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Subsistence Exposure Scenarios for Tribal Applications

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Abstract

The article provides an overview of methods that can be used to develop exposure scenarios for unique tribal natural resource usage patterns. Exposure scenarios are used to evaluate the degree of environmental contact experienced by people with different patterns of lifestyle activities, such as residence, recreation, or work. in 1994, U.S. President Bill Clinton's Executive Order 12898 recognized that disproportionately high exposures could be incurred by people with traditional subsistence lifestyles because of their more intensive contact with natural resources. Since then, we have developed several tribal exposure scenarios that reflect tribal-specific traditional lifeways. These scenarios are not necessarily intended to capture contemporary resource patterns, but to describe how the resources were used before contamination or degradation, and will be used once again in fully traditional ways after cleanup and restoration. The direct exposure factors for inhalation and soil ingestion rates are the same in each tribal scenario, but the diets are unique to each tribe and its local ecology, natural foods, and traditional practices. Scenarios, in part or in whole, also have other applications, such as developing environmental standards, evaluating disproportionate exposures, developing sampling plans, planning for climate change, or evaluating service flows as part of natural resource damage assessments.

Keywords

tribal subsistence exposures; subsistence lifestyles; exposure scenarios; tribal risk assessment; Superfund; traditional tribal practices

INTRODUCTION

Many federal and state regulations are intended to protect human health, and some of these regulations, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (US Congress 1980), consider sensitive populations, particularly children. Highly exposed populations must also be explicitly considered under Executive Order 12898 (Clinton 1994), which directs federal agencies to identify and address unevenly

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high exposures. Further, when traditional activities are identified as a reasonably foreseeable land use (USEPA 1995) or when tribal resources are affected, a careful and appropriate evaluation of tribal risk should be supported by regulatory agencies.

While contemporary tribal resource use is often higher than in non-native communities, resource uses would be even higher under baseline conditions (*i.e.*, in the absence of resource degradation or contamination). The methods described in this article address the fully traditional baseline resource use patterns as they existed pre-contamination and as they would occur at a site in the absence of institutional controls, advisories, or knowledge about contamination. These scenarios do not necessarily reflect current resource usage patterns, which are often lower than fully traditional (baseline) uses due to degradation or restrictions. This article provides a tool to address the requirement to conduct baseline risk assessments with the assumption of unrestricted (baseline) resource use. Depending on the length of time that resource use has been altered by the presence of contamination or other factors, literature reviews become an increasingly important tool for understanding traditional resource use. This is particularly true in the continental United States, as opposed to circumpolar regions where there has been less interference with subsistence practices and most information can be acquired by asking people directly.

Even though tribal baseline risks must be estimated at CERCLA sites,[1] when relevant, tribal risks are still often overlooked, underestimated, or mischaracterized. In many cases, this is simply due to a lack of knowledge about traditional subsistence lifestyles, or a lack of understanding about why those activities are important to the heritage and identity of the native sovereign nation and its citizens. While individual exposure pathways may be recognized, the entire lifestyle and all resource uses must be incorporated into a single exposure scenario in order for risks to be properly estimated.

The initial trigger for this work occurred because regulatory agencies need to understand tribal exposures in order to evaluate risks and set risk-based remedial goals at contaminated sites if tribal lands, health, or resources are affected either on- or off-reservation. At the time the earlier scenarios were developed, it was recognized that traditional tribal lifestyles are distinct enough from suburban lifestyles that environmental exposures could be substantially higher for traditional tribal members, but numerical representation of those environmental contact rates did not exist. This was a critical deficiency because in order to set proper cleanup goals or develop environmental quality goals and standards to protect tribal health, it is necessary to understand how resources would be used by tribes if they were clean and whole. This requires an understanding of traditional patterns of natural resource use, and the translation of this understanding into the conventional risk assessment format. Affected tribes play a critical role in tribal risk assessment, and it is incumbent on the affected tribe to be able to describe its exposure patterns and educate regulators about resource use, exposure pathways, and exposure factors.

[1]Editor's note: these are uncontrolled hazardous waste sites that fall under the provisions of the U.S. Comprehensive Environmental Response, Compensation, and Liability Act, as amended.

Since then, a number of scenarios have been prepared, and several are posted along with a methods manual and specific exposure factors (inhalation, soil ingestion) at http://health.oregonstate.edu/research/featured-projects/tribal-grant. Each of these tribal exposure scenarios is based within a different ecological setting that supplies different sets of key staple foods and materials (Figure 1), for example:

- Confederated Tribes of the Umatilla Indian Reservation (CTUIR) (Columbia Plateau ecosystem): salmon, elk, roots, berries (Harris and Harper 1997; Harper *et al*. 2007).
- Spokane (Okanagan highlands; upper plateau, Ponderosa ecosystems): salmon, deer, roots, berries (Harper *et al*. 2002).
- Washoe (Eastern flanks of the Sierra Mountains, Lake Tahoe, and Pinyon-juniper ecosystems): pinyon nuts, rabbit, fish, game (Harper *et al*. 2007).
- Elem Pomo (Clear Lake central California ecosystems): acorns, tule (bulrush), game, fish, fowl, and seeds (Harper *et al*. 2007).
- Quapaw (intersection of tall grass prairie and Ozark highlands (oak-hickory) ecosystems): maize, game, fruits and berries (Harper *et al*. 2007; Harper 2008).
- Wabanaki (Maine statewide with anadromous rivers, non-anadromous water bodies, and coastal ecosystems): variable ratios of resources allocated among ecosystems (Harper and Ranco 2009).

When used in a risk assessment, these scenarios are combined with information about contaminant concentrations in the various media and biotic resources to estimate dose and risk. Risk results are almost always higher when using a tribal scenario than when using suburban, recreational, or occupational scenarios, depending on which media are contaminated, because environmental contacts are more frequent, more intense, and/or of longer duration. For example, soil ingestion is 2× or 4× higher; fish ingestion can be up to 100× greater, inhalation rates can be 1.5× higher, dietary exposures can be 0 to 10× higher, and the exposure duration is a lifetime, not 30 years. Risk estimates are proportionally higher, often 10–100× higher. If exposure patterns were not known, risks could be substantially underestimated, cleanups could be unprotective, and tribes could be disproportionately affected.

In order to create tribal scenarios, it is helpful to understand several important concepts about tribal lifeways:

- Despite impoverished conditions on many reservations today, the traditional homelands supported its peoples for thousands of years as they survived, thrived, and maintained stable societies through the application of traditional values and natural, traditional, customary, and common laws. Language, art, commerce, religion, and education were melded into ecocentric lifeways. Tribal scenarios are designed to reflect those traditional heritage lifeways, not contemporary restricted and suppressed lifeways (*e.g*., suppressed ingestion rates; O'Neill 2003; Donatuto and Harper 2008), nor hybrid urbanized lifeways. Much of the supporting information comes from the anthropology literature, depending on how long a

contaminated condition has existed. For example, mining districts began displacing people and polluting their resources more than a century ago, so historical literature can help confirm or even enhance contemporary knowledge of resource use.

- Traditional lifeways are not captured in a scenario by simply adding more fish or some wild food to a suburban scenario. Traditional lifeways are not simply suburban during the week with camping out or attending pow-wows on the weekends. Substantial modification of surburban scenarios is required.
- Traditional lifeways are not anachronistic attempts to revive impossible ideals through reenactments. The lifeways were not lost; they have always been followed, although often hidden for obvious reasons and impaired by external factors to the point that some forgotten aspects can be recovered during the process of developing a scenario. They are also being revealed, recovered, and reconstructed in accordance with the policies of tribal sovereign governments and with more open support by modern federal policies for restoration of natural resources, languages, values, and healthy diets and lifestyles.
- Original homelands were extensive but are now much smaller. This means that the original traditional lifeways generally have been restricted to smaller areas, and some resource staples may have been replaced by other resources as the land base shrank. In addition, carrying capacity may limit the amount of resources to ceremonial use, which may be enough to remember the essence but not enough to sustain entire families, communities, and economies. Subsistence may now be constrained to a smaller geographic base but it is still self-supporting and may be functionally equivalent to the non-native homestead that is often used as the Reasonably Maximally Exposed (RME) individual as defined in USEPA documents (USEPA 1997, 2003a).

BASIC PRINCIPLES AND PREMISES

Based on 15 years of experience, we present the following checklist for developing tribal scenarios. It is intended to be useful for both tribes and for state and federal agencies, whichever one develops the risk assessment scenarios. This list does not satisfy all the aspects of government-to-government consultation, but it is an important component for ensuring that tribes have opportunities for truly meaningful participation in federal or state risk-based decisions.

1. **Know what information is needed.** Contemporary uses of natural resources may be restricted or suppressed due to contamination, lost access, and other reasons (Donatuto and Harper 2008). It is important to determine whether the goal of the scenario is to describe current resource uses in order to estimate current exposures and risks, or whether the goal is to understand how resources were used and will be used again, once the site is remediated and restored and traditional uses are regained. These two questions require different information to answer.
2. **Research ethics and informed consent.** Basic rules of human subjects research requires ensuring that the tribe understands both the benefits and risks of developing scenarios. Ethics of community-based participatory research,

indigenous research, and intellectual property must also be considered. The basic ethical principle is to enable tribes to speak for themselves, not to speak for them or to "discover" their ideas and publish them. Protecting tribal interests includes ensuring informed consent and developing confidentiality and data-sharing agreements (Smith 1999; Quigley 2001; Harding *et al*. 2012). The greater risk may lie in documenting only contemporary use, which may be misinterpreted as a willingness to give up traditional practices or rights; conversely, continuing to eat contaminated fish, for example, may be misinterpreted as a willingness to accept a health risk. Neither is done willingly. Having a robust resource-based scenario is one step toward self-determination, and one defense against further erosion of health, rights, and resources.

3. **Learn about the tribe.** A good investigator will learn about the tribe, its history, its treaties, and its homeland area and heritage resources, whether the tribe has been moved, and whether multiple tribes with different languages and natural resource interests are now co-located. We recommend learning about the range of lifestyles in which people are engaged, and not to assume that traditional lifestyles are historical curiosities that have long since faded into the anthropological archives. We recommend asking the tribe about its restoration goals, its views on the federal fiduciary trust obligation, and its history with researchers and with consultation.

4. **Data quality objective—precision versus accuracy.** Human health exposure scenarios used in Superfund risk assessments are not very detailed. Therefore, we have found that a statistical approach to cataloging resources and activities is not justified. Lists of species used (often consisting of more than 200 species for a given tribe), lists of places visited, and statistical surveys are all intrusive and data-intensive, yet inevitably incomplete. We believe that data precision (*i.e*., the need for a statistical database based on contemporary data) may be confused with overall scenario accuracy (*i.e*., a reasonable, complete, and replicable description of traditional lifeways) (Donatuto 2008; Harper *et al*. 2006, 2007). Therefore, we recommend an approach that identifies major food staples and cultural key-stone species relevant to the local ecology. Rather than trying to measure how many mg/d each of (typically) 200 foods and medicines are currently consumed from a particular set of local ecologies, we recommend accounting for a 2000–2500 kcal/d diet with an approximate but justifiable ratio of traditional food groups as it was actually eaten. Obviously, some traditional diets are based on fish, others on game, and still others on maize. We further believe that the basic components of tribal lifeways that contribute to direct exposure (particularly the inhalation rate, soil ingestion rate, and water and sediment exposure rates) can also be reasonably estimated in order to be useable for risk assessment. Again, because they cannot be statistically measured, this approach is less statistical but more comprehensive and, we believe, more accurate in the overall scenario.

5. **Data sources.** Since statistical data to support exposure factors for traditional subsistence activities are not available, traditional lifeways scenarios must be reconstructed from anthropology and other literature, along with confirmatory interviews with traditional tribal members. The literature base includes

ethnobotany, foraging theory, ecological history, historical records, journals of explorers and other early observers, conventional exposure science, paleomedicine, isotopic ratios of remains from archeological sites, oral tradition, language and names, physiology, human phenotypic and enzymatic polymorphisms, and nutritional information about wild foods. Because much of this information may be qualitative or semi-quantitative, the accuracy and completeness of the dietary and lifestyle reconstruction is ensured through multiple lines of evidence and extra peer review (Harper *et al*. 2007). The confirmatory interviews with tribal members who practice subsistence activities add confidence to the numerical estimates for dietary components and direct exposure factors by drawing on traditional environmental knowledge.

6. **Admissibility.** A set of technical, ethical, and procedural rules have been developed to ensure quality, objectivity, utility, and admissibility pursuant to *Daubert* and Federal Rule of Evidence 702 (Harris and Harper 1997; Harper *et al*. 2002; Harper and Ranco 2009; US House of Representatives 2009). The technical substance of the scenario must be objective, transparent, and reproducible. In order to make this process as reliable and transparent as possible, the scenarios referenced in this article primarily relied on open peer-reviewed literature and ethnographic documents and reports concerning traditional lifestyles and practices rather than proprietary information. Objectivity is ensured through multiple rounds of peer review, and though the use of multiple lines of evidence that lead to the same general conclusion. Culturally reliable results are ensured through extensive interactions with tribally recognized cultural experts, including ethnographic methods if necessary for more formal information collection. Cultural expertise derives from a person's traditional or indigenous environmental knowledge, and from his or her acknowledged expertise and standing in the community. Further, oral history is a hallmark of Tribal knowledge and education, so direct interaction with elders and the trust that this builds is important for accuracy.

7. Ecological basis and ecocultural context of the scenarios. A clean and intact environment is a significant and inseparable part of tribal economy, religion, health, and everyday life. In traditional tribal communities, the people and their geographic place, resources, culture, health, art, religion, trade networks, social and survival activities, and their past and future are all interconnected into dynamic ecocultural or biocultural system (Arquette *et al*. 2002; Cajete 1999; Donatuto 2008; Harper and Harris 2000; Harris 1998). For this reason, a description of the ecology is an early step in scenario development.

For the CTUIR, these ecocultural relationships form the basis for the unwritten laws or *Tamanwit* that were taught by those who came before, and are passed on through generations by oral tradition in order to protect those yet to arrive (Harris 1998; Harris and Harper 1999). The ancient responsibility to respect and uphold these teachings is directly connected to the culture, the religion, and the landscape. The cultural identity, survival, and sovereignty of the native nations are maintained by adhering to, respecting, and obeying these ancient unwritten laws. The elements of CTUIR *Tamanwit* include Energy, Light, Food, Dress, People/Generations, Land/Earth, Water, Speech, Air, and Dwellings. The

tangible and intangible aspects of *Tamanwit* and the co-located ecocultural system give meaning to each other through biosemiotic processes and relationships such that the distinctions between animate and inanimate, and sacred and secular, are blurred. The principles of *Tamanwit* are reflected in CTUIR priorities, restoration goals, and environmental codes. In order to meet its responsibility, the CTUIR needs cold, clean, uncontaminated water; clean, clear uncontaminated air; uncontaminated soil; clean, vibrant, and uncontaminated biological resources; clean, uncontaminated, and wholesome foods; and clean, uncontaminated, and healthful medicines (Harris and Harper 1999). These ecosystem attributes are reflected in exposure scenarios and tribal risk assessments.

ELEMENTS IN A SCENARIO REPORT

After the initial steps of informed consent and receiving tribal approval, the next step is to gather a bibliography of records and references. The entire bibliography should be reviewed by the Tribe for accuracy, as there are often references or authors that are regarded by tribal experts as having greater or lesser accuracy. Thereafter, the following format for a scenario report has proven to be complete and useful.

Section 1—Tribal Circumstances and History

This section provides an introduction to the specific Tribal Nation and sets the context for a tribe and its environs. Information in this section could take various forms. It might explain the tribe's name for itself and how its national seal was designed. Some tribes are identified by a primary food (*e.g.*, the derivation of Menominee is *manoomin*, or wild rice). This section might describe whether a tribe has moved, or whether several bands or tribes have been consolidated onto reservations and whether different resource use patterns are still present among families originally from different ancestral locations. It might include historical reports such as trading records or Indian Agent reports that reveal information about resource importance and abundance, ways the tribe managed its regional resources, and early environmental conditions that the tribe might hope to preserve or restore. It could include some linguistic and oral history that describes how tribes identify with and use natural resources, and might include some names of places, areas, or families that reflect natural resources. For example, many place names reflect an environmental characteristic such as water (*e.g.*, place with muddy water; area that frequently floods; place with good springs) or resources (*e.g.*, place of good pines; place where wapato—*Sagittaria latifolia*—grows). For example, the names of almost half of the states and thousands of cities and rivers have Indian origins. Arizona—“Arizonac,” meaning “little spring”; Chicago—Algonquian for “garlic field”; Indiana—“land of Indians”; Michigan http://www.infoplease.com/id/A0108228—“Michigana” meaning “great or large lake”; Minnesota—from a Dakota Indian word meaning “sky-tinted water”; Missouri—“town of the large canoes.” This is indicative of a natural and indigenous landscape underlying the present geopolitical landscape, and suggests some original features and ecosystem services that might be of value to restore.

Section 2—Environmental Setting

The purpose of the scenario is to describe traditional lifeways that were uniformly followed prior to resource degradation, because support of traditional lifeways is often a cleanup and restoration goal as well as a cultural and heritage goal. The ecological description provides information about plants, animals, biodiversity, relative proportions of different habitat types, seasonality, and physiographic features of the environment. This information is needed to support estimates of dietary staples (the resources that are most abundant and reliable), and environmental characteristics that affect contact rates with soil, sediment, and water (for example, ratio of wetlands to upland habitats).

Because tribal lifeways are embedded within and emergent from the ecology of a region (Oren Lyons, personal communication), the base data layer of information for a scenario is an ecoregion map (Abell *et al*. 2000; Bailey 1995; Bryce *et al*. 1999; Ricketts *et al*. 1999; USEPA 2003b, 2004). Ecological regions have been described on a variety of scales. Ecoregions are mapped using a hierarchical framework developed to show enduring ecosystem components and patterns in the capacities and potentials of ecological systems by defining regions of similar biotic, abiotic, aquatic, and terrestrial ecosystem components (CEC 1997; McMahon *et al*. 2001; Omernick 1995, 2004). Level I and II ecoregion maps, developed for North America, divide the continent into 15 and 52 ecoregions, respectively (USEPA 2003b) (Figure 2). Level I ecoregion maps highlight major ecological areas and provide the broad backdrop to the ecological mosaic of the continent. Level II ecoregions provide a more detailed description and national/regional perspective of the large ecological areas nested within the Level I regions. More refined ecoregion maps, such as the Level III ecoregion boundaries shown in Figure 1 or the finer scaled Level IV regions, are available for the conterminous United States, and provide a spatial framework for ecological assessment at the regional and local scale (USEPA 2003b). Depending on the goal of the scenario, a generic scenario for a large ecoregion might be developed, which would serve as a starting point for other nearby tribes to modify according to localized resources or for a regulator to develop a regional application. Alternatively, more detailed Level IV maps or site-specific maps and scenarios might be developed for site-specific applications (USEPA 2003b). Cultural zones have also been described based on resources used for food and materials such as a maize zone or a bison zone (Figure 3). Of necessity, these are similar but not identical to their ecoregions (Driver and Massey 1957; Waldman 2000).

Section 3—Resource Use Patterns

This section of a scenario report compiles information from the various types of literature about resources used for food, shelter, materials, and other cultural activities by the tribe itself, or in some cases by other tribes or predecessor groups previously living in a study area. It also draws on the tribe's traditional environmental knowledge. As examples, the ethno-botanical literature describes plants used for food, medicine, or materials and gives an indication of the degree of biodiversity. The ethno-historical literature illustrates how tribes learned natural laws based on observations of the environment over time and developed their oral histories. In some cases there may be information from foraging theory research (caloric returns per time spent hunting, gathering, or fishing) (Kelly 1995).

Resources are obtained from different locations throughout the year, and this cycle is often referred to as a "seasonal round." A seasonal round may have been developed for a tribe showing which key resources are available each month throughout the year (see Umatilla Seasonal Round, Figure 4). Historical records from sources such as explorers, traders, missionary-naturalists, settler letters, colonial re-enactors, and old texts or recipes give clues about resources used or traded, sometimes with numerical data. Paleomedicine and archaeology reports can describe dietary components based on isotope ratios, pollen counts, bone examination, coprolite examination, and material use (Kelly 1986; Krech 1991; Sanger 1988; Sobolik 1994; White 1999; Winterhalder 1981). Traditional ecological knowledge combines anthropological and environmental knowledge with tribal knowledge, teaching, and observation, and oral history adds information about language, places, and their relationships (Greaves 1996; Ranco 2006; Turner *et al*. 2008).

Section 4—Traditional Diet

The goal of the dietary section is to describe the traditional diet at a level of detail equivalent to a food pyramid. When reconstructing a fully subsistent diet, the information on natural resources and their abundance allows the identification of food staples and the relative importance of the major food categories to account for 2000 to 2500 kcal/d. A tribal food pyramid is not a simple substitution of native foods for contemporary commercial foods, but describes what the tribes actually eat or used to eat. The ratios of food groups may or may not match the contemporary food pyramid (USDA 2010); rather it illustrates the actual traditional diet. In some cases, a calorically complete diet may have been identified in the foraging theory literature, but more often the major dietary staples are identified but not fully quantified within a nutritionally complete diet (Harper *et al*. 2006, 2007). Shown in Figure 5 are the Umatilla First Foods (served at every ceremonial meal) and the two food pyramids based on the two types of ecologies relevant to the Confederated Tribes. One ecology and diet is based on the mainstem Columbia River and major tributaries; this diet is based on fish. The other ecology is based in the Blue Mountains and headwaters of the tributary rivers; this diet is based on game.

An important step is to consider caloric adequacy for a particular activity level. We have used a basic assumption of 2 h of high activity, 6 h of moderate activity, 8 h of low and sedentary activity, and 8 h of rest. Basic nutritional and energy requirements were compared to information on resource abundance to develop the initial estimated diet. The initial estimates were then refined based on information on paleonutrition (Sobolik 1994; Wing and Brown 1979), and the findings of other authors (Kuhnlein *et al*. 1996,2006; White 1999). In addition, because animal organs are often eaten, and because some contaminants are lipophilic, the ingestion rate may be raised based on an assumption such as 10% of the animal protein consists of organs, with a higher level of contaminants.

The percent of food groups from the food pyramid or food wheel is then combined with nutrient information (kcal/100 g portion of actual or nearest food) from the USDA nutritional database for either the exact species or a member of the same or nearest plant or animal family. The data for fresh or cooked foods matches the form of native plants eaten as closely as possible (USDA 2010). The diet is formatted as kcal/day or grams/day for each

food group or key food element (the format most often used in risk assessment) (Table 1). An example of a diet adapted to a Maine coastal environment is shown in Figure 6 and Table 2.

Section 5—Direct Exposure Factors

Direct exposure factors are those that involve direct exposure to abiotic media (inhalation, water ingestion, soil ingestion, dermal exposure). For the general U.S. public, risk assessors usually use USEPA's Exposure Factors Handbook (USEPA 1989 as amended), which reviews decades of exposure science and gives recommendations for default inhalation rates, drinking water rates, and soil ingestion rates suitable for the average U.S. lifestyle as well as for some unique activities such as recreation or construction work.

The approach for developing a tribal scenario is similar, except diat large statistical databases and default recommendations are not available. It is not possible to replicate the massive amount of statistical data for indigenous lifestyles that is available for the general non-native population. Therefore, in order to make reasonable estimates we use extensive literature reviews and an understanding of the entire lifestyle (Harper *et al*. 2006, 2007). The basic assumption is that traditional Native American lifeways continue to be active outdoor lifestyles that are moderately physically demanding in all climates, even with some modern conveniences.

The abiotic exposure pathways are considered across conventional activity categories (*e.g*., hunting, fishing, and gathering). The process of developing these direct exposure factors is to estimate of activity levels and the frequency, duration, and intensity of each activity category (Harper *et al*. 2007). This is an iterative process that relies on multiple lines of evidence and cross-walks between tribal activity categories, exposure pathways, resource uses, ecosystem stories and traditional environmental knowledge, and the technical literature. The general steps in this process are:

1. Understand the lifestyle and the activities that comprise the lifestyle, and are required to obtain necessities and engage in the community culture;
2. Describe the day, the year, and the lifetime of men and women to identify any significant differences in activity levels between genders or ages;
3. Cross-walk activities with exposure pathways on the basis of frequency and duration of major activities, activity levels, and degree of environmental contact; and
4. Estimate cumulative exposure across activity categories factors.

This crosswalk is a semi-quantitative exercise based on multiple lines of evidence such as ethno-historical, archaeological, nutritional, and experimental information, not a statistical summation or a complete list of all activities. As with the approach to dietary reconstruction, it generally accounts for every hour but does not attempt to catalog the minute-by-minute activities of many individuals, again striving for completeness and accuracy ratiier than statistical precision. Shown in Table 3 is an example of the iterative thought process regarding exposure considerations for major activity categories. In addition, thorough

literature reviews for soil ingestion and inhalation rates (Harper *et al*. 2007) provide additional evidence.

APPLICATIONS OF SCENARIOS

Tribal exposure scenarios have many potential applications, particularly in conjunction with data collection and policy development. Several applications are described below.

Superfund

The first and most obvious application of exposure scenarios is in risk assessments at contaminated sites on reservations or affecting tribal sites and resources whether they are on or off a reservation. The basic goal is to understand risks to people practicing their heritage (or Treaty-based) lifestyles, so that remedial goals can ensure clean and restored resources to make those practices safe once again (*i.e*., protect human health and the environment) (NRC 1983, 1994, 1996; Presidential Commission 1997; USEPA 1993, 2010).

Sampling Plans

If a site or project manager has enough foresight to recognize that there may be impacts to tribal resources and uses early enough in a site characterization process, a relevant sampling plan could incorporate particular locations or resources that otherwise might be overlooked. For example, instead of random biota sampling, cultural and ecological keystone species could be sampled, with detection limits low enough to account for more intensive contact rates.

Regulatory Standards

Information within a scenario can be used to develop standards and environmental codes such as water quality standards (*e.g*., Wabanaki, Spokane scenario), or hazardous substances codes and policies (Spokane scenario) (Harper and Ranco 2009; Harper *et al*. 2002). Again, the original contact rates, such as the original fish consumption rate, rather than the lower contemporary consumption rates, must be known if the goal is to ensure that the original practices are safe to return to or continue.

Environmental Justice and Equity Assessments

Environmental Impact Statements under the National Environmental Policy Act (NEPA) (US Congress 1969) are required to evaluate disproportionate impacts. Conventional methods are generally inappropriate for indigenous lifestyles. Where exposure to environmental contaminants might be unequally spread among population segments or where tribal communities are more highly exposed, scenarios can illuminate disproportionate exposures and risks (Donatuto and Harper 2008).

Health Promotion and Well-Being

Tribal definitions of health tend to be broad and reflective of all the relationships identified in natural law or traditional environmental knowledge and teachings. Scenarios help identify the ecocultural attributes of the environment that are required for health and well-being (Harris 1998; Donatuto 2008). They can also focus attention on selected environmental

stressors and co-risk factors that tend to cluster in native communities and make them more vulnerable to environmental impacts.

Cumulative Risks and Impacts

Tribal perspectives are holistic, and we believe those perspectives would enhance understanding of cumulative risks (under regulatory applications and CERCLA) and cumulative impacts (under NEPA). In fact, we believe that CERLCA would benefit from a broader NEPA-like approach. Shown in Figure 7 is a broader risk model that includes the four conventional steps in a human health risk assessment (central four boxes), as well as a prior step where affected resources, systems, and services are identified, and a step where ecological and cultural risks are evaluated as a cumulative system. Risk assessment is often criticized as ignoring much of what is “at risk” in a community that faces contamination or other stressor. A broader approach would address many of these concerns and allow remedies to better protect human health than most do now.

Natural Resource Damage Assessment

The goal of National Resource Damage Assessment (43 CFR 11 1988) is to make the public (and tribes) “whole” by restoring both the resources and the services that flow to people from a healthy environment. Because many of the numerical definitions of natural resource injury are based on risks to human health (*e.g*., fish advisories, risk-based action levels, or institutional controls), a relevant exposure scenario and risk assessment is critical to evaluating whether the resources are clean enough to safely use traditionally. Similarly, health and well-being are ecosystem services that flow from healthy ecologies to people, and a relevant scenario and broader risk framework help define the quality of those services.

Climate Change

The challenge of climate change to tribes is how to maintain a culturally acceptable native diet and healthy lifestyle even as the resource base changes. A relevant exposure scenario will help identify traditional dietary components and lifestyle activities, which in turn will help support recommendations for, perhaps, substituting new native foods and their associated skills and teachings, or selecting specific resources for assisted migration. Because tribes and their health and traditional environmental knowledge are inseparable, an additional challenge to tribes will be to add new teachings and new components to the oral history while keeping their environmental ethic intact.

Federal Policy

Although the USEPA Office of Solid Waste and Emergency Response (OSWER) Directive 9355.7–04 (USEPA 1995) requires the USEPA project managers to identify reasonably foreseeable land use at contaminated sites, tribal resource uses are often overlooked or actively ignored both in the baseline risk assessment and when setting remediation goals. From a tribal perspective, the best solution would be to amend the OSWER Directive or add a criterion at the level of the Superfund National Remedy Review Board (USEPA 1996) to identify the nearest tribe and then ask the tribe directly whether its health and resources have been evaluated and protected.

SUMMARY

Exposure scenarios are used to evaluate the degree of environmental contact people experience living under different patterns of activities and natural resource use. While human health exposure scenarios based on traditional tribal lifeways are required under Executive Order 12898, their application in regulations or cleanups is intermittent at best. To the extent that this is due to lack of familiarity with tribes, treaties, rights, lifeways, and federal trusteeship, an USEPA Directive along with training would be of great benefit. Until this is implemented, the procedures detailed in this document provide a needed step toward the inclusion of traditional subsistence lifestyles into exposure assessments.

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REFERENCES

Abell, RA.; Olson, DM.; Dinerstein, E., et al. Freshwater Ecoregions of North America: A Conservation Assessment. Island Press; Washington, DG, USA: 2000.

Arquette M, Gole M, Cook K, et al. Holistic risk-based environmental decision-making: A native perspective. Environ Health Perspect. 2002; 10(Supplement 2):259–64. [PubMed: 11929736]

Bailey, RG. Description of the Ecoregions of the United States. USDA Forest Service; Washington, DC, USA: 1995.

Bryce SA, Omernik JM, Larsen DP. Ecoregions: A geographic framework to guide risk characterization and ecosystem management. Environ Pract. 1999; 1:141–55.

Cajete, G. A People's Ecology: Explorations in Sustainable Living. Clear Light Publishers; Santa Fe, NM, USA: 1999.

CEC (Commission for Environmental Cooperation). Ecological Regions of North America: Toward a Common Perspective. Montreal, Canada: 1997.

Clinton, William J. Executive Order 12898, Federal actions to address environmental justice in minority populations and low-income populations. Feb 11.1994 32:7629–33. 1994. 59 FR.

Donatuto, J. PhD Dissertation. University of British Columbia; Vancouver, BC, Canada: 2008. When Seafood Feeds the Spirit Yet Poisons the Body: Developing Health Indicators for Risk Assessment in a Native American Fishing Community.

Donatuto J, Harper BL. Issues in evaluating fish consumption rates for Native American tribes. Risk Anal. 2008; 28:1497–506. [PubMed: 18793286]

Driver, HE.; Massey, WC. Comparative Studies of North American Indians. American Philosophical Society; Philadelphia, PA, USA: 1957.

Greaves, T. Tribal rights. In: Brush, SB.; Stabinsky, D., editors. Valuing Local Knowledge. Island Press; Washington, DC, USA: 1996. p. 25-40.

Harding A, Harper B, Stone D, et al. Conducting research with tribal communities: Sovereignty, ethics, and data-sharing. Environ Health Perspect. 2012; 120(11):6–10. supplementary material at http://dx.doi.org/10.1289/ehp.1103904. [PubMed: 21890450]

Harper, BL. Quapaw Traditional Lifeways Scenario. AESE, Inc; Richland, WA, USA: 2008. Available at http://health.oregonstate.edu/research/featured-projects/tribal-grant

Harper BL, Harris SG. Using eco-cultural dependency webs in risk assessment and characterization of risks to tribal health and cultures. Environ Sci Pollut R. 2000; 7(Special Issue 2):91–100.

Harper, B.; Ranco, D. Wabanaki Traditional Cultural Lifeways Exposure Scenario. 2009. Available at http://www.epa.gov/boston/govt/tribes/pdfs/DITCA.pdf

Harper B, Flett B, Harris S, et al. The Spokane Tribe's multipathway subsistence exposure scenario and screening level RME. Risk Anal. 2002; 22:513–26. [PubMed: 12088230]

Harper, B.; Harding, A.; Waterhous, T., et al. Estimating Environmental Exposures for Tribes Practicing Traditional Subsistence Lifestyles: Part 1: Cross-Cultural Methods; and Part 2: Research Results for Specific Exposure Pathways. National Tribal Forum on Environmental Science. Ocean Shores, WA, USA: Sep 24–28. 2006 2006

Harper, B.; Harding, A.; Waterhous, T., et al. Traditional Tribal Subsistence Exposure Scenario and Risk Assessment Guidance Manual. 2007. Available at http://health.oregonstate.edu/research/featured-projects/tribal-grant

Harris, SG. Cultural legacies: Challenge to the risk community. Society for Risk Analysis Annual Meeting; Phoenix, AZ, USA. December 7, 1998; 1998Plenary address

Harris S, Harper B. A Native American exposure scenario. Risk Anal. 1997; 17:789–95. [PubMed: 9463932]

Harris, S.; Harper, B. Using traditional environmental knowledge as a risk characterization framework. Society for Risk Analysis Annual Meeting; Atlanta, GA, USA. December 6, 1999; 1999

Kelly, K. Navajo Land Use: An Ethnoarchaeological Study. Academic Press; Orlando, FL, USA: 1986.

Kelly, RL. The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways. Smithsonian Institution Press; Washington, DC, USA: 1995.

Krech S. The state of ethnohistory. Annu Rev Anthropol. 1991; 20:345–75.

Kuhnlein HV, Soueida R, Receveur O. Dietary nutrient profiles of Canadian Baffin Island Inuit differ by food source, season, and age. J Am Dietetic Assoc. 1996; 96:155–62.

Kuhnlein, HV.; Smitasiri, S.; Yesudas, S., et al. Documenting Traditional Food Systems of Indigenous Peoples: International Case Studies. 2006. Available at http://www.cine.mcgill.ca/documents/manual.pdf

McMahon G, Gregonis SM, Waltman SW, et al. Developing a spatial framework of common ecological regions for the conterminous United States. Environ Manag. 2001; 28:293–316.

NRC (National Research Council). Risk Assessment in the Federal Government: Managing the Process. National Academy Press; Washington, DC, USA: 1983.

NRC. Building Consensus: Risk Assessment and Management in the Department of Energy's Environmental Remediation Program. National Academy Press; Washington, DC, USA: 1994.

NRC. Understanding Risk: Informing Decisions in a Democratic Society. National Academy Press; Washington, DC, USA: 1996.

Omernik, JM. Ecoregions: A spatial framework for environmental management. In: Davis, WS.; Simon, TP., editors. Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishing; Boca Raton, FL, USA: 1995.

Omernik JM. Perspectives on the nature and definition of ecological regions. Environ Manag. 2004; 34(Supp 1):S27–S38.

O'Neill CA. Risk avoidance, cultural discrimination, and environmental justice for indigenous peoples. Ecology Law Quart. 2003; 30(1):1–58.

Presidential/Congressional Commission on Risk Assessment and Risk Management, President's Commission. Framework for Environmental Health Risk Management, Final Report 1. 1997. Available at http://www.riskworld.com

Quigley, D. Compilation on Environmental Health: Research Ethics Issues with Native Communities. 2001. Available at http://www.researchethics.org/uploads/pdf/compilation.pdf

Ranco D. Toward a Native anthropology: Hermeneutics, hunting stories, and theorizing from within. Wicazo Sa Rev. 2006; 21:61–78.

Ricketts, TH.; Dinerstein, E.; Olson, DM., et al. Terrestrial Ecoregions of North America: A Conservation Assessment. Island Press; Washington, DC, USA: 1999.

Sanger D. Maritime adaptations in the Gulf of Maine. Archaeology Eastern North America. 1988; 16:81–99.

Smith, LT. Decolonizing Methodologies: Research and Indigenous Peoples. Zed Books; New York, NY, USA: 1999.

Sobolik, KD., editor. Paleonutrition: The Diet and Health of Prehistoric Americans. Center for Archaeological Investigations, Occasional Paper Series 22. Southern Illinois University; Carbondale, IL, USA: 1994.

Turner NJ, Gregor R, Brooks C, et al. From invisibility to transparency: Identifying the implications. Ecology and Society. 2008; 13(2):7.

US Code of Federal Regulations (43 CFR 11). Natural Resource Damage Assessments. 1988. Available at http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title43/43cfrll_main_02.tpl

US Congress. The National Environmental Policy Act of 1969 (42 USC 4321–4347). 1969. Available at http://www.epa.gov/compliance/basics/nepa.html

US Congress. Chapter 103—Comprehensive Environmental Response, Compensation, and Liability Act (42 USC 9601–9675). 1980. Available at http://frwebgate.access.gpo.gov/cgi-bin/usc.cgi?ACTION=BROWSE&TITLE=42USCC103

USDA (US Department of Agriculture). Nutrient Data Laboratory Home Page. Agricultural Research Service, USDA. 2010. Available at http://www.ars.usda.gov/main/site_main.htm?modecode=12-35-45-00

USEPA (US Environmental Protection Agency). Exposure Factors Handbook. EPA/600/18–89/043. Washington, DC, USA: 1989.

USEPA. A Guidebook to Comparing Risks and Setting Environmental Priorities. EPA230-B-93–003. Washington, DC, USA: 1993.

USEPA. Exposure Factors Handbook. EPA/600/P-95/002Fa-c. Washington, DC, USA: 1997.

USEPA. OSWER Land Use Directive “Land Use in the CERCLA Remedy Selection Process,” EPA/OSWER Directive No. 9355.7–04 (5/25/95). 1995. Available at http://www.epa.gov/superfund/community/relocation/landuse.pdf and EFH

USEPA. Superfund National Remedy Review Board. Washington, DC, USA: 1996. Available at http://www.epa.gov/superfund/programs/nrrb/index.htm

USEPA. Framework for Cumulative Risk Assessment. Risk Assessment Guidance for Superfund (RAGS) Part A. EPA/630/P-02/001F. Washington, DC, USA: 2003a. Available at http://www.epa.gov/oswer/riskassessment/ragsa/index.htm

USEPA, Western Ecology Division. Level III Ecoregions of the Continental United States (revision of Omernik, 1987). Corvallis, Oregon, USA: 2003b. Available at http://www.epa.gov/wed/pages/ecoregions.htm

USEPA, Western Ecology Division. Ecoregions of North America. Corvallis, Oregon, USA: 2004. Available at http://www.cpa.gov/wcd/pages/ecoregions/na_eco.htm

USEPA. Superfund Remedial Investigation/Feasibility Study—Detailed Analysis. Washington, DC, USA: 2010. Available at http://www.epa.gov/superfund/cleanup/analys.htm

US House of Representatives, Committee on the Judiciary. Federal Rules of Evidence. 2009. Available at http://judiciary.house.gov/hearings/printers/111th/evid2009.pdf

Waldman, C. Atlas of the North American Indian. Checkmark Books; New York, NY, USA: 2000.

White, CD. Reconstructing Ancient Maya Diet. The University of Utah Press; Salt Lake City, UT, USA: 1999.

Wing, ES.; Brown, AB. Paleonutrition: Method and Theory in Prehistoric Foodways. Academic Press; New York, USA: 1979.

Winterhalder, B. Foraging strategies in the Boreal forest: An analysis of Cree hunting and gathering. In: Winterhalder, B.; Smith, EA., editors. Hunter-Gatherer Foraging Strategies: Ethnographic and Archaeological Analyses. The University of Chicago Press; Chicago, IL, USA: 1981. p. 66-98.

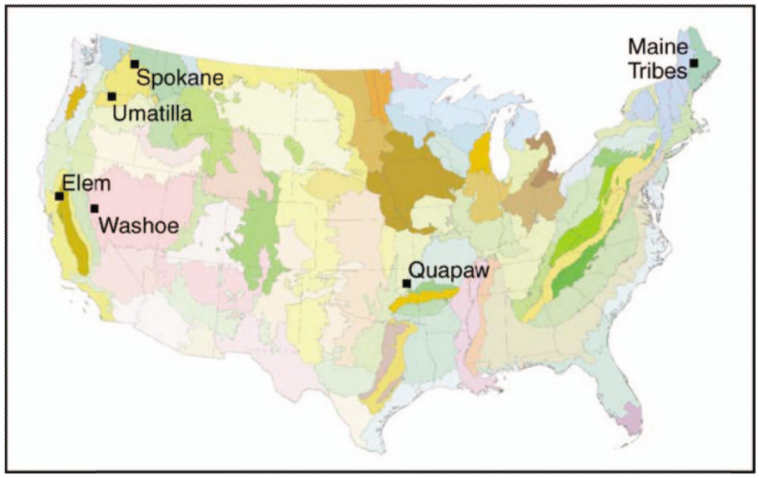

Figure 1.
Tribal exposure scenario locations and their relationship to Level III ecoregions.

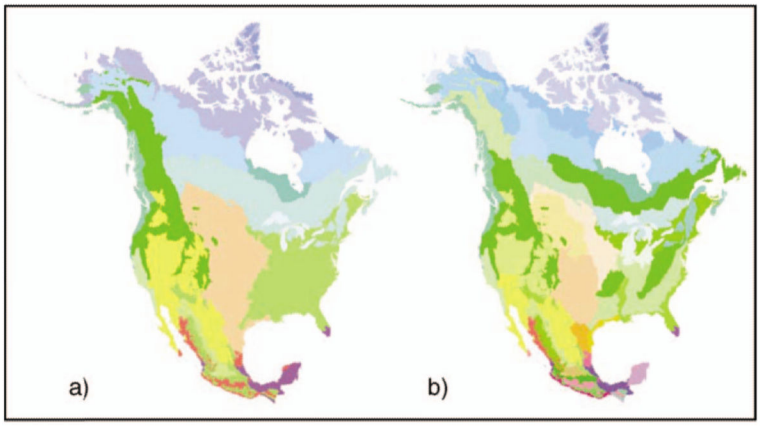

Figure 2.
Ecoregion maps of North America: (a) Level **I** and (b) Level **II** (USEPA 2003b).

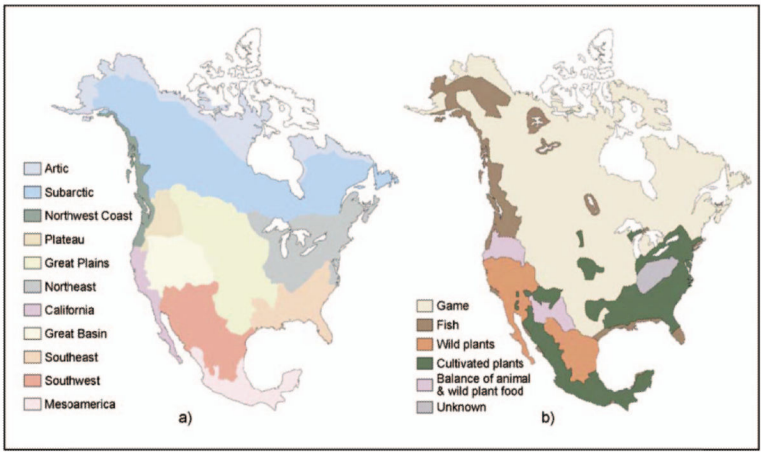

Figure 3.

Examples of other regional classifications (a) Culture Areas after Waldman, 2000 and (b) Subsistence Food Categories after Driver and Massey, 1957. Redrawn from Harper *et al*. 2007.

Figure 4.
Confederated Tribes of the Umatilla Indian Reservation seasonal round (reprinted with permission).

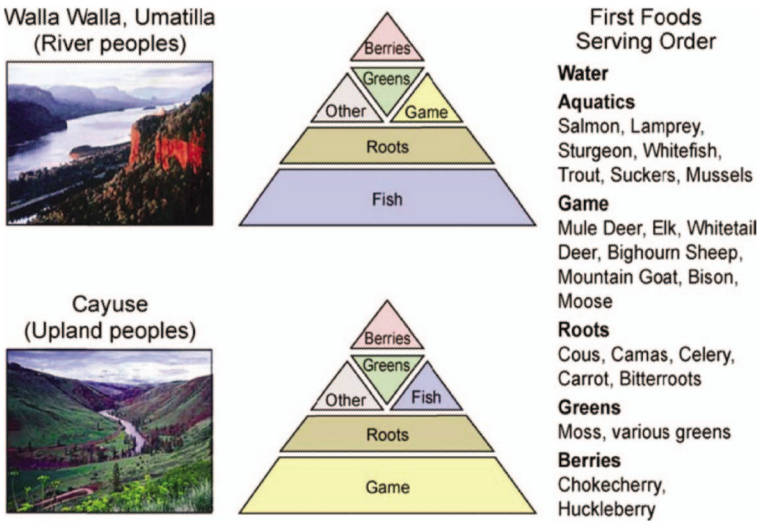

Figure 5.
CTUIR food pyramids and first foods.

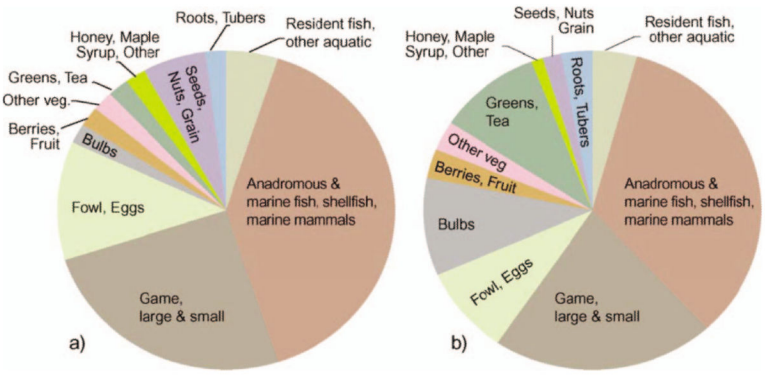

Figure 6.
Maine coastal food wheels showing (a) calorie distribution and (b) quantity distribution.

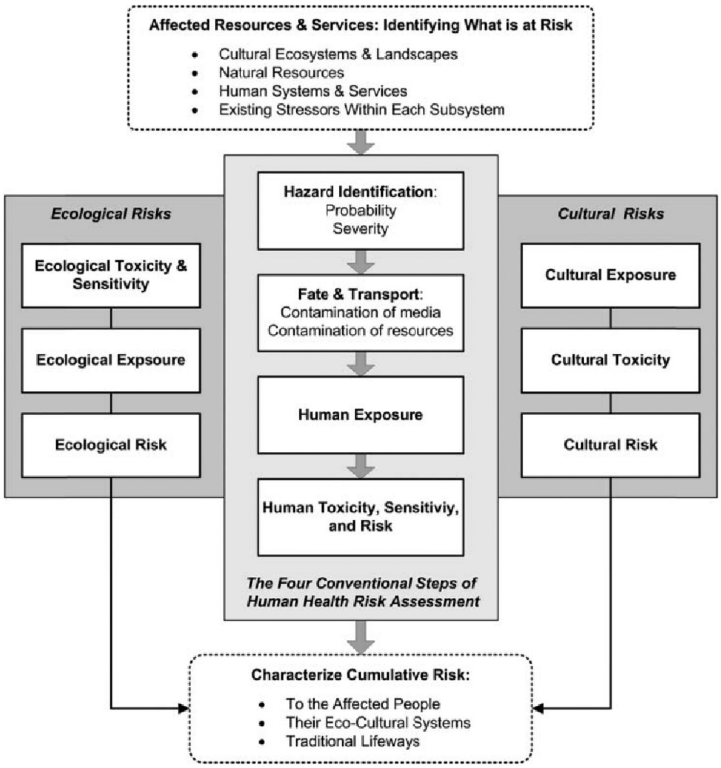

Figure 7.
A broader risk assessment model.

Table 1

Example of food category and calorie conversion for Maine.

Food category	Kcal per 100 g
Resident fish and other aquatic resources	Mixed trout, cooked—190
	Crayfish, wild cooked—82
	Turtle, raw—89
Anadromous and marine fish and shellfish	Salmon, cooked—180
	Shad, cooked—252
	Herring, dry cooked—200
	Pollock, dry cooked—118
	Eel, dry cooked—236
	Oyster, dry cooked—70
	Clam, moist cooked—148
	Lobster, moist heat cooked—98
	Seal, raw—142
	Beluga, raw—111
Game, large and small	Deer, roasted—158
	Moose, roasted—134
	Moose liver, braised—155
	Rabbit, wild, roasted—173
	Beaver, roasted—212
	Muskrat, roasted—236
Fowl and eggs	Quail, cooked—234
	Duck, cooked—200
	Duck eggs—185
	Pheasant (for wild turkey)—247
Bulbs	Leek, onions, and other bulbs (bulb & leaf)—31
Berries, fruits	Raw elderberries—73
	Raw strawberries—70
Other vegetables (above-ground)	Beans, cooked pinto, kidney, or white—143
	Peas, boiled pigeon or split—120
	Squash, cooked winter—37
	Squash, cooked Navajo—16
Greens, tea (includes leaves, stems, medicinal plants, flavorings)	Dandelion greens, raw—45
	Watercress, raw—11
	Fiddleheads, raw—34
Honey, maple syrup, other	Honey—304
	Maple syrup—261
Seeds, nuts, grain	Corn, Navajo strain steamed—386
	Sunflower seeds, dried, raw—570
	Chia seeds—490
	Hazelnut, dry roast—646

Food category	Kcal per 100 g
	Butternuts, dried—612
Roots, bulbs, tubers	Chicory root, raw—73
	Burdock root, boiled—88
	Potato, baked tuber—200

Table 2

Maine-coastal ecosystem example of food category grams per day.

Food Category	% of 2000 kcal	Equiv. kcal/day	Rep kcal/100 g	Grams per day
Resident fish and other aquatic resources	5	100	175	57
Anadromous & marine fish, shellfish, marine mammals	40	800	175	457
Game, large and small	25	500	175	286
Fowl & eggs	12	240	200	120
Bulbs	2	40	30	133
Berries, fruits	2	40	100	40
Other vegetables	2	40	100	40
Greens, tea	2	40	30	133
Honey, maple syrup, other	2	40	275	15
Seeds, nuts, grain	6	120	500	24
Roots, tubers	2	40	100	40
TOTALS	100	2000		1345

Table 3

Examples of exposure considerations for major activity categories.

Exposure pathway	Activity category					
	Hunting and associated activities	**Fishing and associated activities**	**Gathering and associated activities**	**Ritual purification and associated activities**	**Material and food processing and use**	**Totals for major exposure factor categories**
Food, medicine, tea ingestion	*n* deer/yr; total game; organs eaten	*n* fish/yr; number of meals; organs eaten	Where are foods, firewood is gathered; foraging theory	Herbal particulates	Fresh and stored forms; storage methods; cooking methods	Must account for all calories, breadth of foods; parts eaten
Soil, dust, sediment, mud ingestion	Terrain types such as marshes	Sediment contact; weir construction in tide flats, dusty conditions	Digging, cooking method	Includes building the lodge, gathering wood	Includes incidental soil adhering to roots	Must consider living area, unpaved roads, regional dust load, smudging
Inhalation	Days per terrain type, load, and grade; exertion during hide scraping.	Exertion level for nets, gaffing; cleaning effort, smoking method	Exertion level; gardening or ranching as appropriate; travel time, wood chopping	Steam inhalation, singing	Exertion level while grinding, pounding, making items	Must include additional cultural activities and social activities
Groundwater and surface water	Ritual purification, drinking water, wash water, water-to-biota pathways	Drinking water, incidental ingestion, washing and cooking	Drinking water, soaking	Steam in lodge, rehydration during and after use	Soaking, washing, leaching, other uses	Must consider local climate
Dermal exposure	Soil, air, and water pathways, pigments	Immersion events	Immersion events	Immersion with open skin pores	Material crafting may include wounds and abrasions	Skin loading may be higher and longer for different practices and habitats