OFF THE HOOK: CLIMATE AND COMMUNITY VULNERABILITY OF U.S. INLAND SUBSISTENCE FISHERIES

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ABSTRACT

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Inland fisheries serve as important sources of food security and nutrition in vulnerable communities globally. However, research has focused largely on low-income countries and very little information specific to subsistence inland fisheries and the communities that depend on them is available for the United States, especially in non-Indigenous populations. These hidden contributions of inland fish harvest to food security and community resilience often go unreported, masked by a fuzzy boundary between recreational and subsistence fishing activities. Complicating the understanding of these fisheries are numerous threats and the compound implications of climate change. This study addresses the relatively unexplored socio-ecological dimensions of fishing for food in the context of climate change in the U.S. Spatial analysis of demographic and ecological data informs a high-level overview of potential hotspots where inland fisheries may be more likely to serve as an under-reported contributor to food security. Surveys of fishery managers, fishers, and other relevant actors then provide a more in-depth perspective on the current perception of subsistence fishing activities and their role in climate vulnerability across scales. This study suggests recommendations and a call for further research on the interface of survival, climate change, and culture tied to inland subsistence fisheries (ISF) and the "invisible" communities whose livelihoods depend on them. Fishery managers, policymakers, and other decision-makers in fishing communities can play an important role in increasing awareness and supporting the sustainability of these undervalued socio-ecological systems.

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Chapter 1. Introduction and Literature Review

Recreational fishing from inland waters is an increasingly popular activity in the United States, with over 52.4 million participants in 2021, a 4.5 percent increase over 2019 (Cooke et al., 2018; RBFF, 2022). Simultaneously, over 10% of households experienced food insecurity at some point during 2021. A growing body of literature supports that harvest from what would often be considered purely recreational fishing activities actually contributes to the food security and nutrition of diverse communities (Cooke et al., 2018; Nyboer et al., 2022). A fuzzy boundary exists between fishing for fun and fishing for food; an individual may simultaneously enjoy the recreational benefits of fishing as an accessible outdoor hobby while also reaping the benefits of bringing home their catch for affordable protein. Research on inland subsistence fishing (ISF) is limited on a global scale, including in the United States. Existing studies largely focus on subsistence fishing as a lifestyle element of exclusively Indigenous and sometimes rural communities; however, evidence suggests that non-Indigenous and urban communities are also utilizing inland fisheries as a direct source of nutritional and cultural value (Embke et al., 2020; Quimby et al., 2020). This study investigates the undervalued role of inland fisheries as a source of food in the United States and explores the potential climate vulnerability of this socio-ecological system.

Subsistence fishing refers to the activity of individuals harvesting aquatic organisms to directly supplement or serve as a primary source of nutrients; inland fisheries are a comparatively affordable animal protein resource and are accessible from both remote and urban areas, making them a critical aspect of food security in many lower income socioeconomic groups (Lynch et al., 2017). Fishing for food is a multi-faceted socio-ecological issue and can be complex to track and quantify with data, as a singular lake or river can serve as a subsistence, recreational, and/or

commercial fishery simultaneously. A notable challenge presented by the study of inland subsistence fishing is the distinction between this activity and that of recreational fishing, which is currently the predominant form of inland fishing in the United States (Coleman-Jensen et al., 2020).

1.1 Food Security

Approximately 10% of U.S. households were food insecure at some point during 2021, with 4% experiencing *very low* food security (consistent broken eating patterns and reduced food intake) (Coleman-Jensen et al., 2020). Broken eating patterns can be characterized by diverse behaviors but generally refer to the disruption of "normal" eating patterns (like skipping meals or eating very small amounts of food during the day), or lack of access to food throughout the year due to lack of money, access to transportation, or other obstacles that prevent an individual from being food secure (Coleman-Jensen et al., 2021). Food insecurity is associated with increased risk for other public health concerns, including diabetes, obesity, and even cancer (Jernigan et al., 2017). Modern food insecurity is also complex in that it is multi-dimensional, comprising both under and over-consumption, and solutions must also account for simultaneous dynamics of quality and quantity of food (Nesbitt & Moore, 2016). While certain communities may report consistent access to food, it is important to consider the nutritional content of this food and the implicit health consequences of consuming high amounts of low-quality foods as well. Important considerations like the rate of consumption of protein and micronutrients are rarely included in food security studies. However, diet quality is critical to public health issues, such as increasing hypertension and micronutrient deficiencies (Ashe & Sonnino, 2013).

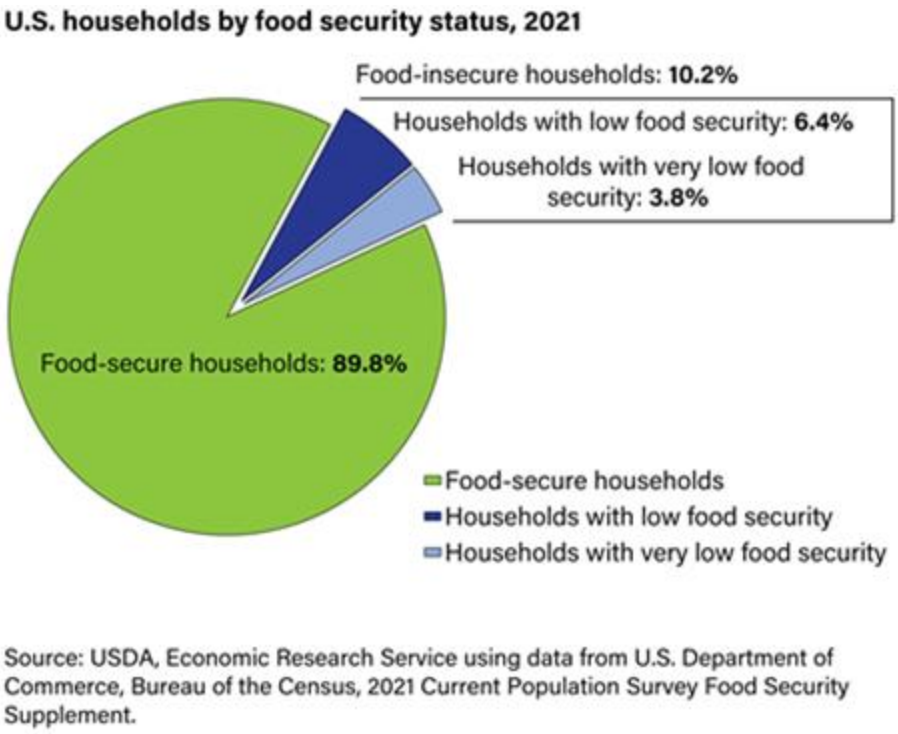

Figure 1.1: Food security status of U.S. Households in 2021 (USDA ERS, 2022)

These nationally averaged statistics, however, do not accurately reflect the important variances between specific demographics. Vulnerable groups like ethnic minorities and low-income urban and rural populations are significantly more likely to experience food insecurity (Jernigan et al., 2017). Nesbitt & Moore (2016) showed that Indigenous communities are considered to be among the most vulnerable to food insecurity. A large-scale study by Jernigan et al. (2017), based on the Current Population Survey Food Security Supplement (CPS-FSS) for the years 2000-2010, found that Indigenous people were twice as likely to be food insecure compared to those people who are classified as 'White' but are not part of a specific Indigenous group. The CPS-FSS is a yearly supplement to the American Current Population Survey conducted by the Bureau of the Census that takes a deep analysis of food security information, including food expenditure and dependency on food assistance programs (*USDA ERS, 2016*). While the lowest

rates of food insecurity were consistently reported for Whites and Asians, Jernigan et al.'s (2017) study found increases in food insecurity across all racial and ethnic groups compared to historic averages nationally, with the strongest increases occurring in low-income Whites. While discussions of food security often focus on rural communities, urban settings can also present many obstacles to obtaining food-security, and low-income populations in highly developed urban areas may struggle with the increased costs for nutrient-dense foods (Coleman-Jensen et al., 2020).

While food security information specific to Indigenous communities residing on reservation land is limited, it is known that some of the nation's largest food deserts exist on reservations, with just 25.6% of the population residing within 1 mile or less from a supermarket compared to 58.8% of the U.S. population overall (Kaufman et al., 2014; Sowerwine et al., 2019). In the United States, the Department of Agriculture (USDA) Food Distribution Program on Indian Reservations (FDPIR) is intended to provide nutrition assistance and actively monitors food security in Indigenous communities (Pindus & Hafford, 2019). In the first national update since 1990, a 2016 FDPIR revealed that households participating in food assistance programs reported significantly higher rates of food insecurity than national averages; 34% experienced low food security and just over 22% experienced very low food security (Pindus & Hafford, 2019). The *Map the Meal Gap* project by 'Feeding America' also indicated that higher percentages of Indigenous people were positively correlated with higher food insecurity rates at the county level (Feeding America, 2020).

In an economy rattled by the global coronavirus pandemic, the cost of food is rising at historic rates and many communities are likely feeling the pressure of higher prices without increasing wages to match (Aday & Aday, 2020). The USDA Economic Research Service found that the average annual price of "food at home" was 11.4 percent higher in 2022 than in 2021,

while the 20-year historic level of retail food price inflation is closer to two percent per year (*USDA ERS, 2023*).

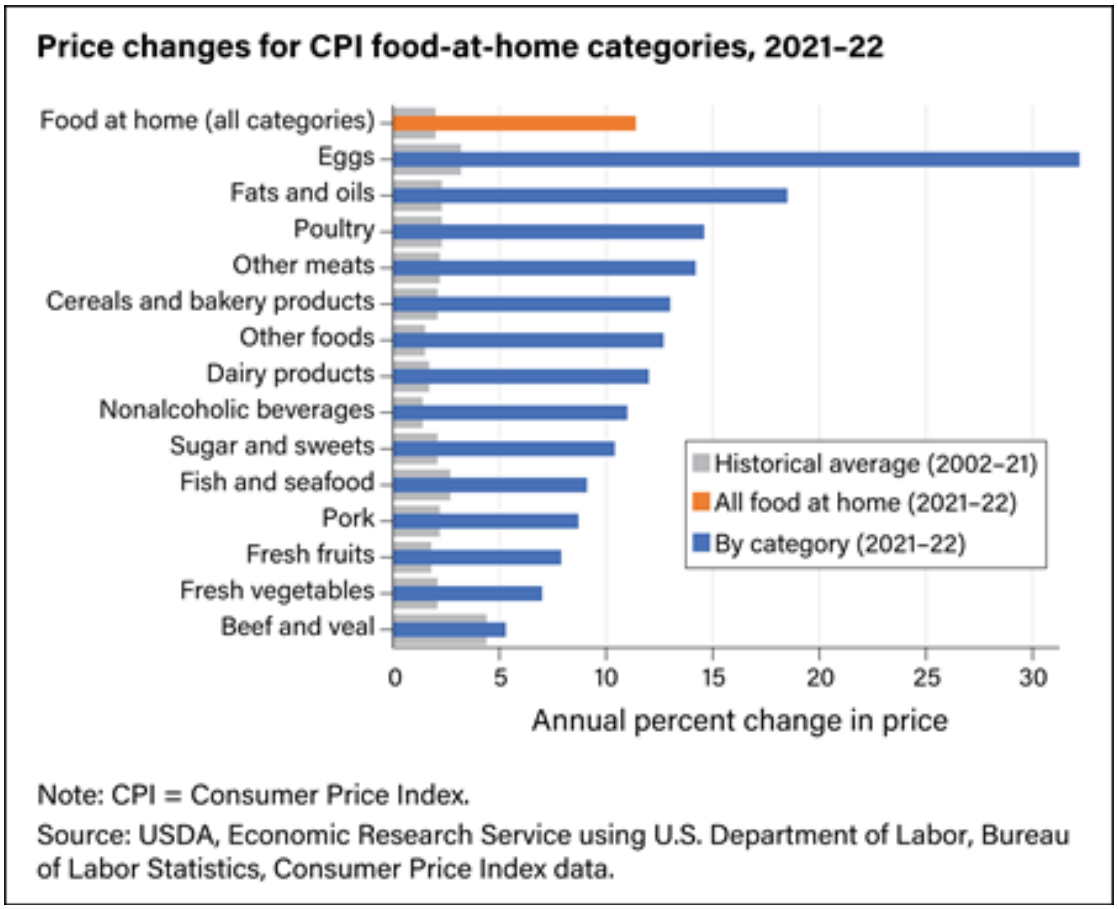

Figure 1.2: Price changes for Consumer Price Index food-at-home categories (USDA ERS, 2023)

Looking forward, the cost and types of food available to diverse communities across the U.S. will also become increasingly susceptible to the influence of climate change. As shown in Figure 1.3, climate change is projected to significantly reduce food access within the next 50 years through potential increases of food prices resulting from decreased supply, increased demands for water inputs, and through influences on rural livelihoods (El Bilali et al., 2020; Wiebe et al., 2019).

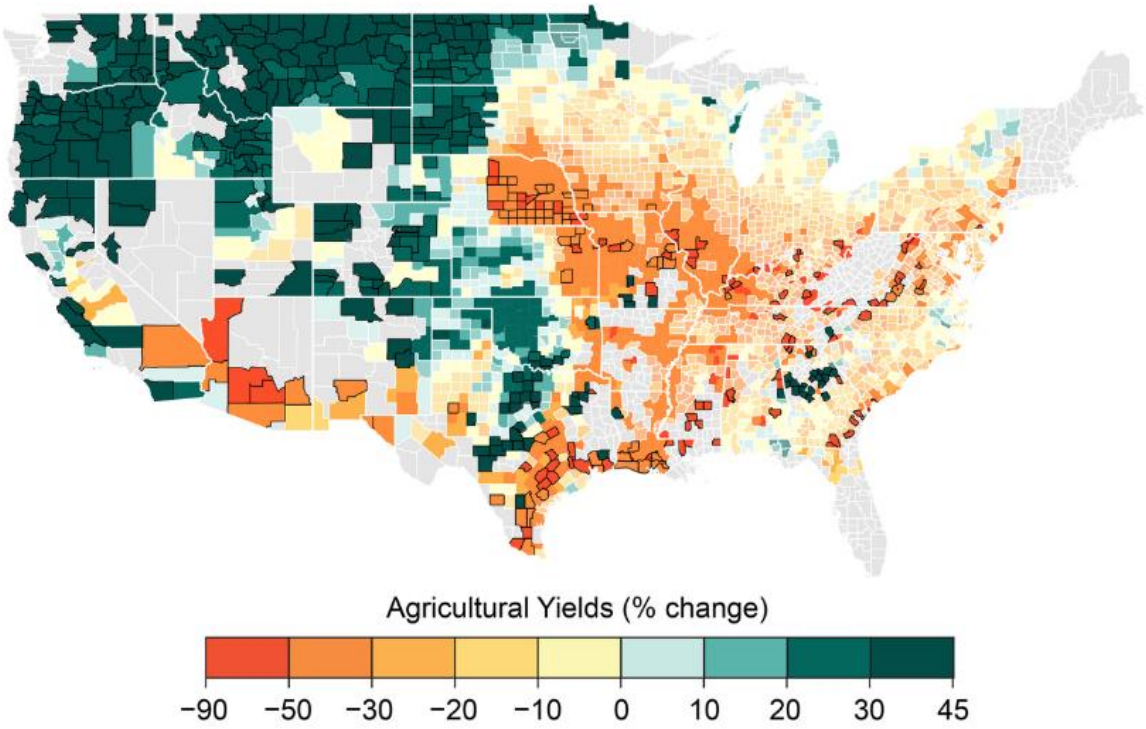

Figure 1.3: Projected percent change in agricultural yield during 2080-2099 in a high-emissions scenario (El Bilali et al., 2020)

While these projections demonstrate a baseline estimate of emerging and expected trends, the incredible non-stationarity of climate, as well as socio-economic and political conditions, creates significant uncertainty around how food access may change over time. Given the extent of these unknown variables, food security considerations in climate vulnerability assessments and adaptation plans must be flexible and adaptive to change. The uncertainty around how climate change will influence food access and consumption behaviors remains a key theme throughout this research, as subsistence fishing behaviors in the contiguous U.S. are inextricably linked to external motivations (such as changes in food prices at the grocery store).

1.1 Inland Subsistence Fisheries

The contribution of inland fisheries to food security in any given community can depend on a number of complex cultural and socio-economic factors. FAO identifies the productivity of the fisheries, intensity of stress on the ecosystem, vulnerability of the populations dependent on fishes for economic or nutrition motives, and the cultural and societal relations of the community as key determining factors for how much a fishery may contribute to food security (Funge-Smith, 2018). However, lack of relevant data makes assessing inland fisheries an extremely difficult task for many parts of the world, and research on the importance of inland fisheries to food security is limited. Creel surveys, usually conducted on site at a specific waterbody and focused on effort, catch, and harvest, are highly valuable, but also highly variable (Lynch et al., 2021). The term "creel" is used widely in the fisheries management field to refer to an individual's recreational fish harvest. These methodologies are not standardized, especially for freshwater, and often don't include questions about motivation or food security. Nevertheless, it is evident that inland fisheries constitute the main source of income for millions and serve as a key source of nutrition for many more across the globe each year (Funge-Smith, 2018). Beyond serving as a substantial protein source, fishes are also high in micronutrients that are otherwise difficult to access for many food-insecure communities due to lower variety in food consumption, including iron, calcium, zinc, omega 3 fatty acids, and vitamin A (Youn et al., 2014). These nutrients, specifically omega-3 fatty acids and calcium, are of increased importance for pregnant and lactating women, especially those in socioeconomic groups with limited access to other sources of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are abundant in freshwater fishes with high levels of omega 3 fatty acids (Gogus & Smith, 2010). As it is well-known that a healthy diet must include sufficient

amounts of bioavailable vitamins, essential fatty acids, and protein, fishes can provide numerous benefits to the public health of a community (Funge-Smith, 2018).

It is reasonable to project that the economic fallout of COVID-19 on a global scale has resulted, and will continue to result, in increased levels of poverty and food insecurity, with over 40 million Americans filing for pandemic unemployment during the summer of 2020 (Bureau of Labor Statistics, 2020). A recent study revealed that while certain ecosystems are experiencing a period of recovery in response to reduced human activity during the pandemic, fisheries with a high provisioning value are under greater pressure while lacking the capacity to adapt to increased human dependency in concert with the myriad of other threats already present (Stokes et al., 2020). It is logical to conclude that Americans who can no longer afford to purchase their proteins at the grocery store or market (and now have more free time available to them due to decreased employment opportunities associated with the economics of the pandemic) are turning to fisheries as a cheap and accessible source of food, resulting in increased reported fishery pressure (Cooke et al., 2021).

Inland fisheries serve as a comparatively affordable animal protein resource and are accessible from both remote and urban areas, making them a critical aspect of food security in many lower income socioeconomic groups (Lynch et al., 2017; and see above). Subsistence fishing has largely been studied as a lifestyle element of exclusively indigenous, rural, and developing communities; however, significant evidence suggests that non-indigenous, urban communities are also utilizing inland fisheries as a direct source of nutritional and cultural value (Quimby et al., 2020). A notable challenge presented by the study of inland subsistence fisheries is the distinction between this activity and that of recreational fishing, which is currently the predominant form of inland fishing in the United States (Funge-Smith & Bennett, 2019). FAO defines recreational

fishing as the fishing of aquatic animals that do not constitute the individual's primary resource to meet basic nutritional needs and are not generally sold or otherwise traded. However, comprehensive data on subsistence fishing has previously been limited by diverse complicating factors (Buklis, 2002).

The role of inland fisheries to human livelihoods and food security is well recognized as an important issue for developing parts of the world (McIntyre et al., 2016). However, inland subsistence fisheries (ISF) are also very important to specific communities in developed nations, including low-income groups in both rural and urban settings and Indigenous groups with strong cultural ties to subsistence fishing itself (Cooke & Murchie, 2015). Inland fisheries contribute significantly to the food security of large groups of people across the United States; not only do they serve as a source of employment and income, but as an important source of protein and micronutrients (Barange et al., 2015). As discussed in Cooke et al. (2017), a complicated nexus can exist between fishing for fun and fishing for food; while recreational fisheries, by definition, do not serve as a primary or sole source of nutrition, there is still a significant ecosystem service to consider when fishers may simultaneously enjoy the practice of fishing while also reaping the benefits of bring home their catch (Nyboer et al., 2022).

1.2 Cultural Significance of Inland Fisheries

Inland fisheries also hold a great deal of cultural significance, specifically to the development and transmission of intricate systems of Indigenous and Local Knowledge (ILK) throughout Native communities in the United States (Walsey & Brewer, 2018). ILK is rooted in observations and interpretations that stem from centuries of direct dependence on ecosystems, which are then passed down from generation to generation and enriched over time (Baptiste &

Pacheco, 2017). Indigenous peoples often provide perspective and expertise that may be preserved through individual or collective community knowledge, requiring detailed oral history approaches to record such information. This has also meant that such information has, unfortunately, often been overlooked in the past by Western scientists, despite the fact that Indigenous peoples are important contributors to the study and management of biodiversity in ecosystems from local to global scales (Baptiste & Pacheco, 2017). Many Indigenous value systems acknowledge an intrinsic connection between people and freshwater ecosystems, establishing a balanced relationship with harvesting which respects both the needs of human and aquatic communities (Kahui & Richards, 2014). The Alaska Native Villages are considered a primary example of communities with deep cultural ties to subsistence fishing, as subsistence activities are foundational to both economic and cultural continuity in this region (Ristroph, 2019).

1.3 Threats to Inland Subsistence Fisheries

There are numerous threats to freshwater ecosystems, habitat modification and loss (to the aquatic systems and their neighboring riparian habitats, alteration of flows, pollution, and introduction of invasive species (Reid et al., 2019; Tickner et al., 2020). The drivers of these threats come from multiple different anthropological actions, associated with economic development, such as hydropower development, irrigation for agriculture, and municipal water demand. Dam construction, channelization, and land use changes (due to urbanization, agricultural, and certain forestry management practices) can influence the water dynamics of entire watersheds and affect groundwater flows (Tickner et al., 2020). Increasing water demand for development, agriculture, and power generation is associated with increased rates of sedimentation, water contamination like eutrophication, and even notable changes in water temperature in affected watersheds (Dudgeon et al., 2006; Tickner et al., 2020). These development-driven threats affect the fishes in the

ecosystems and hence also the fisheries that depend on them, reducing the productivity of inland subsistence fisheries (Nguyen et al., 2016). These threats create high levels of vulnerability at the socio-ecological watershed level (Funge-Smith & Bennett, 2019).

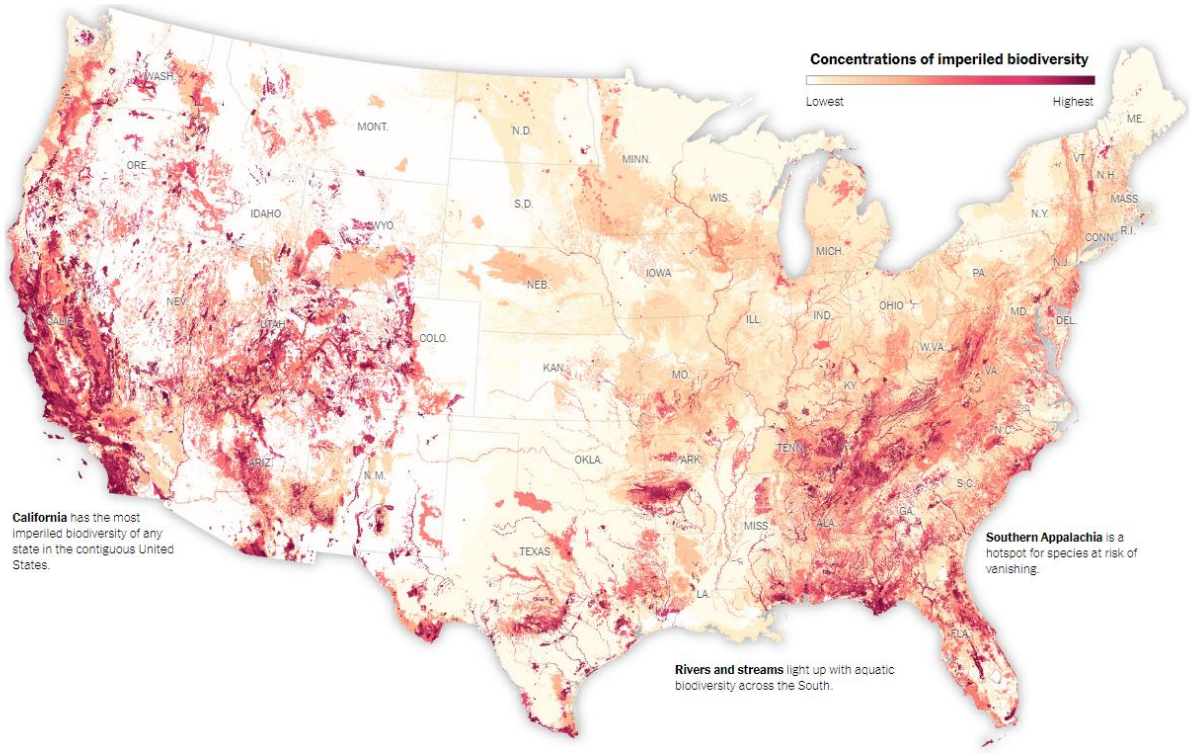

Figure 1.4: Concentrations of imperiled biodiversity based on gap analysis of permanent protections for biodiversity (Hamilton et al., 2021)

Freshwater ecosystems may be limited spatially when compared to terrestrial and marine habitats, but they are extremely rich with biodiversity (Darwall et al., 2018; Ticker et al., 2020). Freshwater vertebrate populations are estimated to be declining twice as quickly as land and ocean vertebrates (Tickner et al., 2020). The need for effective policy solutions that balance human demands for water security with natural freshwater ecosystem integrity is urgent on a global scale (Vollmer et al., 2023). In the U.S. specifically, large scale conservation policy systems exist but permanent protections for biodiversity are extremely limited compared to the spatial distribution of imperiled species (see Figure 1.4, based on Hamilton et al., 2021).

Part of the reason for this threat to inland fishes and the fisheries they support is because of a massive underestimation of the importance of inland fisheries to food security. This underestimation has led to lower prioritization of their protection when compared to other freshwater ecosystem services that are provided by some of the other development actions noted above, like hydropower and irrigation, which are deemed more economically pertinent (Lynch et al., 2020; Richter et al., 2010). The current dominant social paradigm places high value on large commercial fishing operations (but these are principally marine). Comparatively, inland fisheries are consistently undervalued from an economic and biological standpoint due to the difficulty of obtaining high-quality, accurate data on these smaller, widely dispersed communities (Fluet-Chouinard et al., 2018; Youn et al., 2014). The increasing pressure on inland fisheries is often referred to as the ‘‘Death by 1000 Cuts’’; multi-dimensional threats are inflicted on small-scale fisheries by fishing itself (whether through overfishing or even introduction of invasive species) in concert with pollution, changing climate, and other forms of human habitat disturbance (as noted above) that are difficult to quantify individually (Fluharty, 2000).

Climate change is a significant threat to freshwater systems that compounds existing threats (Reid et al., 2019). According to the Intergovernmental Panel on Climate Change (IPCC)’s Sixth Assessment Report, human influence has been detected in warming of the atmosphere and surface water as well as in changes in the global water cycle; it is extremely likely to have been the dominant cause of the observed warming since the mid-20th century (IPCC, 2022). These changes in temperature, along with changes in the timing and intensity of precipitation, are anticipated to alter watershed systems significantly, including increases in evaporation from rivers, lakes, and wetlands, evapotranspiration from riparian vegetation, and precipitation (IPCC, 2022). Each of these consequences of climate change pose a further potential threat to the long-term sustainability

of inland subsistence fisheries, especially in the U.S. where air temperature increases are projected to be higher than the global average under almost all emission scenarios (IPCC, 2022). These climate change threats become particularly important when there are existing landscape threats. For example, a global study showed a 25% decrease in catch from lakes in response to relatively small changes in air temperature, precipitation, and agricultural land use in areas where there was limited access to clean water for local communities (a characteristic shared by many fishery-dependent communities in the U.S.) (Kao et al., 2020).

Analysis of change in water temperatures, flows, and the spatial distribution of appropriate thermal habitats for commonly fished species were modeled for the U.S., using a range of projected changes in temperature and precipitation caused by increased greenhouse gas emissions (Jones et al., 2013). The spatial distribution of cold-water fisheries (which includes a large number of "food fish" species like salmon, tuna, mackerel, herring, and trout) is expected to contract significantly by 2100 (Jones et al., 2013). These projections become increasingly concerning in high emission scenarios, with a projected decline in cold-water fisheries of approximately 50% by 2100 under the IPCC's highest emissions scenario (Jones et al., 2013). These projected changes in water temperature and stream flow would push almost all cold-water fisheries further north. Particularly vulnerable regions include the Pacific Northwest, where several Indigenous communities rely heavily on Columbia Basin salmon, and areas surrounding the Great Lakes, which are currently cold-water fisheries projected to become "rough" fisheries by 2100 (Jones et al., 2013). The term "rough" fish or fisheries has been used for centuries in the western fisheries management field in reference to species considered less desirable for harvest, however, this term is problematic due to its harmful colonial roots (Rypel et al., 2021). As the hypothetical concept of a rough fishery "lumps together diverse fishes and life-history strategies perceived as having low-to-zero value"

(Rypel et al., 2021, pg. 605), this thesis does not employ the term “rough” fish to explore the potential impact of shifting species composition and distribution on harvest motivations. However, the concept is present throughout the relevant literature and changes in the types of fish available to catch and effort required to catch them are critical considerations for the study of inland subsistence fisheries.

Nevertheless, research into the vulnerabilities of subsistence fishing is limited, especially in the U.S.. Moreover, there is a need to adopt ‘systems-thinking’ approaches for the research and the management of inland fisheries, integrating freshwater ecosystems and their fisheries into broader, wholistic decision-making for the entire watershed. These approaches recognize the complexity of freshwater habitats and the ecosystem services they supply, which are closely integrated within social-ecological systems (van Rees et al., 2021). A social-ecological system can be defined as the combination of “people, their natural and human-made resources and the relationships among them,” and therefore recognizes that ecosystems are linked to and influenced by human activity and management decisions (Kingsford et al., 2012) The importance of bringing together environmental, social, and economic components of the conservation and management of natural resources is recognized in the growing body of work focused on ‘coupled human-natural systems.’ Fisheries are a complex example of such systems (Liu et al., 2007). The process of bringing together natural and social science, conservation practice, and fisheries practice will be critical for the development of the appropriate management and policy for sustainable inland fisheries (see below). But it is also widely recognized that this development of management and policy should be informed by contemporary research and data (van Rees et al., 2020).

1.4 Policy Analysis

An important factor in the efficiency of fishery policies is the interaction between local, state, tribal, and federal entities that make up the "policy-shed" (the overlapping geographic area in which governing institutions have legislative authority), as misalignment in goals or enforcement can result in fragmented and inefficient management of inland fisheries (Nguyen et al., 2016). This study investigates existing policies from a top-down perspective, evaluating first how national laws and precedents influence the resilience and/or vulnerability of inland fisheries to climate change before turning to state level policies and watershed specific case studies to develop a comprehensive understanding of subsistence fishery protections.

1.4.1 Federal Policies

Considered an extreme form of government intervention at the time of its creation, the Endangered Species Act (ESA) works to protect and restore threatened species and their critical habitats through a framework of incentives and regulations on a national scale (Brown & Shogren, 1998). Established in 1973, the ESA provides states with funding and incentives to initiate conservation and restoration programs designed specifically to target species classified as "endangered" under the Act, with the listing process itself serving as one of the primary functions of the legislation (Schwartz, 2017). While the ESA has successfully prevented hundreds of species from reaching predicted extinction and has improved population trajectories of hundreds more, full recovery rates of listed species have not kept pace with expectations (Evans et al., 2016). Critics cite insufficient funding and uneven distribution of money across species as major limiting factors, with some estimates claiming that at least ten times more species than those already protected by the ESA qualify to be listed as endangered (Evans et al., 2016). Climate change is

exacerbating these problems, as threats are becoming increasingly pervasive and additional species will require conservation protections. However, experts still consider the ESA to be one of the most comprehensive national policies influencing management strategies to prevent extinctions (Schwartz, 2017).

Salmon fisheries experience some of the most notable impacts of the ESA as it relates to inland subsistence fisheries management. Several governing entities are required to perform status assessments and implement conservation and recovery plans for these species to comply with the Act due to their anadromous nature (Myers et al., 1998). As marine fisheries are considered to hold higher economic value and are more broadly researched in the U.S. (Cooke et al., 2016), salmon and other anadromous species play an important role in the application of the ESA to inland fisheries. For example, the National Marine Fisheries Society was petitioned in 1994 to list stocks of steelhead trout (the anadromous populations of rainbow trout, *Oncorhynchus mykiss* and its subspecies) and stocks of salmon species originating from the Columbia River, as well as from other rivers of the U.S. Pacific Northwest due to their critical role as prey for endangered marine mammals in the region (Myers et al., 1998). The inventories resulted in several listings of salmonid species and subspecies for protection under the ESA, including four species of Columbia River Basin salmon and steelhead subspecies (Northwest Indian Fisheries Commission, 2017; U.S. Fish and Wildlife Service, 2021). The ESA prohibits the "take" of listed species, which refers to their capture but includes degradation of their critical habitat. As such, the Washington Department of Fish and Wildlife along with the Puget Sound tribes and other fishery stakeholders developed and submitted harvest management plans for all salmon fisheries under co-manager jurisdiction (Northwest Indian Fisheries Commission, 2017). The ESA interacts heavily with several other federal laws that pertain to the management of aquatic ecosystems, including the Fish and Wildlife

Coordination Act, and Anadromous Fish Conservation Act, which largely facilitate or establish management authority for the U.S. Fish and Wildlife Service (USFWS) and other governing entities.

Another major piece of federal legislation designed to protect free-flowing rivers is the Wild and Scenic Rivers Act of 1968 (WSRA), enacted to protect and enhance the Outstanding Remarkable Values (ORVs), including fish habitat through interjurisdictional protections (Perry, 2017; 2021). Currently, the WSRA protects 13,413 miles of 226 rivers, which represents less than 0.005 percent of the country's total river miles (National Wild and Scenic Rivers System, 2019). Fisheries in these protected waterways can be directly addressed by the Comprehensive River Management Plans that are a requirement of the WSRA. In many cases, eligibility and suitability studies seeking protection for rivers under the WSRA include objectives that limit the implementation for disruptive water resource development projects that could harm fisheries, like fish passage barriers that may impact the natural free-flowing state of the river (U.S. Forest Service, 2019). Similarly, new water rights for rivers protected under the WSRA must be allocated in a manner that considers both the needs of human communities and the requirements of adequate flow for fish and other wildlife (Brougher, 2010). While effective for protecting free-flowing rivers, acquiring Wild and Scenic designation is an intensive process, and the variety of stakeholders impacted by such a decision often hold widely varying perspectives and values (Hunt et al., 2021; Field-Juma & Roberts-Lawler, 2021). Few rivers in the Southwest and Rocky Mountain regions of the United States have been designated, and the Center for Biological Diversity (2018) argues that even rivers that are designated are still neglected by management agencies. According to Perry (2017), this situation stems from the lack of federal appropriations to manage rivers adequately.

The Clean Water Act (CWA), enacted in 1948 and expanded in 1972, establishes the foundational regulation of pollutant discharge into inland waters in the United States, in turn influencing the management and protection of fisheries that exist within these waters. Largely enforced by the U.S. Army Corps of Engineers (USACE) and the Environmental Protection Agency (EPA), the CWA serves to protect water bodies from degradation by human influence through regulations which aim to "create a reasonable and appropriate balance between Federal and State waters" (Copeland, 2010). As fish populations are sensitive to contamination of water resources, interpretation and enforcement of the CWA is increasingly critical to the long-term sustainability of inland subsistence fisheries. Interpretation of the CWA is particularly important because the Act is famously controversial for the broad nature of the term "navigable waters" as a determining factor for the eligibility of a water body for federal protection.

The CWA, like many federal policies, is vulnerable to dramatic shifts in interpretation and implementation aligned with shifts in administration. In early 2020, an amendment to the CWA, entitled the Navigable Waters Protection Rule (NWPR), significantly contracted the network of water bodies eligible for federal protection and subsequently increased the vulnerability of many inland fisheries. While enforcement agencies have previously used a definition of "navigable waters" based on an "ordinary high-water mark," the NWPR replaced this definition with one that requires proof of "perennial or intermittent flow," therefore excluding ephemeral waters (Ward & Walsh, 2020). The interpretation of these navigable waters, also referred to as the Waters of the United States (WOTUS), is critical to how the CWA is implemented. While ephemeral waters are not present year-round, significant scientific evidence supports that many ephemeral streams and rivers are critical for the life-cycle stages of freshwater fish, amongst other aquatic species. For example, a study on Cottonwood Creek (an ephemeral tributary of the Gunnison River in

Colorado), found that high numbers of flannelmouth suckers, *Catostomus latipinnis* were using the intermittent stream to spawn (Hooley-Underwood et al., 2019). Fish movement through "dry" channels, especially in the arid Southwest where flash precipitation during monsoon seasons creates numerous ephemeral connections between water bodies, is also a widely recognized occurrence which can contribute to the dispersal of invasive species and influence species assemblages (Stefferud & Stefferud, 2007). As a result of the rule change, individual states needed to determine whether adjustments were necessary to their current regulations. The EPA's National Economic Analysis of the NWPR found that protections under the CWA were significantly reduced during this period (EPA, 2021). As a striking example of the turbulent nature of this act and its implementation, the Biden administration officially reverted the definition of WOTUS back to the pre-NWPR regulatory definition in late 2022, citing relevant Supreme Court decisions and the need for a "durable definition" (EPA, 2023).

The National Environmental Policy Act of 1969 (NEPA) is one of the first broad frameworks for environmental protection that notably requires Environmental Assessments (EAs) and Environmental Impact Statements (EISs) for federal actions that could potentially have negative environmental impacts. Included under this policy is the requirement for the Federal Energy Regulatory Commission (FERC) to produce and defend an environmental study analyzing the consequences of issuing a license for hydropower infrastructure development, along with reasonable alternatives to the proposal. As FERC relicensing of energy projects requires re-evaluation of environmental impacts under NEPA, this policy is considered a potential "window of opportunity" for dam removal and the restoration of fish habitat (Chaffin & Gosnell, 2017).

Additionally, federal level policies exist to coordinate and enhance efficiency of efforts between different state and watershed level management agencies. For example, the Federal

Subsistence Management Program (FSMP) is a multi-agency management entity that focuses on supporting sufficient studies and protections for subsistence culture for rural Alaskans. However, a large majority of inland fishery management falls under the jurisdiction of the states, and transboundary policies are extremely lacking. Alaska remains the only state with an established "interagency" management approach, including a Federal Subsistence Board, which allows for clear communication and collaboration with Canada (as many water resources in Alaska are in some capacity under the shared jurisdiction of Canada). It is clear that the impact of federal policy on the long-term sustainability of inland subsistence fisheries is significant, with potential for expanded protections to facilitate more consistent climate adaptation planning in fishery management on a national scale.

1.4.2 Tribal Policies

As subsistence fishing plays an important role in both the food security and culture of many Indigenous communities, Tribal policies in relation to the management of inland subsistence fisheries are also relevant to assessing their vulnerability to climate change. While jurisdiction of Tribal governing bodies is limited beyond reservation land, several Tribes along the west coast have long-standing treaties that protect their right to fish in "usual and accustomed" (U&A) fishing areas, in which treaty tribes are entitled to up to half of the harvestable surplus of fish stocks (Bureau of Indian Affairs, 1999). In this capacity, in some cases tribes serve as co-managers of inland fisheries beside state and federal entities. Unlike federal and state managers, tribal frameworks for fisheries management largely revolve around stewardship and acknowledgement of the inextricable link between human communities and the environment (Holtgren & Auer, 2022; Carothers et al., 2021; Holtgren, 2014).

An influential example of tribal policymaking is the Northwest Indian Fisheries Commission (NIFC), which acts on the *US v. Washington* Supreme Court Case of 1974 (the "Boldt Decision") to affirm that the tribes are jointly responsible with the state of Washington for managing fisheries resources. The NIFC contributes every year to decisions on salmon fishing seasons (including catch limits and escapement targets) and management objectives for fisheries overall. Due to the coastal nature of the region, there is significant overlap between inland and marine fishery management policies under NIFC, though important food fishes like salmon and other anadromous species have critical spawning habitat in inland waters. Similarly, the Kuskokwim River Intertribal Fish Commission and Yukon River Intertribal Fish Commission, among others, represent the Alaska Native Villages in the policymaking process and at meetings of the Federal Subsistence Board and Pacific Salmon Commission (McDevitt, 2018).

Tribal fishing practices at the watershed level also impact the long-term sustainability of fisheries, as prioritization of in-river and selective fishing tools like weirs, traps, wheels, and dip nets effectively avoid bycatch and reduce environmental disturbances (Holtgren & Auer, 2022). By targeting salmon runs in river systems (inland fisheries) and allowing more vulnerable marine populations to replenish, Indigenous communities can harvest individual salmon runs sustainably while still meeting subsistence and cultural needs (Atlas et al., 2020). Indigenous management systems serve as potential alternatives to contemporary resource management approaches, which currently dominate federal and state policies. Resource management by Indigenous peoples emphasizes multigenerational sustainability focused on resilience (Atlas et al., 2020), which could play an important role in the protection of inland fisheries in the face of the climate crisis.

1.4.3. State Level Policies

States have significant influence over the monitoring and management of inland fisheries, and approaches vary broadly depending on the level of prioritization of freshwater ecosystems, cultural and economic dependence on fishing, and overall political tendencies among other factors. State fisheries management foundationally relies on the concept of ownership of the fishery resource, or the common property principle. This approach indicates that if the fishery is considered a public resource, it is thereby owned by the people and the State must maintain and protect access to the resource while also ensuring long-term sustainability and productivity (Holtgren, 2014). This task is largely assumed by variations of Game and Fish Departments established at the state level, which set and enforce regulations regarding fishing practices and fishery management in accordance with federal requirements and state objectives. Separate regulation for subsistence fishing is fairly limited, however, several states have implemented policies that either prioritize subsistence fishing for consumptive allocation or waive licensing requirements and fees. For instance, North Carolina's Subsistence Unified Inland/Coastal Recreational Fishing License Waiver offers free fishing, however, residents must receive aid through the county Department of Social Services (e.g., Food Stamps, Medicaid, or Work First Family Assistance) to qualify (North Carolina Wildlife Resources Commission, 2018). Similarly, Alaska has separate regulations for subsistence and personal use fisheries, some of which require a permit or enforce season, gear, and bag limit restrictions. Colorado is now requiring everyone on State Wildlife Areas and State Trust Lands to purchase and present a fishing license, regardless of whether they are actually participating in fishing or hunting activities (Colorado Parks & Wildlife, 2020). This policy is aimed at supporting a number of conservation initiatives, but may also encourage increased resource extraction and decrease accessibility of fisheries (Blevins, 2020). Title VIII of the Alaska National Interests Lands Conservation Act of 1980 (ANILCA) mandates

that rural residents receive priority subsistence use of fish and wildlife resources on public lands, however, this priority is only available to rural residents and actual implementation has been widely criticized (Finegan, 2015). Regardless, the subsistence priority established by ANILCA is the first and only of its kind, representing a major step forward for the protection of subsistence fishing in that state.

1.4.4. Watershed Level Policies

Inland fishery managers often work in small spatial region scales and focus specifically on a single lake/river or watershed, creating a unique space in which management policies (in terms of a course of action less so than a legislative statement) are determined based on the needs and objectives of the specific fishery and dependent human communities. These influences are often the most impactful, and can set objectives, regulations, and enforcement plans for subsistence fisheries in capacities not attainable by state and federal level approaches (Midway et al., 2016). Management objectives at this scale are also relatively short temporally, often approached for single-year periods.

Climate Adaptation Plans for fisheries are an emerging approach to ensure fishery resilience to climate change threats in communities with a high dependency on subsistence fishing for food security, however, most existing plans do not address long term sustainability of fishery management practices. Risks of community level policies include increased prevalence of maladaptation, as these policies tend to be much more specific and therefore can have more direct consequences (for example, the decision to introduce a new species into the ecosystem to encourage trophic rebalancing). Maladaptation, when an adaptive management approach increases vulnerability of the system rather than decreasing it, can result from limited planning or improper

implementation approaches (Shelton, 2014). For example, the Alaska Native Villages have reported local fishing policies that were too "heavy-handed" led to the fisheries being "managed out of existence" (Walsey & Brewer, 2018). Recommendations for the improvement of policies to increase resilience of inland subsistence fisheries to climate change must consider the capacity and inherent risks of actions at each level of management and consider the policy-shed as a whole.

1.4.5 Transboundary Fisheries Science and Policymaking

Inland waters like lakes and rivers provide critical habitat for anadromous and catadromous species and fall under the jurisdiction of the states, creating significant variation in management authority and protection approaches. Rivers may flow across political borders, therefore comprehensive protection policy in one state may be completely negated by negligence in another downstream. Transboundary Fisheries Science (TFS) is "fisheries science that crosses two or more socio-political boundaries (e.g., state, provincial, tribal, or national) in order to secure usable information for management action" (Midway et al., 2016). Fishery managers at the watershed level can adopt structured decision making through TFS, which works to create a stronger connection between management action and research on the broader ecosystem. For example, while a certain species of fish may not be considered important in one state upstream, TFS-based policymaking would recognize and incorporate larger-scale data which might show that a state downstream does harvest that species for food or sport and considers the species for protection/management. Given that most inland fisheries are managed at the state/provincial level, there is a need to adopt management strategies that are holistic, coordinated, and trans-jurisdictional if inland fisheries in North America are to be sustainable in the future. There is also a critical need for information management systems that enable regional data to be scaled up to the national or continental level to facilitate the generation of inland fisheries status reports and

the monitoring of trends through time. However, it is still relatively unclear where subsistence fisheries exist. Thus, this thesis proposes the following research questions.

1.5 Research Questions

The guiding question that drives this research is:

What communities in the United States rely on inland subsistence fishing as a contribution to their food security?

To investigate this guiding question and analyze the currently unexplored dimensions of climate and community vulnerability, this study proposes the following subsequent research questions:

- Are communities that depend on inland subsistence fisheries in the U.S. vulnerable to climate change?
- What policy and management implications should be considered across scales to support resilient inland subsistence fisheries?

Chapter 2: Methods

This research was conducted between the fall of 2021 and spring of 2023. In addition to the foundational literature review found in Chapter 1, the primary methodologies employed were online surveys to collect quantitative and qualitative data, and geospatial analysis. Approval to conduct the human research portion was granted by the Northern Arizona University Institutional Review Board in August 2022 under the Project ID 1926653-2.

2.1 Online Survey

An online survey was designed using the Qualtrics platform and was accessible via an open link between September and December of 2022. The survey was targeted to individuals that interact with inland fisheries and/or fishing communities in the entire United States, including fisheries professionals, researchers, and inland fishers. Survey participation was promoted through various fishery professional networks, such as through email invitations sent via relevant listservs and social media posts in fishing-oriented Facebook groups.

All survey recruitment efforts included a request to forward the invitation to others in their network who may be eligible to participate in the study, resulting in a "snowball" sampling approach. Snowball sampling is a non-probability method based on referrals from initially sampled respondents to other people believed to be part of the target audience (Johnson, 2014). The original list of email invitations sent directly to survey recruits was based on targeted research of potentially relevant contacts, including through organizations such as the American Fisheries Society, State Departments of Fish and Game / Wildlife / Natural Resources, and the U.S. Fish and Wildlife Service. Similarly, permission was obtained from the administrative personnel of several fishing-focused Facebook and LinkedIn pages to make initial posts which contained very similar text to

that included in an email invitation. The email or post was then forwarded as requested in the recruitment language, and the "snowball effect" of survey recruitment occurred over the three-month data collection period (Ibid). A notable drawback of this approach is the inability to control for potential biases that may arise if more people in one user group tend to forward it to their colleagues, who may then reinforce this bias by forwarding it to more in that group. The most prevalent risk, when using snowball sampling, is therefore a "community bias" (Parker et al., 2019). However, as there is not a clearly defined or realistically accessible population of individuals suitable for this study that could be randomly sampled at this scale, the approach is justified as the most effective way to access what is considered to be the "hidden" target population (Lambert, 1990).

2.2.1 Survey Design

The survey consisted of five primary content sections that focused on (1) relationships to inland subsistence fisheries, (2) perception of inland subsistence fisheries, (3) perception of climate change impacts on inland subsistence fisheries, (4) perception of inland subsistence fishing behavior changes in response to climate change, and (5) policy and management applications (see Appendix A for full survey questions). To participate in the survey, respondents were required to click an acknowledgement of informed consent. The survey then began with a multiple-select-allowed dichotomous choice question that served as a sample qualification filter. Respondents were asked to self-identify their relationship(s) to inland fisheries. To qualify for participation, respondents needed to identify with one or more of the following statements; (1) I personally participate in inland fishing (or members of my family do), (2) My job or volunteer position relates to the management or stewardship of an inland fishery, waterbody, freshwater system, etc., (3) My job or volunteer position relates to fishing communities (including retail, advocacy, education,

outreach, and other work related to people who participate in fishing), or (4) I have studied or performed research related to inland fishery systems. It is important to note that respondents were asked only about their relationship to inland fisheries to qualify for further participation in the study, not inland subsistence fishing specifically. This was an intentional effort to avoid exclusion of fishery professionals and/or inland fishers who may not initially resonate or identify with the term "subsistence fishing", considering the survey seeks to explore broad perceptions of fishing for food and the nexus of recreational and subsistence fishing.

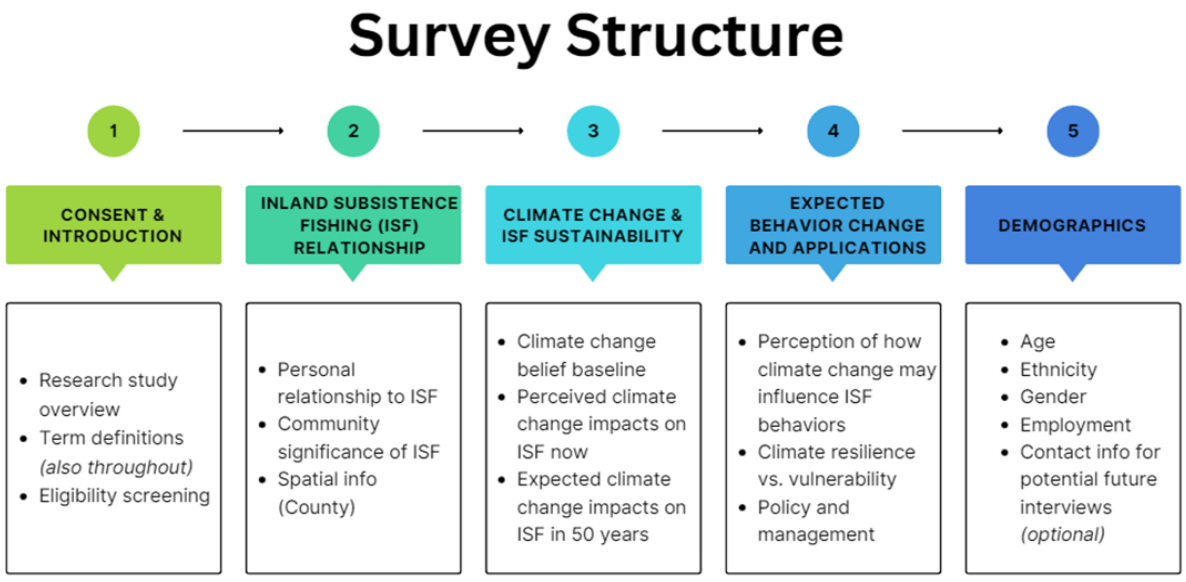

Figure 2.1: Survey Structure Diagram

Respondents were asked to rate their agreement to a series of statements on a five-point Likert scale (with 1 = strongly disagree, 2 = disagree, 3 = neutral (neither agree nor disagree), 4 = agree and 5 = strongly agree). This approach to measuring attitude is widely accepted in the social sciences (Likert, 1932), though many of the Likert scale questions in the survey have been paired with an open-response question to combat some of the contemporary concerns about over-simplification and validation associated with attitude scales (Joshi et al., 2015).

To investigate perceptions of inland subsistence fishing amongst the inland fishery community, the survey posed questions intended to gauge the type of relationships the respondent perceived between people and inland fisheries. Before answering these questions, respondents were provided with the following definitions:

> In this study, **subsistence fishing** is defined as harvesting of aquatic organisms with a primary motivation of consumption (by the fisher or their family). **Food security** refers to consistent access to sufficient quantity and quality of food.

The decision to include data collected from respondents in Alaska was significant to this study. Subsistence fishing in Alaska is a different practice than in the contiguous U.S. in many ways, with highly unique social, cultural, and political factors (Medred, 2016; Thornton & Thomas, 2008, as examples). While this study focuses on the contiguous U.S. (the "lower 48"), the decision to include responses from Alaska was based on the opportunity to use this information as an informal benchmark in the spatial analysis of survey results. As the importance of subsistence fishing is highly studied and widely recognized in Alaska, comparing the results from Alaskan respondents to that of other regions in the country may provide some interesting context.

2.2.2 Survey Analysis

Qualitative data collected through the survey was coded using the processing software NVivo to facilitate qualitative analysis, such as thematic and discourse analysis. This work was guided by methodology literature such as Dierckx de Casterlé et al., 2012, Marks, 2015, and Allsop et al., 2022. The qualitative analysis was performed using an open coding approach, which is an iterative process involving the assignment of codes to participant responses to facilitate thematic pattern analysis (Allsop et al., 2022). A code refers to "a meaningful word or phrase which

represents and conveys the messages and meanings of participant words", whereas coding is "the process of looking through data to find, and additionally assign, codes to participant words" (Allsop et al, 2022, p. 143). With an open coding approach, there is no predetermined code list with definitions; rather, core themes (codes) are identified and refined through several rounds of review and then sorted into "Nodes" (code categories), a feature in the NVivo software which serves as containers for coded text (Dierckx de Casterlé et al., 2012; Allsop et al., 2022). The frequency of and relationships between these nodes then facilitates an aggregated analysis and discussion of the large quantity of qualitative data collected through the online survey.

Quantitative analysis, such as statistical analysis of numerical findings like percentages and average Likert scores, was performed in Microsoft Excel and IBM SPSS. Average Likert scores were calculated by converting responses to their numerical equivalent in excel (see page 28, ex. Strongly agree = 5) and then calculating the mean of the relevant responses. Statistical relationships were analyzed using the bivariate Pearson Correlation tool in SPSS (Denis, 2018).

2.2 Geospatial Analysis

To establish an exploratory framework of potential relationships between inland subsistence fisheries, food security, and subsequent human vulnerability to climate change impacts on those fisheries, preliminary analysis of socio-economic, climate change risk, and survey data from this study was performed at a regional scale. While analysis of inland fisheries may be more directly suited to watershed-scale analysis, socio-economic data are more efficiently approached through the spatial lens of political boundaries, such as state and county boundaries or census tracts. The transboundary nature of both freshwater ecological systems and human communities is an important consideration of this analysis; while political boundaries are utilized to create

geospatial representations of proxy data (such as social vulnerability index scores to represent food insecurity risk by county), the realities of inland subsistence fishing activity, cultural and socio-economic communities, and actualized climate change impacts are not limited in this way. These existing spatial data sources, described in more detail below, were primarily used to inform the development of survey questions that provide a more nuanced and grounded perspective of these relationships compared to the existing literature (or lack thereof).

To visualize existing socioeconomic and climate data in a format conducive to analysis on a national scale, percentile-ranking scores for several data sets described below were calculated for each region in the United States (excluding Hawaii). These regions were assigned based on

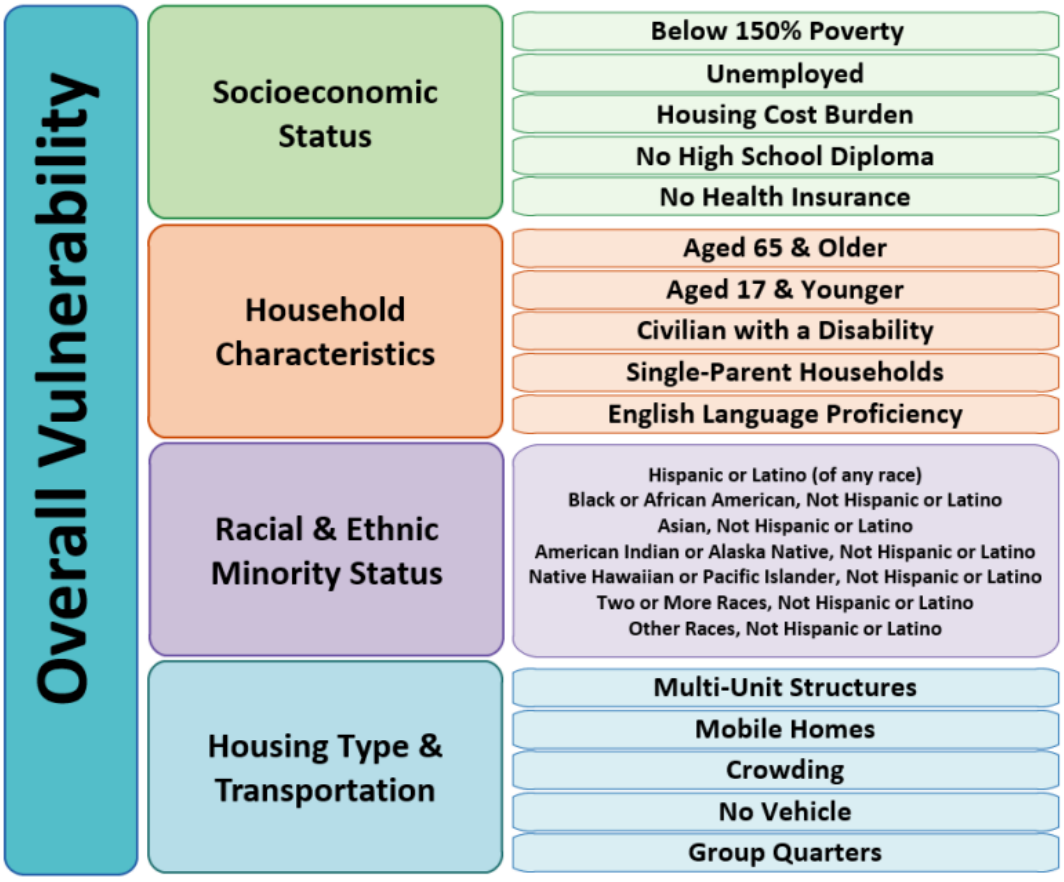

Figure 2.2: Social Vulnerability Index data categories and variables (CDC/ATSDR, 2023)

those used in the 4th U.S. National Climate Assessment, described in more detail on page 33.

Generating percentile-rank (PR) scores allow for comparative analysis of a region's condition in specific categories (such as socio-economic vulnerability) relative to that of all others in the nation; percentile rank represents the proportion of scores in a distribution to which a specific score is greater than or equal to. These scores can then be used to evaluate regions where comparatively high levels of socio-economic vulnerabilities, that may be related to higher need for alternative food sources (like subsistence fisheries), exist in regions where climate change is expected to have the most significant impacts over the next century. For socio-economic input, this work has already been performed by the Geospatial Research, Analysis, and Services Program (GRASP) at the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry for the Social Vulnerability Index (hereafter referred to as the SVI). The SVI was originally intended for disaster preparedness and management applications, last updated in 2022 utilizing fifteen census variables in four categories described in Figure 2.2.

The SVI dataset serves as a relevant socio-economic input for this analysis in that the overall vulnerability scores for each region can serve as a proxy for likelihood of dependence on alternative food sources (such as subsistence fishing) for food security. While datasets specific to food insecurity do exist and are referenced throughout this analysis, the SVI is here used as the primary socio-economic indicator because communities relying on inland subsistence fisheries to provide some portion of their food may not currently self-identify as "food insecure" if they are reliably able to catch and eat fish as part of their lifestyle. As inland subsistence fishing is difficult to delineate from recreational fishing and even more difficult to quantify due to lack of data availability, the contribution of subsistence fishing to food security is likely underreported and underrepresented in policy and management decisions (Nyboer et al., 2022).

Climate change data considered in this study are sourced from the database created for the United States Climate Vulnerability Index (CVI) from Tee Lewis et al., (2023). The CVI utilizes a percentile rank system for 184 indicators in seven primary categories, making this input highly compatible with the SVI dataset. The CVI incorporates both baseline vulnerabilities (such as public health and socioeconomic data) as well as climate change risks (environmental and climate data), however, this study utilizes only the climate change risks portion to avoid double counting for socio-economic factors already accounted for (more comprehensively) by the SVI.

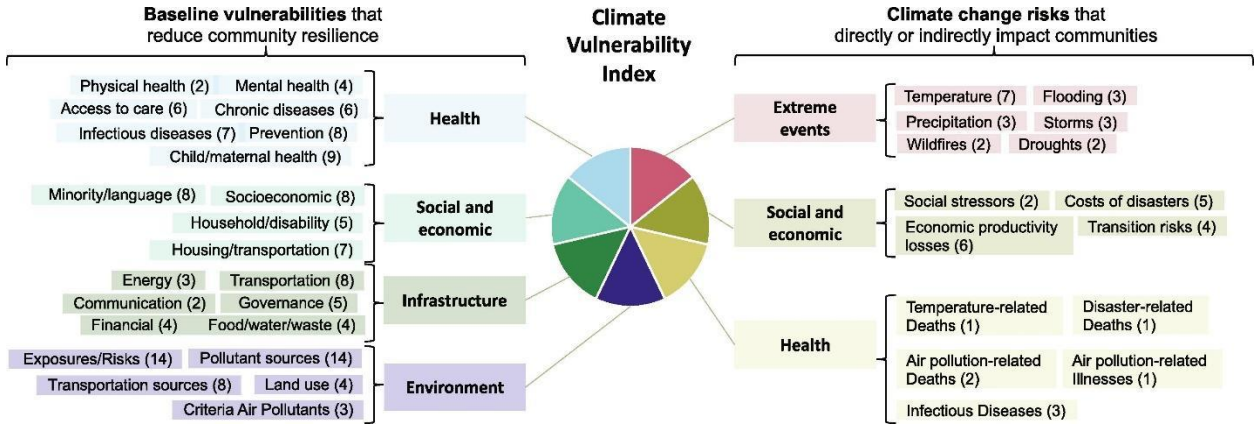

Figure 2.3: Climate Vulnerability Index data categories and variables (Tee Lewis et al., 2023)

An important caveat of this approach is that while these climate inputs may serve as relevant measures of a specific location's level of climate change risk, these inputs may not directly correspond to the freshwater ecosystem's risk. This is especially true for flowing rivers and streams, which may traverse between multiple elevations, habitat types, and land-use contexts. This study operates on the generalization that large areas with a higher risk of climate change factors influencing the physical environment (like changes in temperature, infectious diseases, and other categories described above) also have a higher risk of threats to freshwater ecosystems associated with these changes. This study does not attempt to perform climate vulnerability

assessments or other scientific evaluations of the expected conditions of specific inland subsistence fisheries. Rather, the intent of this spatial analysis is to inform the prioritization of and justification for further investigations of the potential long-term effects of climate change vulnerability at the regional scale on fishing behaviors and motivations.

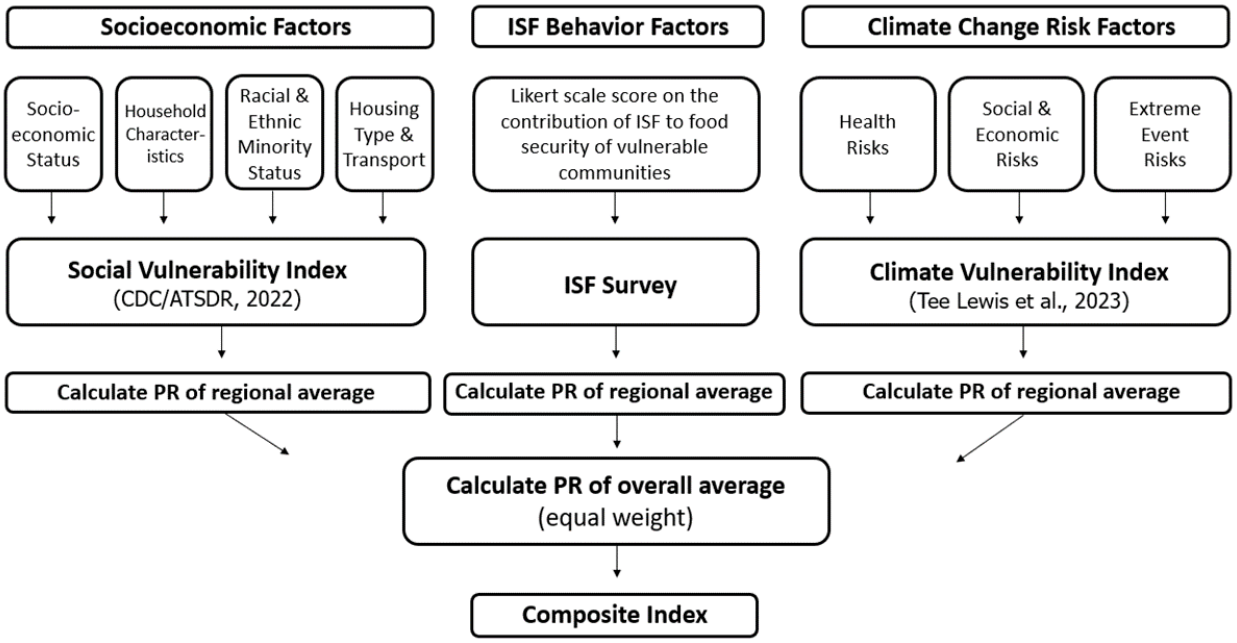

Figure 2:4: Data inputs and analysis process for spatial composite index (PR = Percentile Rank)

ArcGIS Pro was utilized to analyze these variables together in the form of a spatial composite index. To create this composite index, the Calculate Composite Index geospatial analysis tool in Esri's ArcGIS Pro was implemented to calculate the percentile rank of the regional average score from each input dataset. The process used to develop the composite index is illustrated in Figure 2.4.

The Composite Index then represents the equally weighted average of the three subindices, which was then once again calculated as a percentile rank so that the overall score shows each

region's score to all other regions. The highest score of the composite index (1.0) represents the highest convergence of socio-economic vulnerability, climate change risk, and level of confidence that inland subsistence fishing does contribute to the food security of vulnerable communities in that region, relative to all other regions in the United States.

Chapter 3: Results and Discussion

3.1 Online Survey

A full copy of the online survey questions is included in Appendix A. While demographic information was collected in the final section of the survey, this is discussed here first because it provides contextual data that are critical to address prior to analyzing the rest of the survey results. Of the 600 survey participants, 74% identified as male and 85% identified as White/Caucasian. Table 1 provides the detailed breakdown of respondent gender, ethnicity, and employment sector. These sample demographics are reflective of the survey audience, which was targeted largely towards fisheries professionals and researchers. In a 2016 national study, it was estimated that women represent about 25% of the fisheries science workforce (declining to about 15% as position rank increased) and roughly 10% of fisheries science manager and faculty positions identified as minorities (Arismendi & Penaluna, 2016). This study shows similar results, indicating that responses are accurately reflective of the gender balance in these professions. The only demographic factor that demonstrated a relatively equal distribution was age (when considering that the minimum age for participation was eighteen). While indicative of the dire lack of diversity

Gender		Ethnicity		Employment Sector	
Male	74%	White/Caucasian	85%	State Government	43%
Female	24%	Hispanic or Latine	4%	Research/Academia	23%
Nonbinary or other	2%	Other	4%	Federal Government	11%
		Asian	3%	Other	8%
		Native American	3%	Private industry	8%
		Black or African American	1%	Nonprofit	4%
				Other Government	2%

Table 3.2: Relationshios of survey participants to inland fisheries in the U.S.

in the fisheries science field (Arismendi & Penaluna, 2016), these demographics also support that the sample is statistically similar in demographics to the population.

Relationship to Inland Fisheries	Number of Respondents (n = 600)	Percent
I personally participate in inland fishing (or members of my family do)	486	81.0%
My job or volunteer position relates to the management or stewardship of an inland fishery, waterbody, freshwater system, etc.	484	80.7%
My job or volunteer position relates to fishing communities (including retail, advocacy, education, outreach, and other work related to people who participate in fishing)	302	50.3%
I have studied or performed research related to inland fishery systems	479	79.8%

Table 3.1: Demographics of survey particpants

While the perspectives of these fisheries professionals, researchers, and community experts provide a valuable overview of the current perception of inland subsistence fishing behaviors, it is important to acknowledge that these data are generally not drawn directly from subsistence fishers themselves. Of the survey respondents (N=600), 75% indicated that they or their family participate in inland fishing. Of those, approximately 5% reported that they eat the fish that they catch "always", 23% "most of the time", and 28% "occasionally." On average, respondents reported that fish they harvest represents about 9.5% of their diet yet, of them only 26% reported that they believe inland subsistence fishing is a part of their lifestyle. These data indicate that while much of the sample is familiar with and/or participating in the practice of fishing for food, most of their responses are likely drawing from their perception of others' relationships to inland subsistence fishing, rather than their own experiences. It is intended that these survey results serve as a basis for further (likely more localized) studies that seek the direct perspective of people that rely on the fish they catch from inland waters as a contribution to their personal food security.

Figure 3.1 provides the detailed breakdown of sample representation by region, as defined by the 4th United States National Climate Assessment (2018).

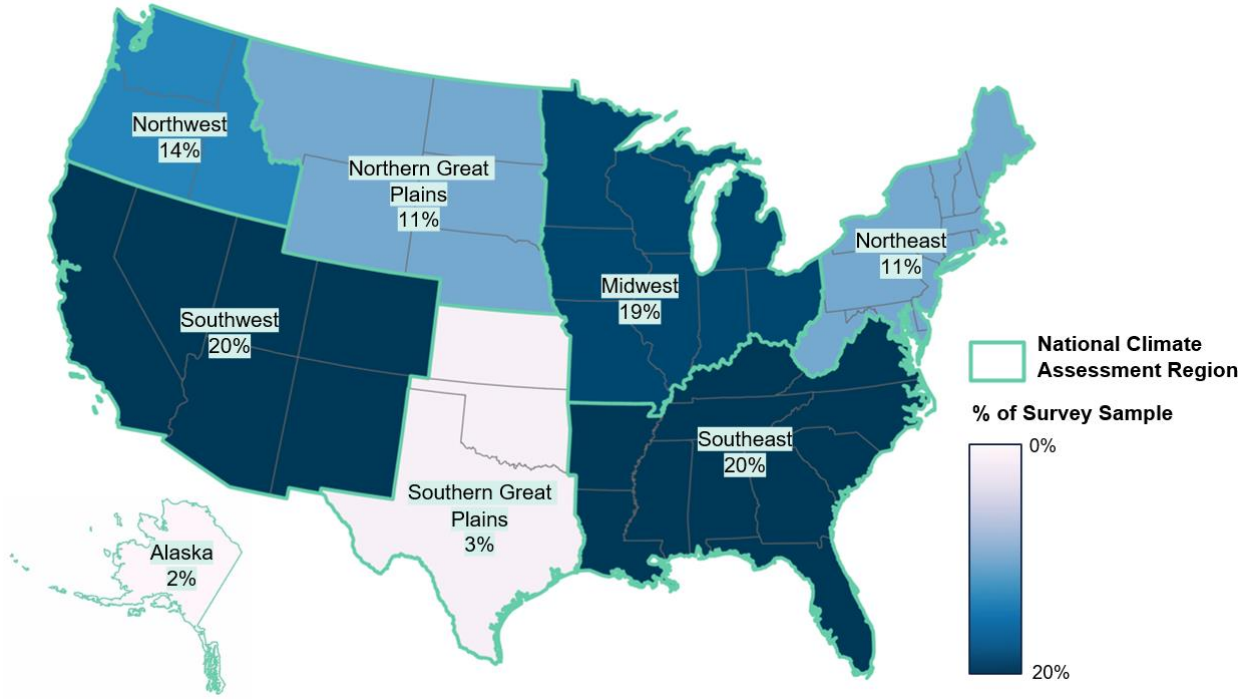

Figure 3.1: Survey sample by region

3.1.1 Perceptions of Inland Subsistence Fishing

The sample overwhelmingly reported that they believe subsistence fishing from inland waters occurs in their region; 78.6% of respondents reported that they either agree or strongly agree with that statement. Of that portion of the sample, 80% went on to agree that inland subsistence fishing contributes to the food security of vulnerable communities in their region. The 21.4% of the sample who were either neutral or disagreed that inland subsistence fishing occurs in their region were instead offered a Likert scale for the statement "Subsistence fishing from inland waters contributes

to the food security of some vulnerable communities in the United States." Of that portion of the sample, 80% indicated that they agree or strongly agree with that statement.

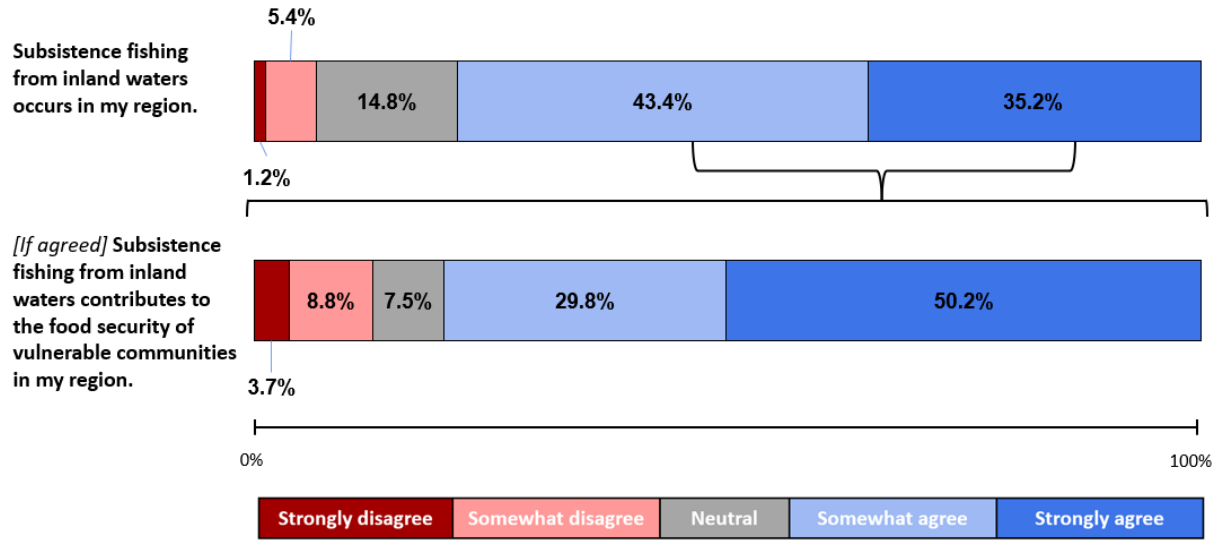

Figure 3.2: Perceptions of inland subsistence fishing and contribution to food security

Breaking down the responses to the latter question by region reveals some interesting patterns, though variation in sample size for each region (as illustrated in Figure 3.1) is an important consideration when granulating these data. As expected, Alaska's average score on the Likert scale is exceptionally high, with the other regions falling into less polarized scores. The unique characteristics of the fisheries in each region will play a critical role throughout this analysis. For example, regions like the Southern Great Plains and the Southeast are well known for the prominence of fishing (including fish fries and crawfish boils) as part of their culture (Wilson, 2018). The Northwest (and California, in the Southwest) have some of the most significant anadromous fisheries in the country. The Midwest includes the many states bordering the Great Lakes, a complex fishery system that is unique in scale in the U.S. but which tends to include significant commercial activities as well as subsistence.

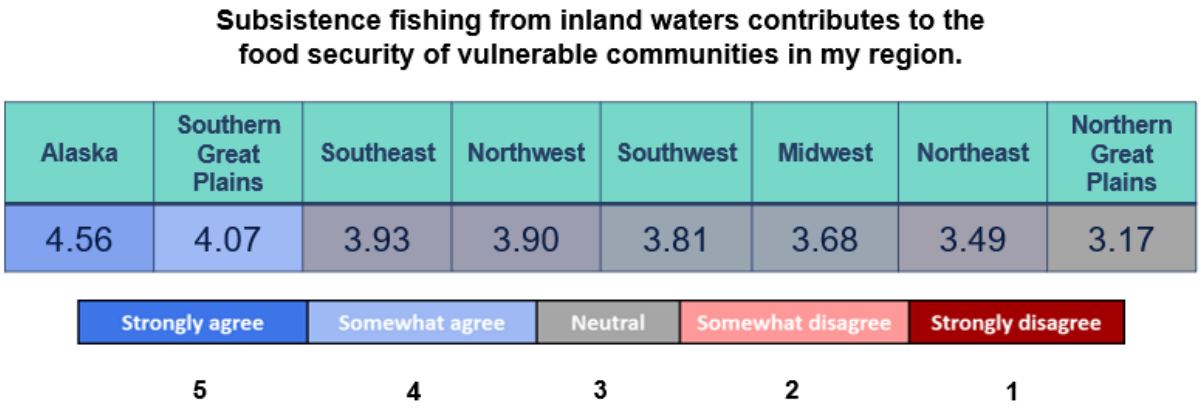

Figure 3.3 Contributions of inland subsistence fishing to food security by region

The survey then examined the cultural significance of inland subsistence fishing by asking the question "Do you consider eating aquatic animals caught from inland waters to be part of your community's culture?." A majority of the respondents answered in the affirmative, with 60% selecting "yes" and an additional 15% selecting "maybe" (see Figure 3.4). This question was intentionally written broadly to invite diverse perspectives of culture and significance. It is important to acknowledge that the role of subsistence fishing in many Indigenous communities is a deeply cultural and spiritual practice that extends beyond simply fishing with a primary motivation of consumption, though these communities were not the target population for the survey. In many cases, it would be inappropriate and ineffective to compare the cultural role of fishing in Indigenous vs. non-Indigenous communities, and that is not the intention of this question. Rather, these questions are intended to explore the diverse ways in which fishing for

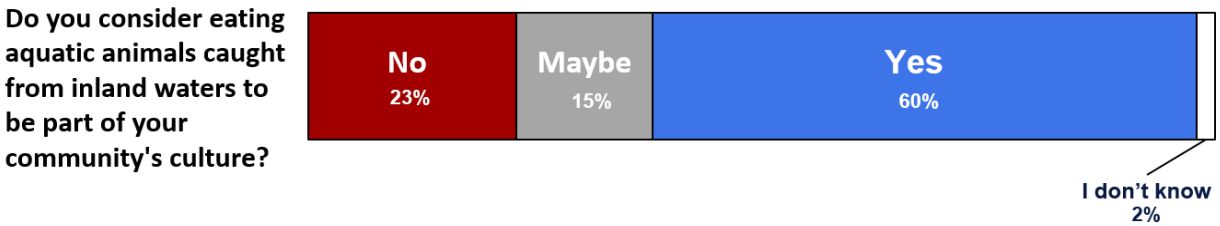

Figure 3.4 Cultural Significance of inland subsistence fishing

food may be perceived as not only a source of nutrition, but also a cultural practice, in addition to a source of nutrition.

Additional insights on this topic were drawn from the associated open response question inviting respondents to explain their answer. Table 3.2 highlights the frequencies of major themes in the responses. The most common theme across responses was language indicating high confidence or a strong emphasis of a long-standing cultural significance of subsistence fishing, spanning generations in the community. Some conflicting values emerged between the “Yes" and “No” responses to this question, with the second most common theme being the mention of “catch and release ethics”, or indications that harvest is perceived as bad stewardship of the fishery in the respondent’s community.

Theme	**Percent of Responses (n=600)**
Emphasis of long-standing significance	18% (N=108)
Catch and release ethics / moral values	14% (N=84)
Disadvantaged or minority populations	12% (N=72)
Fish-centered social and cultural gatherings	7% (N=45)
Importance of specific species	7% (N=42)

Table 3.2: Emerging themes in qualitative data on cultural significance of inland subsistence fishing by participants

Conversely, some respondents that emphasized a long-standing cultural significance indicated that harvest was an important part of their values. One respondent from the Midwest wrote that “My family espouses the idea that hunting and fishing should supplement our food sources. It is a source of pride to prepare food that has been harvested by a member of the family.” Others

extended beyond their personal values and reported widespread significance of fishing for consumption in their area. For example, a state government employee from the Southeast shared:

> *In South Florida, fishing is a way of life. Wherever there is water, there are folks fishing and keeping their limit for consumption. If you were to drive down the major canal system on any given day of the week (especially on the weekend), you would see folks from coast to coast fishing for consumption.*

The importance of subsistence fishing as a cultural practice for Indigenous communities was also clearly demonstrated in the qualitative data for this question. Several non-Indigenous respondents acknowledged their awareness of inland subsistence fishing as a significant practice of tribes in their region, and the limited number of responses directly from Indigenous people were rich with unique perspectives of cultural and spiritual relationships with fisheries.

Social gatherings centered around the consumption of inland catch were also a significant theme, especially for respondents in the Southeast and Midwest. The terms “Fish Fries” or “Fish Fry” specifically were used in 24 responses, and several others made broader comments about the cultural value of people coming together to cook and consume the fish they catch. Respondents often mentioned tradition and feelings of camaraderie, with phrases like “Friday night fish fry is a tradition” and “Fish fries generally involve a gathering of people, and the fish served is usually accompanied by other comfort foods - leading to much excitement for the meal.” Others dove deeper into the significance of the practice in socioeconomic and sociocultural contexts, such as this response from a researcher in the Southeast:

I live in Mississippi, so much of the culture revolves around catfish and crawfish. Crawfish boils are a staple activity to do along with fish fry's [sic]. There are many in the Delta region (the most socio-economically depressed region of Mississippi) who will go out and catch all the fish they can regardless of size to feed their families and themselves. The fish and collection of said fish are crucial to their identity and survival.

The survey next asks "Are there any health and safety concerns associated with consuming aquatic animals harvested in your region, such as advisories against consumption due to contamination?." This question provides key context as to the prevalence of potential risk associated with the consumption of inland fish. A large majority of the respondents indicated "Yes" at 76%, and an additional 7% indicated "Maybe" (see Figure 3.5). Given that the results of previous questions established a strong agreement amongst respondents that inland subsistence fishing is both occurring and contributing to food security, this high rate of perceived health and safety concern is foundational to the discussion of related community vulnerability.

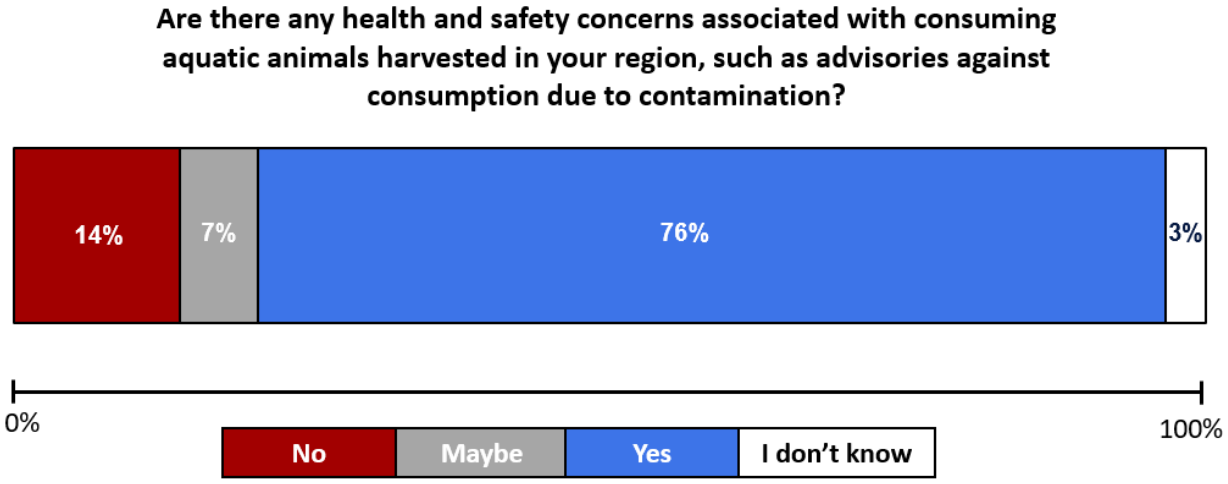

Figure 3.5: Perceived health and safety concerns associated with consuming aquatic animals by survey participants.

3.1.2 Climate Change and Inland Subsistence Fishing

Regarding the perception of present and future climate change impacts on ISF, respondents were asked to report whether they believe in "human-caused climate change."Of the sample, 88% selected "Yes," 3% selected "No," 6% selected "Maybe," and 3% selected "I don't know." Respondents that did not select "Yes" were not excluded from the analysis; rather, this question was intended to establish the general attitude of the sample towards anthropogenic climate change. According to the 2021 Yale Climate Opinion Survey, it is estimated that about 72% of Americans believe that climate change is happening, and about 57% believe that climate change is caused mostly by human activities (as opposed to natural changes) (Marlon et al., 2022). This indicates that the sample is slightly more inclined to believe in anthropogenic climate change than overall population of the country, which makes sense considering that a large majority of the sample is made up of government employees in management positions and/or people working in academia (therefore likely to have higher education) (Lee et al., 2015).

After establishing whether respondents believed in climate change, respondents were asked through two questions whether they consider climate change (i) to be influencing sustainability of inland fisheries now; or (ii) expect it to influence the sustainability of inland fisheries 50 years in the future. The term "sustainability" was defined as "the ability of the fishery system to continue operating efficiently over time." Respondents were also offered the opportunity to explain why they selected their answer in an associated open-response question. The majority (63%) indicated climate change is already influencing the sustainability of ISF in their region. The number increased to 81% when asked about whether climate change *will* impact the sustainability of ISF over the next fifty years. Figure 3.6 illustrates the full breakdown of responses.

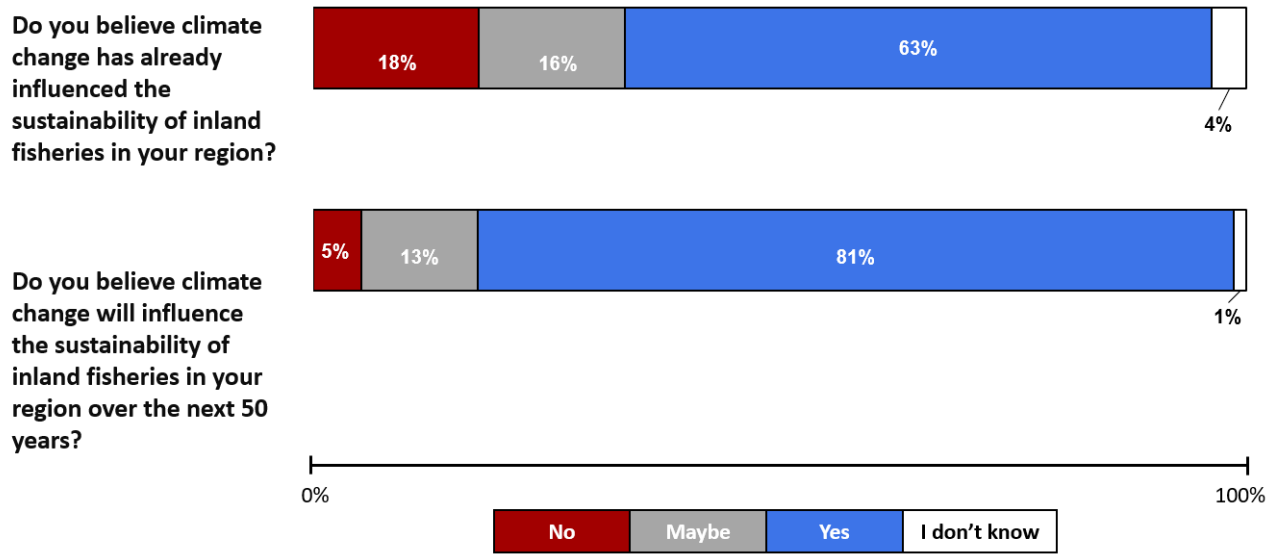

Figure 3.6: Perceived and expected influence of climate change on inland subsistence fisheries

Two primary themes dominated the qualitative data, especially in reference to how climate change has *already* influenced the sustainability of ISF. Respondents that selected "Yes" were most likely to identify water quality (including changes in temperature) or water quantity (including changes in flow rate, timing, etc.) as their overarching/primary explanations. These themes generally align with the literature on threats to and impacts on inland fisheries (see Chapter 1). Changes in species distribution or composition were also frequently coded, with the most common sentiment being that the populations of highly desired species for consumption are reduced or the range is shifting, making it harder for subsistence fishers to successfully harvest what they want to. Table 3.3 shows the breakdown of major themes.

Theme	Percent of Responses
Water quality (including temperature)	19% (N = 111)
Water quantity (including flow rate/water level)	14% (N = 81)
Change in species distribution or composition	11% (N = 64)

Climate change is not a priority concern	11% (N = 62)
Extreme events (weather, algae, disease, etc.)	8% (N = 47)

Table 3.3: Emerging themes in qualitative data on climate change influence on ISF by participants.

Respondents indicated varying levels of severity when discussing the climate change impacts, they've already seen in inland fishery systems, with many responses indicating that climate-related changes have been observed but the actual sustainability of ISF does not seem to be threatened yet. Several others cited reports from their region or shared detailed stories to justify their belief that climate change is already influencing ISF. For example, a state government fishery manager from the Northwest wrote:

> *I work in a transitional biome where the desert meets the mountains. As such, the effects of climate change are rather apparent here. We've had more frequent blue algae blooms in our reservoirs, have documented elevation shifts in species distributions, and recently needed to close a White Sturgeon fishery in an impoundment of the Snake River due to a mortality event that may be associated with angling during periods of environmental stress (hot water, low dissolved oxygen).*

The nature of ISF as socio-ecological systems means that many of the threats and symptoms described by respondents are inextricably linked and difficult to code into separate thematic categories. For example, it is the changes in water quality and quantity that drive the shifts in species composition and distribution. Less water quantity (like lower stream flows or reservoir levels) resulting from drought may also lead to changes in water temperature (since less water takes less energy to heat). This portion of the survey was not intended to quantify climate

change impacts on ISF, but rather to investigate the attitude and perception of respondents. In this sense, some of the most insightful findings of the qualitative data from this section involved projections about how these climate change impacts will influence ISF going forward, especially on the 50-year time scale. For example, a researcher from the Southeast noted:

> *As the climate warms, temperature sensitive fish are moving further and further upstream to reach cooler waters. Not only does this have implications for species conservation and management, but it also affects vulnerable communities who rely on fish for sustenance and may not have the ability to 'follow' populations as ranges shift.*

3.1.3 Expected and Perceived ISF Behavior Changes in Response to Climate Change

As most respondents reported that they do believe climate change is already influencing the sustainability of ISF, or will in the future, it is relevant to then investigate how these changes may disrupt ISF behaviors over time. This section of the survey revealed much more significant ambivalence exists among the respondents in terms of their opinion on behavior change. There are higher "neutral" or "I don't know" responses than for previous sections. These findings make sense given the context of the questions in this section; the study participants were no longer being asked to report their lived experiences or informed perspective, but rather to apply that perspective to make projections about how subsistence fishing behaviors might respond to change over time. As discussed throughout this study, the fuzzy boundary between recreational and subsistence fishing behaviors is extremely difficult to quantify and interpret in most (non-Indigenous) communities in the U.S. This will make it even more difficult to predict trends in behavior change in the future. Hence it is recognized that this section of the survey poses hypothetical and likely oversimplified

questions about future ISF behavior trends; but recognizing that, the results still provide an informative starting point from which future research and management discussions may be developed.

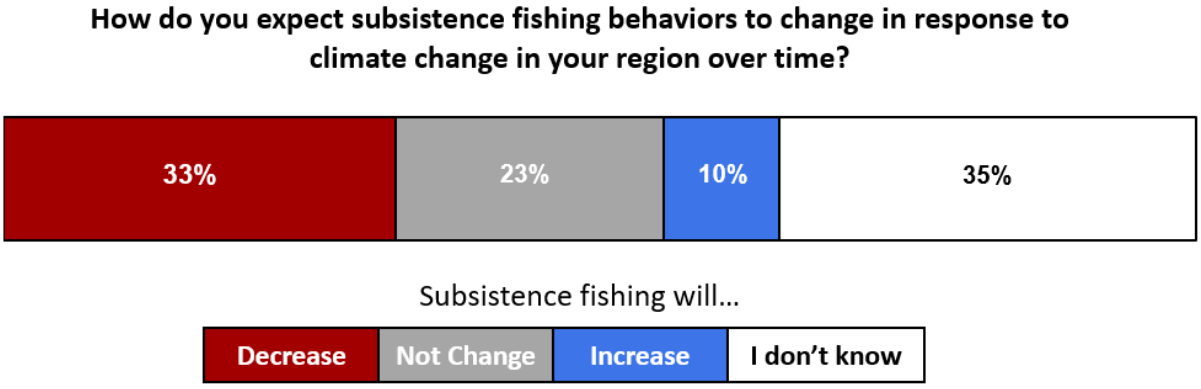

Figure 3.7: Expected inland subsistence fishing behavior change in response to climate change over time.

Most respondents were unsure about how subsistence fishing behaviors would change in response to climate change over time (with 35% selecting "I don't know", see Figure 3.7). The next largest portion of the sample reported that they believe subsistence fishing will decrease. There was notably less qualitative data associated with this question than others (likely because over half of the sample selected "will not change" or "I don't know", and therefore may not have felt compelled to elaborate on their response). The most common justification, in generalized terms, was that "less fish will mean less fishing." Over half of the respondents that indicated "subsistence fishing will decrease" went on to mention decreased fish populations, shorter fishing seasons, stricter regulations, and other topics related to generally less accessible catch in the associated open-response question. Similarly, those that selected "subsistence fishing will increase" were also in relative consensus; climate change will make other food sources less reliable or accessible, pushing more people towards subsistence. For example, a state government employee from the Midwest wrote:

Climate changes cause prices for food to increase due to shortages. The price increases as well as food shortages will cause more people to turn to hunting and fishing to help feed their families.

Another less prevalent but interesting theme in the qualitative data for this question was the concept that policies and conservation measures in response to climate change will lead to stricter regulations on harvest, making subsistence fishing more difficult. For example, a respondent from the Southwest shared:

It will be harder to catch fish, so people will fish less. Regulations will also be strict, and it will reduce people's desire to fish if they think the fisheries are too limited.

Maintaining its consistency as the benchmark subgroup, the Alaska sample was by far the most confident that ISF will decrease (67%, see Figure 3.8). This is supported by extensive literature on the rapidly declining anadromous fish runs in Alaska, and highly controversial regulations on harvest associated with this decline (Medred, 2016; Ristroph, 2019; Thornton & Thomas, 2008). It is logical, then, that the Northwest and Southwest regions would also have above-average agreement that subsistence fishing will decrease, as anadromous fishes play a significant role in these regions as well. While there is a statistically significant degree of uncertainty in the Northwest and Southwest samples (with 36% and 31% selecting "I don't know," respectively), it does seem to be generally accepted that subsistence fishing will *not* increase; only 4% and 8%, respectively, of respondents of the Northwest and Southwest groups stated that they thought there would be an increase.

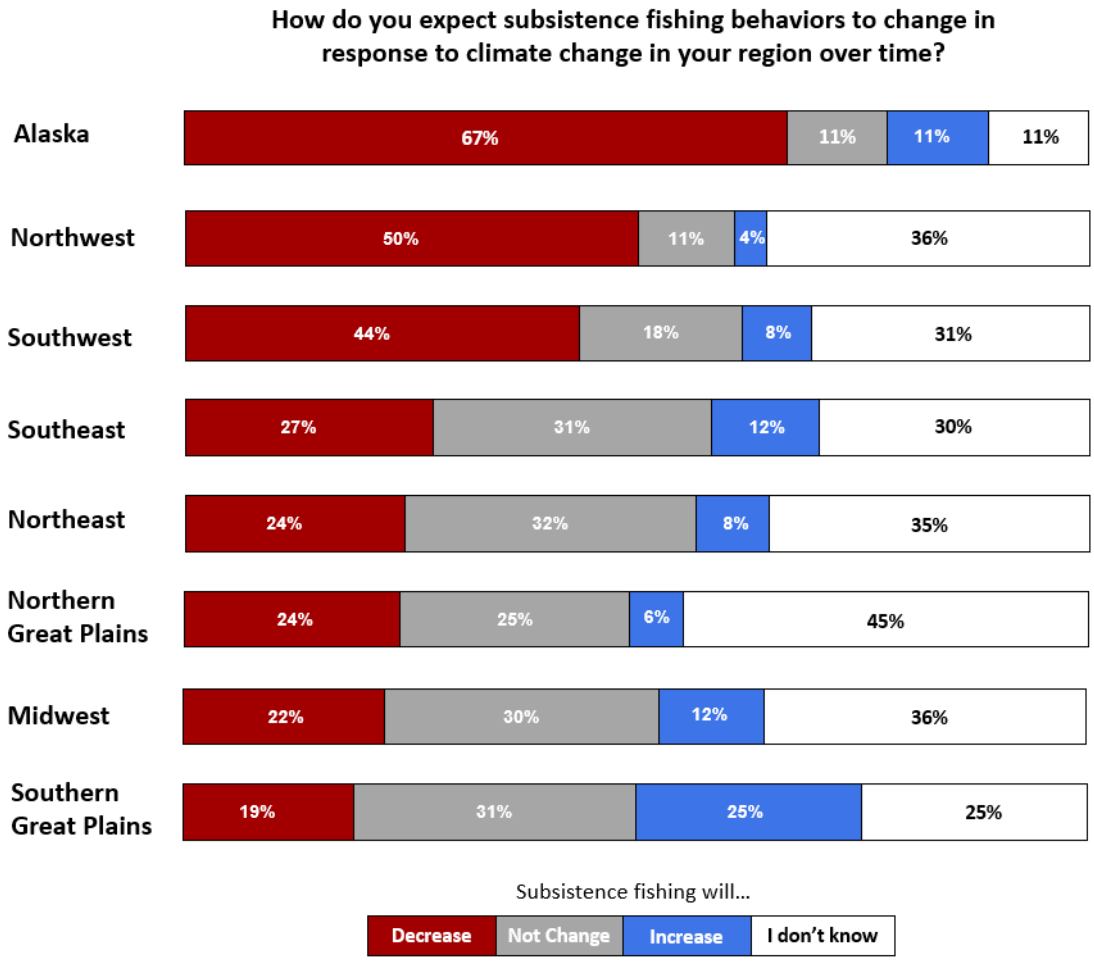

Figure 3.8: Expected ISF behavior change in response to climate change by region

Despite high levels of agreement that climate change will influence the sustainability of ISF over the next fifty years (see Figure 3.6), many regions (and 23% of the overall sample) indicated that they do not believe ISF behaviors will change. The Southeast stands out again as a striking example of potential disconnect. Despite having high rates of socioeconomic vulnerability, high risk of climate change impacts on ecosystem services, and reporting a high level of cultural significance associated with ISF, 31% selected that they do not expect ISF to change over time. Beyond projecting how the role of ISF might shift in their region over time, respondents were also asked to consider the implications of this role in the climate vulnerability and resilience of diverse communities. Respondents were asked to answer based on the following definitions:

The term "vulnerable" refers to the risk of being adversely affected by change. The term "Resilient" refers to the ability to withstand, respond to, and recover from change.

Climate vulnerability and resilience are exceptionally nuanced concepts that affect, and are affected by multiple different, and interlinked parameters; community reliance on ISF as a contribution to food security is just one of these. Nevertheless, the respondents' perception of how a community's relationship with inland subsistence fishing may contribute to either vulnerability or resilience could provide some valuable insight into how inland fishery systems should be considered (or leveraged) for climate adaptation planning.

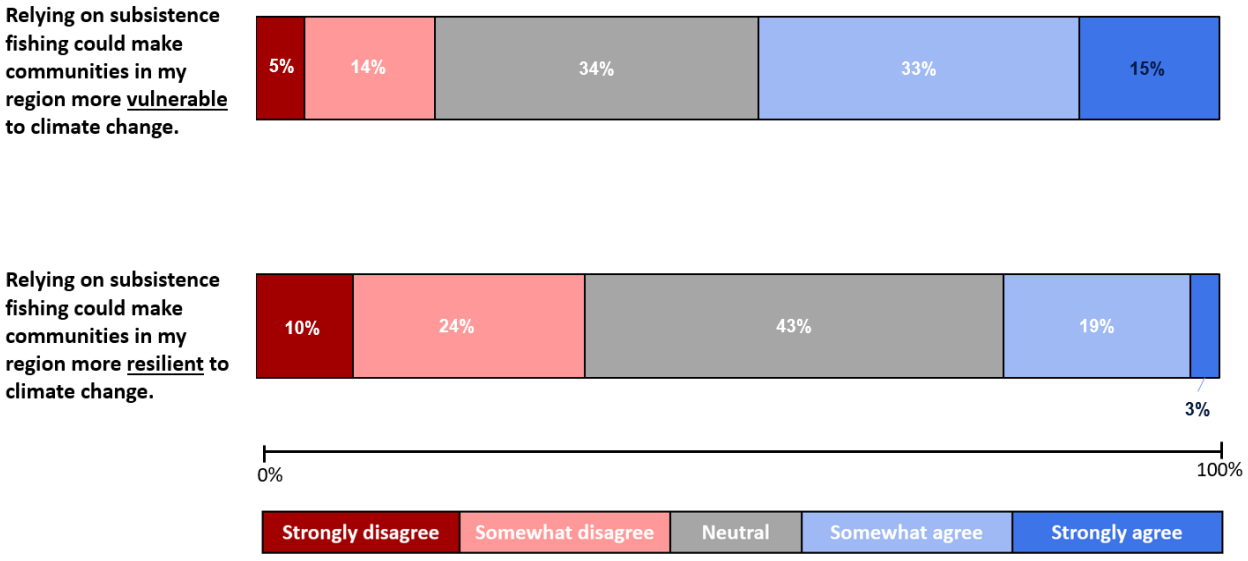

Figure 3.9: Perceptions of ISF contribution to climate vulnerability and resilience

The survey respondents showed a greater proportion agreeing, rather than disagreeing, that reliance on ISF could make communities more vulnerable to climate change. This response was mirrored by slightly higher rates of disagreement that it could make communities more resilient (see Figure 3.9). However, these trends are not definitive. Neutral responses dominated these questions, especially when asked about resilience. Ambivalence was by far the most common

theme in the qualitative data, with respondents frequently going back and forth between the benefits of ISF as a tool for independence versus the potential for unreliability going forward. This passage from a respondent in the Midwest exemplifies this theme:

> *Individuals that subsistence fish are likely to rely on food sources that may vary with climate change impacts which could make individuals more vulnerable to climate change if they rely too frequently on subsistence fishing for their only food. However, fishing could act as food security for individuals hard hit by rising energy bills to combat climate change, temperature and humidity patterns as less income would be spent providing food.*

This section of the survey thus emphasized the lack of clarity around how the relationship between vulnerable human communities and the fisheries from which they harvest some or all of their diet might play into climate vulnerability (or resiliency). There are conflicting ideas amongst inland fishery professionals as to whether relying on personal harvest is a potential strength and tool to buffer against the economy in a changing climate, or a weakness that may create more risk for the community over time. It is likely that these dynamics are highly specific to each individual ISF and the context in which they are used. Regardless, localized studies of these behaviors may provide valuable insight for effective climate adaptation and environmental justice planning.

3.1.4 Management and Climate Action Applications

The final content-focused section of the survey assessed perceptions of ISF in application to fishery management and climate adaptation plans (see Figure 3.10). The respondents were slightly more likely to agree, than disagree, that ISF (specifically, its contribution to food security)

is already adequately addressed in inland fishery management decisions (49% agree, compared to 20% neutral, and 31% disagree). As part of this question, participants were provided with the following definition:

> *"Inland fishery management decisions" refers to any decisions that influence the processes of inland fishery systems, including ecological interventions, regulations on fishing activities, and other courses of action taken by local, state, tribal, or federal institutions.*

These decisions could reasonably include policies such as harvest limits, licensure fees, consumption advisories, and fish stocking, amongst other activities primarily conducted by agencies. However, interpretation of the term will vary significantly between individual participants.

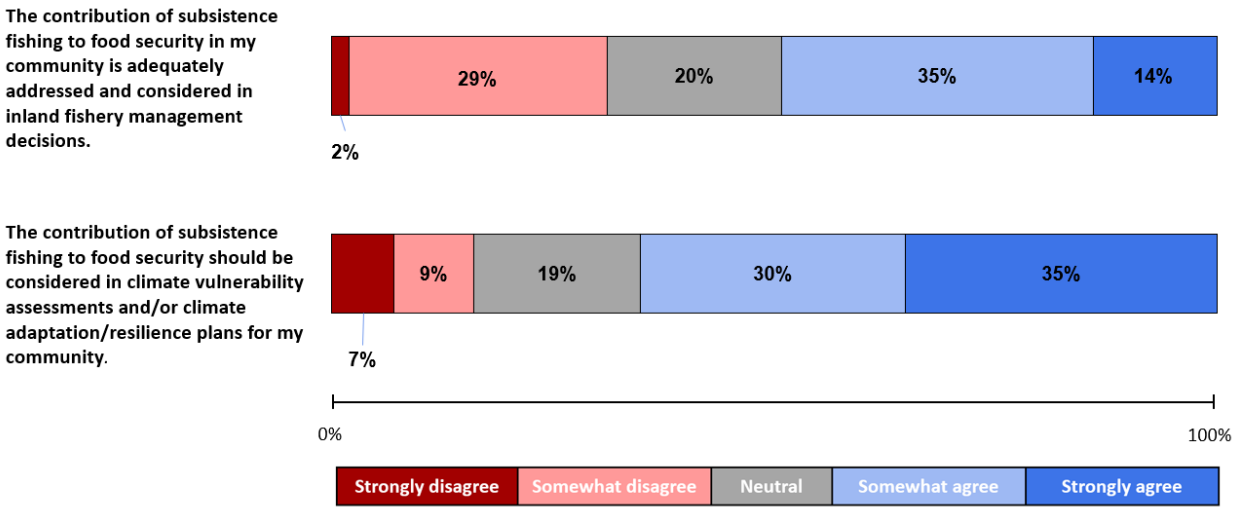

Figure 3.10: Survey sample perceptions of inland subsistence fisheries in application to fishery management and climate adaptation plans

The sample felt more strongly that the contribution of ISF to food security *should* be considered in climate vulnerability assessments and/or climate adaptation and resilience plans (see figure 3.10, 65% agreement). While the first question, about management decisions,

specifically sought out perception of current conditions, the question about climate change assessment and planning used the word "should" to allow for a more hypothetical framing. The responses to the survey seem to bear out the results gained from the literature review that showed that ISF is arguably intertwined with inland fishery related policy and management frameworks in the U.S. (see section 1.4). However, outside of Alaska, there is no evidence to indicate that the contribution of ISF to food security has yet been included in climate vulnerability assessments (and therefore, climate adaptation planning). The survey responses clearly show a perception of this *need* for climate change impacts on ISF to be considered as part of broader analyses of climate vulnerability and related action plans.

NCA Region	The contribution of subsistence fishing to food security in my community is adequately addressed and considered in inland fishery management decisions.	The contribution of subsistence fishing to food security should be considered in climate vulnerability assessments and/or climate adaptation/resilience plans for my community.
Alaska	2.22	4.78
Midwest	3.43	3.90
Northeast	2.85	4.07
Northern Great Plains	3.15	3.58
Northwest	3.30	4.08
Southeast	3.29	3.88
Southern Great Plains	3.44	4.19
Southwest	2.94	3.92

Table 3.4: Average Likert scale scores by region for inland subsistence fishery management and climate action application questions.

There was significant variation between regions when analyzing the average Likert scale scores for these questions (see Table 3.4). Notably, the Southern Great Plains had the highest agreement that ISF is adequately addressed in management decisions,

3.4 Geospatial Analysis

A spatial composite index was generated to further investigate where ISF exist and contribute to both food security and potential climate vulnerability in the U.S. Following the

procedures described in Chapter 2, an equally-weighted composite score was calculated for each of the NCA regions, excluding Hawaii. The results of the geospatial analysis align with findings from the survey, indicating that communities in the Southeast and Southern Great Plain regions are most likely to have vulnerability as a result of climate change influencing the sustainability of inland subsistence fisheries.

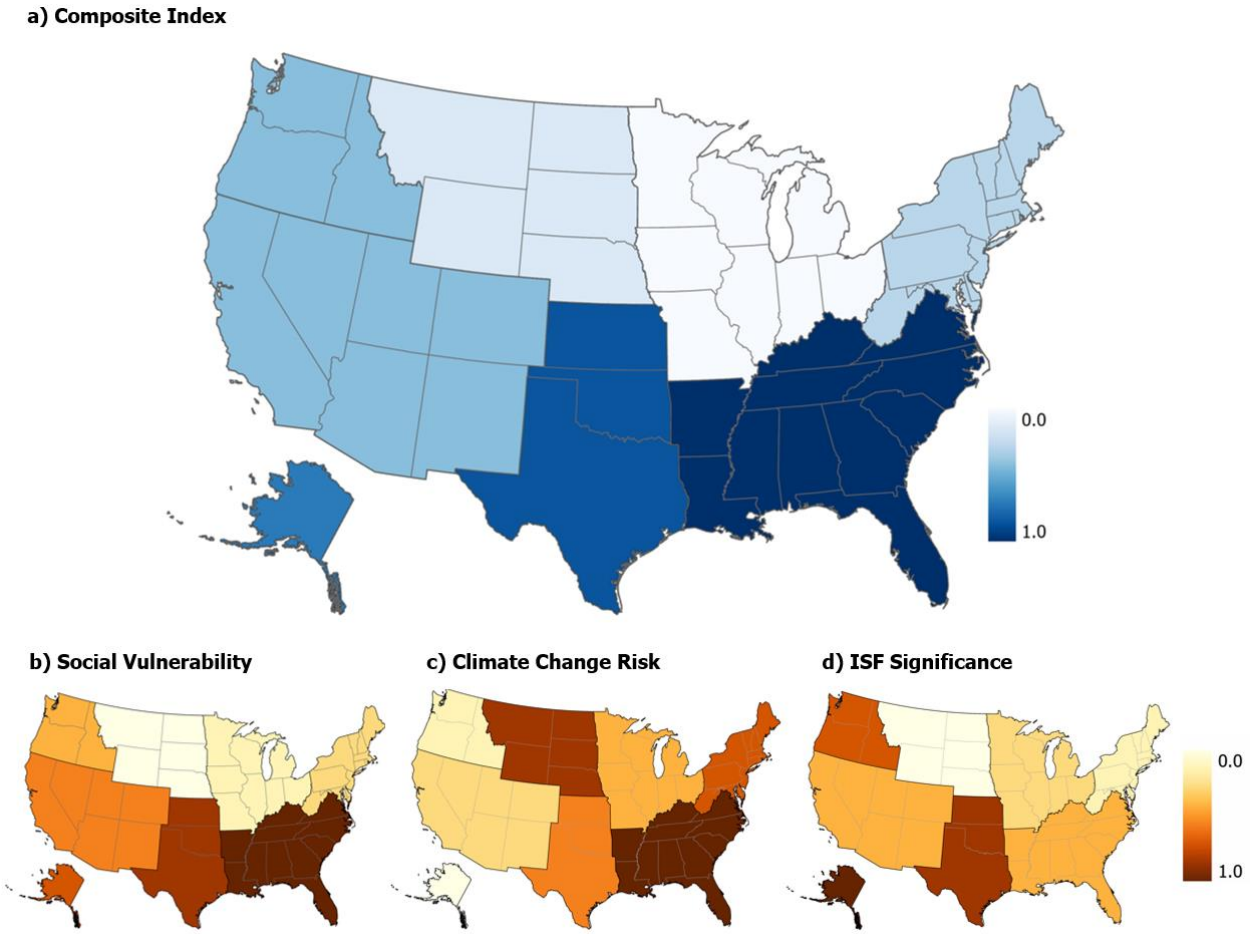

Figure 3.11: a) Spatial composite index results map, which is an equally weighted representation of b) social vulnerability as determined by the regional average PR of the SVI (CDC/ASTDR, 2022),c) climate change risk as determined by the regional average PR of the CVI (Tee Lewis et al., 2023), and d) the significance of inland subsistence fisheries based on the regional average PR of the average Likert scale score from survey question 4b. PR = Percentile Rank.

Region	Social Vulnerability	Climate Change Risk	ISF Survey	Composite Index Score
Alaska	0.71	0.00	1.00	0.71
Midwest	0.14	0.43	0.29	0.00
Northeast	0.29	0.71	0.14	0.29
Northern Great Plains	0.00	0.86	0.00	0.14
Northwest	0.43	0.14	0.71	0.43
Southeast	1.00	1.00	0.43	1.00
Southern Great Plains	0.86	0.57	0.86	0.86
Southwest	0.57	0.29	0.43	0.43

Table 3.5: Average percentile rank scores by region for the spatial composite index and each data input category.

The Southeast has the highest convergence of social vulnerability, climate change risk, and belief amongst the survey sample that ISF contributes to the food security of vulnerable communities, relative to all other regions. Table 3.5 shows the specific score values for each region. Survey respondents answering about the Southeast were also the most likely to report that ISF holds cultural significance in their region. These findings indicate that research and management discussions seeking to gain a stronger understanding of these socio-ecological systems should be prioritized in the Southeast.

3.5 The Significance of ISF to Food Security in Vulnerable Communities

A relevant insight of the regional breakdown of the survey data is its clear reflection of the 2020 Social Vulnerability Index (SVI) data. To quantify this relationship, an average SVI score for each NCA region was calculated by taking the mean of the SVI scores of each county in each

region. A Pearson correlation coefficient was computed to assess the linear relationship between a region's average SVI score and its average Likert scale score from the survey regarding ISF contribution to the food security of vulnerable communities, as shown in Figure 4.1.

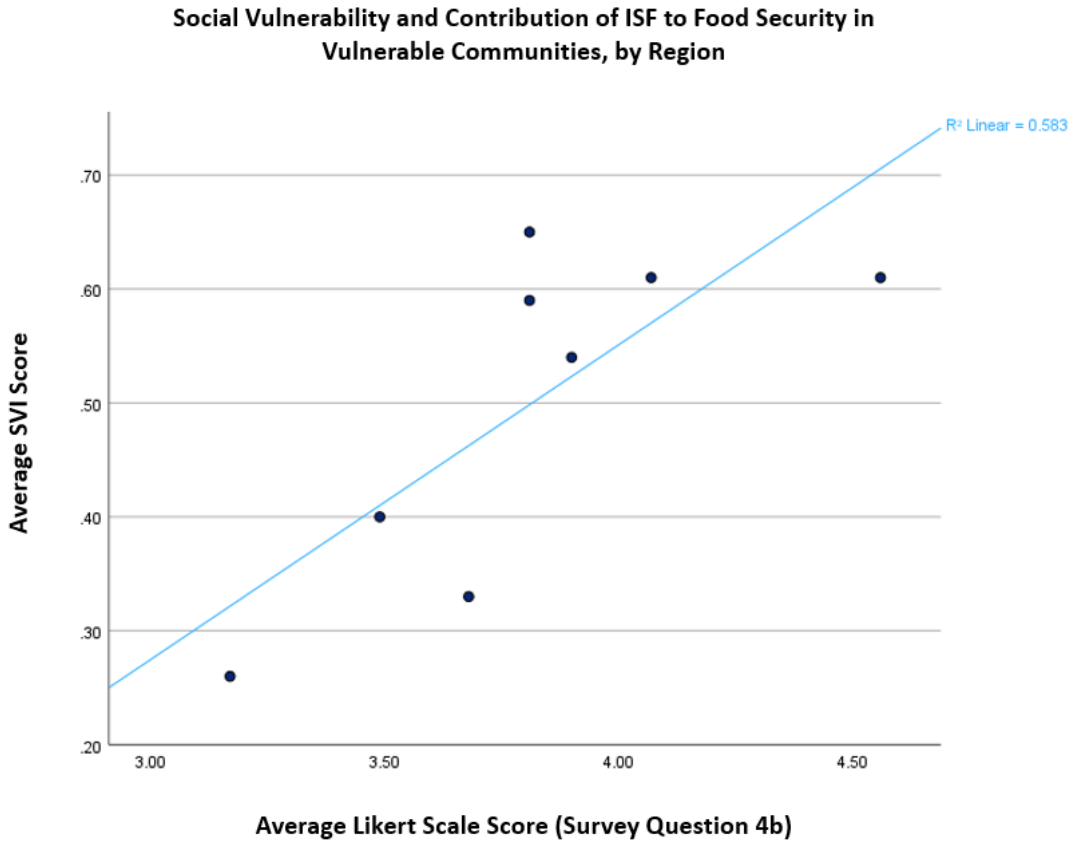

Figure 3.12: Pearson correlation between social vulnerability and contribution of inland subsistence fishing to food security by region.

There was a strong positive correlation between the two variables, r(522) = .763, p = .028. Figure 4.1 provides the scatter plot of the two variables. These findings support the hypothesis that communities with higher social vulnerability are more likely to rely on ISF as a contribution to food security. It is important to note that this strong positive correlation does not persist in the survey sample when broken down to the state or county level. However, this high-level relationship is still an interesting indication that ISF may be operating as a tool for affordable access to protein and potentially contributing to food security in places with high rates of poverty,

unemployment, and other disadvantaged demographics. Fishery managers and other key decision makers may be unintentionally creating a blind spot to the relevance of fishing for food as an ecosystem service by assuming any harvest occurring in their region is negligible to food security, especially in regions with high levels of socio-economic vulnerability.

Additionally, the regional breakdown of respondents' opinion on whether climate change will influence the sustainability of inland fisheries in their region over the next 50 years was more reflective of the spatial distribution of climate change beliefs in the U.S. than it was of actual climate threats. According to the 2021 Yale Climate Opinion Survey, the Southeast, Southern Great Plains, and Midwest regions all have lower average percentages of residents that believe climate change is mostly caused by human activities, than other regions of the country (Marlon et al., 2022, see Figure 3.13). Respondents from these regions were also the least likely to select "Yes" when asked about whether climate change will influence the sustainability of ISF in the future, as illustrated in Figure 3.8.

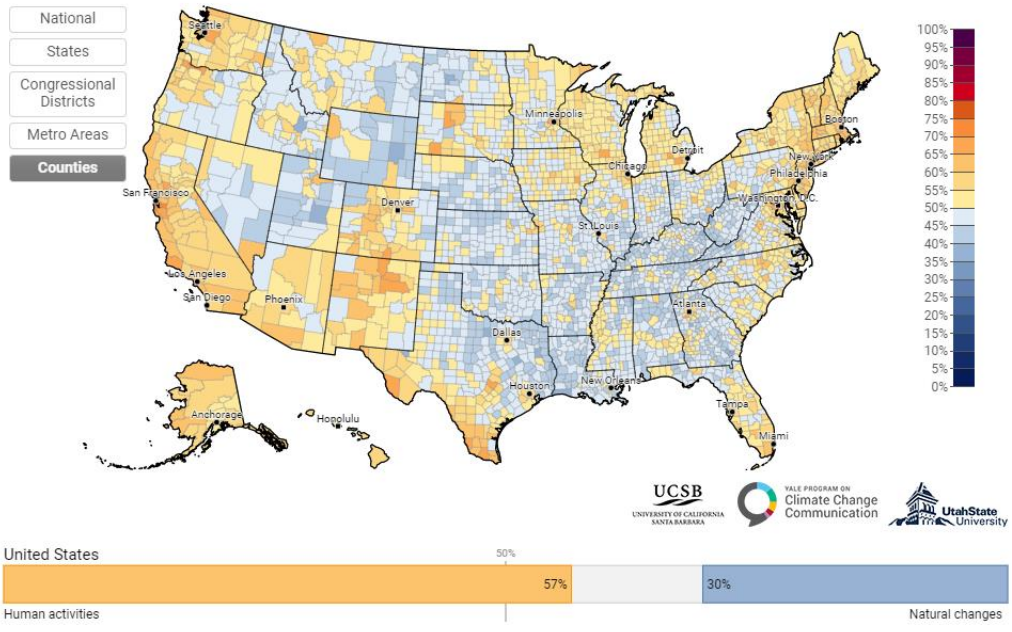

Figure 3.13: Estimated % of adults who think global warming is mostly caused by human activities (nat'l avg. 57%) (Marlon et al., 2022).

Conversely, the Southeast and Southern Great Plains have some of the highest scores on the Climate Vulnerability Index (Tee Lewis et al., 2023) and the Southeast specifically has the highest concentrations of imperiled aquatic biodiversity (Einhorn & Popovich, 2022). These findings suggest a potential disconnect between the perceptions of climate change threats held by inland fishery decision-makers (like state fishery managers) in the places where it is most important to prioritize addressing them. The significance of this disconnect is intensified by the fact that the Southern Great Plains and Southeast reported the highest belief (other than Alaska) that inland subsistence fishing contributes to the food security of vulnerable communities in their region (see Figure 3.3).

Chapter 4: Conclusion

Understanding how and why human communities are utilizing inland fisheries is critical to making effective and equitable management and policy decisions. The results of this study indicate a need for further research and discussions about the relatively unexplored and potentially undervalued dimensions of fishing for food in the U.S., especially as climate change and other threats to inland fisheries progress. Key applications of these discussions may include but are not limited to the effective design of outreach efforts for fish consumption advisories and related research, harvest regulation considerations, climate change assessments and advocacy, and environmental justice.

4.1 Health and Safety

The assumption that fish harvested from inland waters are negligible to food insecurity has the potential to create equity gaps in fisheries management decision-making. As the survey results indicate that inland subsistence fishing is occurring and contributing to the food security of vulnerable communities (see Figures 3.2 and 3.3), the corresponding high rate of respondents reporting health and safety concerns associated with consuming inland fish in their region (76%, see Figure 3.5) raises critical questions about the long-term sustainability of this socio-ecological system. Climate change will also increase this potential health risk over time. For example, warming water temperatures, rising water carbon dioxide levels, and changes in rainfall can all contribute to increased occurrences of Harmful Algal Blooms (Chapra et al., 2017); this may cause bioaccumulation of freshwater cyanotoxins in fish, which can potentially be a significant health and safety risk (Brooks et al., 2016; Carmichael & Boyer, 2016).

Consumption advisories are recommendations issued by public agencies for safe fish consumption. These are not legally binding regulations on harvest, but rather are intended to provide the public with information about health and safety concerns that may be associated with the consumption of fish from a specific fishery. Figure 4.1 is an example of a fish consumption advisory infographic published by San Bernadino County and the California Department of Parks and Recreation to provide guidelines for safe frequencies and serving sizes associated with specific species.

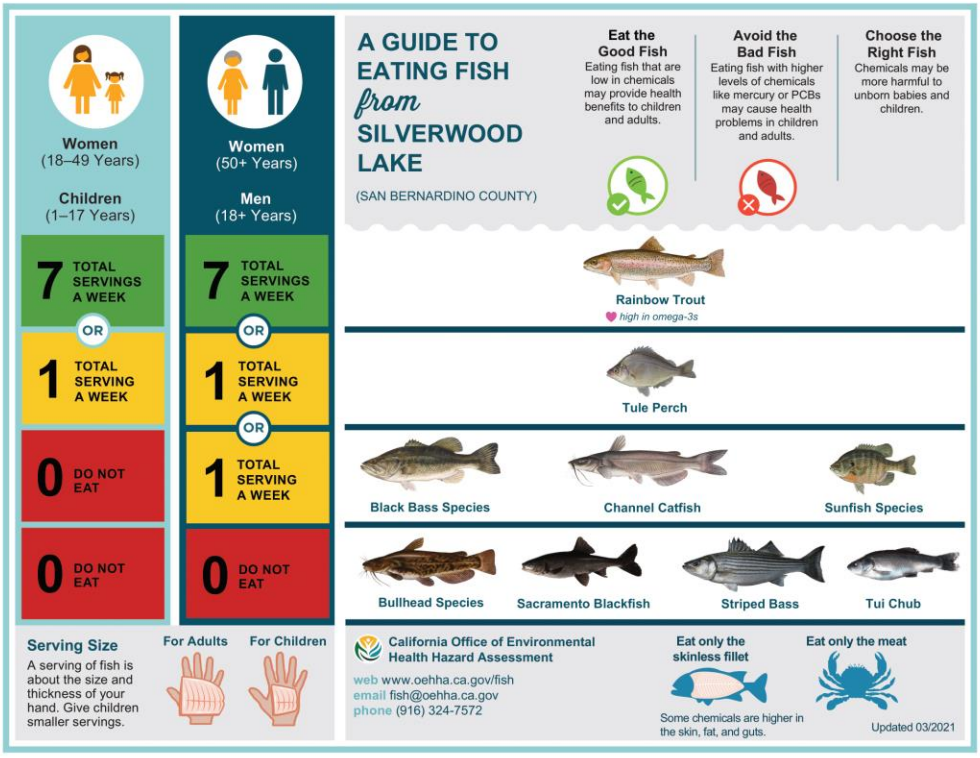

Figure 4.1: Fish consumption advisory infographic with guidelines for safe consumption of inland fishes harvested from Silverwood Lake in San Bernadino County, California.

As advisories against consumption become increasingly prevalent over time in response to climate change, it is foundational to effective research design and prioritization, community outreach efforts, and policymaking that fishery managers have a strong working knowledge of how people are using inland fisheries within their jurisdiction. The Environmental Protection

Agency released the *Nine-Step Fish Consumption Advisory Risk Communication Cycle* report in early 2023, detailing the in-depth process required to develop an effective Fish Consumption Advisory (FCA) (See Figure 4.2). The importance of outreach is heavily emphasized in the cycle, because the nature of these fish consumption advisories means that the right people accessing and understanding the information is foundational to efficacy. As discussed throughout this study, subsistence fishing is likely important to diverse and potentially vulnerable communities. A strong working knowledge of the relationship between human communities and fisheries in any given region is critical to facilitate effective outreach. For example, if subsistence fishing is prominent amongst communities that do not speak English or that may not have consistent access to the internet, then posting Figure 4.1 on a public agency website may be an ineffective and inequitable approach to disseminating key public health information.

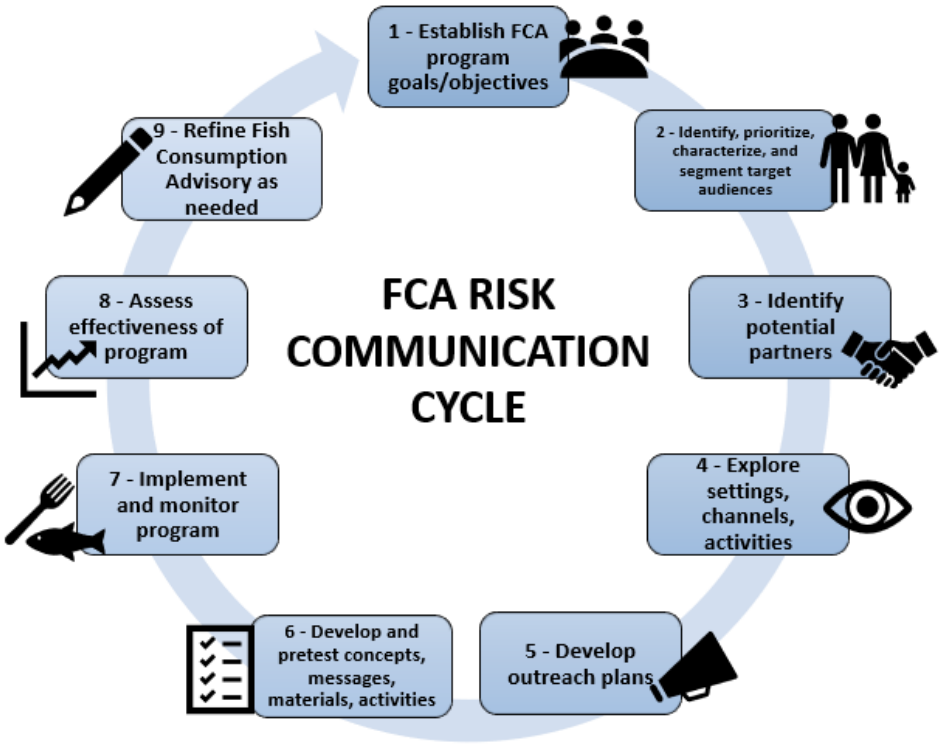

Figure 4.2: EPA's Nine-Step Fish Consumption Advisory (FCA) Risk Communication Cycle (2023).

The lack of specific studies on the role of inland subsistence fishing in food security (outside of Alaska) revealed by the literature review indicates that this working knowledge likely does not exist for most inland fisheries in the U.S. Given that the communities relying on inland subsistence fishing as a contribution to their food security are likely to be disproportionately disadvantaged and/or marginalized already, fishery managers need to consider the potential significance of underreported harvest and consumption when dealing with potential health risks. Does issuing a consumption advisory actually reduce or eliminate harvest by inland subsistence fishing communities that rely on their catch? Would different approaches be more effective to communicate this critical health and safety information specifically to subsistence-motivated fishers, compared to purely recreational fishers? These are just some of the many additional questions that must be addressed by future research based on the results of this study.

4.2 Harvest Regulations

Similarly, the underreported nature of fishing for food in the contiguous U.S. creates potential disconnect in fishery regulation, specifically harvest regulations. Harvest regulations may include policies such as licenses and permits, catch-and-release orders, creel and possession limits, length limits, and fishing seasons or closures (Hill, 2022). Harvest regulations may be implemented for a variety of reasons, not all of which are biological (Isermann & Paulkert, 2011). Fishery managers can utilize regulations as strategic tools; for example, setting a low bag limit (number of fish allowed to harvest in a day) may be intended to reduce fishing mortality of a species, whereas setting a high bag limit may be intended to encourage harvest (Hill, 2022). Other policy drivers may include improving recreational fishing quality, maintaining population viability, removing invasive species, and generating revenue for agencies (such as through license sales) (Isermann & Paulkert, 2011).

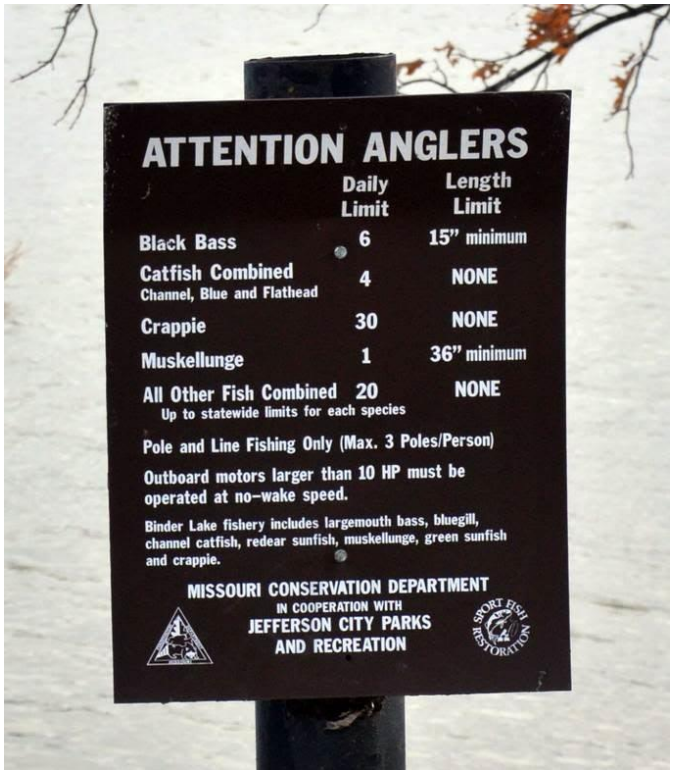

Figure 4.3: A sign detailing harvest regulations posted on the shore of a lake by the Missouri Conservation Department.

Figure 4.3 is an example of harvest regulations physically posted by the Missouri Conservation Department on the shore of a lake for anglers to reference. More common is the approach shown in Figure 4.4, which is clipped from the New York State Department of Environmental Conservation's website. Harvest regulations have a direct effect on inland subsistence fishers, as they can significantly influence the socio-political dynamics of relying on a fishery for food security. To legally harvest a fish, the fisher must be able to access and understand the kind of information provided in Figure 4.4, as well as accurately identify the species they catch. Additionally, given that the survey data suggests that inland subsistence fishing contributes to the food security of vulnerable communities, choosing to release a fish caught that does not meet harvest regulations may be a highly complex decision for these communities. Harvesting and consuming the fish may be of key importance to their physical and/or economic

wellbeing, whereas the risk of consequence if caught by fishery law enforcement (such as the revocation of their fishing license) may be high stakes as well.

Statewide Freshwater Fishing Seasons, Sizes, and Catch Limits

Exceptions may apply to the statewide freshwater fishing regulations below.

Check the Special Regulations to determine if other rules apply to the water you'll be fishing.

Statewide Regulations Effective April 1, 2022

Species	Open Season	Minimum Length	Daily Limit
Brook Trout (in lakes and ponds)	April 1 - Oct 15	None	5
Brown Trout, Rainbow Trout, and Splake (in lakes and ponds)	All year	5 (only 2 longer than 12")	
Trout in inland trout streams (*see Definitions*)	April 1 - Oct 15	5 (only 2 longer than 12")	
	Oct 16 - Mar 31	Catch and Release only	Artificial lures only
Lake Trout	April 1 - Oct 15	21"	3
Atlantic Salmon (Landlocked)	All year	15"	3
Coho and Chinook Salmon	See Great Lakes and Tributaries Special Regulations		
Black Bass (Largemouth and Smallmouth)	June 15 - Nov 30	12"	5
	Dec 1 - June 14	Catch and Release only	Artificial lures only
Muskellunge	June 1 - Nov 30	40"	1
Northern Pike	May 1 - Mar 15	18"	5

Figure 4.4: A partial table of freshwater fishing harvest regulations posted on the New York State Department of Environmental Conservation's website.

Balancing confounding ecological factors like stock structure with the harvest needs of inland subsistence fishers is complex; allowing exploitation through over-harvest could be harmful to long-term sustainability, as could enacting strict regulations which limit the livelihoods of vulnerable communities. As these decisions are unavoidably complicated by nature, it is critical that fishery managers have a full picture of the relationship between the species they regulate and the human communities that may rely on them to support informed management objectives. In many states, the process of developing new harvest regulations involves several layers of review, including a public review and comment period (Isermann & Paulkert, 2011). One possible pathway for fishery managers to gain a stronger understanding of the relationship between harvest regulations and food security in their region could be to assess the equity and accessibility of these public reviews. What voices dominate the public comments, and what voices are absent? What

steps can be taken to make the process more inclusive of subsistence fishing communities? As fishery managers aim to develop a comprehensive understanding of the systems they steward, this study calls for a closer look at the dynamics of fishing for food in diverse socio-ecological contexts.

4.3 Climate Outreach, Advocacy, and Environmental Justice

Outreach and education about climate change is also essential for inland subsistence fishing communities, whose livelihoods are deeply intertwined with the changing conditions of inland fishery systems over time. Neal et al. (2021) synthesizes a toolkit of best practices for communicating climate science specifically for fisheries professionals, emphasizing that it is a responsibility of fishery researchers and managers to not only understand climate impacts on fisheries, but be able to effectively communicate them to the public. Given that inland fisheries are highly susceptible to climate change and other threats (see section 1.3), understanding the implications of climate change and the role of community advocacy in mitigation and adaptation efforts is extremely important for subsistence fishing communities. Additionally, subsistence fishers may represent a critical emerging constituency in parts of the country with complex discord around climate discussions. For example, many communities in the Southeast rely heavily on fossil fuels for economic livelihood while also having a deep cultural connection to nature, creating a mix of science and policy perceptions that is often oversimplified by stark labels like "climate denial" (Hudson & Spencer, 2017). Nevertheless, views on climate change and the sustainability of inland subsistence fisheries amongst fishery managers and fishers over time must be further investigated. Communities that rely on inland fisheries as a contribution to their food security are likely to be invested in supporting the resilience of these systems, opening the door to discussions about climate mitigation and adaptation policies in a context that aligns with the values of otherwise conflicted constituencies. Resources like "A Hunter's and Angler's Guide to Climate

Change: Challenges, Opportunities, and Solutions" by the National Wildlife Federation are beginning to build on this concept, emphasizing that as witnesses to climate change, anglers can play a key role in changing the narrative. As subsistence fishers are likely to be part of frontline communities experiencing the "first and worst" of climate change impacts, the outcomes of inland fishery management and policy is a matter of environmental justice (Sanders, 2021). Inland fishery managers need to prioritize investigating the role that any given fishery may play in community vulnerability and/or resilience.

4.4 Key Takeaways

While we generally know little about how much the consumption of inland fish matters to diverse communities in the U.S., we do know that inland fisheries are changing. While food security is rarely the focus of inland fishery management discussions, the assumption that harvest is negligible may contribute to the undervaluation of fishing for food as an ecosystem service (especially in regions with high levels of socio-economic vulnerability). Further, perceptions of potential climate vulnerability amongst inland fishery managers may not align with the places where it is most prevalent. The disconnect between climate change risk levels and the related survey responses from the Southeast and Southern Great Plains indicate a concerning potential for misalignment of fishery management decisions as climate change accelerates. Ultimately, sustainable and equitable policymaking requires a stronger understanding of the relationship between human communities and inland fisheries in the United States. For many, fishing is more than just a pleasant pastime, and it is past time we acknowledge that.

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Appendix A: Copy of Survey Questions

Creel, Climate, and Community Vulnerability: Unexplored Dimensions of Subsistence Fishing in the United States

Start of Block: Consent Statement

Consent You are being invited to participate in a study titled "Creel, Climate, and Community Vulnerability: Unexplored Dimensions of Subsistence Fishing in the United States." This study is being conducted by Caitlin Brogan, M.S. from Northern Arizona University.

The purpose of this study is to investigate the role of subsistence fishing in food security and climate vulnerability of diverse communities. If you agree to participate in this study, you will be asked to complete an online survey/questionnaire. This survey asks about your perception of subsistence fishing activities across different scales and contexts. It will take approximately 20 minutes to complete.

You may not directly benefit from this research; however, we hope that your participation in the study will positively contribute to the sustainability of inland subsistence fisheries in the U.S. We believe there are no known risks associated with this research study; however, as with any online related activity, the risk of a breach of confidentiality is always possible.

Your participation in this study is completely voluntary and you can stop the survey at any time. You are free to skip any question that you choose. If you choose not to participate it will not affect your relationship with Northern Arizona University or result in any other penalty or loss of benefits to which you are otherwise entitled.

Your responses will be assigned a code number. If you choose to provide your contact information at the end of the survey, the list connecting your identifiable information to this code will be kept in an encrypted and password protected file. Only the research team will have access to the file. When the study is completed and the data have been analyzed, the list will be destroyed.

If you have questions about this project or if you have a research-related problem, you may contact the researcher, Caitlin Brogan, at crb575@nau.edu or (623) 377-6426. If you have any questions concerning your rights as a research subject, you may contact the Northern Arizona University IRB Office at irb@nau.edu or (928) 523-9551.

○ By submitting this survey, I affirm that I am at least 18 years of age and agree that the information may be used in the research project described above. (1)

End of Block: Consent Statement

Start of Block: Section 1: Introduction

1 Where do you live? **(County, State)**

_____

2 Which of these statements best describes the capacity in which you interact with inland fisheries? Select all that apply.

- ☐ I personally participate in inland fishing (or members of my family do) (1)
- ☐ My job or volunteer position relates to the management or stewardship of a fishery, waterbody, freshwater system, etc. (2)
- ☐ My job or volunteer position relates to fishing communities (including retail, advocacy, education, outreach, and other work related to people who participate in fishing) (3)
- ☐ I have studied or performed research related to inland fishery systems (4)
- ☐ None of the above (5)

End of Block: Section 1: Introduction

Start of Block: Section 1a

1a How often do you participate in fishing activities (e.g., with poles/rods, nets, traps, etc.)?

- ○ At least once a week (1)
- ○ Several times a month (2)
- ○ At least once a month (3)
- ○ Several times a year (4)
- ○ At least once a year (5)
- ○ Other (less often than once a year) (6)

2a How often do you and/or your family eat what you catch?

- ○ Never (1)
- ○ Rarely (2)
- ○ Occasionally (3)
- ○ Most of the time (4)
- ○ Always (5)

3a Do you consider subsistence fishing (fishing with a primary motivation of consumption) to be part of your lifestyle?

- ○ Yes (1)
- ○ No (2)
- ○ Maybe (3)
- ○ I don't know (4)

4a Approximately what percentage of your and/or your family's diet consists of food you catch from inland fisheries?

0 10 20 30 40 50 60 70 80 90 100

Use the slider to indicate the percentage. ()	

5a What is your approximate net annual household income (in $USD)?

_____

End of Block: Section 1a

Start of Block: Section 2: Perceptions of subsistence fishing activity

Intro Sec 2 In this study, we define **subsistence fishing** as harvesting of aquatic organisms with a primary motivation of consumption (by the fisher or their family). **Food security** refers to consistent access to sufficient quantity and quality of food. **Please respond to these questions based on the places where you most often fish, work on, or otherwise interact with fisheries; this will be referred to as your "region" throughout the survey.**

3 Where do you most often interact with fisheries? Please name the **County and State** where the fisheries you most often interact with (such as fish from or work on) are located (ex. Maricopa County, Arizona).

_____

_____

_____

_____

_____

4 *Please indicate your level of agreement with the following statement:*

Subsistence fishing from inland waters occurs in my region.

- ○ Strongly agree (1)
- ○ Somewhat agree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat disagree (4)
- ○ Strongly disagree (5)

End of Block: Section 2: Perceptions of subsistence fishing activity

Start of Block: Section 2a

4a In your opinion, which statement best describes the degree to which subsistence fishing occurs *in your region*?

- ○ It is an important and significant use of fisheries on a consistent basis (1)
- ○ It is sometimes a significant use of fisheries (2)
- ○ It may occur occasionally but is not a significant use of fisheries (3)
- ○ It does not occur in my region (to my knowledge) (4)

4b *Please indicate your level of agreement with the following statement:*

Subsistence fishing from inland waters contributes to the food security of vulnerable communities in my region.

"Vulnerable communities" in this statement specifically refers to populations with a higher risk of experiencing food insecurity or other socioeconomic challenges.

- ○ Strongly agree (1)
- ○ Somewhat agree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat disagree (4)
- ○ Strongly disagree (5)

End of Block: Section 2a

Start of Block: Section 2b

4c *Please indicate your level of agreement with the following statement:*

Subsistence fishing from inland waters contributes to the food security of some vulnerable communities in the United States.

"Vulnerable communities" in this statement specifically refers to populations with a higher risk of experiencing food insecurity or other socioeconomic challenges.

- ○ Strongly agree (1)
- ○ Somewhat agree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat disagree (4)
- ○ Strongly disagree (5)

End of Block: Section 2b

Start of Block: Section 2 continued

5 Do you consider eating aquatic animals caught from inland waters to be part of your community's culture?

- ○ Yes (1)
- ○ No (2)
- ○ Maybe (3)
- ○ I don't know (4)

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6 Explain your answer to the above question in as much detail as you like, providing examples if possible.

_____

_____

_____

_____

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7 Are there any health and safety concerns associated with consuming aquatic animals harvested in your region, such as advisories against consumption due to contamination?

- ○ Yes (1)
- ○ No (2)
- ○ Maybe (3)
- ○ I don't know (4)

End of Block: Section 2 continued

Start of Block: Block 3

8 Do you believe in human-caused climate change?

- Yes (1)
- No (2)
- Maybe (3)
- I don't know (4)

9 Do you believe climate change has already influenced the sustainability of inland fisheries in your region? *The term "sustainability" refers to the ability of the fishery system to continue operating efficiently over time.*

- Yes (1)
- No (2)
- Maybe (3)
- I don't know (4)

10 Please explain your answer to the above question. Provide as much detail as you like, including examples if possible.

_____

_____

_____

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_____

11 Do you believe climate change will influence the sustainability of inland fisheries in your region over the next 50 years?

- ○ Yes (1)
- ○ No (2)
- ○ Maybe (3)
- ○ I don't know (4)

End of Block: Block 3

Start of Block: Section 3a

11a How do you expect climate change will influence the sustainability of inland fisheries in your region over the next 50 years? Provide as much detail as you like, including examples if possible.

_____

End of Block: Section 3a

Start of Block: Section 4: Perceptions of observed and expected behavior changes

12 How do you expect subsistence fishing behaviors to change in response to climate change in your region over time?

- ○ Subsistence fishing will increase (1)
- ○ Subsistence fishing will decrease (2)
- ○ Subsistence fishing will not change (3)
- ○ I don’t know (4)

End of Block: Section 4: Perceptions of observed and expected behavior changes

Start of Block: Section 4a

12a Why do you expect subsistence fishing behavior to change in response to climate change? Provide as much detail as you like, including examples if possible.

_____

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_____

End of Block: Section 4a

Start of Block: Section 4 continued

13 *Please indicate your level of agreement with the following statement:*

Relying on subsistence fishing could make communities in my region more vulnerable to climate change. *The term "vulnerable" refers to the risk of being adversely affected by change.*

- ○ Strongly agree (1)
- ○ Somewhat agree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat disagree (4)
- ○ Strongly disagree (5)

14 *Please indicate your level of agreement with the following statement:*

Relying on subsistence fishing could make communities in my region more resilient to climate change. *"Resilient" refers to the ability to withstand, respond to, and recover from change.*

- ○ Strongly agree (1)
- ○ Somewhat agree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat disagree (4)
- ○ Strongly disagree (5)

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15 Please explain your answers to the above questions. Provide as much detail as you like, including examples if possible.

_____

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End of Block: Section 4 continued

Start of Block: Section 5: Applications

16 *Please indicate your level of agreement with the following statement:*

The contribution of subsistence fishing to food security in my community is adequately addressed and considered in inland fishery management decisions.

"Inland fishery management decisions" refers to any decisions that influence the processes of

inland fishery systems, including ecological interventions, regulations on fishing activities, and other courses of action taken by local, state, tribal, or federal institutions.

- ○ Strongly agree (1)
- ○ Somewhat agree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat disagree (4)
- ○ Disagree (5)
- ○ Strongly disagree (6)

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17 *Please indicate your level of agreement with the following statement:*

The contribution of subsistence fishing to food security should be considered in climate vulnerability assessments and/or climate adaptation/resilience plans for my community.

- ○ Strongly agree (1)
- ○ Somewhat agree (2)
- ○ Neither agree nor disagree (3)
- ○ Somewhat disagree (4)
- ○ Disagree (5)
- ○ Strongly disagree (6)

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18 Is there anything else you would like to share about your knowledge of or experience with subsistence fishing in your region?

_____

_____

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_____

_____

End of Block: Section 5: Applications

Start of Block: Closing: Demographics & Follow-Up

19 What sector best describes your employment?

- Federal Government (1)
- State Government (2)
- Regional/County/Local Government (3)
- Private industry (4)
- Nonprofit organization (5)
- Research/Academia (including students) (6)
- Unemployed (7)
- Other (8)

20 What is your gender?

- Male (1)
- Female (2)
- Non-binary or other (3)
- Prefer not to say (4)

21 What is your age group?

- ○ 18 - 25 (1)
- ○ 26 - 30 (2)
- ○ 31 - 35 (3)
- ○ 36 - 40 (4)
- ○ 41 - 45 (5)
- ○ 46 - 50 (6)
- ○ 51 - 55 (7)
- ○ 56 - 60 (8)
- ○ 61 + (9)
- ○ Prefer not to say (10)

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22 What is your ethnicity? Check all that apply.

- ☐ African-American (1)
- ☐ Asian (2)
- ☐ Latino or Hispanic (3)
- ☐ Native American (4)
- ☐ Native Hawaiian or Pacific Islander (5)
- ☐ White/Caucasian (6)
- ☐ Other (7)
- ☐ Prefer not to say (8)

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23 If you are interested in participating in a follow-up interview, please provide your contact information here. *Please note that providing this information is optional and does not impact your participation in the survey.*

- Name (1) _____
- Email Address (2) _____
- Phone Number (3) _____

End of Block: Closing: Demographics & Follow-Up
