frontiers | Frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 14 April 2022
doi: 10.3389/fsufs.2022.774701

Role of Wild Food Environments for Cultural Identity, Food Security, and Dietary Quality in a Rural American State

Selena Ahmed [1], Teresa Warne [1], Alyssa Stewart [1], Carmen Byker Shanks [1,2] and Virgil Dupuis [3]*

[1] Food and Health Lab, Department of Health and Human Development, Montana State University, Bozeman, MT, United States, [2] Gretchen Swanson Center for Nutrition, Omaha, NE, United States, [3] Extension, Salish Kootenai College, Pablo, MT, United States

Wild foods are primary components of traditional and Indigenous food systems that are valued for food security while being vulnerable to global change. This case study examines practices, experiences, and perceptions associated with wild food environments through a household survey in the rural American state of Montana. Findings highlight that wild food environments contribute to cultural identity, sense of place, food security, and dietary quality of surveyed households while being vulnerable to loss of traditional ecological knowledge as well as climate and land-use change. Of the 182 informants, 80% hunt, 83% fish, and 68% forage wild botanicals. More than half of the informants agreed that wild food procurement is part of their cultural identity (66%). Collectively, informants procure more than 172 wild food species with the most prevalent being deer, waterfowl, elk, trout, bass, a range of berries, mushrooms, and botanicals used medicinally. Participants have a multidimensional value system where wild food procurement is valued for diets, recreation, family time, spirituality, and connection to the environment. The majority of participants agreed that the consumption of wild foods contributes to the nutritional quality (87%) and diversity (82%) of their diets while lowering food costs (59%). At least half of the informants reported observing changes in climate patterns over the past decade including increased temperature (50%) and more extreme and variable weather patterns (38%) that they perceive are impacting wild food environments including shifts in wild game, fish, and edible plant populations. Based on findings, we support that wild food environments and associated bio-cultural resources are a critical place to understand, conserve, and promote for nutrition. We thus advance the concept of "conservation for nutrition". Community engagement, education, and policy plans are called for to promote wild food environments toward supporting sustainable diets and planetary health.

Keywords: wild foods, food environments, food security, dietary quality, climate change

Edited by:
Rebecca Kanter,
University of Chile, Chile

Reviewed by:
Andrea Pieroni,
University of Gastronomic Sciences, Italy
Yash Pal Sharma,
University of Jammu, India

****Correspondence:***
Selena Ahmed
selena.ahmed@montana.edu

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Sustainable Food Systems

Received: *12 September 2021*
Accepted: *22 March 2022*
Published: *14 April 2022*

Citation:
Ahmed S, Warne T, Stewart A, Byker Shanks C and Dupuis V (2022) Role of Wild Food Environments for Cultural Identity, Food Security, and Dietary Quality in a Rural American State. Front. Sustain. Food Syst. 6:774701. doi: 10.3389/fsufs.2022.774701

INTRODUCTION

The food system is critically dependent on healthy ecosystems while presenting greater environmental sustainability challenges compared to all other human activities (Foley et al., 2011; West et al., 2014). Concurrently, poor diets are a leading risk factor of the global burden of disease (Development Initiatives., 2018; IHME, 2018; Murray et al., 2020). These food system challenges are exacerbated by global environmental change including climate change and land-use change (IPCC., 2013; McConnell and Viña, 2018; Dury et al., 2019; Swinburn et al., 2019). Previous studies highlight that traditional and indigenous food systems of communities that have a deep understanding and connection to their surroundings can provide sustainability solutions for reconciling food production with human and planetary health (Bharucha and Pretty, 2010; Smith et al., 2019).

Traditional and indigenous food systems have been variously defined, including those that are place-based where communities procure wild and cultivated foods from their surroundings, or natural food environments (Downs et al., 2020), and prepare these foods in ways that are culturally acceptable and reflect cultural heritage (Kuhnlein and Receveur, 1996). Food environments are the consumer interface of the food system that influence the availability, affordability, convenience, desirability, and sustainability of food (Herforth and Ahmed, 2015; Downs et al., 2020). More specifically, natural food environments include wild and cultivated food environments such as forests, fields, and gardens (Ahmed and Herforth, 2017; Downs et al., 2020). Historically, wild foods procured through hunting, fishing, and foraging in wild food environments were primary components of food systems and continue to be valued globally for their contribution to multiple dimensions of sustainability (Kuhnlein and Receveur, 1996; Powell et al., 2009; Ahmed et al., 2010; Bharucha and Pretty, 2010; Turner et al., 2018; Reyes-García et al., 2019).

On an environmental basis, sustainable wild food procurement encourages stewardship and valuation of biodiversity, natural resources, and ecosystems (Kuhnlein and Receveur, 1996). Based on human health, wild food consumption contributes to food security, dietary diversity of nutrient-dense foods, and dietary quality by combatting micronutrient deficiencies and chronic disease through their rich nutrient and phytochemical profiles (Vinceti et al., 2012). Wild foods are further part of cultural heritage and contribute to a sense of place where food is entwined with the identity of communities and their surroundings. Economically, the procurement of wild foods contributes to affordable diets by providing a non-market source of diverse foods without a direct monetary cost to support food security (Ford, 2009), though not accounting for costs associated with acquisition.

Despite the role of wild foods for advancing sustainability, global environmental change is threatening wild food environments and associated food systems (Reyes-García et al., 2019; Smith et al., 2019). Drivers of global environmental change including economic growth, climate change, land-use change, globalization, urbanization, industrialization, and technological changes are associated with food environment transitions (Downs et al., 2020) and nutrition transitions (Popkin et al., 2001) away from traditional and indigenous diets toward more processed foods from built food environments (Popkin, 2004; Hawkes, 2006; HLPE, 2017; Reyes-García et al., 2019). The global trend of increasingly purchasing foods from built food environments is associated with diets high in saturated fat and sugar as well as ultra-processed foods while being simultaneously low in fiber, fruits, and vegetables that are associated with obesity and diet-related chronic disease (Popkin et al., 2001; Popkin, 2002; Boutayeb and Boutayeb, 2005), with disproportionate health impacts on indigenous and rural populations (Damman et al., 2008; Ploeg et al., 2009). Wild food environments are thus a critical place to understand to support nutritional outcomes globally.

This paper seeks to contribute to the need to understand wild food environments and associated practices, experiences, and perceptions in the context of environmental change through a case study in the rural American state of Montana. The locality of Montana serves as a compelling case study for assessing wild food environments because of its long history of hunting, fishing, and foraging coupled with its diverse socio-ecological context (Mehn, 1989; Josephy, 2002; Groessler, 2008; Smith et al., 2019; Byker Shanks et al., 2020). Our study team designed and administered a structured survey to address the following overall research question: What are practices, perceptions, experiences, and knowledge associated with wild food environments in the context of global environmental change? Findings have the potential to inform local programs and policies that promote the conservation of biocultural resources associated with wild food environments toward supporting sustainable diets and planetary health.

METHODS

Study Area

Montana is a rural, land-locked, montane state in the Rocky Mountains of the north-west United States with an economy that is primarily based on agriculture, including cereal grain farming and ranching, along with energy (oil, gas, and coal), lumber, and tourism. Historically, Montana is home to multiple indigenous tribes whose food systems relied on the wild food environment (Groessler, 2008; Grinnell, 2012); currently, the state is home to seven Native American reservations where households hunt, fish, and forage (Smith et al., 2019). The state has a population of 1,084,225 that is primarily Caucasian (88.9%) with the remaining being primarily Native American (6.7%) (U.S. Census Bureau., 2020). Additionally, the state has a relatively low population per square mile of 6.8 (U.S. Census Bureau., 2020).

In 2019, the number of people that were food insecure in Montana was 111,080 (Feeding America., 2019). Of those food insecure, an estimated 39% were above the Supplemental Nutrition Assistance Program (and other nutrition programs) threshold, and 61% were below. Of the 56 Montana counties, several counties were identified with higher rates of food insecurity and include Lincoln, Glacier (which share boundaries with the Blackfeet Reservation), Blaine (share boundaries with Fort Belknap Reservation), Mineral, Roosevelt (Fort Peck

Reservation), and Big Horn (Crow Reservation and Northern Cheyenne Reservation). The majority of Montana is defined as "rural" with approximately 44% of the population living in rural areas of the state (Montana State Legislature., 2020).

Montana's diverse topography and climate, ranging from mountains and forests in the west to prairies and badlands in the east, supports rich biodiversity including approximately 115 mammal species, 450 bird species, over 100 fish species, and over 4,600 plant species (Montana National Heritage Program., 2019). These species include a range of high-quality nutrient-dense wild foods such as deer, elk, bison, trout, and various berries (Jonkel and Greer, 1963; Groessler, 2008; Shores et al., 2019; Smith et al., 2019). Overall, Montana is a cold temperate state that is increasingly experiencing climate change (Whitlock et al., 2017). Previous studies in Montana indicate that tribal households perceive impacts of climate change on wild food environments (Smith et al., 2019) while farmers and ranchers perceive impacts of climate change on their agricultural systems (Grimberg et al., 2018). These perceptions are in line with climate data that demonstrates that temperatures in Montana increased during the 20th century (Pederson et al., 2010; Whitlock et al., 2017), and are expected to further rise between 2.5–3.3°C, along with a decrease in precipitation during the summer months (Whitlock et al., 2017).

Numerous federal and state agencies oversee the protection of conservation lands in Montana and associated biodiversity including the U.S. Department of Agriculture Forest Service, Montana Department of Fish, Wildlife and Parks, Montana Department of Natural Resources and Conservation, and Tribal Councils. Specifically, the U.S. Department of Agriculture Forest Service administers 16,800,000 acres of forest land across 10 National Forests across Montana that includes 3,300,000 acres in 12 wilderness areas as part of the National Wilderness Preservation System (Montana Interagency Council., 2018). The Montana Department of Fish, Wildlife, and Parks (MT FWP) operates approximately 275,265 acres of state parks and access points on the state's rivers and lakes while the Montana Department of Natural Resources and Conservation manages 5,200,000 acres of School Trust Land for the benefit of public schools and institutions in the state, and the Bureau of Land Management (BLM) administers about 8.1 million acres of federal lands (Montana Interagency Council., 2018). Tribal lands account for 8.3 million acres across Montana (Montana Legislative Services Division Margery Hunter Brown Indian Law Clinic., 2016). In partnership with Montana Fish Wildlife and Parks, the BLM manages more wildlife habitat than any other federal agency to ensure abundant, self-sustaining, and diverse wildlife populations on public lands (BLM, 2022a). Specific to Montana, FWP manages and conserves over 600 species of birds, mammals, reptiles, and amphibians throughout the state, including deer, elk, and antelope, prevalently harvested in the study area, as well as numerous fish and game bird populations (MT FWP, n.d.). While the state of Montana and native plant species therein are not included in the BLM Rare and Cultural Plant Conservation program, the BLM conserves, maintains, and restores native plant communities under its "multiple-use" and "sustained yield" mandate to support multiple uses including recreation, wildlife habitat provision, and grazing (BLM, 2022b).

Structured Survey

A structured survey was designed based on previous research on food environments and interview tools implemented by members of the study team regarding perceptions and observations on the impact of environmental change on food systems (Ahmed et al., 2014; Grimberg et al., 2018; Smith et al., 2019) along with literature on climate vulnerability and adaptation strategies (Mertz et al., 2011). The survey on wild food environments was reviewed for face validity based on a panel of five experts in the fields of agriculture, cultural anthropology, ethnobotany, nutrition, and climate science. Revisions were made upon receiving feedback from the field experts. The survey instrument was pilot tested with an independent group of key informants ($n = 13$) for further validity through interviews with who have a history of hunting, fishing, and foraging, revisions were then made upon receiving feedback. Key informants were not targeted in the recruiting efforts for the final survey tool distribution.

The final survey on wild food environments (Supplementary material: survey tool) consisted of 55 questions divided into the following five sections: (1) Background (eight questions); (2) Practices and Valuation on Hunting (11 questions), Fishing (11 questions), and Foraging (11 questions); (3) Wild Food Perceptions (six questions); (4) Observations and Perceptions of Environmental Change (13 questions); and (5) Protecting Community Resources (1 question).

Section Background of the survey included questions focused on demographic information (length of time living in Montana, age, gender; racial/ethnic and/or tribal affiliation including enrolled membership and/or descendancy was not collected); length of time harvesting wild foods; and brief screen for food insecurity. Section Practices and Valuation on Hunting, Fishing, and Foraging of the survey included questions regarding: (1) whether participants and/or family members engage in a specific wild foods activity; (2) what they value about the wild foods activity; (3) who they learnt the wild foods activity from; (4) types of animals, fish, and foraged wild edible species of plants and mushrooms they procure (herein: foraged edibles / foraged foods); (5) how often they procure wild foods; (6) types of habitats where they procure wild foods; (7) how often they consume wild foods and; (8) rituals and stories associated with wild foods. Section Wild Food Perceptions included questions on perceptions regarding the role of wild foods to diets, cultural identity, and traditional ecological knowledge and transmission. Section Observations and Perceptions of Environmental Change elicited informant observations and perceptions regarding changes in environmental variables over the past decade including changes in the timing of seasons and species populations as well as concerns regarding land-use changes, the availability of wild foods, water quality, and weather patterns. The final section, Section Protecting Community Resource included a question that elicited suggestions for protecting the community's food, water, land, and cultural resources.

Prior to administering surveys, the approval of human subjects to participate in this study was obtained by the Institutional Review Board (IRB) at Montana State University. Informed consent was retrieved from all of the study participants following IRB guidelines prior to taking the survey. The survey was administered online using the Survey Monkey platform. Participants were recruited by sending the survey to various organizations that have listservs of at least 1,500 community members who hunt, fish, and forage including: (1) Montana State University Extension, (2) Montana Organic Association, (3) One Montana, (4) Montana Food Bank Network, (5) Montana Co-op, (6) Montana Rural Education Association, (7) Montana Bowhunters Association, (8) Backcountry Hunters & Anglers, (9) Montana Wildlife Federation, (10) Montana Hunters Against Hunger, (11) Trout Unlimited and, (12) Montana Hook & Bullet News. The goal of the survey was to reach 1,500 people. Inclusion criteria for the study included that participants must have hunted, fished, or foraged wild foods, lived in Montana, and answered 75% or more survey questions. Since not all participants responded to every question, sample size varied based on survey question.

Qualitative Coding of Survey Responses

Responses from open-ended survey questions were transcribed by two members of the study team (TW and AS) and were coded to identify themes (Saldana, 2008) using a grounded theory approach (Glaser and Strauss, 1999). Following the process of transcribing interviews, a thematic qualitative codebook was created using strategies from Saldana (2008) by identifying approximately four to five common coded responses to each survey question. Two members of the study team trained in qualitative research methods applied the codebook to code the open-ended survey questions to identify prevalent themes. Each survey response was coded by two separate coders for inter-rater reliability and discrepancies were resolved. Coded responses to each survey question were then tabulated to determine frequencies of prevalent themes.

Foraged edible foods in particular, often have multiple uses. For example, dandelion can be used as greens in a salad, or in tinctures and teas. As such, the themes of foraged wild edible foods were classed into themes at the discretion of the two-code research team and reported in the results section (for further detail see **Table 2**).

Quantitative Analysis

Food Insecurity Screen

Food insecurity was measured using a validated two-question adaptation (Young et al., 2009) of the U.S. Adult Food Security Survey Module: Six-Item Short Form (USDA, 2012). The two-item measure included: (1) *'(I/we) couldn't afford to eat balanced meals.' Was that often, sometimes, or never true for (you/your household) in the last 12 months?"*, and (2) *In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?"*. An affirmative response ("often true", "sometimes true", and "yes") to one or both questions indicates food insecurity. Based on this screening, when reporting food insecurity, respondents are either food insecure (yes), or not food insecure (no).

Wild Food Procurement Score

Following methods outlined in Smith et al. (2019), a Wild Food Procurement score (WFPSc) was tabulated based on a scale of either zero or one with a code of zero indicating that the participant did not engage in a particular wild food procurement activity (hunting, fishing, or foraging). Total WFPSc was based on a scale of one to three and calculated by totaling the WFPSc from each of the three wild food procurement activities (hunting, fishing, or foraging); a code of one or two indicated the participant engaged in at least one or combination of two wild food procurement activities respectively, and a code of three indicated that the participant engaged in all three wild food procurement activities.

Wild Food Dietary Diversity Score

In line with methods outlined in Smith et al. (2019), Wild Food Dietary Diversity score (WFDDSc) was calculated by tallying the number of food species or types consumed in each food category (game, fish, and foraged edibles). Similarly, Total WFDDSc was calculated by summing all three wild food categories to find the total number of wild food types consumed by each participant.

Frequency of Survey Responses and Statistical Analysis

The survey was tabulated for frequency of responses to all survey questions. JMP statistical software (version 12.0 SAS Institute Inc., Cary, NC) was used to carry out Analysis of Variance and Contingency Analysis to understand relationships between generation, gender, or food insecurity among survey responses to select questions. A Oneway Analysis of Variance (ANOVA) was completed to examine relationships in mean Wild Food Procurement Scores and Wild Food Dietary Diversity Scores based on (1) generation (Millennial (born between 1981 and 1996), Generation X (born between 1965 and 1980), and Baby Boomer+ (born between 1928 and 1964), (2) gender (male/female), (3) food insecurity indicator (yes/no), and (4) location (rural (county participant reported living in with population $\leq$49,999 people) or urban (county with population $\geq$50,000 people) (U.S. Census Bureau., 2017). The probability F-statistic p-value is reported at a significance level $p < 0.05$. Further statistical tests were completed to find directional differences when appropriate, including a Fisher's Exact Test was completed or a test probability with Pearson p-values reported, at a significance level $p < 0.05$. Further, a Contingency Analysis was completed to understand differences in responses to specific questions among generation, gender, food insecurity, and location.

RESULTS

Informant Demographic Background and Food Security Status

A total of 182 informants completed the majority (75% or more) of the survey, with most being male (68%). Informants

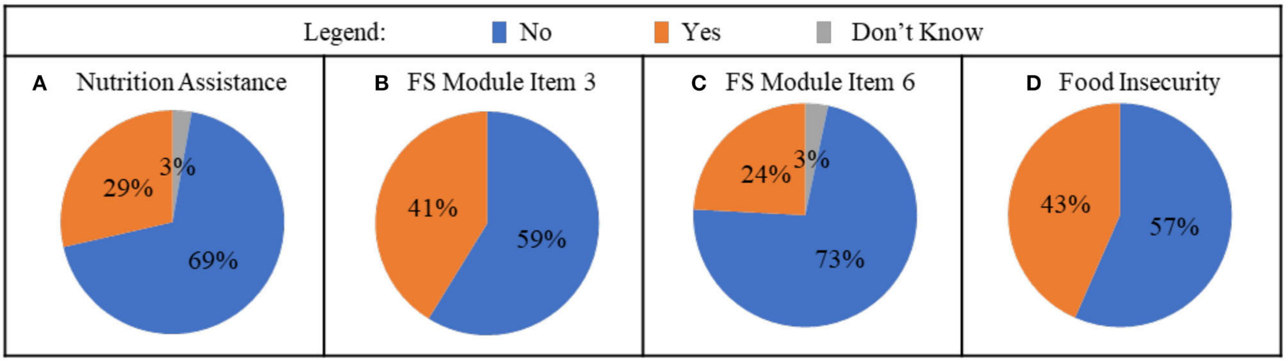


FIGURE 1 | Frequency of informants that reported **(A)** they receive nutritional assistance, **(B)** an affirmative response to USDA Food Security Module Item 3, **(C)** an affirmative response to USDA Food Security Module Item 6, and **(D)** composite food insecurity measurement.

were between 21 and 71 years, with a mean age of 42 years. Almost half of the informants are Generation X (47%), followed by Millennials (35%), and Baby Boomer+ (18%). Informants reported they lived in either rural (51%) or urban (49%) counties. Informants reported procuring wild foods between about 2–73 years or more, with the average experience of wild food procurement being 24 years. Around a quarter of informants reported that their household receives nutrition assistance to supplement the food they purchase including from the Supplemental Nutrition Assistance Program, food banks, and community kitchens (29%) (**Figure 1A**). Just under half of the informants were food insecure (43%) (**Figures 1B–D**) on the basis of their responses to the two-item food security screen (Young et al., 2009), and as a composite. Significant differences were found in food security status based on gender ($p = 0.0475$), generation ($p = 0.0047$), and location ($p = 0.0040$). Males were more likely to be food insecure than females ($p = 0.0335$), the Baby Boomer+ generation was the least food insecure ($p = 0.0004$), and rural participants ($p = 0.0031$) were more food insecure than urban.

Practices and Valuation on Hunting, Fishing, and Foraging

Hunting

The majority of survey informants reported they hunt (80%) and have members in their household that hunt (76%), including household members reported as partners (58%), friends (56%), extended family (33%), parents (33%), siblings (26%), and grandparents (9%). Significant differences were found for those that reported they hunt based on generation ($p = 0.0348$), gender ($p < 0.0001$), and food insecurity ($p = 0.0119$). Specifically, informants that reported they hunt included a higher proportion of Millennials (87%), compared to Generation X (80%), and Baby Boomer+ (65%). Informants that reported they hunt had a higher probability of being male ($p < 0.0001$), with the proportion of those that hunt higher for males (93%) compared to females (53%). In addition, informants that reported they hunt had a higher probability of being food insecure ($p = 0.0090$), with the proportion of those that hunt higher for those food insecure (89%) compared to the proportion of those not food insecure (73%). Differences were not significant among rural and urban participants that reported they hunt. Most informants learned to hunt from parents (59%) particularly their fathers. Informants shared multiple reasons they value hunting with the most prevalent themes reported being: (1) for food and/or health (78%); (2) recreation and/or self-fulfillment (72%); and (3) companionship (50%) (**Table 1**).

Informants reported they and/or their families hunt over 42 types of wildlife with the most prevalent animals being: deer (88%), birds and waterfowl (69%), and elk (65%) (**Table 2**). The types of wildlife participants reported hunting most often include deer (59%), birds and waterfowl (29%), and elk (29%) (**Figure 2**). Informants notably varied in how often they go hunting ranging from once to over 100 times per year, with a mean of 16 times per year ($n = 91$; SD = 15.68). Informants reported to primarily hunt on public (82%) and private (51%) lands while some informants also hunt in other areas (3%) such as tribal land. The majority of informants reported they consume the meat they hunt on a weekly basis (60%) while others reported they consume hunted meat one to three times per month (23%) or less than once per month (17%) (**Figure 3**). Informants shared a range of practices, rituals, and stories associated with hunting with the most prevalent being related to recipes and preservation techniques (70%). The most frequently reported preservation techniques for hunting included freezing, drying, canning, and smoking. Other practices shared included family traditions, connections, and stories (28%), harvesting practices (23%), and practices of a spiritual nature (19%) (**Table 3**).

For hunting, the majority of informants had a Wild Food Procurement score of 1 (91%) and an average Wild Food Dietary Diversity score of 3.19 ($n = 110$; SD = 1.61) that ranged from one to nine types of animals they harvest. Differences in mean WFPSc for hunting were not significant based on generation, gender, or location, and were significant based on food insecurity ($p = 0.0055$). Specifically, respondents that were food insecure had a higher mean WFPSc for hunting than those that were not food insecure. Differences in mean WFDDSc for hunting were not significant based on generation, gender, or location, and were significant based on food

TABLE 1 | Values related to hunting, fishing, and foraging coded into the most prevalent themes: food and/or health, recreation and/or self-fulfillment, companionship, conservation and education, and economic.

Wild food valuation

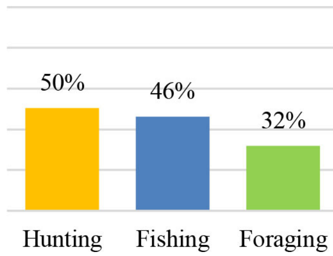
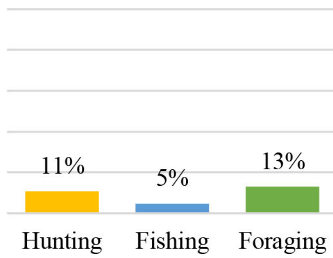
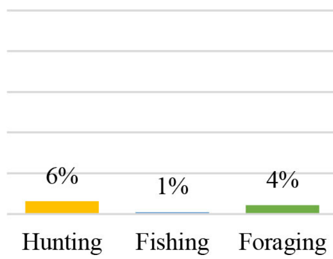
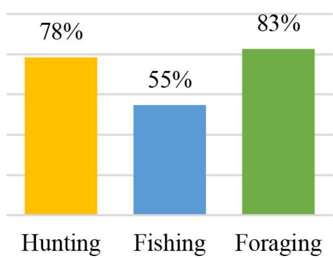
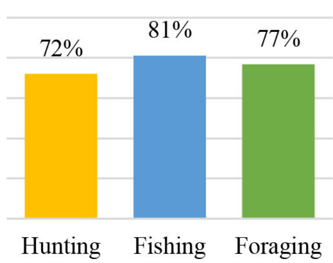
Research theme	**Subthemes**	**Sample quotations**	**Frequency of theme**
Theme 1: companionship	Subthemes: friendship, family, and social time.	*"Valuable time with friends and family."* *"My grandmother taught me about wild plants when I was a kid. We spent a lot of time together collecting wild plant foods.*	
Theme 2: conservation and education	Subthemes: teaching and learning from others, supporting conservation, and wildlife management.	*"Contributing to conservation through advocacy for wild animals and public lands."* *"I enjoy… teaching my young children about wild edibles."*	
Theme 3: economic	Subthemes: saving money and the inexpensive nature of wild food procurement.	*"I value… the money we get to save on groceries."* *"Free food."*	
Theme 4: food and/or health	Subthemes: healthy food, the quality and taste of wild foods, and knowing where their food comes from.	*"Knowing exactly how the animals I eat lived and died."* *"Cold water fish provides a good source of omega-3 fatty acids."*	
Theme 5: recreation and/or self-fulfillment	Subthemes: physical exercise, time spent outdoors, the connection to nature, and personal satisfaction.	*"I love just enjoying the nature and getting outdoors to have a good time."* *"Enjoying Montana's waterways, seeing new places, and spending a day outside."*	

TABLE 2 | Types of wild foods procured through hunting, fishing, and foraging.

Common name	Scientific name	Family	Food type
Hunting			
Black bear	Ursus americanus	Ursidae	Bear
Big Horn sheep	Ovis canadensis	Bovidae	Bighorn sheep
Canada geese	Branta canadensis	Anatidae	Birds/waterfowl
Coot	Fulica americana	Rallidae	Birds/waterfowl
Dusky grouse	Dendragapus obscurus	Phasianidae	Birds/waterfowl
Eurasian collared dove	Streptopelia decaocto	Columbidae	Birds/waterfowl
Gray/Hungarian partridge	Perdix perdix	Phasianidae	Birds/waterfowl
Mergansers	Mergus merganser	Anatidae	Birds/waterfowl
Mouring Dove	Zenaida macroura	Columbidae	Birds/waterfowl
Pigeons	Columba livia domestica	Columbidae	Birds/waterfowl
Quail	Callipepla californica	Odontophoridae	Birds/waterfowl
Ring-necked Pheasant / common pheasant	Phasianus colchicus	Phasianidae	Birds/waterfowl
Ruffed grouse	Bonasa umbellus	Phasianidae	Birds/waterfowl
Sage grouse	Centrocercus urophasianus	Phasianidae	Birds/waterfowl
Sandhill cranes	Antigone canadensis	Gruidae	Birds/waterfowl
Sharp-tailed grouse	Tympanuchus phasianellus	Phasianidae	Birds/waterfowl
Snow Geese	Anser caerulescens	Anatidae	Birds/waterfowl
Spruce grouse	Canachites canadensis	Phasianidae	Birds/waterfowl
Swans (this is trumpeter)	Cygnus buccinator	Anatidae	Birds/waterfowl
Tundra Swan	Cygnus columbianus	Anatidae	Birds/waterfowl
Turkey	Meleagris gallopavo	Phasianidae	Birds/waterfowl
Wood duck	Aix sponsa	Anatidae	Birds/waterfowl
Bison	Bison bison	Bovidae	Bison
Mule deer	Odocoileus hemionus	Cervidae	Deer
Whitetail deer	Odocoileus virginianus	Cervidae	Deer
Elk/Wapati	Cervus canadensis	Cervidae	Elk
Mountain goat	Oreamnos americanus	Bovidae	Goat
Moose	Alces alces	Cervidae	Moose
Bobcat	Lynx rufus	Felidae	Mountain lion or bobcat
Mountain lion	Puma concolor	Felidae	Mountain lion or bobcat
Badger	Taxidea taxus	Mustelidae	Other
Pronghorn/Antelope	Antilocapra americana	Antilocapridae	Pronghorn
Cotton-tail	Sylvilagus floridanus	Leporidae	Rabbit, squirrel, other rodent
Jack rabbit	Lepus townsendii	Leporidae	Rabbit, squirrel, other rodent
Red squirrel	Tamiasciurus hudsonicus	Sciuridae	Rabbit, squirrel, other rodent
Richardson ground squirrel	Urocitellus richardsonii	Sciuridae	Rabbit, squirrel, other rodent
Coyote	Canis latrans	Canidae	Wolf/fox/coyote
Fox	Vulpes vulpes	Canidae	Wolf/fox/coyote
Wolf (gray)	Canis lupus	Canidae	Wolf/fox/coyote
Porcupine	Erethizon dorsatum	Erethizontidae	Other
Racoon	Procyon lotor	Procyonidae	Other
Turtle (this is Western painted)	Chrysemys picta	Emydidae	Other
Fishing			
Bigmouth / Largemouth bass	Micropterus salmoides	Centrarchidae	Bass
Smallmouth bass	Micropterus dolomieu	Centrarchidae	Bass
Bluegill	Lepomis macrochirus	Centrarchidae	Bluegill
Large mouth / Bigmouth buffalo	ctiobus cyprinellus	Catostomidae	Buffalo
Small mouth buffalo	Ictiobus bubalus	Catostomidae	Buffalo
Burbot	Lota lota	Lotidae	Burbot

(Continued)

TABLE 2 | Continued

Common name	Scientific name	Family	Food type
Common Carp	Cyprinus carpio	Cyprinidae	Carp
Channel catfish	Ictalurus punctatus	Ictaluridae	Catfish
Mudcat / Flathead catfish	Pylodictis olivaris	Ictaluridae	Catfish
Crappie	Pomoxis nigromaculatus	Centrarchidae	Crappie
Freshwater drum	Aplodinotus grunniens	Sciaenidae	Drum
Redfish / red drum	Sciaenops ocellatus	Sciaenidae	Drum
Gar	Lepisosteus platostomus	Lepisosteidae	Gar
Goldeye	Hiodon alosoides	Hiodontidae	Goldeye
Mullet	Mugil cephalus	Mugilidae	Mullet
Musky	Esox masquinongy	Esocidae	Musky
Northern Pikeminnow	Ptychocheilus oregonensis	Leuciscidae	Northern pikeminnow
Paddlefish	Polyodon spathula	Paddlefish	Paddlefish
Perch	Perca flavescens	Percidae	Perch
Yellow perch	Perca flavescens	Percidae	Perch
Northern Pike	Esox lucius	Esocidae	Pike
Rock fish / Striped bass	Morone saxatilis	Moronidae	Rock fish
Steelhead	Oncorhynchus. m. irideus	Salmonidae	Salmon
Sauger	Sander canadensis	Percidae	Sauger
Shovelnose Sturgeon	Scaphirhynchus platorynchus	Acipenseridae	Sturgeon
Brook Trout	Salvelinus fontinalis	Salmonidae	Trout
Brown trout	Salmo trutta	Salmonidae	Trout
Bull trout	Salvelinus confluentus	Salmonidae	Trout
Cutthroat trout	Oncorhynchus clarkii	Salmonidae	Trout
Golden trout	Oncorhynchus aguabonita	Salmonidae	Trout
Kokanee Salmon	Oncorhynchus nerka	Salmonidae	Trout
Lake trout	Salvelinus namaycush	Salmonidae	Trout
Rainbow trout	Oncorhynchus mykiss	Salmonidae	Trout
Westslope cutthroat trout	Oncorhynchus clarkii lewisi	Salmonidae	Trout
Yellowstone cutthroat trout	Oncorhynchus clarkii bouvieri	Salmonidae	Trout
Walleye	Sander vitreus	Percidae	Walleye
Lake Whitefish	Coregonus clupeaformis	Salmonidae	Whitefish
Mountain Whitefish	Prosopium williamsoni	Salmonidae	Whitefish
Foraging			
Apples	Malus pumila	Rosaceae	Berries and fruits
Bearberries / Kinnikinnick	Arctostaphylos uva-ursi	Ericaceae	Berries and fruits
Blackberries	Rubus laciniatus	Rosaceae	Berries and fruits
Buffalo berries	Shepherdia argentea	Elaeagnaceae	Berries and fruits
Chokecherries	Prunus virginiana	Rosaceae	Berries and fruits
Crab apples	Malus sylvestris	Rosaceae	Berries and fruits
Currants	Ribes aureum	Grossulariaceae	Berries and fruits
Elderberries	Sambucus cerulea	Adoxaceae	Berries and fruits
Gooseberry	Solidago canadensis	Grossulariaceae	Berries and fruits
Hawthorne berries	Crataegus douglasii	Rosaceae	Berries and fruits
Huckleberries	Vaccinium membranaceum	Ericaceae	Berries and fruits
Juneberries / service berry / Saskatoon	Amelanchier alnifolia	Rosaceae	Berries and fruits
Oregon grape	Berberis repens	Berberidaceae	Berries and fruits
Raspberries	Rubus idaeus	Rosaceae	Berries and fruits
Red Elderberry	Sambucus racemosa	Caprifoliaceae	Berries and fruits
Rhubarb	Rheum rhabarbarum	Polygonaceae	Berries and fruits
Rose hips	Rosa rugosa	Rosaceae	Berries and fruits

(Continued)

TABLE 2 | Continued

Common name	Scientific name	Family	Food type
Strawberry	Fragaria vesca	Rosaceae	Berries and fruits
Thimbleberries	Rubus parviflorus	Rosaceae	Berries and fruits
Thorn apple	Datura stramonium	Solanaceae	Berries and fruits
Whortle berries	Vaccinium scoparium	Ericaceae	Berries and fruits
Wild Plums	Prunus americana	Rosaceae	Berries and fruits
Asparagus	Asparagus officinalis	Asparagaceae	Greens
Dandelion and dandelion greens	Taraxacum lyratum	Asteraceae	Greens
Goosefoot / Lamb's quarters	Chenopodium berlandieri	Amaranthaceae	Greens
Mustards	Sinapis arvensis	Brassicaceae	Greens
Watercress	Rorippa nasturtium-aquaticum	Brassicaceae	Greens
Yellow dock	Rumex crispus	Polygonaceae	Greens
Arnica	Arnica fulgens	Asteraceae	Herbs and medicinal plants
Aster	Aster alpinus	Asteraceae	Herbs and medicinal plants
Belladonna	Atropa belladonna	Solanaceae	Herbs and medicinal plants
Bistort	Polygonum bistortoides	Polygonaceae	Herbs and medicinal plants
Burdock	Arctium minus	Asteraceae	Herbs and medicinal plants
Calendula	Calendula arvensis	Asteraceae	Herbs and medicinal plants
Camas	Camassia quamash	Liliaceae	Herbs and medicinal plants
Chicory	Cichorium intybus	Asteraceae	Herbs and medicinal plants
Cleaver	Galium aparine	Rubiaceae	Herbs and medicinal plants
Devil's club	Oplopanax horridus	Araliaceae	Herbs and medicinal plants
Equistium / Horsetail	Equisetum telmateia	Equisetaceae	Herbs and medicinal plants
False Solomons Seal	Maianthemum racemosum	Asparagaceae	Herbs and medicinal plants
Feverfew	Tanacetum parthenium	Asteraceae	Herbs and medicinal plants
Fireweed	Chamerion angustifolium	Onagraceae	Herbs and medicinal plants
Gentian	Gentiana affinis	Gentianaceae	Herbs and medicinal plants
Gerenium	Geranium bicknellii	Geraniaceae	Herbs and medicinal plants
Glacier lily	Erythronium grandiflorum	Liliaceae	Herbs and medicinal plants
Goldon Rod	Solidago canadensis	Asteraceae	Herbs and medicinal plants
hanbene / hebenon	Hyoscyamus niger	Solanaceae	Herbs and medicinal plants
Hounds tongue	Cynoglossum officinale	Boraginaceae	Herbs and medicinal plants
knapweed	Centaurea jacea	Asteraceae	Herbs and medicinal plants
Lady fern	Athyrium filix-femina	Athyriaceae	Herbs and medicinal plants
Lomatium	Lomatium triternatum	Apiaceae	Herbs and medicinal plants
Mallow	Malva neglecta	Malvaceae	Herbs and medicinal plants
Mint	Mentha arvensis	Lamiaceae	Herbs and medicinal plants
Motherwort	Leonurus cardiaca	Lamiaceae	Herbs and medicinal plants
Mountain mint / Escoba de la sierra	Monardella odoratissima	Lamiaceae	Herbs and medicinal plants
Nettle	Urtica dioica	Urticaceae	Herbs and medicinal plants
Osha	Ligusticum porteri	Apiaceae	Herbs and medicinal plants
Oxeye daisy	Leucanthemum vulgare	Asteraceae	Herbs and medicinal plants
Pearly everlasting	Anaphalis margaritacea	Asteraceae	Herbs and medicinal plants
Pedicularis	Pedicularis canadensis	Orobanchaceae	Herbs and medicinal plants
Pepermint	Mentha balsamea	Lamiaceae	Herbs and medicinal plants
Rabbit brush	Ericameria nauseosa	Asteraceae	Herbs and medicinal plants
Rein orchid	Piperia unalascensis	Orchidaceae	Herbs and medicinal plants
Sage	Artemisia scopulorum	Asteraceae	Herbs and medicinal plants
Salsify	Tragopogon dubius	Asteraceae	Herbs and medicinal plants
Solomon Seal	Polygonatum multiflorum	Asparagaceae	Herbs and medicinal plants
Sorrel	Rumex paucifolius	Polygonaceae	Herbs and medicinal plants
Sweet cicely	Myrrhis odorata	Apiaceae	Herbs and medicinal plants

(Continued)

TABLE 2 | Continued

Common name	Scientific name	Family	Food type
toadflax	Comandra umbellata	Santalaceae	Herbs and medicinal plants
Valerian	Valeriana acutiloba	Valerianaceae	Herbs and medicinal plants
Vitex	Vitex agnus-castus	Lamiaceae	Herbs and medicinal plants
Western Pasque	Anemone occidentalis	Ranunculaceae	Herbs and medicinal plants
Yarrow	Achillea millefolium	Asteraceae	Herbs and medicinal plants
Chanterelle	Cantharellus cibarius	Cantharellaceae	Mushroom
Morels	Morchella esculenta	Morchellaceae	Mushroom
Oyster mushroom	Pleurotus ostreatus	Pleurotaceae	Mushroom
Porcini	Boletus edulis	Boletaceae	Mushroom
Puffballs	Calvatia booniana	Agaricaceae	Mushroom
Amaranth	Amaranthus retroflexus	Amaranthaceae	Nuts and seeds
Flax	Linum usitatissimum	Linaceae	Nuts and seeds
Pine nuts	Pinus edulis	Pinaceae	Nuts and seeds
Sunflower	Helianthus annuus	Asteraceae	Nuts and seeds
Chives	Allium schoenoprasum	Liliaceae	Wild chives, onions, leeks
Leeks	Allium tricoccum	Amaryllidaceae	Wild chives, onions, leeks
Wild onion	Allium textile	Liliaceae	Wild chives, onions, leeks
Cattail	Typha latifolia	Typhaceae	Other
Cocklebur root	Xanthium strumarium	Asteraceae	Other
Cottonwood buds	Populus deltoides	Salicaceae	Other
Fir cones	Pseudotsuga menziesii	Pinaceae	Other
Juniper	Juniperus communis	Cupressaceae	Other
Spruce tips	Picea glauca	Pinaceae	Other
Willow bark	Salix bebbiana	Salicaceae	Other

insecurity ($p = 0.0002$). In particular, respondents that were food insecure had a higher mean score than those that were not food insecure.

Fishing

The majority of informants (83%) reported they fish and have members in their household that fish (77%) including partners (65%), friends (54%), parents (33%), extended family (29%), siblings (28%), and grandparents (11%). Significant differences were found for those that reported they fish based on gender ($p < 0.0001$). Specifically, those that fish had a higher probability of being male than female ($p < 0.0001$), with the proportion of those that fish higher for males (91%) than females (67%). Most informants learned to fish from parents (57%), particularly their fathers. Informants shared multiple factors they value about fishing with the most prevalent themes reported being: recreation and/or self-fulfillment (81%), food and/or health (55%), and companionship (46%) (**Table 1**).

Informants and their families harvest approximately 38 types of fish with trout (77%) and bass (36%) most prevalently reported (**Table 2**). Further, informants reported the fish they catch the most include various species of trout (57%) (**Figure 2**). Informants varied in how often they go fishing ranging from once a year to over 100 times per year, with a mean of 19 times per year. Informants reported that they fish primarily on public land (87%) as well as private land (30%) with some informants fishing in other areas (1%) such as tribal land. Consumption of fish was variable, with about a third of informants that reported they consume fish on a weekly basis (38%), while others reported they consume fish less than once per month (35%) or one to three times per month (27%) (**Figure 3**). Informants shared a range of practices, rituals, and stories associated with fishing, with the majority focused on recipes and preservation techniques (55%). For example, multiple informants shared statements to indicate that they utilize cooking and/or processing techniques such as smoking and canning fish (**Table 3**). Other rituals and practices reported by informants included responses associated with tradition, connection, and stories (41%), harvesting practices (9%), and rituals being spiritual in nature (9%).

The majority of informants had a WFPSc of 1 for fishing (91%) and an average WFDDSc of 2.75 ($n = 104$; SD = 2.30) that ranged from one to 18 different species or types of fish. Differences in Wild Food Procurement Score for fishing were not significant based on gender, food insecurity, or location, and were significant based on generation. Specifically, in a means comparison using Student's t-test, the Millennial group had a higher mean WFPSc for fishing than the Baby Boomer+ group. Differences in mean WFDDSc for fishing were not significant based on generation, gender, food insecurity, or location.

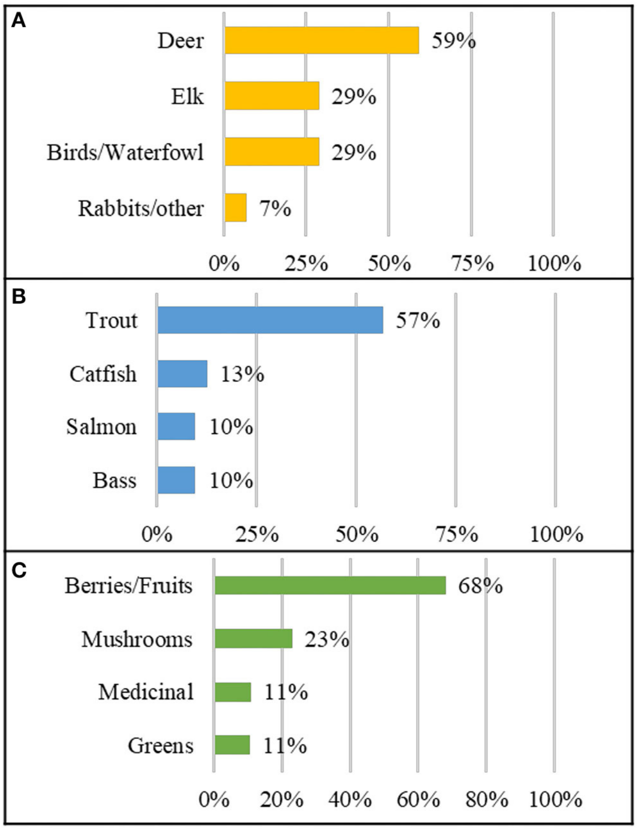


FIGURE 2 | Types of wild foods procured most often as reported for **(A)** hunting, **(B)** fishing, and **(C)** foraging.

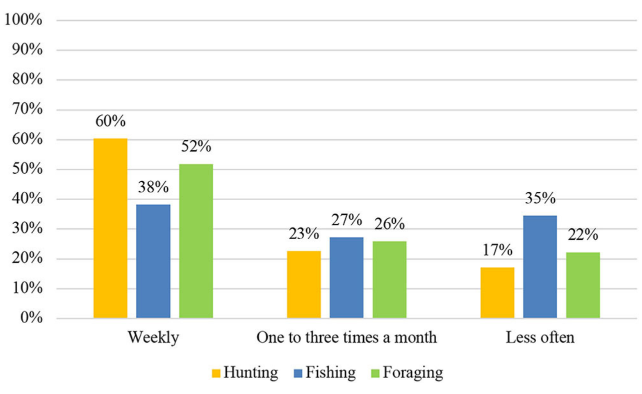


FIGURE 3 | Frequency of wild food consumption for hunting, fishing, and foraging.

Foraging

The majority of participants reported they forage (66%) and have members in their household that forage (59%) including partners (63%), friends (50%), parents (45%), extended family (28%), siblings (20%), and grandparents (11%). Significant differences were found for those that reported they forage based on generation ($p = 0.0035$) and gender ($p = 0.0040$). Specifically, those that reported they forage had a higher probability of being female ($p = 0.0028$), with the proportion of those that forage higher for females (81%) compared to males (59%). Most informants reported they learned to forage from parents (35%) and through a variety of sources (42%) other than their immediate family and friends including books, classes, and online learning. Informants shared multiple factors that they value about foraging (with the most prevalent themes reported being: food and/or health (83%), recreation and or self-fulfillment (77%), and companionship (32%) (**Table 1**).

Informants and their families forage over 92 wild edible plants (**Table 2**) with the most prevalent being: berries and fruits (87%), mushrooms (69%), and other botanicals used medicinally (25%). Further, informants reported the foods most foraged are fruits and berries (68%) (**Figure 2**). The majority of informants reported they primarily forage on public (64%) and private (36%) lands with few reporting they forage in other areas (2%) such as tribal land. Informants varied in how often they consume wild edible foods with just over half reporting their consumption is varies based on season (56%). Around half of the informants reported they consume wild edible foods weekly (52%), while other informants reported they consume wild edible foods about one to three times a month (26%) or less than once a month (22%) (**Figure 3**).

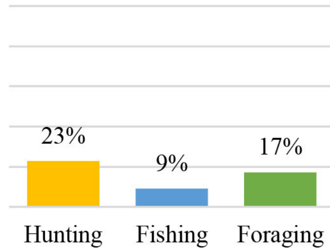
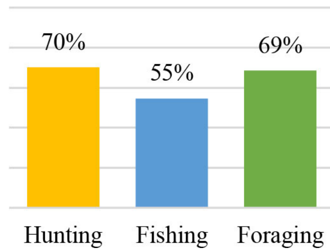
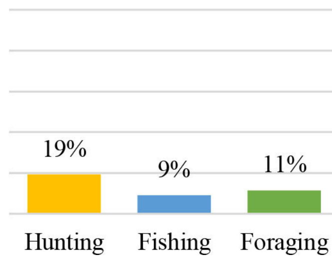
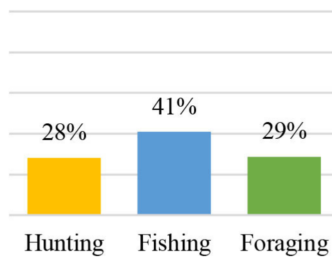
Informants reported numerous preservation techniques for foraged goods with the most frequent being freezing, drying, canning, and pickling. Informants also reported that they make a range of "home-made" food products using foraged wild edible plants including salads, soups, smoothies, and sides (73%); jams, jellies, and syrups (61%); desserts such as pies or baked goods (43%); and medicinal tonics including teas/tisane, salves, and tinctures (22%). Informants shared a range of practices, rituals, and stories associated with foraging, with the majority focused on recipes and preservation techniques (69%) (**Table 3**). Other rituals and practices reported by informants included responses associated with tradition, connection, and stories (29%), harvesting practices (17%), and rituals being spiritual in nature (11%).

The majority of informants had a WFPSc of 1 for foraging (68%) and an average WFDDSc of 2.70 ($n = 67$; SD = 1.47) that ranged from one to seven different types of foraged edible foods. Differences in Wild Food Procurement Score for foraging were not significant based on food insecurity or location and were significant based on generation ($p = 0.0132$) and gender (0.0078). Specifically, in a means comparison using Student's t-test, the Baby Boomer+ group had a higher mean WFPSc for foraging than both the Millennial ($p = 0.0033$) and the Generation X group ($p = 0.0369$), and females had a higher mean WFPSc than males. Differences in mean WFDDSc for foraging were not significant based on generation, gender, food insecurity, and location.

Wild Food Perceptions and Total Wild Food Procurement and Dietary Diversity Scores

The majority of informants agree that eating wild foods contributes to the overall nutritional quality (87%) and diversity

TABLE 3 | Prevalent themes associated with practices and rituals regarding the procurement of wild foods through hunting, fishing, and foraging.

Wild food harvesting practices			
Research theme	**Subthemes**	**Sample quotations**	**Frequency of theme**
Theme 1: harvesting practices	Subthemes: butchering the animal themselves and mindful harvest of a plant community	*"I process or butcher all of the game I take."* *"We try to dig roots when the plant is in seed, so we fill the hole with seeds. We intentionally spread seeds, and we caretake specific patches of all of our foods and medicines, keeping close eyes on how they are doing."*	
Theme 2: recipes and preservation techniques	Subthemes: specific family recipes and preservation techniques like freezing, drying, canning, pickling, and smoking	*"It's simple but it's hard to beat, cooking fish in a foil over open fire."* *"Morels fried in butter and used as a topping for pork loin sandwiches on ciabatta."*	
Theme 3: spiritual or rituals	Subthemes: harvest rituals, mindfulness, and saying a prayer when harvesting	*"When an animal is shot it is thanked and fresh branches are put in its mouth and on the wound."* *"When I harvest medicines, I consider it an activity that I need to pay special attention to and to be mindful."*	
Theme 4: tradition, connection, and stories	Subthemes: time spent with family, visiting traditional or special locations	*"My dad and I go out to a local burger place as a celebration of filling a tag."* *"My grandfather knows the best fishing spots. We make this a contest of who can catch "the biggest and the most.*	

(variety) of their diet (82%), as well as lowers the cost of their diet (59%). Furthermore, the majority of informants agreed (66%) that collecting and/or eating wild foods is part of their cultural identity, and they are concerned that younger generations in their community are losing both their desire to collect (73%) and traditional knowledge of collecting (73%) wild foods.

In parallel, the majority of informants had a WFPSc of 1, on a scale of 0–1, for hunting (91%), fishing (91%), and foraging (68%) (**Figure 4A**). More than half of informants had a WFPSc of 3 (58%), on a scale of 1–3, which indicates they procure wild foods from hunting, fishing, and foraging; while one-third of informants had a WFPSc of 2 (33%), which indicates they procure foods from a combination of two wild food activities. The remaining informants had a WFPSc of 1 (9%), indicating they procure wild foods from a single activity (**Figure 4B**). Differences in Total WFPSc were not significant based on generation, gender, food insecurity, and location.

The mean Total WFDDSc for informants was 6.34 ($n = 129$; SD $= 4.26$) with a range of one to 31 different types of total wild foods consumed from hunting, fishing, and foraging activities. Differences in mean Total WFDDSc were significant based on food insecurity status of participants ($p = 0.0181$), with a higher mean score among informants that were not food insecure (6.9) compared to those that were food insecure (5.1). Total WFDDSc was not significantly different based on generation, gender, and location.

Environmental Change and Protecting Community Resources

Over half the informants reported they perceived some type of environmental change over the past decade (increase, decrease, or become more variable). Specifically, a notable percentage of informants reported they have observed an increase in drought (56%), temperature (50%), and intensity (42%) and frequency (40%) of wildfire (**Figure 5**). Over a third of informants further observed greater variability in overall snowfall (44%) and overall weather patterns (43%) as well as a decrease in snowpack (40%) and water availability (33%). Specific changes informants reported include "changes in rainfall and availability of animals", "higher temperatures with more frost-free days", "warmer weather with winter not lasting as long", "hotter summers fueling more wildfire" or "hotter with less precipitation", and "getting hotter and more rain".

Around two-thirds of participants noted some type of change (starting earlier, later, become more variable) for all four seasons

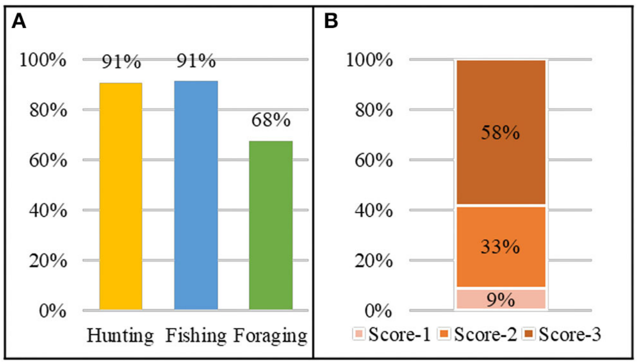


FIGURE 4 | Wild food procurement score. Wild food procurement score of 1 (on a scale of 0 to 1) for **(A)** hunting, fishing, and foraging, and **(B)** total wild food procurement score on a scale of 1 to 3.

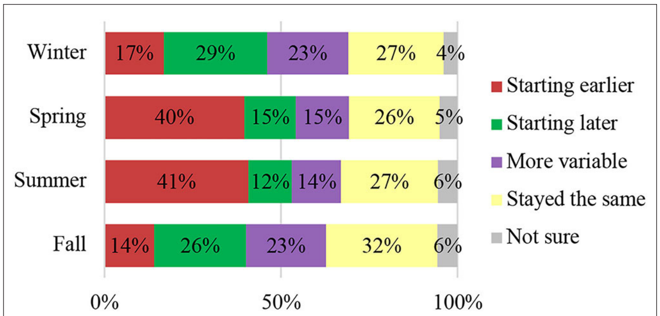


FIGURE 6 | Observations in seasonal variation. Percentage of informants that reported they perceived seasonal changes including seasons starting earlier, later, become more variable, no change, or were not sure of change.

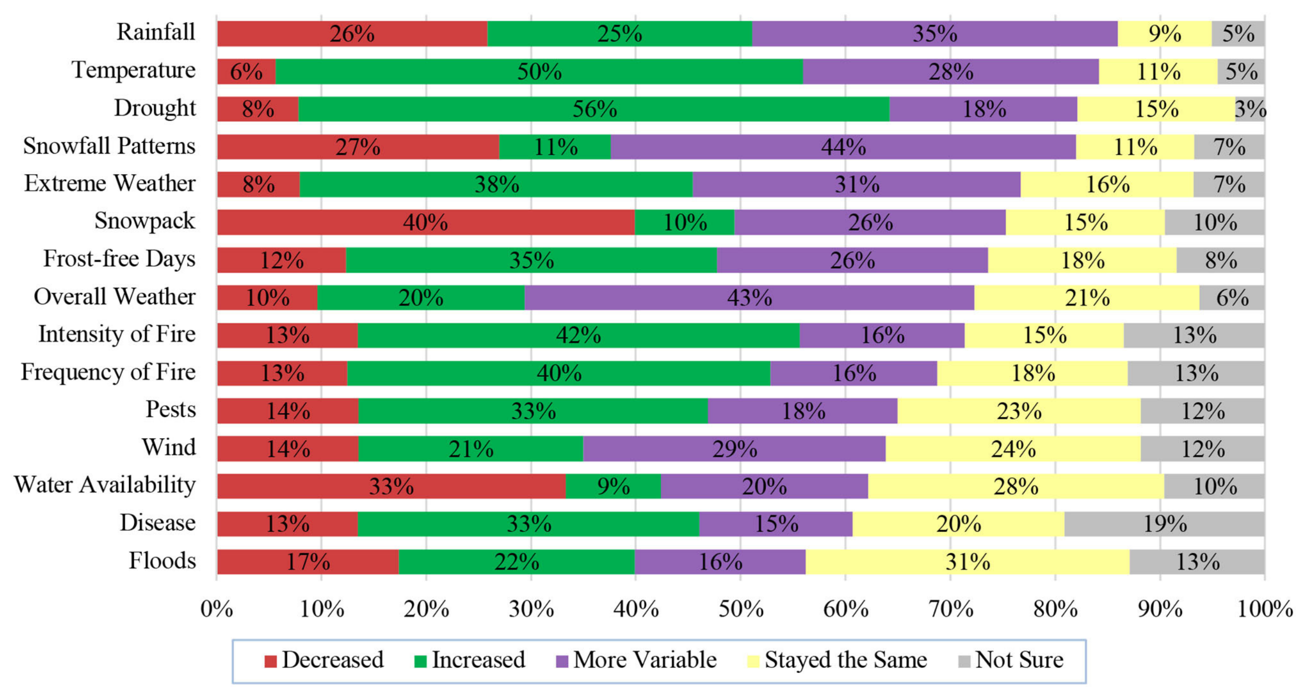


FIGURE 5 | Observations and perceptions on environmental change. Percentage of informants that reported they perceived a decrease, increase, variability, no change, or were not sure of change in environmental factors.

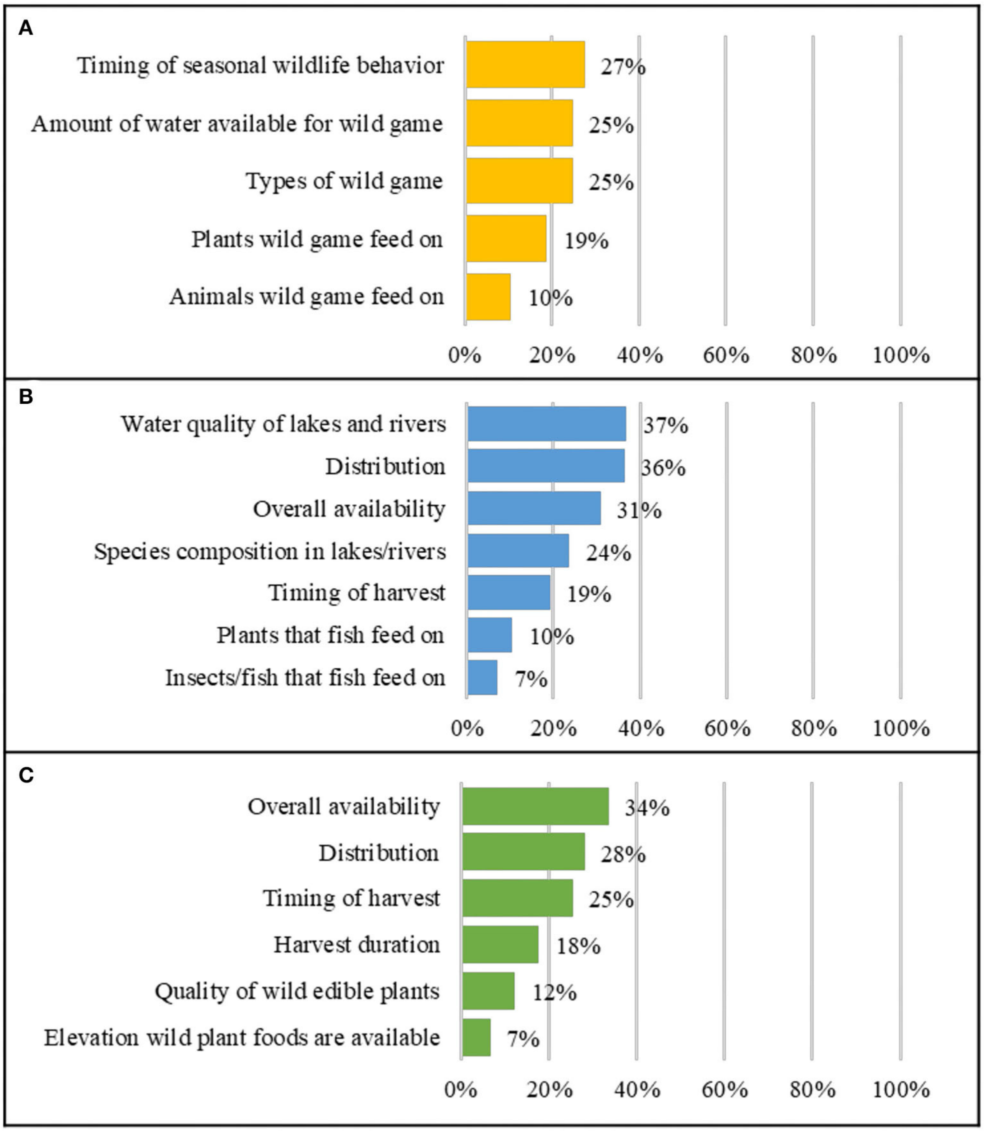


FIGURE 7 | Observed environmental changes. In the past decade observations that have resulted in changes in **(A)** wild game, **(B)** fish, and **(C)** edible plant populations.

(**Figure 6**). Specifically, over one-third of informants reported they have observed both summer (41%) and spring (40%) starting earlier. Approximately a quarter of the informants further reported they observed the winter (29%) and fall (26%) seasons starting later. For example, some changes informants reported include "growing season has increased", "extended growing season", "variable temperatures rather than stable cycles", "hotter spring and summer with winter and fall not as cold", and "higher winter temperatures and more pests in forests".

The majority of informants reported they have observed environmental changes in the past decade that have resulted in changes in wild game, fish, and edible plant populations (**Figure 7**). Some of the changes reported include: (1) changes in the timing of seasonal wildlife behavior (27%); (2) water quality of lakes and rivers (37%); and (3) overall availability or abundance of wild plant foods (34%). A few informants also noted changes in the types of wild animals that other wild game feed on (10%), aquatic organisms that fish feed on (7%), and the elevation wild plant foods are available (7%). Some of the specific observations reported by informants regarding changes in wildlife include "changes in big game winter distribution", "changes in timing or rut", "less elk", and "more deer". Changes reported for fish include "not as cold in the winter", "lake water level has decreased", and "less fish" and "lower abundance of fish". Changes reported for foraged edibles include "an increase in the amount of wild plant foods", "earlier harvest", "drier and less productive plants", and "longer season".

TABLE 4 | Protecting community food, water, land, and cultural resources.

Research theme	Subthemes	Sample quotations
Theme 1: community engagement and education	Subthemes: education, participate in community activities, communication and relationship building	*"We need to talk about these issues more and education kids in school (let's start a sustainable agriculture and environmental science program in K-12!)."* *"Proactive and positive citizen participation in land use decisions."* *"Get more people interested in wildcrafting."*
Theme 2: Conservation and responsible resource use	Subthemes: protect open/green space, recycle, reduce waste and/or pollution, renewable energy, conservation practices	*"Promote sustainable land use practices, renewable energy, and promotes a lifestyle that reduces carbon emissions."* *"Support land conservation and opportunities for people to have access to nature and ways to connect with nature."* *"By wasting less and saving more."*
Theme 3: management, policy, and/or legislation	Subthemes: federal management, political leadership, public lands, laws/fines	*"Improving agricultural practices to reduce dewatering, pesticide & fertilizer reduction, public lands grazing allotment reduction, atmospheric carbon reduction"* *"Increase in funding to conservation efforts, protect open space (ranches and public land)"* *"Proper legislation to regulate game and fish populations. Putting funds toward fire prevention and resources needed to fight wildfires. Logging overgrown areas that lead to larger fires."*
Theme 4: planning and/or development	Subthemes: long-term management, smart development, environmental sustainability plans	*"Regulate sprawl, create more habitable cities, provide public transportation and services to allow people to live in cities and easily visit wild areas without building in them"* *"Place limits on building in wild lands, especially forested areas, while incentivizing urban infill."* *"Have a quality land use master plan for the county and all public lands."*

Themes, subthemes, and suggestions reported by informants to help protect their community's food, water, land, and cultural resources.

The majority of informants reported they agree they are concerned about land-use changes in and around their community (80%), water quality (77%), and future decrease in availability of wild foods (72%). Approximately two-thirds of informants reported they agree that changes in weather patterns were impacting the wellbeing of their community (65%). Informants shared a range of ideas for protecting food, water, land, and cultural resources in their community that focused on the following themes: (1) management, policy, and/or legislation (43%); conservation and responsible resource use (38%); community engagement and education (29%); and mindful planning and development (17%) (**Table 4**).

DISCUSSION

This case study highlights that wild food environments are an important biocultural resource that contributes to cultural identity, dietary quality, dietary diversity of nutrient-dense foods, and food security through lowered cost of diets. Informants, and members of their social networks, frequently engage with wild food environments to hunt, fish, and forage a diversity of species including 42 types of wildlife, 38 types of fish, and 92 types of edible and medicinal plants. The most prevalent types of wild foods procured among informants are deer, birds and waterfowl, elk, trout, bass, and a range of berries, mushrooms, and medicinal plants. Wild foods are frequently consumed by the informants; over half consume wild meat and plants on a weekly basis, while just over one-third consume fish weekly. The procurement of wild foods represents cultural heritage and traditional ecological knowledge with informants learning to hunt, fish, and forage from elder members of their families. The species that informants hunt, fish, and forage dually represent both local biodiversity and food sources that are rich in nutrient profiles (Dinstel et al., 2013; USDA, 2020). However, informants expressed concern that wild food environments are vulnerable to global change and have been impacted by climate change and land-use change. In addition, informants expressed concern that traditional ecological knowledge associated with wild food environments is at risk with the younger generation losing knowledge and motivation associated with wild foods. On the basis of findings, we support that wild food environments are a critical place to understand and conserve. Future research is called for to understand the social implications of wild food procurement and associated cultural heritage and traditional ecological knowledge within the context of their study region.

Coded responses regarding values associated with hunting, fishing, and foraging highlight the multidimensional value system among informants regarding wild foods procurement. The most prevalent value reported for procuring wild foods was for diets followed by recreation, family time, spirituality, and connection to the environment. Wild food procurement is associated with a range of practices and rituals ranging from food preparation and cooking activities to those spiritual in nature. Findings of the multidimensional valuation and practices associated with wild foods are in line with previous research (Groessler, 2008; Smith et al., 2019; Byker Shanks et al., 2020). For example, Groessler 2008 reported food preparation and storage techniques for berries such as huckleberry, serviceberry, and bitterroot, as well as preparation techniques for fish such as salmon as a prevalent wild food procurement practice.

The high valuation of wild foods for diets among participants is demonstrated in the relatively high frequency of consumption reported by informants. More than half of informants reported they consume wild meat and plants they procure on a weekly basis, while just over one-third reported they consume fish weekly. Findings on the frequency of consumption of wild meat and plants are higher than reported in a previous study in a tribal community in Montana, where approximately one-third of participants reported consuming wild meat and foraged plants at least once a week, while the frequency of consumption is the same.

Participants' valuation of wild foods for diets coupled with the frequency of consumption contributes to food security and dietary quality of informants. A majority of informants agreed that the consumption of wild foods contributes to the overall nutritional quality and diversity of their diet while lowering food costs. These findings are of importance to food security as a notable percentage of participants (43%) are food insecure and receive food and nutrition assistance (29%) through the Supplemental Nutrition Assistance Program, food banks, and community kitchens. The promotion of wild foods, and associated food environments and cultural resources, has the potential to contribute to enhancing food security and nutritional outcomes through non-market access to diverse and nutrient-dense foods. Previous research highlights that wild foods contribute to commonly consumed foods and food security as a non-monetary resource that can supplement diets through non-market sources (Ford et al., 2009; Smith et al., 2019; Byker Shanks et al., 2020). Given the role of wild foods for food security, it is essential for citizens to continue to have access to these resources. While access issues did not emerge as a key theme in this study for procuring wild foods, previous studies (including in the study area) have highlighted how access to natural resources can serve as a barrier for wild food consumption (Smith et al., 2019).

Wild foods are further recognized to contribute to dietary quality, nutrition, and health through enhancing dietary diversity of nutrient-dense foods with their rich nutrient and phytochemical profiles (Vinceti et al., 2012). For example, North American ruminants (elk, deer, and antelope) are a source of lean protein with a beneficial fatty acid composition that may help prevent chronic disease (Crawford, 1968; Cordain et al., 2002). Fowl, including pheasant and grouse, are lean sources of protein, with pheasant being relatively high in selenium and choline (USDA, 2020). Fish, including wild-caught trout and bass, offer unadulterated sources of protein high in potassium (USDA, 2020). Wild mushrooms such as morels and puffballs are high in vitamin D, with morels also substantially high in iron (USDA, 2020). Huckleberries and raspberries are high in both vitamin C and antioxidants (Dinstel et al., 2013; USDA, 2020).

While wild foods contribute to food security, dietary quality, and sustainable diets, these natural resources are vulnerable to global change including climate change, land-use change, and loss of biodiversity (Galloway et al., 2003; Tscharntke et al., 2012; Lowry et al., 2019; Willett et al., 2019; Prevéy et al., 2020). A notable percentage of informants have observed shifts in climate over the past decade including an increase in temperature, more variable rainfall, increased drought, more variable snowfall, decreased snowpack, increase in extreme weather, more variable weather patterns, increase in frequency and intensity of wildfires, greater variability of wind, decrease in water availability, and increase in frost free days. In addition, a notable percentage of informants further reported they observed seasonal variation in the past decade including spring and summer starting earlier and fall and winter starting later. Informants also observed an increase in the number of pests and diseases. Informant observations are in line with the Montana Climate Assessment (Whitlock et al., 2017) and have similarities to observations and perceptions reported by households in tribal communities in Montana (Smith et al., 2019) as well as farmers and ranchers in Montana (Grimberg et al., 2018). For example, the Montana Climate Assessment demonstrates that the area has experienced changes in precipitation patterns that are impacting snowpack, water availability, and increasing the severity of wildfires in the region (Whitlock et al., 2017).

Informants linked the observed changes in climate with impacts on wild food populations and associated biodiversity including: (1) overall abundance and distribution of fish and foraged wild edible plants; (2) changes in the types of wild game available; and (3) changes in the timing of seasonal behavior for game and fish, and timing of seasonal harvest of foraged edibles. In some cases, these observations include an increase in specific wildlife such as deer, while in other cases it includes a decrease in specific species such as a lower abundance of certain types of fish. Informants further noted shifts in the habitats of wild foods such as shifts in the water quality of lakes and rivers. Previous research highlights that wild foods are vulnerable to global change including climate change and land-use change (IPCC., 2007; Ford et al., 2009). For example, members of the Crow Nation in Montana observed reductions in freshwater fish populations due to warming waters (Doyle et al., 2013), while informants of the Flathead Reservation in Montana are concerned that changes in climate and land use coupled with overpopulation could decrease the availability of wild foods (Smith et al., 2019).

Informants shared a range of ideas to mitigate the impacts of environmental change on wild foods including enhancing education, research, and communication to community building efforts, policy, and conservation and management efforts. A third of informants shared ideas specifically targeted toward conservation and responsible resource use, perhaps due to feelings related to risk of restrictions on wild lands. Findings reinforce the need for research, education, evidence-based interventions, and policy to enhance wild food environments and associated cultural resources in the context of climate change (Cordalis and Suagee, 2008; Bharucha and Pretty, 2010; Lynn et al., 2013; Smith et al., 2019). For example, research is needed to better understand how climate change is impacting wild food populations, including quality, quantity, harvesting practices, and how this varies geographically.

Previous research provides evidence on the linkages between biodiversity and dietary diversity of nutrient-dense foods (Lachat et al., 2018; Gergel et al., 2020). Biodiversity is particularly critical to conserve given its role in ecosystem functioning coupled with its' current status outside of environmental limits within which humanity can safely operate (Steffen et al., 2015). Dietary diversity of nutrient-dense foods is recognized to support dietary quality (Gómez et al., 2020). To foster linkages between biodiversity and dietary diversity of nutrient-dense foods, we support that wild food environments (Downs et al., 2020) and associated bio-cultural resources are a critical place to understand, conserve, and promote for nutrition. While the role of food environments for advancing nutrition is increasingly recognized, wild food environments remain under-recognized in the nutrition literature and practice (Downs et al., 2020), including in nutrition-sensitive interventions. Central to promoting wild food environments is systematic and comprehensive documentation of the composition of wild foods using metabolomics and other foodomics technology. Along with biochemical composition data, there is a need to document ethnographic and environmental information on the context of wild foods including perceptions of how food composition varies based on environmental factors (Ahmed and Stepp, 2016). Further, there is a need for clinical studies to document the impacts of wild food consumption on human health outcomes, including the gut microbiome.

Given the vulnerability of wild food environments to land-use change including development in the study area, conservation efforts are needed to preserve wild food environments that support biodiversity, ecosystem services, sustainable diets, and planetary health while giving communities access to these resources for sustainable harvests. In addition to natural resources, this study highlights the importance of ecological knowledge and value systems maintaining wild food resources including their safe and sustainable procurement. Numerous research documents the special cultural knowledge regarding the identification, harvesting, preparation, and processing required to utilized and consumer wild foods (Turner et al., 2011). In addition, multiple studies document the detriments to diets and wellbeing associated with a loss to traditional ecological knowledge (LaRochelle and Berkes, 2003; Turner et al., 2011). We thus support advancing the concept of "conservation for nutrition" which we define as, "the preservation and management of biocultural diversity associated with wild food environments including biodiversity, ecosystem services, ecological knowledge, values, and practices with the goal to support both human and planetary health".

Nutrition interventions in communities with a cultural practice of procuring wild foods should recognize these resources through supporting wild food environments as well as the ecological knowledge and values that foster their sustainable harvest and consumption. Previous studies have highlighted the role of forest conservation as a potential nutrition-sensitive intervention in low- and middle-income countries (Rasolofoson et al., 2020) as well as in rural communities globally (Hickey et al., 2016; Gergel et al., 2020) for supporting both ecosystem and human wellbeing. Forest conservation as a nutrition-sensitive intervention is recognized to provide a range of ecosystem services such as pollination that food crops are dependent on (Rasolofoson et al., 2020) along with providing nutrients for human diets through wild foods (Fungo et al., 2016). Gergel et al. (2020) highlight how forests are key sources of dietary diversity in rural settings. Fungo et al. (2015) found that foods harvested from forests in forest-dwelling communities in Cameroon contribute to 93% of daily vitamin A intake of women. The study presented here supports that ecological conservation efforts for nutrition are also important in high-income countries. In addition, this study supports that a range of wild food environments in addition to forests should be conserved including rivers, lakes, and grasslands.

Nutrition education that acknowledges wild food environments including ecological knowledge of sustainable and safe harvesting practices associated with wild foods could enhance the sustainability of wild food environments as well as their role for food security and dietary quality (Smith et al., 2019). Such initiatives should be place-based and culturally grounded for each context. For example, storytelling is a culturally-relevant way of transmitting ecological knowledge in many Indigenous cultures, "*Our past is preserved and explained through the telling of stories and the passing of information from one generation to the next*" (Inuit Tapiriit Kanatami) (Kuhnlein, 2013). Efforts should also be made to remove access barriers for wild food procurement in addition to knowledge. For example, previous research found that access to land and water, time, and costs for procuring wild foods were major barriers for the consumption of wild foods (Smith et al., 2019).

Some potential shortcomings and limitations of this study include the following with respect to survey distribution and the demographic background of participants that were reached through distribution efforts. The data is limited to what can be elicited to an online semi-structured survey where we cannot ask clarifying and follow-up questions to participants. Further, as this was an online survey it was not accessible to people who do not use the internet, or have internet access. The survey was distributed to various groups / listservs but is not representative of everyone who may procure wild foods in Montana that may not be part of those groups. Tribal affiliation was not collected given feedback from our Tribal Partners about cultural and sensitivity issues regarding the comparison between tribal communities, and with non-tribal populations.

CONCLUSION

Improving the nutritional quality of foods available in the food environment has been identified as a strategy to improve diets and health outcomes (Damman et al., 2008; Chodur et al., 2016). While the majority of food environment interventions have focused on the built or market food environment, this study highlights the importance of wild food environments where communities hunt, fish, and forage to support food security and dietary quality. Findings further highlight the vulnerability of wild food environments to environmental change and call for education, community building efforts, policy, and conservation plans to strengthen the sustainability of food systems to support both human and environmental wellbeing. On the basis of findings, we support that wild food environments and associated cultural resources are a critical place to understand and conserve to overcome the global burden of disease and improve nutritional and planetary health outcomes. Specifically, we recommend the following for supporting healthy, safer, and sustainable food procurement from wild food environments. These recommendations call for multi-sector collaboration between natural resource managers, public health, communities, cultural anthropologists, botanists, zoologists, dieticians, food system scientists, and other stakeholders.

(1) **Conservation of Nutrition**. Communities with a cultural practice of procuring wild foods should recognize these resources and support conservation of wild food environments and associated cultural resources including ecological knowledge and values. We thus support advancing and operationalizing the concept of "conservation for nutrition" which we define as, "the preservation and management of biocultural diversity associated with wild food environments including biodiversity, ecosystem services, ecological knowledge, values, and practices with the goal to support both human and planetary health". Advancing conservation for nutrition should focus on equitable access to promote inclusivity of people from a range of cultural and socioeconomic backgrounds to access the wild food environment. For example, community provided transportation can help remove barriers to accessing wild foods. Our concept of conservation for nutrition acknowledges nutrition-sensitive landscapes that set nutrition, social, and environmental targets to benefit all three (Kennedy et al., 2017).

(2) **Research on Socio-Ecological Determinants on Wild Food Procurement**. In order for wild food procurement to continue in communities in a sustainable manner, research is needed to understand the socio-ecological determinants that enable this practice and how it contributes to community resilience. For example, what implication could wild food heritage have in terms of safeguarding the perception of "common goods"? Can wild foods represent a pillar of resilience or resurgence of a common goods-driven ethic?

(3) **Place-based Education on Wild Food Procurement**. Development and dissemination of a wide range of place-based educational offerings about safe food procurement in wild food environments including: plant identification, sustainable harvesting, harvesting from safe areas, and preparation of wild foods. Such education can be offered by community organizations and developed with the support of key informants who have expertise on wild foods such as community elders. These initiatives should also be place-based and culturally grounded for each context such as through storytelling. Several opportunities exist in the study area for those interested in procuring wild foods such as a certified hunter education course which includes education on conservation in addition to ethical and sustainable harvest of animals; wild plant identification courses and; community sponsored "field days".

(4) **Biochemical Profiling of Wild Foods and Dietary Interventions**. Future research is called for to characterize the impact of wild food consumption on dietary quality and human health outcomes. This requires comprehensive profiling of wild food composition using cutting edge metabolomics and other foodomics technology. Such interventions also require profiling of human health biomarkers including impacts on the gut microbiome as well as perceptions of wellbeing.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board (IRB) at Montana State University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SA designed the survey tool with input from CB and VD. SA, CB, and VD contributed to administering data collection. TW and AS led the qualitative data analysis and TW led the quantitative data analysis with input from all authors. SA and TW wrote the manuscript with input from all authors. All authors contributed to data interpretation.

FUNDING

This work was funded by NSF RII Track-2 FEC OIA grant number 1632810, the National Institute of General Medical Sciences of the National Institutes of Health under grant number P20GM103474, and the National Institute of General Medical Sciences of the National Institutes of Health under grant number P20GM104417. The content is solely the responsibility of the authors and does not necessarily represent the official views of National Science Foundation or the National Institutes of Health.

ACKNOWLEDGMENTS

We are grateful to: (1) the survey respondents for sharing their knowledge and experiences; (2) Zachariah Miller, Anna Herforth, Ryan Huish, and Emily Salois for providing feedback on the survey tool; (3) former students of the Montana State University Food and Health Lab for supporting in logistical aspects of implementing the survey instrument, organizing data, and preliminary coding of data including Elizabeth Svisco, Debra Kraner, Erin Smith, and Emelia Hitchcock.

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