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Provisioning food and medicine from public forests in the United States☆

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ABSTRACT

Forests contribute to the nutritional and medicinal needs of billions of people worldwide. In the United States, the extent and impacts of provisioning forest foods are not fittingly understood. This study seeks to elucidate the scope and scale of forest food harvest. Using publicly available data, hunting surveys and proprietary data from the Wild Harvest Initiative®, we provide estimates of the amount of foods and medicines from wild-harvested flora and fauna, and meat produced from domesticated livestock grazed on public forest lands. The evidence strongly supports the assertion that large volumes of forest-dependent fauna and flora contribute to the health and well-being of a substantial portion of the country's population. Each year, >255 thousand metric tons of forest foods and medicines are harvested across public lands of the United States. Our findings are relevant to the global challenge of providing more nutritional food to a growing population through ecologically sustainable sources. The study provides more clarity to the importance of wild flora and fauna harvesting in the United States. The case of the State of Alaska, which codifies subsistence harvesting in its constitution, exemplifies the potential benefits of recognizing the importance of these natural resources to its residents. Concerted institutional efforts recognizing the importance of forest food and medicines to people and communities would shed more light on these natural resources and could lead to improved land management and food security.

1. Introduction

The conventional approach to achieving food security has resulted in a substantial loss of forest and grassland biodiversity that directly and indirectly support the nutritional, economic and cultural needs of billions of people, especially in the Global South (Smith-Hall and Chamberlain, 2023a). One of the great challenges of this century is producing and distributing enough food to nourish people without detriment to biodiversity (FAO, 2018). More than a quarter of the world's population depends on forests and trees for their livelihood, and for their nutritional and medicinal needs (Angelsen et al., 2014; Ickowitz et al., 2016; Pimentel et al., 1997). Direct provision of food from forest lands may represent a small portion of global food supply, but the volume of foodstuffs provided by these landscapes is remarkable. Many communities rely on wild-harvested products as crucial components of their dietary quality and diversity, family health, economic security and wellbeing. Yet, the contributions of forests in providing these necessities are not well documented.

Forests around the world are the source of plant and animal-based foods for sustenance and commercial consumption (Emery and Pierce, 2005), and this provisioning is not limited to the Global South (Chamberlain and Smith-Hall, 2024). A recent pan-European study of households that collect forest plant-based foods for subsistence consumption found that the average amount collected by household was

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approximately 60 kg per year (Lovrić et al., 2020). >13 million residents of the European Union reportedly hunt wild animals, and in 2005 approximately 26 thousand metric tons of wild meat were sold on the European market, with a reported value of USD $416 million (Schulp et al., 2014). Likewise, in the United States, 14.4 million people hunt, and the wild meat obtained from hunting is generally not sold (U.S. Department of the Interior, U.S. Fish and Wildlife Service, 2023).

Harvesting of forest foods from federal lands takes place throughout the United States (U.S.) and is vital to the material and social well-being of diverse peoples (Alexander et al., 2011; Chamberlain et al., 2018a). A noteworthy portion of the U.S. population relies on forests for subsistence, and a growing portion participates in wild food procurement for personal consumption (Baumflek and Chamberlain, 2019; Trozzo et al., 2019; U.S. Department of the Interior, U.S. Fish and Wildlife Service, 2023). Forest foods are critical to rural communities, and of high cultural value to Indigenous Peoples across the U.S. (ADFG, 2023), yet the amounts provided by these ecosystems remain invisible.

The availability of data for some forest products, such as timber and forage, are more readily available than others (e.g., non-timber forest products, fish and wildlife). To estimate the volumes of plant and animal-based food provisioned from public forest lands is particularly challenging as data are lacking or are not clearly parsed. This complicates efforts to assess benefits and weigh tradeoffs among uses which may be, at times, competing. Despite the limitations and inconsistencies of data, the overall hypothesis is that analyses of existing data presents a picture of diverse and sizable harvesting of food resources from public forests.

This study is an attempt to provide more detailed evidence of the diversity, volume, and importance of food resources derived from public forest lands. We estimate the amount of food and medicine from the harvest of wild flora and fauna on public forest lands, and the amount of meat generated through the grazing of domesticated livestock on public lands. Further, we estimate the amounts of foods derived from subsistence hunting, fishing and foraging in forests of Southeast Alaska to showcase the benefits that arise when these resources are recognized for their value. We extrapolate the data to provide estimates of meal servings based on accepted standards. Articulation of the amount of plant and animal-based food and medicine provisioned from forests could fill a critical gap in knowledge about these resources and lead to them receiving greater focus in forest management policies and practices. The fundamental premise is that documenting and understanding the scope and scale of these activities will demonstrate their importance and the need for their consideration in land management practices and policy.

2. Methods

Determining the amount of food and medicine provisioned from forests is challenging because forest management plans and strategies have not explicitly considered such products. As a result, data needed to estimate production may be lacking, dissimilar and not well delineated. Estimating the amount of food and medicine harvested from forests requires a multi-pronged approach. Therefore, we utilized available literature, public and proprietary databases, survey data, and a case-study to assess the contribution of public forest lands to provisioning food and medicine. This science-based approach provides the means for an initial assessment of the amount of food and medicine that is provided by public forest lands in the U.S.

2.1. Study location

For these analyses we focus on public lands across the entire U.S. managed by the U.S. Forest Service (USFS), the Bureau of Land Management (BLM), and State governments. The federal government owns about 260 million hectare (ha), about 28 percent of the total land area of the U.S. (Congressional Research Service, 2020). The BLM (∼ 99.15 million ha), and the USFS (∼78.1 million ha) allow harvesting products and manage for multiple uses. Together they administer about 72 percent of all federal lands (Fig. 1). The two agencies are tasked with

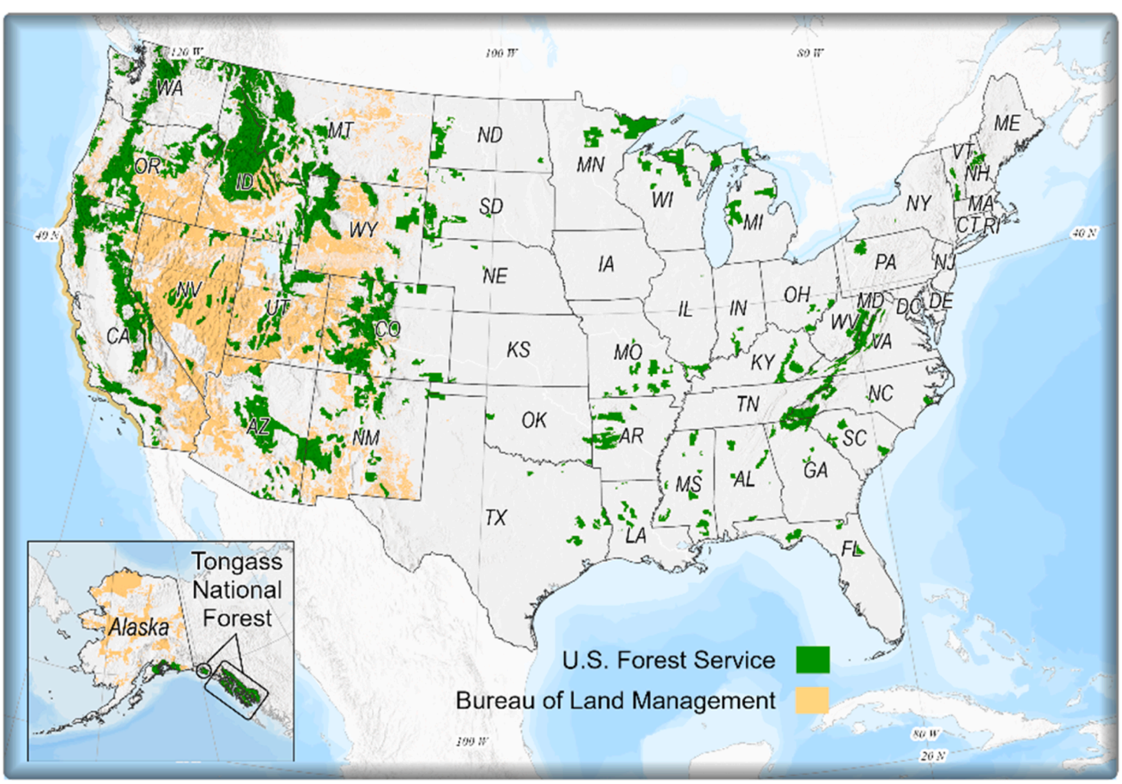

Fig. 1. Location of lands administered by the Forest Service and Bureau of Land Management in contiguous United States and Alaska. Image produced by Kelly Christiansen, USDA Forest Service.

weighing trade-offs among priorities and outcomes to achieve mandates for the multiple use of lands they administer. Legislation guiding the work of these agencies mandate that the public benefit from timber, water, recreation, forage, and fish and wildlife resources (e.g., Multiple Use and Sustained Yield Act of 1960, National Forest Management Act of, 1976). According to the Congressional Research Service (2020), federal lands are concentrated in the state of Alaska (~ 61 percent of state area) and 11 western states (~46 percent of state area).

While hunting, fishing, and gathering food and medicine take place across most biomes in the U.S., the primary focus of this study is forest lands. Though many definitions exist for forests, we adopt the definition codified in the Forest and Rangeland Renewable Resources Planning Act of (1974) where forests are defined as lands with at least 10-percent canopy cover by trees at least 5 m high, or trees able to reach these thresholds *in situ*, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and non-forested lands with at least 10-percent canopy cover with trees and forest areas adjacent to urban and built-up lands. The minimum area for classification of forest land is 0.4 ha and 36.6 m wide measured stem-to-stem from the outer-most edge. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if <36.6 m wide. The Forest Inventory and Analysis program of the USFS definition of forest land also includes afforested areas and pinyon-juniper and chaparral areas in the West. In 2019, there was an estimated 310 million ha of forest land in the United States (Oswalt et al., 2019), of which approximately forty-four percent was federally owned (Northern Research Station, 2008).

Livestock grazing on federal lands is not restricted to rangleand, as animals are free to range wherever. As noted above, forest lands may be sparsely stocked with trees providing ample opportunity for grazing these lands. Rangelands are defined as "lands on which the indigenous vegetation is predominately grasses, grass-like plants, forbs, and possibly shrubs or dispersed trees. Disturbed lands that have been revegetated naturally or artificially are included." Accordingly, Reeves and Mitchell (2011) identified roughly 267.9 million ha of rangeland in the lower 48 states and another 48.6 million ha in Alaska. Deconstructing domesticated livestock production between the broad definition of forest lands and rangelands is not possible. Hence, we include in these analyses rangeland under the administration of USFS and BLM.

2.2. Data collection

The purposes for harvesting food from forests are varied and complex. A general perception is that people harvest for subsistence, recreation, or commercial gain. The distinction between subsistence and commercial harvesting has been articulated (e.g. Angelsen et al., 2014; PEN, 2007), while recreational harvesting is not as well delineated. Recent scholarship on terminology of environmental products delimits three basic purposes for harvesting – subsistence, commercial and cultural (Smith-Hall and Chamberlain, 2023b). Estimating the amount of forest foods harvested for each of these objectives is challenging as the data sources do not present them as such. The USFS and BLM do not identify the purposes for harvesting, and the Wild Harvest Initiative® of Conservation Visions includes hunting data collected by state and federal wildlife agencies which also do not identify the reasons for harvesting (U.S. Department of the Interior, U.S. Fish and Wildlife Service, 2023). The State of Alaska is a unique case as subsistence practices have distinguished regulations and are recognized by state and federal governments. We use subsistence harvest data from ADFG (2023) for a case-study analyses of subsistence harvesting from forests of Southeast Alaska. We utilize data from USFS and BLM with that from the Wild Harvest Initiative® to estimate the amount of food from wild fauna and flora in the U.S., regardless of purpose. Additionally, we include estimates of meat production derived from domesticated livestock from grazing on public lands.

2.2.1. Wild harvest flora and fauna

Providing estimates of the amount of flora and fauna harvested from public forests requires several assumptions. We assume that harvest data of flora from USFS and BLM reflect the actual amount taken, although these data are for permitted harvest amounts. Permit data may in fact over or underestimate actual amounts harvested. Hence, these analyses, represent the best estimate of the amount of food and medicine derived from wild flora on public forest lands in the U.S. We recognize that our assumptions simplify a complex reality, and thereby may create some limitations to these analyses, yet to alleviate their impacts would require additional resources and infrastructure.

Estimating volume and value of flora-based food and medicine closely followed methods used in previous scholarship (Alexander et al., 2011; Chamberlain et al., 2018a). The data are based on harvest permits issued by the USFS and the BLM. Data for harvesting from the USFS were obtained through the *Cut and Sold* Reports that are available in the Timber Information Management System (TIMS) database. TIMS is the agency-wide system for storage and retrieval of data pertaining to forest products and is organized by products that are convertible to units of measure used to describe timber and those that are not. This latter category includes forest products designated as "edible fruits, nuts, berries and sap" and "herbs and medicinals" which were combined to 'food and medicine'. Data from the BLM were gleaned from the Timber Sale Information Systems and the Special Forest Products databases. Two product categories – "edibles and medicinals" and "mushrooms and fungi" constitute 'food and medicine' harvested from BLM lands.

To obtain wild fauna-based harvest data, we utilized the Wild Harvest Initiative® database (Conservation Visions, 2019). The Wild Harvest Initiative® database contains comprehensive hunting harvest data, collected from state wildlife agencies and the United States Fish and Wildlife Service, across all 50 states, for the hunting seasons 2014–2015, 2015–2016, 2016–2017, 2017–2018, and 2018–2019. Hunting data do not include subsistence harvest data from Alaska that are housed in the Community Subsistence Information System (CSIS) database, as described in the Alaska case-study, animals caught through fishing, the harvests administered through sovereign Tribal nations, or illegal and unreported species harvests.

The Wild Harvest Initiative® harvest data are at the species and demographic level (e.g., adult male, adult female, juvenile) and each harvest entry is paired with estimates of live, dressed, and edible mass. The dressed mass of the animal represents the mass of the animal with entrails removed (i.e., field dressed) and the edible mass represents the boneless mass of the animal's muscle tissue only (i.e., "wild meat"; organs and subcutaneous fat were excluded from the edible mass estimates). To determine the amount of wild meat procured on forested public lands, we filtered the database to include only species that live in forests for any part of their life, even if they may have been hunted outside a forest (appendix 1). For example, several species of waterfowl forage in lakes, ponds, rivers, estuaries and salt bays, but nest in tree cavities in boreal forests and so were included in the analysis (Dyson et al., 2019).

After narrowing the database to include only forest-dependent species, we estimated the proportion of forest-dependent animals harvested on public lands, and the proportion of wild meat (from forest-dependent animals) derived from public lands, in all states. To do this, we used data from the National Wilderness Institute on the proportion of land owned by state and federal governments (i.e., public land), and hunter harvest data collected from Wild Meat Sharing and Consumption Index Surveys (Conservation Visions, 2020, 2022a, 2022b, 2022c; National Wilderness Institute, 1995).

Wild Meat Sharing and Consumption Index Surveys were developed and conducted by Conservation Visions and its state agency partners in Alaska, Arizona, Nevada, Wyoming, and Texas (appendix 2). Resident hunters were asked to report all species harvested in the last hunting season, the number of each species harvested, and if that species was harvested on public or private land, using a 5-point Likert type scale from "public land only" to "private land only". Responses were assigned proportionally by assuming that 100 percent of the animals were harvested on public land if "public land only" was selected, and 0 percent were harvested on public land if "private land only" was selected.

2.2.2. *Domesticated fauna*

Public forest lands provide more than wild harvested food and medicine. The USFS and BLM track and monitor the extent that lands under their administration provide forage for grazing domesticated livestock for meat production. Livestock may graze public lands for part or all the year, yet the agencies do not estimate the amount of time they spend on forest lands as opposed to rangelands (Derner et al., 2023; Huntsinger et al., 2010). The agencies track animal numbers and forage use, not production of meat or fiber. Agencies administer permits for forage based on the Animal Unit Month (AUM) — the amount of forage a 453 kg "beef cow" or equivalent would consume in 30 days, or Head Months (the number of individuals grazing a specific area in a month). We examined published public records and scholarly articles to summarize the number of permittees, total acres grazed, and total AUMs consumed. We utilized USFS and BLM data on permitted grazing, as well as body composition and daily biomass gain data from academic literature to estimate the amount of livestock meat attributable to federal public rangelands in the US.

Attributing the amount of protein from domesticated livestock from rangelands is challenging and we do not attempt to bifurcate this biomass into that which is produced from rangeland versus forest land. Typically, there are no barriers to impede livestock movement between these ecosystems. Further the agency definition of forest lands is such that forage may be plentiful within stands of trees. We obtained the Head Months on all USFS (USDA, Forest Service, Natural Resource Manager, Rangeland Information Management System, 2023) and BLM (BLM Rangeland Administration System, 2023) administered land. These Head Months are organized by animal type and class that includes sheep, goats, bulls, cows with calves, yearlings, cows, and bison from 2007 to 2022. For cattle, we assumed a nominal value was the same for each subclass (e.g., bulls, cows with calves) to simplify national level estimates.

2.2.3. *Subsistence harvest in Alaska*

Forests support subsistence harvest practices throughout the U.S. (Emery and Pierce, 2005), and subsistence uses of forests have constitutional protection in the States of Hawaii and Alaska (Chamberlain et al., 2018b). We provide a case-study of how forests support subsistence harvest in Southeast Alaska, where subsistence practices are recognized by state and federal governments. The State of Alaska defines subsistence uses as "the customary and traditional uses of wild, renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools or transportation, as well as for the making and selling of handicraft articles and for the customary trade, barter or sharing for personal or family consumption" (Alaska Statutes Title 16, 2020). Federally eligible rural Alaskans participate in subsistence harvests on federal public lands as regulated by the Federal Subsistence Board (FSB). The FSB is comprised of multiple agencies and considers recommendations from regional advisory committees in determining subsistence regulations, which can involve different seasons, harvest limits, or more efficient methods of harvest (e.g. dip nets) than sport harvests (US DOI Federal Subsistence Board, 2015).

This case study focuses on the 33 rural communities in Southeast Alaska (SEAK) due to its forested landscape, strong reliance on wild harvest, and availability of subsistence harvest data (ADFG, 2019). Approximately 90 percent of SEAK is federally owned public land (Forest Service and National Park Service,) and the remaining 10 percent is a mix of state, Tribal, and private lands. The Tongass National Forest (Fig. 1) encompasses approximately 80 percent of the region and is the largest national forest in the U.S.

The Alaska Department of Fish and Game, Division of Subsistence conducts periodic household surveys of rural communities to monitor harvest of wild foods (i.e., all finfish, shellfish, wildlife, and vegetation). Community-level subsistence harvest data are housed in the Community Subsistence Information System database (CSIS). Using information from the CSIS and associated summary reports, we estimated the total annual subsistence harvest of different foods in metric tons for rural communities in Southeast Alaska. We considered all species that could be directly or indirectly supported by forest lands. Taxa that are directly supported by forest lands include freshwater fish (including anadromous species), terrestrial wildlife, plants, fungi, and nearshore intertidal organisms that rely on nutrients and organic matter from forests (i.e., mussels and clams). Marine organisms (e.g., marine fish, mammals, invertebrates) are indirectly supported by forests through species interactions with directly supported species and enormous land-to-sea fluxes of nutrients and organic matter exported from forests to sea (O'Neel et al., 2015).

2.3. *Data analysis*

2.3.1. *Wild harvest flora and fauna*

Forest food products harvested from USFS and BLM lands are recorded as pounds of bark, nuts and seeds, fruits and berries, roots, mushrooms, fungi, and herbs. Fruits and berries, and mushrooms also are reported by USFS in gallons, while herbs are reported also in bushels. Data from the USFS and the BLM were combined to present harvest amounts and receipts for permits to harvest food and medicine from federal lands. Throughout, units of measure have been converted to SI units. Following procedures used by Alexander et al. (2011), estimated wholesale values of products are presented in 2022 U.S. dollars.

To estimate the amount of wild meat derived from wild-harvested fauna, we utilized the Wild Harvest Initiative® database and multiplied the total number of forest-dependent animals harvested in each state by its live, dressed, and edible mass. These variables were then summed to yield the total number of animals harvested, and the total live, dressed, and edible mass of the harvest in each state. To estimate the proportion of this harvest derived from public lands, we utilized survey data from Wild Meat Sharing and Consumption Index Surveys. In each of the 5 jurisdictions where a survey was completed, we divided the number of forest-dependent animals reportedly harvested on public lands by the total number of forest-dependent animals reportedly harvested in the state, to determine the proportion of animals harvested on public lands. This approach was also used to determine the proportion of wild meat derived from public lands. Then, using the estimated proportions of animals and wild meat derived from public lands as dependent variables and the proportion of public land area in each of the five states as an independent variable, we performed two beta regressions (both $p < 0.001$, pseudo $R^2 = 0.87$ and 0.85, respectively) using the package Betareg in the programming language R (Cribari-Neto and Zeileis, 2010; R Core Team, 2023). These statistical models described the proportion of forest-dependent animals/wild meat harvested on public lands, as a function of the proportion of public land area in the state.

Using the statistical model described above, we estimated the proportion of forest-dependent animals harvested on public lands in each of the 50 states, by inputting state-level data on the proportion of public land area. Then, in each state, these estimated proportions were multiplied by Wild Harvest Initiative® harvest data on the total, state-wide, quantity of forest-dependent animals harvested. This provided an estimate of the number of forest-dependent animals harvested on public lands in each state. This same approach was used to determine the proportion of wild meat derived from forest-dependent animals on public lands.

This approach carried with it several assumptions. Namely, we assumed that the relationship between the proportional harvest on public lands and the proportional area of public land derived from those 5 states remained the same across all states. This relationship likely varied across states because of differences in habitat quality, hunter regulations and reporting, and hunter access on public and private lands.

2.3.2. Domesticated fauna

Quantifying the precise amount of weight gain per day across the variety of domesticated animals, landscapes and weather regimes was not possible, hence the type and class of domesticated livestock were assigned an average value, representing the mean live carcass mass gained per day, called "average daily gain" (ADG). To estimate ADG of meat for each kind of livestock, we relied on published research. For cattle, the ADG was estimated at 1.13 kg (Raynor et al., 2021), while the ADG of sheep was 0.06 kg and for goats it was 0.04 kg (Sen et al., 2004). For bison, the ADG was estimated at 0.45 kg (Koch et al., 1995).

Estimates of ADG are almost always reported as the daily increase in total animal weight. Not all the weight gained in a day, however, constitutes edible meat: internal organs, hair, hide, and bones all contribute to overall weight gain and need to be factored into estimates. Thus, a coefficient describing the proportion of edible meat to live weight was estimated based on published scholarship: 41 percent for cattle (South Dakota State, 2022), 50 percent for sheep and goats (Sen et al., 2004), and 38 percent for bison (Unchained, 2023). Using this information and ADG above, the average daily gain of edible meat for cattle, bison, sheep and goats, were estimated as 0.463, 0.171, 0.03, and 0.02 kg, respectively.

Finally, for each species of domesticated livestock, we estimated the amount of edible meat gained each day while the animals were on public land. Head months represent the number of animals present monthly. For example, 1000 head months of cattle means that there were 1000 cattle on a given grazing allotment for a 1-month period. The ADG values are expressed on a per day basis, but head months is expressed monthly (nominally 30 days). Thus, multiplying the daily gain of meat by 30 days (e.g., $0.4633 \times 30 = 13.899$ kg) provided an estimate of monthly gain of meat. This in turn was multiplied by the head months (e.g., $5165{,}798 \times 13.899 = 71{,}799{,}426$ kg) to obtain the yearly average gains of edible mass. Estimated number of servings was based on USDA and USDH&HS (2020) recommended serving size for protein.

2.3.3. Subsistence harvest in Alaska

We estimated total weight, proportion of harvest, and number of taxa harvested within each category of species types. Because harvest surveys were conducted over several decades for each community (1987 - 2015), we used the per-capita estimated weights harvested from the latest comprehensive subsistence harvest (see ADFG, 2019 for per capita calculation methods) and multiplied it by the most recent census data (i.e., 2022 population per community) to generate harvest estimates. This analysis is not intended to represent exact harvest estimates for 2022, rather the intent is to provide an approximate estimate of harvest in any given year, as harvest rates and population sizes are subject to inter-annual variability. We report harvest estimates for the direct species (terrestrial, freshwater, and nearshore), and direct and indirect species combined (i.e., including marine organisms). In calculating the number of taxa harvested, we excluded any taxa reported as unknown (e.g., unknown salmon species) or other (e.g., other plant species). Total annual servings and annual servings per person were estimated using recommended serving sizes for fruits, and vegetables and protein (USDA and USDH and HS, 2020).

3. Results

3.1. Wild harvest flora and fauna

The overall estimates of the amount of plant-based food and medicine harvested from USFS and BLM lands indicate that these public forests are sources of large amounts of biomass (Table 1). Over the ten years, 2013–2022, the USFS permitted the harvest of >9.1 million liters and over 705 metric tons of food and medicine. On average, the annual permitted harvest from the USFS has been about 918 thousand liters and 70.5 t of plant-based food and medicine. Over the same period, the BLM permitted over 6.7 thousand liters and >130 t of food and medicine. Combined, the two agencies issued permits for the harvest of about 9.25 million liters and about 2000 t of food and medicine over the decade. Based on recommended serving sizes for fruits and vegetables (USDA and USDH and HS, 2020) this is equivalent to almost 2 million servings per year. During this period examined, the amount of permitted harvest of food and medicine declined (Fig. 2).

In the decade encompassing 2013–2022, the USFS and BLM received approximately $5.7 million in receipts from permits to harvest food and medicine (Table 2) On average, annual receipts for the harvest of food and medicine amounted to approximately $570 thousand which added directly to the U.S. Treasury. Over this time, there has been a general decline in receipts for these products, yet they remain noteworthy. The estimated wholesale value of the permitted harvest of food and medicine from USFS and BLM land over the last decade exceeded $645 million (Table 3). In general, the estimated wholesale value of food and medicine harvested from USFS and BLM lands has declined over the decade of 2013–2022 because of a decline in estimated harvesting.

On average, over five hunting seasons, 2014–2019, approximately 9.9 million animals were harvested each year from public forest lands in the U.S. (Table 4). This harvest generated over 68 thousand metric tons of wild meat (i.e., edible mass), equivalent to 437 million servings (Table 4). Hunters in Idaho harvested more wild meat from forested public lands than any other state: 4160 t of wild meat a year, on average, equivalent to over 26 million servings. There was no clear relationship between the number of animals harvested and the edible mass of the harvest. For example, each year, hunters in Texas harvested, on average, 1.37 million animals, which yielded 3370 t of wild meat; in contrast, hunters in Wyoming harvested only 98.7 thousand animals, but yielded 3450 t of wild meat (Table 4). The five states procuring the greatest

Table 1
Permitted harvest volumes of food and medicine from the US Forest Service (USFS) and Bureau of Land Management (BLM) lands, in metric tons (t) and liters (L), 2013 through 2022, with estimated annual average meal servings.

Year	USFS *Mass (t)*	BLM *Mass (t)*	USFS + BLM *Mass (t)*	USFS *Volume (L)*	BLM *Volume (L)*	USFS + BLM *Volume (L)*
2013	165.68	156.65	322.33	1132,394	15,774	1148,167
2014	70.52	141.66	212.18	864,583	9635	874,218
2015	90.71	126.45	217.15	1059,728	2782	1062,510
2016	59.20	108.51	167.71	1709,030	10,690	1719,719
2017	75.12	111.09	186.21	1117,359	4071	1121,430
2018	113.27	191.87	305.14	878,542	6982	885,523
2019	42.94	105.34	148.28	765,452	8962	774,414
2020	24.02	144.72	168.74	357,683	1391	359,075
2021	19.36	129.79	149.15	608,634	3977	612,611
2022	44.44	93.89	138.33	693,995	2809	696,803
Annual Average	70.53	131.00	201.52	918,740	6707	925,447
Annual Average Servings (0.69l/ 150 g)	470.17	873.30	1343.48	633,931	4628	638,559

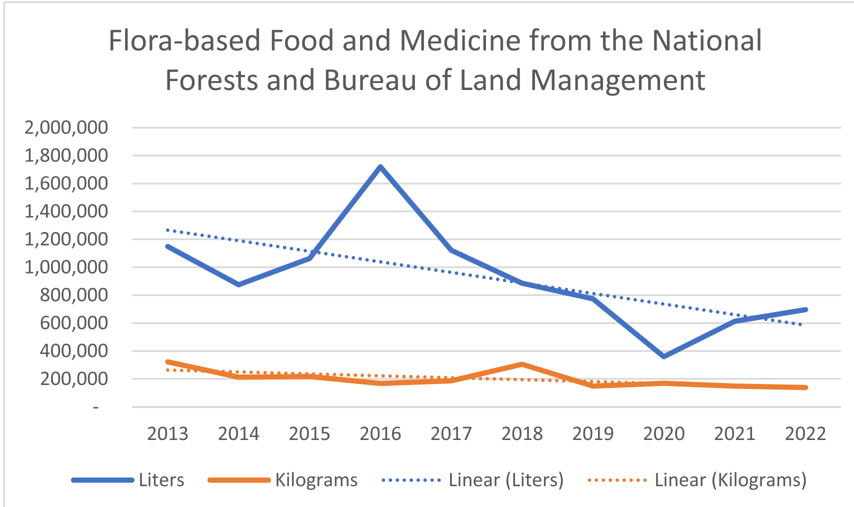

Fig. 2. Trend in the amount of flora-based food and medicine harvested from USFS and BLM lands, for the decade 2013–2022.

Table 2
Receipts from issuance of permits to harvest food and medicine from Forest Service and Bureau of Land Management, expressed in thousands 2022 US Dollars.

Product Category	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
Food	878	614	658	639	564	610	521	281	329	387	$ 5483
Medicine	48	23	23	23	20	22	22	20	9	9	$ 218
Totals in thousand USD 2022	$926	$637	$681	$662	$584	$632	$543	$301	$338	$396	$ 5701

Table 3
Estimated wholesale value of permitted harvests of food and medicine from Forest Service and Bureau of Land Management, expressed in millions 2022 US Dollars.

Product Categories	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Total**
Food	100	70	75	73	64	69	60	32	37	44	$624
Medicine	5	2	2	2	2	3	2	2	1	1	$24
Total in millions USD 2022	$105	$ 72	$ 77	$ 75	$ 66	$ 72	$ 62	$ 34	$ 38	$ 45	$648

amount of wild meat from forested public lands were Idaho, Colorado, Michigan, Montana, and Wyoming.

The amount of meat generated from forested public lands in this study depended on the percentage of such land area in the state, and the total amount of wild meat harvested in the state. For example, Alaska has the most public lands of any state but was only the 9th largest producer of wild meat from forested public lands, and Texas, with <2 percent public land area, was the 6th largest producer of wild meat from forested public lands (Table 4).

States varied in the number of species being hunted in forests and the number of species hunted in forests for which harvest data was available. On average, in each state, forest-dependent species harvest data were available for 2.2 small game species (median = 2), 2.3 (median = 2) upland bird species, and 3.2 (median = 3) big game species. Further, 13 states reported no forest-dependent small game species harvest data. While all states reported harvest data for at least one forest-dependent upland game bird species, this data only consisted of wild turkey in 24 states. Migratory game bird harvest data were collected consistently by the US Fish and Wildlife Service across all continental states. On average, 6.9 (median = 7) forest-dependent migratory game bird species were harvested in each state.

3.2. Domesticated fauna

The total head months (number of animals grazing for a 30-day period) authorized on USFS and BLM lands exceeded 15 million during the 16 years between 2007 and 2022 (Table 5). The largest contributor to this figure was cattle which accounted for approximately 83 percent of the total head months. BLM contributed about 61 percent of the total head months. Over the 16 years analyzed, livestock grazing on BLM and USFS lands accounted for >250 million head months. In total, between 2007 through 2022, approximately 3 million metric tons of meat were derived from domesticated livestock grazing public lands. On average, USFS and BLM lands were responsible for about 185 thousand metric tons of edible livestock biomass, each year. BLM lands produced about 60 percent of the total. This is equivalent to approximately 1.2 billion servings of protein, each year (USDA and USDH and HS, 2020).

3.3. Subsistence harvest in Alaska

This case-study of subsistence harvest in southeast Alaska illustrates that food harvested from forests remains paramount for some communities. An estimated 2055 t of wild food encompassing 157 taxa were harvested by households in rural communities across Southeast Alaska per year (Fig. 3). About 66 percent of the total harvest and 76 percent of total taxa were directly reliant on public forests, with the largest contributions from salmon (28.3 percent) and large land mammals (17.4 percent). Berries contributed 4.7 percent of the total, while herring roe added about 3.4 percent to the total. Nearshore organisms (nearshore crabs, molluscs, seaweed/kelp, other) contributed 8.2 percent to total harvest and other freshwater/anadromous species (char, smelt, trout) contributed 2.9 percent. Finally, other terrestrial organisms (plants/fungi, small land mammals, birds/eggs) contributed 1.2 percent to the total (Fig. 3). Species harvested in the marine environment, which we categorize as indirectly supported by forests, were primarily fish (e.g.,

Table 4
Yearly average wild meat production from hunting forest-dependent species on public lands in the United States by state, in metric tons (t) over 5 hunting seasons (2014–2019), with estimated number of meal servings.

State	Animals Harvested (thousands)	Live Mass (thousands t)	Dressed Mass (thousands t)	Edible Mass (thousands t)	Million Meal Servings (156 g)	Percent of Public land
Idaho	230.06	10.04	7.30	4.16	26.66	66.55
Colorado	157.13	9.22	6.50	3.76	24.14	39.86
Michigan	441.75	7.74	5.91	3.49	22.37	22.47
Montana	110.39	8.26	6.04	3.47	22.25	34.86
Wyoming	98.67	8.34	5.99	3.45	22.12	54.65
Texas	1375.27	7.42	5.67	3.37	21.58	1.92
New York	244.38	6.88	5.28	3.11	19.92	36.97
Utah	167.47	7.28	5.27	3.00	19.23	70.40
Alaska	37.46	6.92	4.96	2.59	16.63	89.22
Wisconsin	332.17	5.42	4.16	2.44	15.63	16.21
Pennsylvania	311.35	5.26	4.02	2.37	15.21	14.74
Georgia	273.03	5.57	4.28	2.36	15.15	4.68
Mississippi	375.93	5.58	4.25	2.30	14.71	5.51
Alabama	256.98	5.21	3.99	2.14	13.71	3.81
Louisiana	471.62	5.05	3.83	2.04	13.05	7.65
Oregon	77.44	4.42	3.19	1.84	11.80	31.58
Minnesota	266.2	3.17	2.44	1.42	9.13	17.57
New Mexico	90.01	3.46	2.45	1.41	9.04	40.62
Arizona	376.01	3.37	2.42	1.40	8.99	53.59
Missouri	324.64	2.98	2.26	1.35	8.62	6.02
Arkansas	140.79	2.77	2.13	1.26	8.06	11.85
Oklahoma	257.71	3.10	2.36	1.25	8.01	2.29
North Carolina	372.43	2.73	2.08	1.21	7.72	6.99
Virginia	272.88	2.57	1.95	1.15	7.38	9.67
South Carolina	279.28	2.58	1.96	1.12	7.22	5.19
Florida	119.95	2.43	1.86	1.09	7.00	26.24
California	763.78	2.29	1.77	0.98	6.32	42.36
Washington	82.19	2.29	1.69	0.97	6.22	36.41
Tennessee	136.86	2.12	1.63	0.97	6.18	10.67
Ohio	235.63	1.71	1.28	0.77	4.91	2.59
Kentucky	344.73	1.66	1.23	0.73	4.72	3.54
Illinois	208.16	1.44	1.09	0.65	4.17	2.35
West Virginia	29.67	1.29	1.00	0.58	3.72	9.92
Nevada	42.93	1.37	1.00	0.57	3.68	81.07
Indiana	48.82	1.01	0.78	0.46	2.94	2.28
Iowa	88.44	0.89	0.68	0.40	2.59	1.04
Maryland	47.75	0.88	0.68	0.40	2.56	6.86
New Jersey	46.22	0.83	0.63	0.37	2.38	17.71
Kansas	169.83	0.81	0.62	0.37	2.36	0.92
South Dakota	53.37	0.72	0.55	0.32	2.06	7.53
Nebraska	46.39	0.59	0.45	0.27	1.70	1.60
Maine	11.52	0.49	0.38	0.20	1.30	5.36
North Dakota	43.13	0.45	0.34	0.20	1.28	4.95
New Hampshire	8.37	0.24	0.19	0.10	0.67	15.83
Vermont	7.22	0.21	0.17	0.10	0.61	8.21
Delaware	12.04	0.16	0.12	0.07	0.46	7.05
Massachusetts	5.19	0.14	0.11	0.06	0.40	5.54
Connecticut	4.30	0.12	0.09	0.05	0.35	5.79
Hawaii	1.46	0.06	0.05	0.02	0.15	13.36
Rhode Island	1.37	0.02	0.02	0.01	0.07	9.14
Total	9900.36	159.53	119.10	68.19	437.13	n/a

Table 5
Estimated contribution of Forest Service and Bureau of Land Management lands to domesticated meat production in the United States (2007–2022).

Animal Type	Average Annual Head Months	Cumulative Head Months	Average Daily Meat Gain (kg)	Average Annual Meat Production (t)	Average Annual Servings (millions @ 156 g)
Bison	15,043	240,688	0.171	77	0.49
Cattle	13,143,893	210,302,288	0.463	182,569	1170.31
Goats	6315	101,040	0.020	3.79	0.02
Sheep	2513,072	40,209,152	0.030	2262	14.50
Total	15,678,323	250,853,168	NA	184,911	1185.33

halibut) and invertebrates (e.g., crabs; Fig. 3). Estimated annual servings of each food group are presented in Table 6. Fruits and vegetables accounted for about 722 thousand servings, while large land mammals added over 2.2 million servings.

4. Discussion

Estimating the amount of plant and animal-based food provisioned from forest land is beset by the diverse forms and incompleteness of data. Quantifying the significance of these harvests is complicated by the

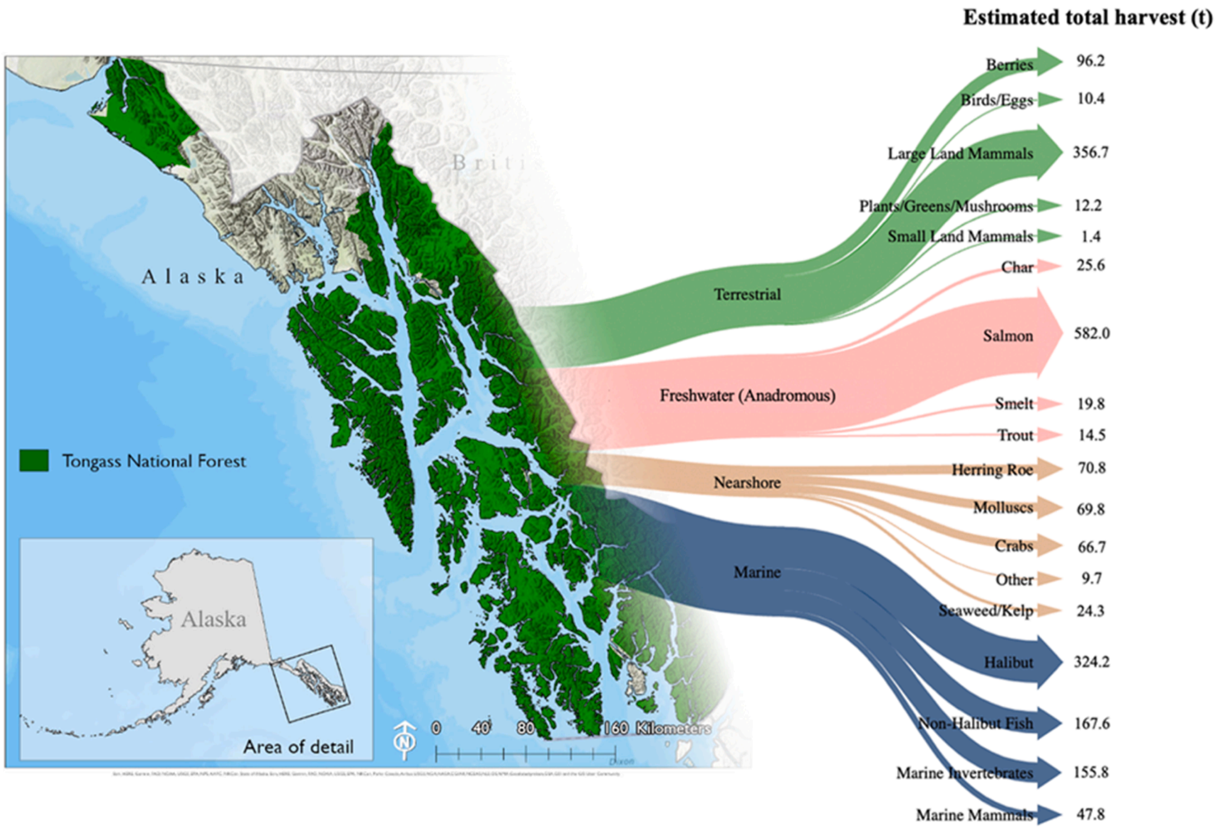

Fig. 3. Estimated annual subsistence harvest in metric tons from public forests in Southeast Alaska. Harvested species groups are categorized by habitat, where terrestrial, freshwater and nearshore are considered directly supported by forest lands. The weight of arrows represents the percentage of overall harvest comprised by each group.

Table 6
Estimated annual subsistence harvest in metric tons (t) and associated number of meal servings from public forests in Southeast Alaska. Estimated servings were determined using USDA serving size recommendations of 156 g for meats and 150 g for plants, fruits and vegetables. Estimated annual servings per person is based on estimated population of 24,312 rural residents in Southeast Alaska in 2022.

Habitat	Food Group	Estimated Annual Total Harvest (t)	Total Estimated Annual Meal Servings (thousands)	Estimated Annual Meal Servings Per Capita
Terrestrial	Berries	96.17	641.11	26.37
Terrestrial	Plants/Greens/ Mushrooms	12.19	81.24	3.34
Terrestrial	Small Land Mammals	1.40	9.01	0.37
Terrestrial	Birds and Eggs	10.44	66.93	2.75
Terrestrial	Large Land Mammals	356.75	2286.83	94.06
Freshwater (anadromous)	Trout	14.48	92.85	3.82
Freshwater (anadromous)	Smelt	19.80	126.91	5.22
Freshwater (anadromous)	Char	25.55	163.76	6.74
Freshwater (anadromous)	Salmon	582.01	3730.85	153.46
Nearshore	Seaweed	24.26	161.73	6.65
Nearshore	Other	9.68	62.07	2.55
Nearshore	Crab	66.72	427.69	17.59
Nearshore	Mollusc	69.82	447.55	18.41
Nearshore	Herring Roe	70.84	454.12	18.68
Marine	Marine Mammals	47.80	306.44	12.60
Marine	Marine Invertebrates	155.83	998.92	41.09
Marine	Non-halibut fish	167.58	1074.25	44.19
Marine	Halibut	324.18	2087.07	85.48

fact that compelling values and rationales ascribed to them extend beyond economic or nutritional and into the realms of personal and cultural identity. In addition, the knowledge regarding the provisioning of these products from forests may be sensitive and protected by the users themselves. Thus, it is not surprising that formal mechanisms for monitoring and collecting the data necessary for regular reporting are not thoroughly developed nor implemented. The methods for data collection and analysis may differ substantially between flora and fauna-based products, making aggregating the findings into a comprehensive representation particularly challenging. Parsing data to landownership and administration, as well as defining hunter demographics present additional analytic challenges. Even with significant limitations of reporting and monitoring the volumes and values of forest food and medicine, the evidence clearly indicates that they contribute much to meeting the needs of a substantial portion of society.

The harvesting of native biodiversity supports the nutritional needs across landscapes (Powell et al., 2015). Findings from this study support the contention that the forests of the U.S., like many nations, provide a great deal of food and contribute considerably to the economy. The provisioning of food from forests is clearly not limited to the Global South, and surely many other countries of the Global North are in similar situations as the US. Copious amounts of flora and fauna are harvested from forests to support the nutritional and financial needs of a considerable number of citizens. Earlier estimates (Alexander et al., 2011; Chamberlain et al., 2018a) corroborate our findings that large quantities of food are being harvested from federal public lands every year.

A significant amount is being harvested for subsistence, as is evident from the Alaskan case-study, although the full extent of subsistence harvesting across the country is limited by the lack of reporting in other states. Kamelamela et al. (2023) found a similar situation in Hawaii. Analysis of pooled wildlife harvest data across states illustrates the significance of wildlife in feeding people. Domesticated livestock production presents another perspective on how public forest lands contribute to food systems. Our findings agree with those reported by Lovrić et al. (2020) and Schulp et al. (2014) who revealed that these products were important to a substantial portion of citizens of the European Union. Capturing the full potential of forests to support the basic needs of people will require better inclusion of these resources in forest management and policies (Chamberlain and Smith-Hall, 2024), and food security policy and programs (Hickey et al., 2016).

4.1. Wild harvest flora and fauna

The harvesting of wild flora and fauna for food from public forest lands contributes much to peoples' physical and mental health, although like other non-timber forest products, these activities have received little scrutiny for their impacts on communities and biodiversity (Chamberlain et al., 2018b; Di Minin et al., 2021). They also are lacking in forest management policies, plans, and actions (Chamberlain et al., 2002; Vaughan et al., 2013). The utilization of wild fauna and flora for subsistence is not limited to Alaska, yet subsistence harvest is often not differentiated from harvesting in general. Many who hunt, fish and forage under a permit live in rural communities, and the foods and medicines obtained constitute an important aspect of their food security and sovereignty, livelihoods, and culture (Kamelamela et al., 2023). Unfortunately, like the evidence revealed in this study, there is little information available to differentiate the available data on wild food production based on the dependence and motivations of those who harvest it.

The evidence indicates a decline in permitted harvesting of flora from federal lands. This may be due to changes in reporting systems, geographic distribution of harvesting patterns, or actual decline in demand for forest food and medicine. Potential contributing factors include shifting distributions of people relative to wild resource availability (i.e., rural out-migration), urbanization, and proliferation of alternate activities (e.g., gaming, social media, etc.) vying for peoples' limited time and attention — factors identified by others as drivers of recent, ongoing declines in hunting participation (Karns et al., 2015). Chamberlain et al. (2002) found that fewer than 25 percent of national forests in eastern U.S. managed for non-timber forest products, and with national legislation passed in the early 21st century integrating these products into management plans may be more restricted (Chamberlain et al., 2018b). Fewer than 60 percent of the southern States allow harvesting of non-timber forest products (Frey and Chamberlain, 2016). Increased restrictions on harvesting from national forests could redirect harvesting pressures onto private lands that have even less monitoring. Baumflek and Chamberlain (2019) reported that harvesting of ramps (*Allium tricoccum*), an iconic forest food, had been increasing over the last few decades. The overall estimates of flora harvest are based on data from public lands and may understate total amounts as harvest data from private lands are lacking. Consideration of the demand on forest lands for food, and management actions that enhance availability and access to sustainable harvesting opportunities could lead to improved forest management thereby benefitting a larger portion of society.

Harvest volumes of forest foods from private lands remain invisible, except for a few products. The USDA National Agricultural Statistics Service (NASS) surveys agricultural products in the U.S. and reports on food and fiber, prices, labor, wages as well as farmer demographics. The NASS tracks production of wild blueberries and maple syrup sourced primarily from private forest lands (USDA NASS, 2023). A query of the national statistics for these forest foods reveals significant production. In 2022, private forest lands provisioned >34.9 t of wild blueberries, and over the decade ending in that year, those lands produced over 371.9 t of wild blueberries. Further, in 2023, private forest lands in the U.S. produced 15.82 million liters of maple syrup. Similar reporting for other forest foods from private lands would help to provide a more comprehensive assessment of the volumes and values of these products.

Collaborative research that combines new remote-sensing technologies, field monitoring, and local and/or Indigenous knowledge could advance our understanding of plant-based foods and associated land uses. For example, remote sensing can trace changes in wild rice resources across the Great Lakes (Drewes and Silbernagel, 2012) and help with the development of co-management planning or access agreements with Tribes. As another example, collaborations among Tribes, federal managers, and social and ecological researchers in the Pacific Northwest have brought to light the role of traditional land management practices, such as prescribed fire, in shaping food related outcomes and have raised regional and national attention to the importance of restoring these practices (Halpern et al., 2022; Long et al., 2021; Long and Lake, 2018; Norgaard, 2019).

Forested public lands in the U.S. are natural food systems that permit the sustainable harvest of 9.90 million animals for consumption, each year, through hunting. This harvest generates at least sixty-eight thousand metric tons of wild meat, or approximately 437 million servings on an annual basis. This is enough volume to provide a 156-gram serving of wild meat to 1.2 million people, the approximate population of the States of Montana or Rhode Island, every day of the year. In 2021, the U. S. consumed >3 times more wild meat harvested from forested public lands than veal (e.g., about 19,870 t) produced on farms (USDA ERS, 2022).

The data do not necessarily reflect the full extent of wild meat harvest on forested public lands, but rather the number of forest-dependent species harvested on public lands. In this analysis, we included species that reside in forests for at least a part of their life cycle (IPBES, 2019). Despite this criterion, the division between forest-dependent and non-forest dependent species is not definitive. As example, we included mule deer and white-tailed deer in the analysis, although some populations of these species reside entirely in forests, others may forage in rangelands and agricultural fields but rely on forests for cover and seasonal food resources only, and others may not utilize forests at all (Koenen and Krausman, 2002). Likewise, many species that were excluded could have been included. For example, the USFS administers an additional 2.9 million ha of wetlands, 161.8 thousand ha of lakes, 254,300 km of streams, and 8000 km of rivers, which provide habitat for many harvested migratory waterfowl species. Had these biomes been included as sources of animal-based food production in this analysis, the contributions of public lands would be even greater.

The amount of wild meat procured from forested public lands may be underestimated for other reasons as well. Few states collect harvest data for all hunted species; data on small game and upland bird species is often unaccounted. Also, many species that are typically considered fur bearers or atypical game species were not included yet contribute to harvest consumption. Undoubtably, many of these species are consumed to varying degrees, and the assumption that all furbearer and unconventional game species are not consumed is a broad and potentially misleading generalization. Data included in this analysis were collected by state fish and wildlife agencies, representing an estimate of harvest by state-regulated hunters. These data, therefore, do not include harvests administered through sovereign Tribal nations, a sizable portion of which occurs on forested public lands. Nor do they include illegal harvests which may be substantial and contribute to the wild food economy, regardless of their pedigree, though this would require additional research.

Variation in harvest data availability among states may explain why we did not find a clear relationship between the number of animals harvested and wild meat production. States that record harvest data for many small game species may boast a relatively large number of animals harvested but exhibit relatively little wild meat production, compared to states with plentiful big game hunting, for obvious reasons. Caution is advised when comparing the magnitude of the hunting harvest across states, because variation in the number of animals harvested, and the availability of species harvest data within the state, may influence the apparent biomass of the hunting harvest.

On a national level, Americans mostly hunt on private land and the number of hunters using only private land increased from 54 percent in 1991 to 64 percent in 2016, while the number of hunters exclusively using public land decreased from 15 percent to 13 percent over the same period (Mozumder et al., 2007; U.S. Department of the Interior, U.S. Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau, 2018). Regionally, however, these numbers do not necessarily reflect where most animals are harvested, as hunting in the western U.S. occurs predominately on public lands, including lands administered by the USFS and the BLM (Conservation Visions, 2022a, 2022b, 2022c; Karns et al., 2015; National Wilderness Institute, 1995; USDA Economic Research Service, 2019; Zhang and Miller, 2019).

Furthermore, we assumed for this study that all hunted animals are consumed. This is likely the case for most species reported, except for feral hogs (*Sus scrofa*). Feral hogs are managed as a nuisance species in the U.S., due to the billions of dollars of damage the species causes to agriculture, livestock, forestry, and property, each year (Beasley et al., 2018). Because of this, regulations on hog hunting are often unrestrictive and wild hog harvest data are poor. Of twenty-eight states that allow hog hunting, only 13 recorded harvest data. Many people hunt feral hogs for food, including capturing live hogs for finishing in confined feeding and for commercial sale (Akkina et al., 2021), but people also hunt feral hogs to control the population size. Further, feral hogs carry many human-transmissible diseases, which may deter consumption (Kinsey, 2020) and thus, for these reasons, an accurate estimate of meat generated from feral hog harvests is difficult to determine.

4.2. *Domesticated fauna*

Federal forest lands have been managed for production of forage for domesticated animals since the founding legislation, and in some cases long before. As Derner et al. (2023) report, most public grazing lands in the U.S. are in the 11 western states, split between BLM, USFS and in trust for Native Americans (Maher et al., 2021). According to these studies (Derner et al., 2023; Maher et al., 2021), grazing on public lands is an important part of an extensive rangeland-based food production systems for over 5000 USFS grazing permittees and nearly 18,000 BLM grazing permittees, with an estimated 16 million AUMs grazed by livestock across BLM and USFS lands (Maher et al., 2021). Over the last sixty years, livestock permitted on public lands has notably decreased; permitted grazing on BLM lands declined 48 percent (Yahdjian et al., 2015) and by 62 percent on USFS lands in Central Idaho (Swette and Lambin, 2021). This is likely a natural consequence of the rapid intensification of agriculture and the increased use of concentrated animal feeding operations (MacDonald and McBride, 2009).

While our primary focus has been forest foods provided from natural populations of wild species, grazing domesticated livestock also contributes to food production from public forest lands by converting wild forage into edible biomass. Our estimate that roughly 185 thousand metric tons of edible mass was produced through livestock grazing on public lands each year from 2007 to 2022 highlights this contribution. There are limitations, however, to our estimates. The process for determining average daily gain (ADG) is complex, and ADG can vary substantially based on dietary composition, weather, animal type, animal density and life cycle, age, and other factors (Raynor et al., 2021). We used published values that represent a "middle of the road approach" and therefore are reasonable for national estimations of ADG. Indeed, the productivity of public grazing lands is dynamic and subject to weather, climate, and ecological variability that can impact forage production. As an example, Raynor et al. (2021) estimated that the sustainable carrying capacity of shortgrass steppe has increased by 72 percent in the past 50 years due to changes in the plant community and changing livestock genetics. This suggests that continual adaptive management is needed to enhance public lands food systems with directional climate change and inherent ecological variability (Derner et al., 2023).

The implications of public lands grazing systems extend well beyond food production. To discuss this, we draw from the literature on rangeland social-ecological systems, which recognizes the interdependence of human and ecological communities on rangelands, the largest ecosystem type on Earth (Reid et al., 2014; Huntsinger and Oviedo, 2014). Common land livestock grazing in North America dates to the early Spanish colonial period (Gulliford, 2018; Specht, 2019) and is still well-adapted to produce high quality food and fiber in highly variable and rugged landscapes. Today, range sheep and cattle production systems continue to perform as relatively low-input, extensive, and climate-adapted forms of food production that are important to local and national economies, food security and to private lands conservation (Charnley et al., 2019; Knight, 2007). The "ecosystem services assessment" framework provides the means to conceptualize and quantify the value of rangeland-based food and fiber production, and the provisioning of social and cultural services and basic life-sustaining ecological processes (Havstad et al., 2007; MEA, 2005). Maher et al. (2021) estimated the total ecosystem services stemming from livestock production systems on public and private lands in the U.S. to include $17.5 billion from recreation (e.g., through greenspace retained in an undeveloped state), $3.8 billion from forage production, and $3.2 billion from other ecosystem services such as biodiversity conservation. Public lands accounted for 35 percent of these values (ibid.). The amount of forage use permitted on public lands has notably declined with shifts in public demands and priorities for rangelands (Swette and Lambin, 2021). The continued contribution of range livestock production to food security relies on the capabilities of stakeholders to adapt and remain flexible as climate, ecological, social, and economic conditions change (Reid et al., 2021). Range livestock production systems could be impacted by trends across interconnected social and agricultural systems, including corn and feeding sectors (Sayre, 2023).

4.3. *Subsistence harvest in Alaska*

The large proportion of total harvest mass and number of species harvested directly supported by the forest lands in Southeast Alaska demonstrate the significant contribution of these lands to subsistence food systems. Yet, it does not include the substantial recreational and commercial harvest of fish (e.g., 75 percent of approximately 50 million salmon) that come from healthy watersheds that drain the Tongass national forest (Johnson et al., 2019). Previous studies have estimated that this subsistence harvest supports 121 percent of daily protein requirements and 17 percent of rural community caloric requirements in

Southeast Alaska (Fall and Kostick, 2018). Attaching a dollar value to subsistence foods is difficult, in part because there are no market transactions, and there are only non-economic values to such products. A reduction in subsistence harvest would necessitate additional food purchases, which can be extremely expensive in rural communities. Assuming a replacement value of USD $10–20 per kg of wild food (Fall, 2018), the simple 'replacement value' of forest foods in Southeast Alaska communities would be USD $20.5 million-$41.1 million per year. Indeed, the forests of southeast Alaska provide considerable wild food to support the cultural, nutritional, and economic well-being of rural communities. Based on a population of approximately 24,312 in 2022, this is equivalent to about $845-$1691 per person. Clearly, the situation in Southeast Alaska reflects at least two benefits of emphasizing wild foods in policy strategies: it may (1) increase the potential contribution that public forest lands across the U.S. can make to local and regional food economies, and (2) improve data collection efforts to better capture the true magnitude of foods that forests provide.

5. Conclusions

This study attempts to assess the extent to which public forest lands provide food and medicine across the U.S. Definitively, we can conclude that public forest lands contribute to the provisioning of food and medicine to support the nutritional, economic and cultural well-being of a large percentage of the nation's population. A considerable portion of the U.S. population would benefit from better integration of these resources into management of public forests. Unfortunately, considerable challenges impede efforts to integrate forest foods into land management policies and practices. Reporting of volumes harvested is rudimentary at best, making the estimation of values extremely difficult. The markets and value chains for forest foods and medicines are not well defined nor well understood (Ingram et al., 2017), and as such that segment of the 'forest products' industry is not well served by institutions that set forest management policies, and make, and implement land management decisions, track production, and promote innovation and market opportunities. As example, forest foods and medicines are sourced to supply pharmaceutical, nutraceutical, and other health sectors, and production volumes of these forest products are seldom tracked nor monitored by either forestry or agriculture institutions and remain invisible in formal markets (Smith-Hall and Chamberlain, 2023a; Sorrenti, 2017).

Indeed, additional research could provide more fine-grained analysis that might help to improve the understanding and awareness of the importance of food and medicine from public forest lands. Research, including work that engages in participatory and collaborative knowledge-sharing methodologies with forest-dependent communities and land users, could help to define transition pathways to expand forest management for food and medicine. Institutional awareness and acknowledgement of these forest resources and their uses and values could help to emphasize the need for adaptive management to maintain productive and resilient forest food systems. This could foster a re-orientation of forest land management amid increasing global concerns for producing food for an expanding population while conserving biodiversity.

Realigning forest production systems to better integrate foods and medicines would benefit from a thorough and critical examination of management priorities to more effectively consider the nutritional needs and food security of people who forage, hunt, fish, and graze livestock for supplemental and subsistence consumption. We postulate that forest management strategies and planning that emphasize food system resilience, productivity, and biodiversity have potential to help sustain Americans' connections with public lands and to bolster positive social and ecological outcomes by increasing opportunities for harvesting wild foods and associated cultural and economic aspects of food systems. Attention to food harvest priorities and trends is needed to help improve the resilience of wild food and medicine systems to stressors (Brice et al., 2020; Powell et al., 2015; Timberlake et al., 2021) with crucial cultural, health, and conservation implications (Greene et al., 2022; Green et al., 2021). Such shifts would affect all levels of society, from subsistence users, and primary processors (harvesters) to commercial producers (grazing, pharmaceutical advancements, etc.) and non-harvesting consumers.

Without a doubt, food and medicine harvested from forests contribute directly and indirectly to a forest-based economy. Producing and providing healthy and safe foods are viewed by many as fundamental objectives of a bioeconomy that supports sustainability, alleviates poverty, and promotes biodiversity conservation (Albrecht et al., 2012; Chamberlain and Smith-Hall, 2024; Levidow et al., 2013; Smith-Hall and Chamberlain, 2023a). In general, most bioeconomic strategies have focused on improving the use of wood, with disregard to other forest products (Chamberlain and Smith-Hall, 2024). Indeed, we can conclude that the forest-based sector of a bioeconomy spans a broader set of products and services which include, and extends far beyond, those derived from timber.

A reframing of forest management practices based in this broadened bioeconomic perspective stands to more effectively address the nutritional, social, economic, and cultural context of local and national forest users and Indigenous communities', who have long called for increased attention to social-ecological relationships and traditional harvests (see: Long et al., 2021; Norgaard, 2019; West, 1994). Our findings contribute to the conversation about the importance of forest-based food production and the need for management approaches to support such systems considering concerns for biodiversity conservation and the need to produce more nutritious food for a growing population.

CRediT authorship contribution statement

James Chamberlain: Writing – review & editing, Writing – original draft, Project administration, Methodology, Conceptualization. **Richard D. Honor:** Writing – review & editing, Writing – original draft, Methodology. **Karl Malcolm:** Writing – review & editing, Writing – original draft, Project administration, Conceptualization. **Shane P. Mahoney:** Writing – review & editing, Writing – original draft. **J. Ryan Bellmore:** Writing – review & editing, Writing – original draft. **Matthew C. Reeves:** Writing – review & editing, Writing – original draft. **Hailey Wilmer:** Writing – review & editing, Writing – original draft. **Marie K. Gutgesell:** Writing – review & editing, Writing – original draft. **Lauren A. Sill:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tfp.2024.100738.

Data availability

Data will be made available on request.

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