M.S. THESIS PROPOSAL

Name: Nicole Doran **Faculty Adviser:** Mark Scheuerell **Date:** 2/17/23

This is to certify that this student's M.S. Supervisory Committee had read and approved the M.S. Thesis Proposal titled: "Viewing Heavy Metal Contamination of a Threatened Salmonid Through an Environmental Justice Lens"

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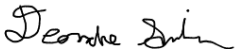
MEMBER	Deondre Smiles		2/2/2023
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Viewing Heavy Metal Contamination of a Threatened Salmonid Through an Environmental Justice Lens

Master's Thesis Proposal

Nicole Doran

The University of Washington
School of Aquatic and Fisheries Sciences

Committee:
Dr. Mark Scheuerell
Dr. Gordon Holtgrieve
Dr. Deondre Smiles

Introduction:

Anthropogenic forces have altered global ecosystems physically, chemically, and biologically through processes such as urbanization, industrial agriculture, and exploitation of natural resources (Vitousek et al., 1997). Studies in the environmental sciences have long sought to find solutions to the myriad problems faced by degraded ecosystems, and yet there has been little attention paid to the root cause of many of these problems: settler colonial political and industrial economic processes that necessitate physical and chemical manipulations of lands and waters (Reeder-Myers et al., 2022; Sluyter, 2001). The role of political dynamics in shaping the environment and subsequent distribution of societal impacts has become much more widely

recognized through the advancement of the environmental justice and political ecology fields (Bullard, 1996; Robbins, 2004). However, environmental injustice issues impacting Indigenous cultural sovereignty are relatively underrepresented in environmental justice literature (Hernandez, 2019; Norgaard et al., 2011). Within these gaps lie opportunities to further expand upon environmental justice studies by critically examining the role of settler colonialism in producing environmental injustice through multiple pathways beyond simple environmental contamination (Van Sant, 2021).

The pathways for environmental injustice on Indigenous Lands that I will explore include physical manipulation of aquatic environments, industrial contamination of waterways, introduction of non-native species, and extirpation of culturally significant species. The ecological impacts of these environmental changes have been studied in depth (Alava et al., 2017; Gallardo et al., 2016; Gallardo & Aldridge, 2013; Mattocks et al., 2017; Walsh et al., 2016), as has their implications on Indigenous water rights (Bray, 2021; Chandler, 1994; Chief et al., 2016; Gautam et al., 2013), but there has been relatively little discussion on how these environmental changes impact Indigenous cultural sovereignty. Thus, for the first chapter of my thesis, I will undertake a comprehensive literature review the ecological impacts of transitioning from Indigenous to settler colonial water resource management, as well as the connection between biological diversity and cultural diversity (Garibaldi & Turner, 2004; Wilder et al., 2016).

Waterways have been physically manipulated to promote industrial agriculture and settler colonial economies (McLeester et al., 2022; Wagner, 2008). Physically altering waterscapes impacts Indigenous Peoples' relationships to their lands and traditional knowledge systems. The environmental injustice produced by dam construction, in particular, has been thoroughly discussed in the literature, and so I will investigate how other forms of physical manipulation of waterscapes, such as draining of wetlands, canal construction, and large-scale flow diversions have produced environmental injustice for Indigenous Peoples. Industrial harvest of aquatic species has also had direct impacts on Indigenous Peoples' access to traditional resources, thereby infringing on cultural sovereignty by disrupting traditional foodways. The fur trade and industrial whaling industry are two examples of how settler colonial economies restricted Indigenous Peoples' access to traditional resources (Johnson-Bice et al., 2018; Lightfoot et al., 2013; Moerlein & Carothers, 2012).

The cultural sovereignty impacts of settler introduction of non-native species to waterways is severely underrepresented in the literature. Studies have shown that invasive species can have negative environmental impacts (Walsh et al., 2016); however, the consequences of settler colonialism in introducing non-native species has yet to be comprehensively reviewed. In this literature review, I will provide an overview of the literature that has discussed invasive species impacts on Indigenous Peoples, and ways in which Indigenous perspectives on invasive species may differ from settler colonial invasive species management approaches (Alexander et al., 2017; Reo et al., 2017).

Finally, chemical contamination of ecosystems is an issue that has been thoroughly examined through ecological science, environmental justice, and Indigenous sovereignty frameworks ((Taylor, 2014)). Environmental contamination is a universal problem that challenges the integrity and health of ecosystems globally, and thus affects the way humans interact with the natural resources we depend on for water, food, energy, and other ecosystem services. It is becoming more widely recognized that industrial contamination originates from capitalistic, extractive economies, and exerts disproportionate impacts on marginalized populations that have been disadvantaged by those same processes (Churchill & Laduke, 1983; Max Liboiron, 2021; Voyles, 2015; K. P. Whyte, 2019). Chemical contamination affects Indigenous Peoples' water security and food security due to traditional foods becoming unsafe for human consumption (Lewis et al., 2017; Takahashi et al., 2003; K. Whyte, 2018). However, Western science-based approaches to studying environmental contamination as it relates to Indigenous water and food security are inadequate in promoting environmental justice. Interrelated to these stressors to Indigenous cultural sovereignty is climate change, which is widely discussed in the literature regarding how it will disproportionately impact Indigenous Peoples, and so it will not be thoroughly discussed in this review (K. Whyte, 2017).

Standard risk assessments for the impacts of environmental contamination on human health are narrow in scope, and not inclusive of Indigenous communities that uphold multi-dimensional relationships with the environment (Carroll et al., 2017; Chiblow, 2019). Government agencies that propose fishing and water advisories have failed to create guidelines that are inclusive of Indigenous environmental perspectives and communicate the risks associated with industrial pollution to human health in culturally relevant ways (Chess et al., 2005). Another outcome of fishing advisories is the cultural loss associated with not being able to fish for traditional food sources (Donatuto et al., 2011; Roe, 2003). Settler colonial environmental governance has failed to uphold tribal sovereignty in preventing, mitigating, and resolving contamination issues by appropriating Indigenous lands to serve as sites of extraction, depositing hazardous waste, and experimentation with nuclear weapons (Voyles 2015, Taylor 2014). Integrating environmental justice frameworks to toxicology studies is vital to ensure studies on contaminants align with the perspectives and concerns of the impacted communities to produce equitable outcomes.

The second chapter of my thesis will serve as a case study for studying environmental contamination using western science methodologies with the goal of promoting Indigenous cultural sovereignty. I will conduct a study of heavy metal contamination in fishes from Lake Sammamish, Washington. Lake Sammamish is an urban lake in the ancestral lands of the Snoqualmie Tribe and is home to a threatened population of Kokanee salmon (*Oncorhynchus nerka*)(Berge et al., 2013). Kokanee are a culturally significant species as a traditional food source for the Snoqualmie Tribe, and so their persistence is important for maintaining Snoqualmie cultural sovereignty. The Kokanee declines are likely due to multiple factors aligned with those discussed above, including 1) physical manipulation of lake and stream shorelines that subsequently affects the connectivity of Kokanee's spawning habitat; 2) the introduction of

sportfish that prey upon and compete with Kokanee; and 3) environmental contamination from the extensive urbanization within the Lake Sammamish watershed as well as the persistence of legacy contaminants from historical industrial activity. The potential for contamination to making Kokanee unsafe for human consumption is a pressing concern of Snoqualmie Tribal members that hope to see a return of a traditional fishery, and so my research attempts to address those concerns by investigating the extent of total mercury contamination in the muscle tissue of Kokanee, as well as the other sportfish in the lake that people could be consuming. Environmental mercury concentrations from the water will be taken into consideration in analysis. To understand the relationship between urbanization and mercury contamination across the freshwater foodweb, results of total mercury concentration in fishes from Lake Sammamish will be compared to reference lakes across an urbanization gradient. Lake Washington and Lake Sammamish will represent highly urbanized systems. Intermediately urbanized and non-urbanized lakes for sampling will be identified in collaboration with our partners at Washington Department of Fish and Wildlife. Documenting mercury contamination in Kokanee will determine if Kokanee are safe for human consumption, which is a vital step towards restoring traditional Snoqualmie foodways and preventing future harm from eating contaminated fish.

Objectives:

The overarching goal of this work is to investigate anthropogenic stressors' impacts on aquatic ecosystems through western scientific methodologies, and integrating the frameworks of Indigenous sovereignty and environmental justice. I will be accomplished this through the following objectives:

- Produce a comprehensive, qualitative literature review that investigates settler colonial impacts on aquatic ecosystems and Indigenous cultural sovereignty via physical manipulation of aquatic environments, contamination, introduction of non-native species, and extirpation of culturally significant species.
- Conduct heavy metal analyses to determine the methyl mercury concentrations in the different fish species in Lake Sammamish, including Kokanee salmon (*O. nerka*).
- Compare the methyl mercury concentrations between fish in Lake Sammamish to fish from lakes that are relatively more and less urbanized.
- Conduct angler surveys to determine culturally relevant risk exposure pathways for the diverse communities that fish Lake Sammamish for subsistence and recreation.
- Determine if methyl mercury concentrations in fish muscle tissue exceed thresholds for safe human consumption based on the pathways identified through angler surveys.

Materials and Methods:

Literature Review

My literature review will explore settler colonial environmental impacts on Indigenous communities through the lens of environmental justice and Indigenous cultural sovereignty frameworks. I have reviewed over 300 academic articles, books, and reports to identify pathways for settler colonial impacts on Indigenous cultural sovereignty via environmental change. I will focus on four themes: 1) physical manipulation of waterways to marginalize Indigenous Peoples, 2) industrial contamination of water resources and its impacts on ecosystem and human health, 3) extirpation of culturally important species through exploitative harvest economies, and 4) the willful introduction of non-native species to serve settler colonial purposes and aesthetics.

Heavy Metal Analysis

I will evaluate the degree of urbanization of the Lake Sammamish and reference lakes along an urbanization gradient using land cover and land-use maps in ArcGIS. Lake Washington and Lake Sammamish will represent the more urbanized reference lake, and the less urbanized reference lakes could be Lake Samish, Lake Kokanee, and Baker Lake. Environmental MeHG concentrations in water and soil samples across study sites will be considered as well. I will collect representative samples of the fish populations in each lake using gill nets. The fish will be euthanized, and dorsal muscle tissue samples collected from individuals using a ceramic knife. Kokanee salmon will be collected from each of the locations during their spawning periods to avoid unnecessary euthanasia of threatened populations.

Sediment mercury will be measured according to EPA Method 7473 using thermal decomposition amalgamation, and atomic absorption spectrophotometry (Environmental Protection Agency, 2007). Sediment samples will be dried and thermally and chemically decomposed to liberate mercury from the sample, and then it will be captured by an amalgamator. The amalgamator will be rapidly heated to release mercury vapor, which will then be carried by flowing oxygen through absorbance cells in the light path of a single wavelength atomic absorption spectrophotometer. Absorbance will be measured at 253.7 nm as a function of mercury concentration. The mercury concentration from the fish muscle tissues will be measured following the same procedure. Mercury in fish tissues is, on average, 100% methyl mercury and so total mercury concentration calculations will be used as a measure of methyl mercury concentration (Wagemann et al., 1997).

Water mercury concentrations will be measured according to the protocol described in EPA Method 1631, Revision E (Environmental Protection Agency, 2002). The mercury in the water sample will be oxidized to Hg-II with BrCl then reduced with $NH_2OH•HCl$, stannous chloride ($SnCl_2$) to convert it from Hg-II to volatile Hg(0). Hg(0) will then be separated from the solution through purging with nitrogen, helium, or argon, or by vapor/liquid separation, and collected on a gold trap. Then the Hg will be thermally desorbed from the gold trap into an inert

gas stream to be carried to a second gold analytical trap, and desorbed again to be carried into the cell of a cold-vapor fluorescence spectrometer for detection.

The results of MeHG analyses will be compared across species within each reference lake, and across reference lakes in comparison to the degree of urbanization determined by the land cover analysis in ArcGIS.

Timeline:

Spring-Fall 2022	Sample collection of fishes from Lake Sammamish
Spring 2023	Sample processing and heavy metal analyses, complete coursework
Summer 2023	Submission of literature review
Summer 2023	Sample collection of fishes from reference lakes and Lake Sammamish
Fall 2023	Sample processing and heavy metal analyses from reference lakes
Winter 2024	Data analysis, manuscript preparation, submission
Spring 2024	Outreach to disseminate results, defend thesis

Expected Results and Interpretation:

Literature Review

My first chapter will compile an extensive amount of literature on the ways environmental change produced by settler colonialism infringe on Indigenous Peoples' food security, food sovereignty, and cultural sovereignty. The following tables will provide a summary of my findings. The disruption of Indigenous foodways cannot be fully understood through the pillars of *food security* as defined by the Food and Agriculture Organization of the United Nations: availability, access, utilization, and stability (FAO, 2008). Food security is an important component of settler colonialism's impact on Indigenous communities and so it is included in this literature review; however, it does not fully consider tribal sovereignty and the right to self-determine food systems (Nyéléni Village, 2007). It also does not consider the cultural aspects of traditional food systems that have been marginalized through settler colonialism such as community cohesion, knowledge and language transmission, and ceremonial use (Cidro et al., 2015; Donatuto et al., 2014; Sowerwine et al., 2019). Food sovereignty, and cultural sovereignty more broadly, moves beyond rights-based food security framework to consider cultural relationships supported through traditional food systems. The tables following this section will provide an overview of my findings (Tables 1-3).

Heavy Metal Analyses

Mercury contamination in Lake Sammamish has not been studied as it relates to fisheries and human health. Due to the level of urbanization on Lake Sammamish's shoreline and historical industrial activity, I expect the methyl mercury analyses to show varying mercury concentrations across fish species. Based on previous studies in the nearby, and highly urbanized, Lake Washington, I expect there to also be evidence of bioaccumulation that affects fish of higher trophic levels (State Department of Health, 2004). The previous study in Lake Washington determined that Sockeye salmon (*O. Nerka*) had the lowest average concentrations of mercury, but the results of this study on Lake Sammamish Kokanee (*O. Nerka*) could differ because of Kokanee's non-anadromous life history. Therefore, Kokanee could be at greater risk of anthropogenic mercury contamination due to their being landlocked in an urban environment. If no significant levels of contaminants are found, it is still important to develop an understanding of community concerns and investigate exposure pathways that could put certain groups at greater risk than the average fisher (Burger & Gochfeld, 2011; Middleton et al., 2019). If it is determined that mercury is not a contaminant of concern in Lake Sammamish through initial analyses, other metals such as arsenic and cadmium can be investigated (Balistrieri et al., 1992; Mandovi, 2019).

Significance:

This work is being done in collaboration with a collective of scientists, policymakers, and community leaders to support ongoing restoration efforts to conserve the Lake Sammamish Kokanee population. Therefore, the results of this study will have immediate and direct impacts on management by providing information on potential stressors Kokanee experience in Lake Sammamish. As stated previously, the objective of studying heavy metal concentration was co-developed with representatives from the Snoqualmie Tribe. The significance of doing this is to ensure community concerns over safety are addressed. Kokanee are a traditional food source for the Snoqualmie, and integral to their traditional foodways, community wellbeing, and cultural identity. Restoring a healthy Kokanee population has been an important objective for the tribe, and ensuring Kokanee are safe for human consumption is one step towards restoring a traditional tribal fishery.

The results of this study will inform future outreach actions to educate the public, including the Snoqualmie Tribe, about the risk toxic contaminants in fish pose to environmental and human health. The results for the heavy metal analyses will be communicated to the diverse communities that fish on Lake Sammamish and the Snoqualmie Tribe through publications in local newsletters and public meetings. This work will also be communicated to the scientific community through publication in academic journals and will be presented at national academic conferences in the fall of 2023, such as the American Indian Science and Engineering Society National Conference, the National Diversity in STEM Conference, and the American Fisheries Society Annual Meeting.

Food Security	Access	Availability	Utilization & Safety	Stability
Manipulation of watersheds	Settler colonial watershed governance restricts Indigenous Peoples' access to water (Bray, 2021; Durette, 2010).		Irrigation and hydroelectric projects have created water security issues for Indigenous Peoples by degrading water quality (Moctezuma Zamarrón & Padilla Ramos, 2017)	
Contamination	Chemical contamination restricts access to traditional resources through harvest closures/advisories (Andrade-Rivas et al., 2022; Varanasi et al., 2021)	Contamination can affect populations of traditional resources through mortality and decreased fitness (Lushchak, 2016; Todd, 2014; Turner & Turner, 2007)	The fossil fuel industry is responsible for many environmental conflicts involving Indigenous communities (Hanaček et al., 2022). Indigenous communities' food security is limited by lack of information regarding concerns over contamination (Liddell et al., 2021; Middleton et al., 2019)	
Extirpated species	Settler colonial conservation management can restrict access to traditional resources (Kakekaspan et al., 2013; Norgaard et al., 2011; Perry & Robyn, 2005)	Extirpated traditional resources become unavailable to Indigenous Peoples and limits the possibility of recovery (Blevins et al., 2019; Braje et al., 2009; Gustafson et al., 2007; Rick et al., 2016)	Increased competition between Indigenous and settler harvesters can create racial violence that threatens Indigenous Peoples' safety in accessing resources (Loew & Thannum, 2011; Zema et al., 2021)	Reduced populations decrease genetic diversity and biodiversity, which can create unpredictable population dynamics (Larson et al., 2002; Pinsky & Palumbi, 2014; Schindler et al., 2010)
Introduced species	Introduced species can cause native species to shift their range and be less accessible to Indigenous harvesters (Butler Harrington & Harrington, 2021)	Introduced species can cause declines in native species populations (Costanza et al., 2017)		
Climate Change	Changing environmental conditions will make traditional foods inaccessible, and force Indigenous Peoples to migrate from their territories (Donatuto et al., 2014; Hauser et al., 2021; Lynn et al., 2013; Maldonado et al., 2013)	Changing environmental conditions pose a threat to the persistence of traditional and ceremonial foods (Berkes et al., 2007; Satterfield et al., 2017; Wang et al., 2021)	Changing sea ice conditions in the arctic make travel and harvest activities more dangerous for Inuit (Durkalec et al., 2015; Panikkar & Lemmond, 2020)	Climate change is making environmental conditions and the timing of ecological cues less predictable (Carothers, 2010; Durkalec et al., 2015; Leonard et al., 2013; Moerlein & Carothers, 2012)

Table 1: The pillars of food security as defined by the Food and Agriculture Organization of the United Nations are used here to categorize the findings of my literature review (FAO, 2008). "Safety", defined as a component of food security by Berkes et al. (2007) is substituted for utilization here to avoid overlap with "Healthy", a pillar of food sovereignty that is included in Table 2.

Food Sovereignty	Healthy	Culturally Appropriate	Ecologically sound and Sustainable	Self-defined
Manipulation of watersheds	Dams restricting access to traditional food sources has degraded the health of Indigenous diets and led to proliferation of health issues such as diabetes (Estes, 2019)	Watershed manipulations have caused displacement of Indigenous Peoples and species, thus restricting access to culturally relevant food resources (Estes, 2019; Gilio-Whitaker, 2019; Gosnell & Kelly, n.d.; Maxwell, 2017; Norgaard et al., 2011)	Settler colonial watershed governance is not sustainable ecosystem management in accordance with Indigenous perspectives (Bednarek, 2001; Claire & Surprise, 2022; Fraser et al., 2006; Wagner, 2008)	Settler colonial watershed governance has restricted Indigenous sovereignty in stewarding environment and self-determining foodways (Dick et al., 2022)
Contamination	Contamination reduces the safety of consuming water and traditional foods and poses health risks to human populations (Jonasson et al., 2019; McGinnis & Davis, 2001; Roe, 2003)	Settler colonial perceptions on contamination and equity differ from Indigenous perspectives, and contamination can limit access to culturally relevant, traditional foods (Chiblow, 2019; Chief et al., 2016; Isaac et al., 2018)	Urbanization and extractive industries that cause industrial pollution are unsustainable and not ecologically sound (Barbier, 2011; Beyer et al., 2016; O'Rourke & Connolly, 2003; Schell, 2020)	Extractive industries and settler colonial governance limit tribal sovereignty in stewarding resources, but Indigenous-led monitoring of contaminants is an expression of sovereignty (Lepsch, n.d.; Torso et al., 2020; White & Millett, 2019)
Extirpated species	Loss of wildlife causes negative health outcomes by creating dependence on commodity and non-traditional foods (Cartledge, 2002; Estes, 2019)	Settler exploitation of species can restrict participation in culturally important harvest practices, and encourage participation in settler colonial harvest economies (Carothers, 2010; Kishigami, n.d.; Lightfoot et al., 2013)	Settler exploitation economies are not sustainable in comparison to Indigenous stewardship (Deur et al., 2015; LaCombe, 2015; Mathews & Turner, 2017; Reid et al., 2021; Rick et al., 2016)	Settler colonial harvest economies restrict tribal sovereignty in stewarding traditional resources (Berkes et al., 2007; Colombi, 2012; Dick et al., 2022; Gauvreau et al., 2017)
Introduced species	Western invasive species control can introduce chemical contaminants to the environment (Kittle & McDermid, 2016; Mattes & Kitson, 2021)	Western invasive species control may be culturally inappropriate to Indigenous Peoples (Adams et al., 2021; Alexander et al., 2017; Bach & Larson, 2017; Reo et al., 2017)	Introduced species and their management can have negative ecological consequences that pose a risk to native species (Gutiérrez et al., 2014; Pfeiffer & Voeks, 2008)	Aquaculture and Indigenous-led invasive species management provide an opportunity to exert sovereignty(Bhattacharyya & Larson, 2014; Luat-Hū'Eu et al., 2021; Page, 2007)

Climate Change	Changing food systems poses a health risk (Pearce et al., 2009)	Climate change impacts the ranges, quantity, and quality of traditional food resources (Lynn et al., 2013; Pearce et al., 2009).	Wild food environments and harvest impacted by environmental change (Smith et al., 2019)	Tribal adaptive capacity in responding to climate change is limited by settler colonial governance (Bethel et al., 2022; Gautam et al., 2013)

Table 2: A summary of literature discussing environmental change impacts on food sovereignty using pillars defined by the Declaration of Nyéléni (2007).

Cultural Health	Ceremonial Use	Knowledge Transmission	Community Cohesion
Manipulation of watersheds	Dams and water diversions have affected integrity of cultural sites and Indigenous Peoples' access to those sites (Corntassel, 2012; Eisenberg et al., 2004; Nelson, n.d.)	Altered waterscapes affect the relevance of traditional knowledge and transmission of knowledge (Daigle, 2019; Gagnon & Desbiens, 2018; Pawling, 2017)	Altered waterscapes have affected community cohesion and wellbeing by affecting eco-social relationships (Mauer, 2021; Moctezuma Zamarrón & Padilla Ramos, 2017)
Contamination	Settler colonial contamination guidelines can be exclusive of ceremonial uses of water and resources (Grinde & Johansen, 1995; K. P. Whyte, 2019)	The negative health impacts can affect elders' health and limit trans-generational knowledge transmission (Carroll et al., 2017)	Negative health impacts of contaminants can affect community members' health. Contamination can also inhibit cultural harvest and activities that promote community cohesion (Moore-Nall, 2015; Roe, 2003)
Extirpated species	Exploitation of traditional resources can interfere with Indigenous ceremony (Atlas et al., 2021; Carothers, 2010; Norgaard et al., 2011)	There is a connection between biodiversity and cultural diversity and language, and extirpation of species can disrupt knowledge transmission and the relevance of TEK (Atlas et al., 2021; Dale & Natcher, 2015; Garibaldi & Turner, 2004; Turner & Turner, 2008; Wilder et al., 2016)	The loss of traditional resources means the cultural activities that promote community wellness and cohesion are lost as well (Blanchet et al., 2021; Garibaldi & Turner, 2004; Kishigami, n.d.)
Introduced species	Wild rice has many ceremonial functions that could be implicated by the introduction of GMO or cross-bred strains (Raster & Hill, 2017)	Reliance on aquaculture could threaten self-sufficiency and knowledge persistence, and invasive species in general impact eco-social relationships informed by TEK (Allen, 1998; Pfeiffer & Voeks, 2008)	Invasive species can impact cultural activities that promote community cohesion and well-being (Pfeiffer & Voeks, 2008; Raster & Hill, 2017)
Climate Change	Changes in phenology and environmental conditions can impact Indigenous ceremonies and traditions (Chisholm Hatfield et al., 2018)	Traditional knowledge is less relevant in the wake of rapid environmental change due to climate change (Chisholm Hatfield et al., 2018; Royster, 2013; Turner & Clifton, 2009)	Climate change can disrupt cultural activities that build community cohesion and affirm cultural identity (Durkalec et al., 2015)

Table 3: Indicators of cultural health as defined by Donatuto et al. (2014), with the omission of food security, which is discussed in Table 1.

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