermal and flow regimes to take advantage of seasonal changes in the availability of resources, such as prey, spawning habitats, and thermal refugia (Lytle and Poff, 2004). As a result, shifts in climactic means and increased variation associated with climate change are predicted to affect recruitment, growth, and survival of fish populations. These demographic shifts can alter age and size structure of populations, shift community composition, and in some cases, transition community dominance from native to non-native species. This interaction between climate change and non-native species poses a serious threat to native fish species persistence and resilience.

Pathogens are an emerging threat that also has the potential to interact with climate change to affect fish population dynamics. There has been a growing recognition of the importance of pathogens as drivers of fish population dynamics, likely due to both an increased understanding of pathogen biology and emergence of novel pathogens on the landscape. Fish pathogens negatively affect fish populations via effects on fish growth, fecundity, and mortality. Identifying how different drivers influence disease severity and the extent of an outbreak remains less clear. In many cases, multiple factors are interacting to drive the pathogenicity and virulence of a pathogen, including fish physiology, pathogen life history, and environmental conditions (Mitro, 2016). Thermal stress can affect the immune system of individual fish, increasing susceptibility to infection, disease development, and mortality (Bly et al., 1997). Temperature can also affect pathogen fecundity, developmental rates, and viability during free-swimming stages (Vigil et al., 2016). At the fish population and community level, the age and size structure of a population influences disease prevalence and community composition can affect disease susceptibility, pathogenicity and virulence, and transmission rates, which often differ across species. Shifts in species composition to communities dominated by susceptible, and often non-native, species can promote pathogens within waterbodies, increasing the distribution, prevalence, and intensity of infection for pathogens that pose threats to native fish populations (Mitro, 2016).

Climate-pathogen dynamics are relatively unstudied for inland fish populations. Gill lice are an emerging pathogen of concern in the Intermountain West that have the potential to negatively affect populations of iconic native salmonids across the region. While the exact mechanisms driving the increase of gill lice remain unknown, we hypothesize that climate, fish population and community structure (e.g., age/size structure, community composition, and ratio of native to non-native species), and gill lice biology are interacting to drive the distribution, prevalence, and intensity of gill lice infestations (Figure 1). While gill lice are proving to be problematic throughout the Intermountain West, it has only recently emerged as a concern for native fish conservation in the Upper Snake River watershed (USR), including Grand Teton National Park (GTNP). Gill lice were first observed in the USR by Wyoming Game and Fish Department (WGFD) fisheries biologists in 2011, but only limited data has been collected to establish a baseline understanding of gill lice in the Greater Yellowstone Ecosystem. This information will be critical to quantifying impacts of gill lice on native fish populations in the USR and assessing effects of climactic and biological drivers on gill lice biology. Furthermore, it will provide scientifically rigorous information to concerned stakeholders about interactions between gill lice and ecologically, economically, and culturally important Snake River Cutthroat Trout (SRC; *Oncorhynchus clarkii behnkei*).

Knowledge of gill lice in the USR is very limited despite WGFD fisheries biologists initially documenting gill lice on SRC at the spawning fish weir on Lower BarBC Spring in 2011. The percentage of fish with gill lice varies annually, with prevalence rates observed as high 30% in some years. Gill lice have been found on SRC in several other locations throughout the drainage; however, the extent of their distribution, prevalence, and infection intensity remains unknown. To date, no systematic studies have sought to develop a basic understanding of gill lice in the USR and the potential risks they pose to native fish populations. This information is essential to test hypothesized relationships between climate, fish population and community dynamics, and gill lice biology (Figure 1).

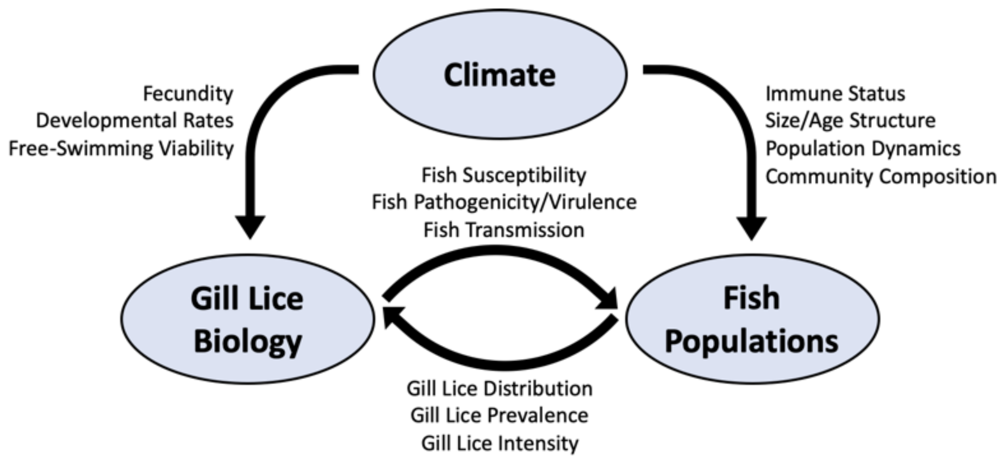

Figure 1. Conceptual figure of synergistic interactions between climate, fish populations, and gill lice biology that can affect the extent and severity of an outbreak.

Despite our expectations that the current distribution of gill lice is geographically limited and prevalence and infestation intensity is low in the USR, evidence from further downstream in the watershed suggests the potential for gill lice to increase in the near future. Immediately downstream in the Henry's Fork watershed, stakeholders have raised concerned about impacts of gill lice on local salmonids following observations of heavily-infested fish and projections of warmer stream temperatures, decreases in flow, and the potential for crowding of fish populations. Our research addressed the following questions: 1) What species of gill lice are present and what fish species are infected within Upper Snake River, Grand Teton National Park?, 2) What is the distribution, prevalence, and infection intensity of gill lice across species in the Upper Snake River watershed? Are these factors correlated with environmental predictors, such as stream temperature, order, and type, and 3) Does gill lice infestation negatively affect metrics of fish condition?

Methods

Fish community surveys were conducted in 2020 and 2021 within the USR. Surveys were led by GTNP, the United States Geological Survey (USGS), the University of Wyoming (UWYO), and WGFD, and included a variety of gears that target a range of fish species found within the USR (Table 1). Waterbodies included small and large lakes and streams. While each survey generally targeted a specific species (e.g., SRC), additional information on community composition was collected for a subset of surveys. Within each survey, we collected biological data on individual fish, such as length, weight, sex, and reproductive status (e.g., ripe vs. spent). In addition to the standard data collection for each survey, biologists assessed the presence/absence of gill lice on individual fish, and if detected, assigned an infection intensity score of low (1-5 gill lice), moderate (6-14 gill lice), or high (>15 gill lice) following the protocols outlined in Mitro and Griffin (2018). An individual fish for each species detected with gill lice was euthanized and frozen for future identification of gill lice to species.

Type of Waterbody	Year	Location	Number of Fish with Gill Lice	Total Number of Fish Inspected	Percentage of Fish with Gill Lice
Lake	2020	Dallas Lake	0	13	0%
Lake	2020	Lower Slide	0	133	0%
Lake	2020	Soda Lake	0	1	0%
Lake	2021	Cottonwood Lake	12	19	63%
Stream	2020	Flat Creek	37	406	9%
Stream	2020	Greys River	7	773	1%
Stream	2020	Gros Ventre River	0	334	0%
Stream	2020	Grouse Creek	0	3	0%
Stream	2020	Leidy Creek	1	5	20%
Stream	2020	Lower Bar BC	16	158	10%
Stream	2020	Rock Creek	0	4	0%
Stream	2020	Snake River	33	2504	1%
Stream	2020	Spread Creek	0	3	0%
Stream	2020	Spread Creek	0	130	0%
Stream	2020	Steer Creek	0	76	0%
Stream	2021	Grouse Creek	0	29	0%
Stream	2021	Hoback River	7	898	1%
Stream	2021	Leidy Creek	0	28	0%
Stream	2021	Little Grey's	0	205	0%
Stream	2021	Lower Bar BC	62	353	18%
Stream	2021	Nawlin Creek	3	14	21%
Stream	2021	Rock Creek	0	8	0%
Stream	2021	Salt River	101	659	15%
Stream	2021	Snake River	28	323	9%
Stream	2021	Steer Creek	0	82	0%
Stream	2021	Willow Creek	0	94	0%
		TOTAL	**307**	**7255**	**4%**

Table 1. Gill lice prevalence across the Upper Snake River watershed during 2020 and 2021.

At a subset of locations, we installed temperature loggers to model the effect of water temperature, stream order or lake size, and hydrologic source on gill lice distributions and prevalence using hierarchical multiple logistic regression. In locations where gill lice were present, we will evaluate the effect of infestation presence, intensity, and temperature on fish condition using multiple linear regression. Finally, we will integrate results from across fish community surveys into a map of the USR to communicate spatial patterns of gill lice distribution, prevalence, and infestation intensity. Data from 2020 and 2021 are currently being collated by UWYO during Fall 2021 and data analyses, report writing, and manuscript preparation will begin during Winter 2021-2022 and completed during the Spring and Summer 2022.

Preliminary results

During the summer and fall of 2020 and 2021, our research team inspected 7,255 fish within the USR for gill lice. Gill lice prevalence differed across years, with 94 out of 4,543 fish inspected containing gill lice in 2020 (2%) compared to 213 out of 2,712 in 2021 (8%; Table 1). This difference across years was also present in the number of waterbodies containing fish with gill lice, increasing from 4 out of 14 waterbodies in 2020 (29%) to 6 out of 12 waterbodies in 2021 (50%; Table 1; Figure 2). Interestingly, 2021 was a low water year with higher than normal temperatures throughout much of the USR; however, we have just recently compiled all the data and have not had time to develop models to evaluate the role of environmental conditions on gill lice prevalence and infestation intensity. In general, gill lice infestation intensity was low, with only a very limited number of individuals containing greater than five (5) gill lice. Across both years, 12 species were inspected for gill lice, including all the dominant recreational sportfish in the region, but gill lice were only detected on Snake River Cutthroat Trout (SRC) and Mountain Whitefish (*Prosopium williamsoni*). Identification of the gill lice species present on both species is ongoing, as our fish disease expert took a job out of state and we are trying to locate a replacement to ensure an accurate identification.

Conclusions

Results from 2020 and 2021 confirmed our a prior expectation that gill lice prevalence and intensity in the USR is low relative to observations from other locations (e.g., Colorado, Idaho, Wisconsin); however, preliminary results suggest low water levels and warmer water temperatures may facilitate gill lice expansions through increasing prevalence within and across waterbodies (i.e., gill lice prevalence within a site and percentage of sites with gill lice). Further work is needed to evaluate this hypothesis and we intend to test this by developing models to evaluate the role of environmental factors, such as temperature and stream order, on gill lice prevalence and infestation intensity. Climate change is projected to have significant impacts on the hydrologic cycle across the Intermountain West and USR, potentially increasing the suitability of the USR for gill lice and leading to higher rates of gill lice prevalence and infestation intensity. While we suspect the current impact of gill lice on fish populations in the USR to be minimal, further expansion could negatively affect fish populations in the USR. Data collected through this project will provide valuable baseline conditions to assess future changes in gill lice and their impacts on iconic fisheries in the USR.

Future work

Our long-term vision is to use preliminary data collected through our UW-NPS small grant program to compete for larger grants, such as those available through the WGFD, USGS, the National Park Service, and the National Science Foundation. Previous research suggests increasing temperatures and reduced flow associated with drought can interact with competition for space between native and non-native fish, leading to severe outbreaks of gill lice and negative population-level effects to native salmonids (Mitro, 2016). Though conditions in the USR have not reached this level of concern yet, a greater understanding of what factors could increase the extent and intensity of gill lice is needed to develop management strategies to improve the resilience of fish populations and communities to multiple stressors, including climate change, non-native species, and emerg-

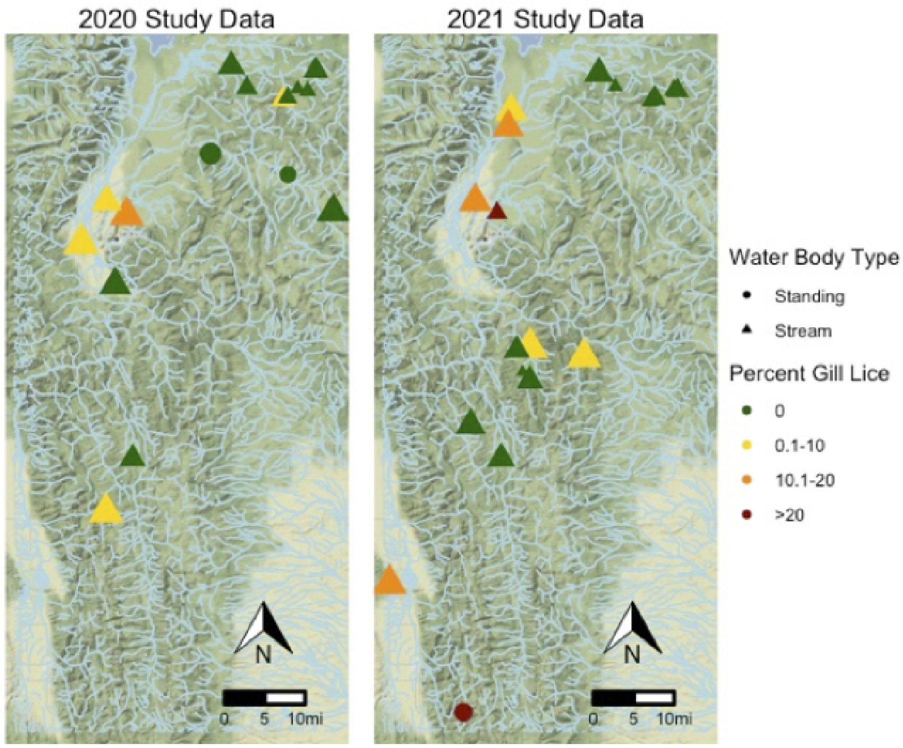

Figure 2. Gill lice prevalence in the Upper Snake River watershed during 2020 (left) and 2021 (right).

ing pathogens. Future studies to quantify impacts of gill lice on fish populations in USR are contingent upon developing a baseline understanding of gill lice biology. We intend to pursue additional studies to: 1) Assess relationships between environmental conditions and gill lice distributions, prevalence, and infestation intensity, 2) Quantify the impact of gill lice infestation on fish health, reproduction, and survival, and 3) Develop monitoring recommendations to track status and trends of gill lice in the USR. Additionally, we hope to collaborate with social scientists to conduct human dimensions research on stakeholder values, attitudes, and behaviors towards gill lice and evaluate how these metrics evolve if gill lice distributions, prevalence, and infestation intensity change.

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