



Wayne State University

Nutrition and Food Science Faculty Research
Publications

Nutrition and Food Science

4-14-2016

North American entomophagy

Joohi Schrader
Wayne State University

Dennis G. A. B Oonincx
Wageningen University, Netherlands

Maria Pontes Ferreira
Wayne State University, maria.pontes.ferreira@fulbrightmail.org

Recommended Citation

Schrader, J., Oonincx, D.G.A.B., & Ferreira, M.P. (2016). North American entomophagy. *Journal of Insects as Food and Feed*, 2(2), 111-120. <http://dx.doi.org/10.3920/JIFF2016.0003>.
Available at: <http://digitalcommons.wayne.edu/nfsfrp/15>

This Article is brought to you for free and open access by the Nutrition and Food Science at DigitalCommons@WayneState. It has been accepted for inclusion in Nutrition and Food Science Faculty Research Publications by an authorized administrator of DigitalCommons@WayneState.

North American entomophagy

J. Schrader¹, D.G.A.B. Oonincx² and M.P. Ferreira^{1*}

¹Department of Nutrition and Food Science, Wayne State University, 5045 Cass Avenue, 48202 Detroit, MI, USA;

²Department of Entomology, Wageningen University and Research Centre, P.O. Box 16, 6700 AA Wageningen, the Netherlands; maria.pontes.ferreira@fulbrightmail.org

Received: 7 January 2016 / Accepted: 16 February 2016

© 2016 Wageningen Academic Publishers

OPEN ACCESS 

REVIEW ARTICLE

Abstract

Eating insects is not a common Northern American practice today. However, in the past a variety of insect species was consumed in Northern America (north of Mexico including Greenland). The aim of this literature review is to provide an historical overview of North American entomophagy based upon both peer and non-peer reviewed sources on this topic. Regional differences in insect consumption and reasons for being underreported are discussed. We show that North American natives, and in certain cases colonists, collected and consumed a large variety of edible insects. These are categorised per order and where available, information on how these species were collected and processed is provided. Lastly, we mention reasons for the renewed interest in edible insects in North America, and make suggestions for future studies.

Keywords: collecting, food, indigenous, insects, native American

1. Introduction

Entomophagy – the consumption of insects by people as food – is a common practice in many parts of the world (Van Huis *et al.*, 2013). Insects inhabit every continent and have historically been consumed by humans on all continents except Antarctica (Bodenheimer, 1951). In most Westernised regions such as Northern America (herein considered north of Mexico, including Greenland), entomophagy is currently uncommon. However, in the last decade interest in entomophagy has redoubled, and several companies have started to produce edible insects for the North American market (Martin, 2014). Furthermore, insect-based foods (e.g. restaurant offerings) and derivative products (e.g. cricket powder) are currently being produced.

One of the reasons for this piqued interest is the urgency to sustainably respond to an inflated demand for cheap protein-rich food. This is largely caused by an expected growth of the human population (from seven to nine billion by 2050) and an enhanced prosperity in developing countries, expected to lead to a 25% per capita rise in animal-based food consumption (FAO, 2009; Herrero *et al.*, 2013). Insects are considered a possible mitigation to

this issue, because they efficiently convert their feed, emit less greenhouse gases, require less land and other resources, and can reproduce rapidly compared to conventional production animals (Oonincx and De Boer, 2012; Oonincx *et al.*, 2010, 2015). Together, these attributes make them a potentially sustainable source of high quality animal protein. Furthermore, insects are a good source of fat, B-vitamins, carotenoids and minerals, such as iron and zinc (Bukkens, 1997; Bukkens and Paoletti, 2005; Finke and Oonincx, 2013). For these reasons it is predicted that the interest in entomophagy will continue to rise, especially as people learn more, and as environmental resources become scarcer (Van Huis *et al.*, 2013).

Consumer acceptance amongst Westerners is an issue (Deroy *et al.*, 2015), as insect consumption is currently considered disgusting in most Western cultures (Rozin and Fallon, 1987). Increasing familiarity with insects-as-food, decreasing food neophobia (Verbeke, 2015), and altering attitudes towards insects, both in general and as food, may be key to gaining this acceptance (Looy *et al.*, 2014).

It is noteworthy that pre-Western cultures embraced entomophagy. Cave drawings dating back some 15,000

years ago were found in the Araña cave in Valencia, Spain, and depict the collection of honey comb, which could mean that not only honey, but also bee larvae and pupae were consumed (Ramos-Elorduy, 1996), as is still the case for instance, in southeast Asian countries (Yhoun-Aree and Viwatpanich, 2005). Many other historical documents in the form of sculptures and texts depict the eating of insects (Berenbaum, 1994). Certain insects are referenced in

biblical texts and in the Sunnah, as being an animal people are allowed to consume:

And the same John had his clothing of camel's hair, and a leather belt about his waist; and his food was locusts and wild honey (King James Bible, Matthew 3:4);



Figure 1. Distribution of native North Americans.

There are, however, some flying insects that walk on all fours that you may eat: those that have jointed legs for hopping on the ground (King James Bible, Leviticus 11: 21);

Of these you may eat any kind of locust, katydid, cricket or grasshopper (King James Bible, Leviticus 11: 22);

It was narrated from ‘Abdullah bin ‘Umar that the Messenger of Allah said: ‘Two kinds of dead meat have been permitted to us: fish and locusts.’ (the Sunnah, Sunan Ibn Majah 28: 3339).

Although numerous historical accounts can be found across cultures/civilisations worldwide, there is relatively little documentation on the consumption of insects by North American natives (Bodenheimer, 1951). However, insects have been used as a food source in Northern America (Bodenheimer, 1951; DeFoliart, 1994). When European explorers began to travel the New World, the various lifestyles of North American natives were documented. This included which foods they ate, how these were collected, and how the foods were prepared and consumed.

Regional differences

The published past practices of entomophagy in western North America are better documented than the practice in eastern and northern areas. North America is biome diverse, and thus gave rise to different food resources, depending on location. Furthermore, biome diversity leads to differences in seasonal availability of staple foods and hence differences in food utilisation by the indigenous people (Fynn, 1907). Some authors argue that natives living in certain regions of North America were more likely to consume edible insects as food than natives from other regions (Berenbaum, 1994; Bodenheimer, 1951; Skinner, 1910).

Insect consumption was thought to be most prominent west of the Mississippi due to the climatic conditions of that area (Berenbaum, 1994). The Great Basin region makes up the greater portion of Nevada, half of the state of Utah, and parts of California, Oregon, Wyoming, and Idaho (Figure 1). In this region, wild game was plentiful but there were also times when grasshoppers would arrive in the ‘tens of thousands’ (Madsen, 1989; Madsen and Schmitt, 1998). These would land in the small brine lakes of the region and wash ashore, naturally salted and sundried. Due to their abundance and proximity, mass collection of these grasshoppers by local natives resulted in higher food energy returns than hunting and processing wild game (Madsen, 1989; Madsen and Kirkman, 1988; Madsen and Schmitt, 1998). Along the Great Lakes and Pacific coasts fishing was the predominant method of food procurement, whereas

in the arid southwest corn made up 90% of the diet of the Pueblo natives (Fynn, 1907).

Whilst much documentation on insect consumption amongst natives west of the Mississippi can be found (Bancroft, 1889; Powers and Powell, 1877; Wright, 1884), it is known that entomophagy occurred across the North American continent and associated islands. Agriculture was predominantly practiced south of the Great Lakes, which led to the belief that only people who relied upon the availability of game and subjected to periodic famine sought insects as an alternative food source (Skinner, 1910). Skinner (1910) states ‘So far as our records show, the Indians east of the Mississippi never made any use of insects as food.’ Tribes located east of the Mississippi River relied more on agriculture, whereas communities in areas with short summers, such as those along the banks of the St. Lawrence River, relied more on hunting and fishing (Fynn, 1907). However, the past practice of entomophagy by natives in the eastern and northern regions of North America has been documented by several authors (Brickell, 1737; Carr, 1951; Hearne, 1795; Waugh, 1916).

Some practices may not have been documented

In certain cases, past practices of entomophagy can be derived from memory culture (remembrance of past traditions in the present time), or from neighbouring communities (Sutton, 1988). However, most data on entomophagy are ethnographic, derived from direct observations by anthropologists; as well as ethno-historical accounts from non-anthropologists (Sutton, 1988). Under the heading ‘Offensive foods,’ it is stated that contrary to the tribes of the Great Basin and California ‘the Menomini [native to the Wisconsin area] were not addicted to eating all kinds of reptiles, insects, and other loathsome food’ (Hoffman, 1896). It seems that Western-culture aversion to insect eating leads to the assumption that entomophagy is prompted by starvation conditions only (Van Huis, 2003). This ethnocentric bias regarding insect consumption may well have prevented natives from sharing indigenous food habits with westerners, and hence contributed to imprecise documentation of dietary patterns. Even today, people are less likely to share food habits when they perceive negative judgment by the interviewer, as noted by Van Huis during his fieldwork for his review on insects-as-food in sub-Saharan Africa (A. van Huis, personal communication).

Sutton (1988) similarly suggests that anthropologists most likely held Western ideals about insects-as-food, and hence the practice of entomophagy in the Great Basin area might be underreported, or underestimated (Sutton, 1988). The arctic Inuit are also suggested to have consumed insects during summer, although the species and frequency of consumption is not clear (Meyer-Rochow, 1972). Also, there is inadvertent entomophagy. A residential school

survivor recalled that as a child they were sometimes fed food that was spoiled and had maggots (of an unknown species) in it, and commented in Toronto in 2015 that the children 'stopped caring and just ate it because they were hungry'. Generally, natives made use of all that nature had to offer, and wasted very little (Bodenheimer, 1951). The indigenous people relied heavily upon nature's resources, and in certain communities insects were part of the diet (DeFoliart, 2002).

2. Species consumed by the indigenous people of North America

Approximately 2,000 species of edible insects have been described globally, of which 90 were used as food in North America (Jongema, 2015). A brief overview of the species known to having been consumed in Northern America is provided and accounts on collection methods, and how the foods were prepared and consumed, are provided where possible.

Coleoptera

Beetles belong to the order Coleoptera, which forms the largest order of the animal kingdom (Hickman *et al.*, 2001). There are approximately 30,000 Coleopteran species in North America, of which 18 have been used as food (DeFoliart, 2002; Jongema, 2015; Milne and Milne, 1980).

Bean weevils, also known as 'seed beetles' belong to the subfamily Bruchinae. These beetles are granivores, and their larvae develop inside seeds (Arnett *et al.*, 2002). Two genera (*Algarobius* and *Neltumius*) were consumed in their larval and pupal phases (Bell and Castetter, 1937; Bye, 1972; Hooper, 1920). The Pima of Arizona would make flour from the seeds of mesquite pods, which often contained larvae and pupae (Bell and Castetter, 1937). Hence, these insects became a part of the food mixture. A similar account is known about the Cahuilla of southern California, who also made flour from seeds of mesquite pods, with many of them being 'worm-eaten' (Hooper, 1920).

Seven species, belonging to the family Cerambycidae (longhorn beetles), were reportedly consumed in North America (Essig, 1931; Powers and Powell, 1877; Roust, 1967). The larvae of *Prionus californicus* Motschulsky (Cerambycidae) were commonly dug out of stumps and logs of both coniferous and deciduous trees by the California natives and consumed raw (Essig, 1931). Based on human coprolites found in western Nevada, it seems that adults of this species were also consumed (Roust, 1967). No head capsules were found in the coprolites, therefore it appears that these were removed prior to consumption.

Other commonly consumed species of Cerambycidae were the ribbed pine borer (*Rhagium lineatum* Oliver),

the pine sawyer beetle (*Ergates spiculatus* Leconte), and the nautical borer (*Xylotrechus nauticus* Mannerheim), which were consumed in their larval stage (Essig, 1931). These were commonly found under the bark of old stumps and decaying branches of coniferous trees. Larvae of both the spotted pine sawyer (*Monochamus maculosus* Halderman) and black pine sawyer (*Monochamus scutellatus* Say) were procured from dead, decaying, and fire damaged trees. Western ash borer (*Neoclytus conjunctus* Leconte) larvae were found under the bark of oak, ash, and willow trees (Essig, 1931). Because there are 900 species of longhorn beetles in North America (Arnett *et al.*, 2002), the actual number of species consumed may have been higher than the seven described species.

Scarab beetles (Scarabaeidae), belonging to three genera (*Cyclocephala*, *Phyllophaga*, and *Polyphylla*) have been historically consumed in North America (Essig, 1931; Nomland, 1938). Adult June beetles, belonging to the genera *Polyphylla*, were consumed by natives in Madera County, California, and by the Bear River people, a band native to northwestern California, who fire-roasted them (Essig, 1931; Nomland, 1938). Other tribes located in central California have been documented to consume adults of the white striped beetle (*Polyphylla crinita* (LeConte)) (Essig, 1931). As late as 1981, June beetles (believed to be *Phyllophaga fusca* Froelich) were prepared in the same way by the Owen's Valley and Mono Lake Paiute, native to the western USA (Sutton, 1988). The June beetles *Cyclocephala dimidiata* Burmeister and *Cyclocephala villosa* Burmeister were also found in the western USA (Sutton, 1988).

Diptera

The order Diptera contains the 'true flies', which is a diverse order with approximately 16,300 species found across North America (Milne and Milne, 1980). Their larvae can be terrestrial or aquatic (Merritt *et al.*, 2009). The most popular and well-documented flies consumed by natives were shore fly pupae (Ephydriidae). Shore flies, also known as 'brine flies' or 'alkaline flies' appear in massive quantities along saltwater shorelines every year (Wirth, 1971). Indigenous people from the Mono Lake and the Great Basin regions made frequent use of these pupae as food (Browne, 1957; Ebeling, 1986; Palmer, 1871). Mono Lake is in the eastern Sierra region of California. The Kutzadika'a Northern Paiute lived along Mono Lake and every spring they harvested the shore fly pupae (*Ephydra hians* (Say)) which washed upon the shores in massive quantities (Brewer and Farquhar, 1975; Essig, 1934). In fact, Kutzadika'a translates to 'fly eater' in English (Fletcher, 2015).

Browne (1957) noted that a 'disgusting deposit of worms, about two feet high by three or four inches in thickness, extends like a vast rim around the shores of the lake'. Similarly Brewer and Farquhar (1975) write that 'hundreds

of bushels' of pupae could be gathered and that native families would travel from all over to collect them. The people left them out in the sun to dry, ate them raw, or fried them in the pupae's own fat (Bodenheimer, 1951; Browne, 1957). Dried pupae would be rubbed between the hands until a small kernel of the body was left (Essig, 1934). This fragment was eaten as a snack or ground into a powder to be made into 'cuchaba,' along with other regional foods including seeds, berries, and acorns (Browne, 1957; Campbell, 1999). The cooked pupae supposedly resembled 'pork cracklings' (Browne, 1957). According to Brewer and Farquhar (1975) they were not 'unpleasant to the taste' and 'if one were ignorant of its origin, it would make fine soup'. Additional shore fly pupae were stored as provisions for the winter or traded with other tribes in the Sierra Nevada region such as the Tubatulabal, Miwok, Washoe, and Monache (Davis, 1974). Collection of shore fly pupae continued into the late 1970's (Sutton, 1988). The shore flies and their larvae are still present today at Mono Lake, but according to the Mono Lake Committee, the Kutzadika'a no longer collect them (Fletcher, 2014).

Botfly larvae (Oestridae) were consumed by Tlicho or the Dog Rib people, from the Northwest Territories of Canada. Traditionally, natives of the northerly regions of North America consumed many lipid-rich foods, such as seal and oily fish, for sustenance in the cold climate (Bodenheimer, 1951). The Dog Rib were known to eat gadfly larvae (thought to be *Hypoderma lineata*), which were found in skins, near the tongue, and in parts of the airway of hunted caribou (Russell, 1898). These larvae would be fully grown in April and the natives left the developing larvae on the caribou meat to be consumed later (Russell, 1898). These were 'always eaten raw and alive out of the skin and are said by those who like them to be as fine as gooseberries' (Hearne, 1795). Sub-arctic bands in eastern Québec such as the Innu (Montagnais), Naskapi, and Cree, might also have consumed *Cuterebra* larvae found in caribou (Skinner, 1910).

Other arctic natives consumed similar insects, such as the larva of *Hypoderma bovis* Linnaeus and *Oedemagena tarandi* Linnaeus (Anderson, 1918; Harper, 1955). Arctic natives living in the areas between Bering Strait, Alaska, USA and Bathurst Inlet, Northwest Territories, Canada, consumed the large warble-fly larvae found under the skin of hunted caribou. These were enjoyed greatly by the natives, but not by the European explorers who thought of the grubs as being watery and tasteless (Anderson, 1918). As previously mentioned, although the USA/Canadian arctic Inuit are known to have consumed insects, less is known about Greenlandic Inuit, or the Dorset people who preceded them. Several experts on Greenlandic Vikings suggest that these Vikings are not documented to have practiced entomophagy.

Hemiptera

There are approximately 4,500 species of Hemiptera located in North America (Milne and Milne, 1980). Three families in this order, Belostomatidae, Aphididae, and Cicadidae, have been documented as a food source to the native North American people (Ebeling, 1986; Essig, 1931, 1949; Palmer, 1871). Within the family Belostomatidae, *Lethocerus americanus* (Leidy) is a common species of water bug, which was consumed by natives (Essig, 1949). Within the family Aphididae, the aphid *Hyalopterus pruni* (Geoffroy) was used as a source of food. Although the insect itself was not consumed, it produces a sweet excretion called 'honeydew.' This exudate was collected by natives and named 'Indian honey' by the California settlers (Essig, 1931; Sutton, 1988). It was also used by other indigenous people, such as the Southern Paiute (Harrington, 1945), Great Basin bands (Palmer, 1871), and Nevada natives (Witherspoon, 1889).

Some species within the family Cicadidae emerge annually during mid- to late summer, or early spring depending on geographical location (Sanborn and Phillips, 2013). Other cicada species have a longer life cycle, with adults emerging every 13 or 17 years (Milne and Milne, 1980). The most commonly mentioned cicadas as being consumed by natives are the 17-year cicada *Tibicen septemdecim* (Marlatt, 1898). Cicadas belonging to the genera *Magicalcicada*, *Okanagana*, and *Platypedia* were also consumed by North American natives (Carr, 1951; Ebeling, 1986; Marlatt, 1898). First, the wings of the adult cicada were removed and the body was then roasted or fried to be used in a soup (Collinson, 1764). Cicadas were often cooked and rarely consumed raw (Sutton, 1988). Their de-winged bodies were sometimes dried and stored to be eaten at a later time (Dixon, 1905). However, Sutton (1988) points out that the term 'cicada' may have been used incorrectly. Other insects such as locusts, which belong to the order Orthoptera, may have been referred to as cicadas and vice versa (Sutton, 1988).

Orthoptera

There are approximately 1000 species of Orthoptera in North America (Milne and Milne, 1980). These can be found almost anywhere there is land, except for extremely cold environments such as the polar regions and alpine zones (Naskrecki, 2004). Orthoptera were a common addition to the native diet. Thirteen species belonging to four families (Acrididae, Gryllacidae, Gryllidae, and Tettigoniidae) were used as food in North America (Jongema, 2015).

The now extinct Rocky Mountain locust (*Melanoplus spretus* Walsh (Acrididae)) was once consumed in large quantities (Bodenheimer, 1951). They inhabited the arid land surrounding the eastern side of the Rocky Mountains,

which reaches from the province of British Columbia and through the states of Montana, Wyoming, Iowa, and North and South Dakota (Garcia, 2000). Natives would collect the swarms of locusts almost as if herding cattle; a large open pit would be formed and the gatherers would beat through bushes and drive the locusts into the pit to collect them (Berenbaum, 1994). Similarly, the Shoshone would beat the ground to drive grasshoppers from bushes into a hole to trap them. Once collected, the insects would be cooked and made into a soup or turned into a paste (Bryant, 1895). The Digger Indians used a similar method to gather the insects, but instead of trapping them in holes, they would set surrounding grasses on fire until the insects were trapped and consequently roasted. Afterwards, they were ground into flour-like powder and, along with berries, used to make small cakes (Bodenheimer, 1951).

The Mormon cricket (*Anabrus simplex* Halderman (Tettigoniidae)), which in fact is not a cricket but a katydid, can be found in the western part of North America, including the majority of the USA and southern parts of Canada (Sutton, 1988). This species is considered responsible for destroying the crops planted by the Mormon settlers in Utah in the year 1848 (Bancroft, 1889). Native bands such as the Shoshoni (Steward, 1943) and Ute collected, dried, and then pulverised the 'crickets' into a 'flour' to form prairie cakes (Reagan, 1934). In the late 1800s European settlers arrived to what is now called Utah. When their crops failed, they turned to the Ute, a native American tribe, for help. They provided the settlers with prairie cakes, which the Europeans considered tasty and helped sustain them through the harsh winter (Van Huis *et al.*, 2013).

The Mormon cricket was an important food resource used by all tribes in the Great Basin region (Steward, 1943). Katydid swarms could last for years and the native communities developed an organised and energy efficient manner for collecting and harvesting them (Sutton, 1988). The Ute would conduct an 'Indian cricket drive' by forming large trenches about 30 cm wide, 30 cm deep, and 10 to 13 m long, which were covered with dried grasses. The native families would walk and swing bundles of grasses from side to side to herd the crickets into the trenches. The trenches were then lit on fire, roasting the crickets inside (Egan and Egan, 1917). Once cooked, the heads and legs were removed and the bodies were eaten, or ground into a powder and added into cakes or soups (Riddell, 1960).

Hymenoptera

There are approximately 17,100 species of Hymenoptera in North America (Milne and Milne, 1980). Some species within this order, which includes ants, bees, yellow jackets and other wasps, form colonies containing large numbers of individuals, sometimes in the millions (Lindauer, 2015).

Twenty-one species of Hymenoptera, belonging to four families, were consumed by North American natives (Carr, 1951; Daguin, 1900; Essig, 1931).

Ants (Formicidae) were consumed as larvae, pupae, and as adults by North American natives (Skinner, 1910). The Northern Paiute (Ogden, 1950), Mono Lake Paiute (Muir, 1911), and Cahuilla (Bean, 1972) consumed ants as food. 'Ant pudding', which consisted of a scoop of ants cooked in coffee were consumed by Paiute natives as late as 1955 (DeFoliart, 1994).

The Onondaga (of the Haudenosaunee Confederacy) ate several ant species raw, and supposedly enjoyed them because of their acidity (Waugh, 1916). These ants were not so much a food necessity, but rather a treat used as a food flavour enhancer, as was also done by the Nishinam or Southern Paiute (Powers and Powell, 1877).

For the collection of large red ants (thought to have been red mound ants belonging to the genus *Formica*) natives would use a wild lettuce leaf to collect them, and once the leaves were covered with insects, they would shake some of them off and enjoy the newly flavoured lettuce (Powers and Powell, 1877). The red stinging ant (*Formica fusca* Linnaeus) was used as a form of medicine by the Yokuts (Essig, 1931). These ants were first boiled and then ingested to treat gastrointestinal illnesses (Powers and Powell, 1877). The Maidu of the northern California region, sometimes called Digger Indians, commonly enjoyed the larvae of the carpenter ant (*Camponotus* sp.); they would bite off the heads and eat only the bodies (Muir, 1911). Native people from the Great Basin region, such as the Western Shoshone, would dig up the 'large black ant' (*Camponotus maculatus* Fabricius) early in the morning when the ants would be stiff from cold overnight temperatures. The collected insects would be sorted from the soil in a basket, dried over hot coals, and ground into a 'flour' (Steward, 1941). Another Shoshoni method to capture ants was to place a piece of fresh animal skin or fresh bark along the tops of the anthills. Once the surface was covered by ants they could then be shaken off into a container and dried for later use (Bancroft, 1889).

Even Whites, such as the lumberjacks in Québec and Maine caught and ate carpenter ants, thought to be *Camponotus pennsylvanicus* De Geer (Provancher, 1882; Riley and Howard, 1893). The Malecites in New Brunswick utilised black ants, which they scoured off of dead trees, and used as a source of food and as a medicine (Carr, 1951). However, whether these also belonged to the genus *Camponotus* is unknown.

Natives from the North and South Carolina regions were documented to have consumed wasp (Vespidae) larvae and pupae (Brickell, 1737; Daguin, 1900), and in northwestern

California, natives were known to smoke out nests of yellow jackets, hornets, and other wasps to collect the larvae, and consume them raw (Essig, 1931). The Miwok from California had a special technique for finding the nests of yellow jackets; a grasshopper leg was used as bait, and once a wasp took the bait they would follow it to its nest (Garth, 1976). The Cherokee dug yellow jacket larvae out of their nests; these were appreciated because of their sweetness (Carr, 1951).

Gall wasps (Cynipidae) were also used as a source of food. When an egg or larva of a gallwasp is present on an oak tree, the tree produces a growth of plant tissue around the insect called a gall (Buss, 2011). The Montauk called the gall 'sour jugs' and used them as food (Carr, 1951).

Lepidoptera

The order Lepidoptera includes butterflies and moths, of which 12,000 species have been described in North America (Milne and Milne, 1980). Natives from the North American west have been extensively documented to consume Lepidoptera. Eleven species, within six families were used as a food source by North American native peoples (Jongema, 2015); amongst them were the tiger moth (*Arctia caja americana* Harris (Arctiidae)), giant skipper (*Megathymus yuccae* Boisduval & Leconte (Hesperiidae)), and tent caterpillars (*Malacosoma* sp. (Lasiocampidae)) (Ebeling, 1986; Essig, 1949; Powers and Powell, 1877).

Larvae of the pandora moth (*Coloradia pandora* Blake (Saturniidae)), called 'pe-aggie' by the Paiute, were collected and consumed by natives in western North America (Aldrich, 1921). These insects generally have a 2-year cycle (Carolin Jr. and Knopf, 1968), which meant that the harvesting period would have been every other year (Aldrich, 1921). In late June or early July, during a period of 12-25 days, larvae 5-6 cm in length would drop from Jeffrey pines (*Pinus jeffreyi* Balfour) to pupate below ground (Essig, 1934; Patterson, 1929). However, before they could do so, the native communities, such as the Modoc, Western Mono, and Klamath, would harvest them by either sorting through the soil, or by digging trenches around the base of the tree (such as done by the Mono Lake and Owen's Valley Paiute) (Aldrich, 1921). Although several authors describe the use of fire by native people to 'smoke out' caterpillars, in 1981 Fowler was told by the Owen's Valley Paiute Elders that building a fire would not make them fall down any faster (Fowler and Walter, 1985). The larvae heads were removed and the bodies would then be prepared in many ways such as being skewered and roasted on sticks, boiled and eaten immediately, or sometimes dried and stored for later usage (Essig, 1931; Fowler and Walter, 1985).

The Cahuilla would travel long distances to gather the large larvae (7-10 cm) of the white sphinx moth (*Hyles lineata*

(Sphingidae) from a variety of plants (Wright, 1884). Once prepared, the larvae could be lightly roasted and eaten immediately, or the heads would be removed and the bodies dried and ground into a powder. The larvae of the tobacco hornworm (*Manduca sexta* Linnaeus (Sphingidae)) were consumed by natives of the continental west (Palmer, 1871). For example, the Pima gathered these caterpillars and sometimes added them to a soup or stew along with vegetables, meal or seeds. As with other larvae, these were also commonly roasted or fried, and sometimes dried to be made into a powder or otherwise stored for the winter (Palmer, 1871).

Odonata

Dragonflies and damselflies make up the order of Odonata. There are approximately 450 named species in North America (Milne and Milne, 1980). The only account of consumption of a species within the Odonata concerns nymphs of the common blue darner (*Rhionaeschna multicolor* Hagen (Aeschnidae)), which was used as a source of food by natives in the west (Ebeling, 1986).

Plecoptera

There are over 400 species within the order Plecoptera, which are collectively called stoneflies (Milne and Milne, 1980). The adult stoneflies can be found near streams and rivers. Their aquatic nymphs feed on algae and underwater plants (Milne and Milne, 1980). Both adults and nymphs of stoneflies were used as a food source by California natives (Ebeling, 1986). The Atsugewi of northern California collected adult stoneflies in the early morning along the sides of streams. Before cooking, the wings would be removed and the insect body boiled (Ebeling, 1986). The California salmonfly (*Pteronarcys californica* Newport (Pteronarcyidae)) is suggested to have been used as food by the people of the Achumawi, Modoc, and Wintu bands, whom also lived in northern California (Du Bois, 1935; Sutton, 1985).

3. Future directions

For the species described in this review, little nutritive information is available. Further studies could determine the nutrient composition of native North American edible insect species, in order to provide insight as to their nutritive value and suitability as a source of modern food. Furthermore, to the best of our knowledge there are no studies being conducted on present day North American communities that currently practice entomophagy, or who have practiced in the past. In order to gain insight into human dietary patterns that include insect consumption, insect foods should be included in research instruments, such as the Food Frequency Questionnaire and food composition databases. Mainstream and 'pocket populations' such as

islanders (e.g. Guam, Hawaii, Puerto Rico, and Greenland) and recent immigrant groups should be surveyed. By collecting these data, insight will be gained regarding the use and the suitability of native insects as food in North America today and into the future.

4. Conclusions

Across Northern America a large variety of insects was consumed as traditional food by some natives and settlers. These were collected with specific methods and prepared for consumption in a variety of ways, depending upon the insect species and the culture of the gatherer. In recent years, insects have been reintroduced into North American diets. In order to gain insight into this trend, dietary research instruments should include insects and research inquiry should focus upon the nutrient composition of insect foods and consumer dietary intake of such foods. It is probable that in the near future species-specific ways of preparation and consumption of native edible insects will resume in Northern America.

Acknowledgements

We would like to thank Dr. Fidji Gendron from First Nations University of Canada, for translating francophone documents.

References

- Aldrich, J.M., 1921. *Coloradia pandora* Blake, a moth of which the caterpillar is used as food by Mono Lake Indians. *Annals of the Entomological Society of America* 14: 36-38.
- Anderson, R.M., 1918. Eskimo food: how it tastes to a white man. *The Ottawa naturalist*. Ottawa Field-Naturalists' Club, Ottawa, Canada, pp. 59-65.
- Arnett, R.H., Thomas, M.C., Skelley, P.E. and Frank, J.H., 2002. *American beetles*. Vol. II: Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, Boca Raton, FL, USA, 880 pp.
- Bancroft, H.H., 1889. *The works of Hubert Howe Bancroft: history of Arizona and New Mexico*. 1889, 17. The History Company, San Francisco, CA, USA, 829 pp.
- Bean, L.J., 1972. *Mukat's people: the Cahuilla Indians of southern California*. University of California Press, Oakland, CA, USA, 201 pp.
- Bell, W.H. and Castetter, E.F., 1937. *The utilization of mesquite and screwbean by the aborigines in the American southwest*. University of New Mexico Press, Albuquerque, NM, USA, 55 pp.
- Berenbaum, M., 1994. *Bugs in the system: insects and their impact on human affairs*. Addison-Wesley, Reading, MA, USA, 377 pp.
- Bodenheimer, F.S., 1951. *Insects as human food; a chapter of the ecology of man*. Dr. W. Junk Publishers, The Hague, the Netherlands, 352 pp.
- Brewer, W.H. and Farquhar, F.P., 1975. *Up and down California in 1860-1864: the Journal of William H. Brewer*. University of California Press, Oakland, CA, USA, 583 pp.
- Brickell, J., 1737. *The natural history of North-Carolina*. James Carson, Dublin, Ireland, 431 pp.
- Browne, J.R., 1957. *Washoe revisited: notes on the silver regions of Nevada*. Biobooks, Oakland, CA, USA, 186 pp.
- Bryant, E., 1895. *What I saw in California*. University of Nebraska Press, Lincoln, NE, USA, 468 pp.
- Bukkens, S.G.F., 1997. The nutritional value of edible insects. *Ecology of Food and Nutrition* 36: 287-319.
- Bukkens, S.G.F. and Paoletti, M.G., 2005. Insects in the human diet nutritional aspects. In: Paoletti, M.G. (ed.) *Ecological implications of minilivestock: potential of insects, rodents, frogs and snails*. Science Publishers, Enfield, NH, USA, pp. 545-577.
- Buss, E.A., 2011. Facts about gall on oaks. Available at: <http://tinyurl.com/p2r2xa7>.
- Bye, R.A., 1972. Ethnobotany of the southern Paiute Indians in the 1870's: with a note on the early ethnobotanical contributions of Dr. Edward Palmer. In: Fowler, D.D. (ed.) *Great basin cultural ecology, a symposium*. Desert Research Institute, Reno, NV, USA, pp. 87-104.
- Campbell, P.D., 1999. *Survival skills of native California*. Gibbs Smith, Layton, UT, USA, 448 pp.
- Carolin Jr., V.M. and Knopf, J.A.E., 1968. *The Pandora moth. Forest pest leaflet*. US Department of Agriculture, Washington, DC, USA, 7 pp.
- Carr, L.L.G., 1951. Interesting animal foods, medicines, and omens of the eastern Indians. *Journal of the Washington Academy of Sciences* 41: 229-235.
- Collinson, P., 1764. Some observations on the cicada of North America, collected by Mr. P. Collinson. *F. R.S. Philosophical Transactions* (1683-1775) 54: 65-68.
- Daguin, A., 1900. Les insectes comestibles dans l'antiquité et de nos jours. *Le Naturaliste*, 29 pp.
- Davis, J.T., 1974. *Trade routes and economic exchange among the Indians of California*. University of California Archaeological Survey. Ballena Press, Ramona, CA, USA, 71 pp.
- DeFoliart, G.R., 1994. Edible insects as minilivestock. *Biodiversity and Conservation* 4: 306-321.
- DeFoliart, G.R., 2002. The human use of insects as food resource: a bibliographic account in progress. Available at: <http://tinyurl.com/jna64w5>.
- Deroy, O., Reade, B. and Spence, C., 2015. The insectivore's dilemma, and how to take the West out of it. *Food Quality and Preference* 44: 44-55.
- Dixon, R.B., 1905. *The Northern Maidu*. Knicker-Bocker Press, Albany, NY, USA, 228 pp.
- Du Bois, C.A., 1935. *Wintu ethnography*, 36. University of California Press, Oakland, CA, USA, 148 pp.
- Ebeling, W., 1986. *Handbook of Indian foods and fibers of arid America*. University of California Press, Oakland, CA, USA, 971 pp.
- Egan, H. and Egan, W.M., 1917. *Pioneering the West, 1846 to 1878: major Howard Egan's diary: also thrilling experiences of pre-frontier life among Indians, their traits, civil and savage, and part of autobiography, inter-related to his father's*. H.R. Egan Estate. Richmond, UT, USA, 302 pp.
- Essig, E.O., 1931. *A history of entomology*. The Macmillan Company, New York, NY, USA, 1029 pp.
- Essig, E.O., 1934. The value of insects to the California Indians. *The Scientific Monthly* 38: 181-186.

- Essig, E.O., 1949. Man's six-legged competitors. *The Scientific Monthly* 69: 15-19.
- Finke, M.D. and Oonincx, D.G.A.B., 2013. Insects as food for insectivores. In: Morales-Ramos, J.A., Rojas, M.G. and Shapiro-Ilan, D.I. (eds.) *Mass production of beneficial organisms: invertebrates and entomopathogens*. Academic Press, London, UK, pp. 583-616.
- Fletcher, T.C., 2014. Kutzadika'a people. Living in harmony with the Mono Basin. Mono Lake Committee, Lee Vining, CA, USA. Available at: <http://tinyurl.com/z64vkjj>.
- Food and Agriculture Organisation (FAO), 2009. The state of food and agriculture 2009 – livestock in the balance. *Animal Genetic Resources* 47, 165 pp.
- Fowler, C.S. and Walter, N.P., 1985. Harvesting Pandora moth larvae with the Owens Valley Paiute. *Journal of California and Great Basin Anthropology* 7: 155-156.
- Fynn, A.J., 1907. *The American Indian as a product of environment: with special reference to the pueblos*. Little Brown and Company, New York, NY, USA, 275 pp.
- Garcia, M., 2000. *Melanoplus spretus*. The Animal Diversity Web, Ann Arbor, MI, USA. Available at: <http://tinyurl.com/nrosjz3>.
- Garth, T.R., 1976. *Atsugewi ethnography*. Kraus Reprint, New York, NY, USA, 84 pp.
- Harper, F., 1955. *The barren ground caribou of Keewatin*. University Press of Kansas, Lawrence, KS, USA, 163 pp.
- Harrington, M.R., 1945. *Masterkey: anthropology of the Americas* 19. Southwest Museum, Los Angeles, CA, USA.
- Hearne, S., 1795. *A journey from Prince of Wales's fort in Hudson's Bay, to the northern ocean*. The Champlain Society, New York, Canada, 1079 pp.
- Herrero, M., Havlik, P., Valin, H., Notenbaert, A., Rufino, M.C., Thornton, P.K., Blümmel, M., Weiss, F., Grace, D. and Obersteiner, M., 2013. Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. *Proceedings of the National Academy of Sciences* 110: 20888-20893.
- Hickman, C.P., Roberts, L.S. and Larson, A., 2001. *Terrestrial mandibulates. Integrated principles of zoology*. McGraw-Hill Companies Inc, New York, NY, USA, pp. 407-435.
- Hoffman, W.J., 1896. *The Menomini Indians*, 14. US Government Printing Office, Washington, DC, USA, 422 pp.
- Hooper, L., 1920. *The Cahuilla Indians*. University of California Press, Oakland, CA, USA, 65 pp.
- Jongema, Y., 2015. List of edible insects of the world. Wageningen UR, Wageningen, the Netherlands. Available at: <http://tinyurl.com/mestm6p>.
- Lindauer, M., 2015. Hymenopteran. *Encyclopædia Britannica*, Inc., Chicago, IL, USA. Available at: <http://www.britannica.com/animal/hymenopteran>.
- Looy, H., Dunkel, F. and Wood, J., 2014. How then shall we eat? Insect-eating attitudes and sustainable foodways. *Agriculture and Human Values* 31: 131-141.
- Madsen, D.B., 1989. A grasshopper in every pot. *Natural History* 7: 22-25.
- Madsen, D.B. and Kirkman, J.E., 1988. Hunting hoppers. *American Antiquity* 53: 593-604.
- Madsen, D.B. and Schmitt, D.N., 1998. Mass collecting and the diet breadth model: a great basin example. *Journal of Archaeological Science* 25: 445-455.
- Marlatt, C.L., 1898. *The periodical cicada*. US Department of Agriculture, Washington, DC, USA, 148 pp.
- Martin, D., 2014. *Edible: an adventure into the world of eating insects and the last great hope to save the planet*. Houghton Mifflin Harcourt Publishing Company, New York, NY, USA, 272 pp.
- Merritt, R.W., Courtney, G.W. and Keiper, J.B., 2009. Chapter 76 – Diptera: (flies, mosquitoes, midges, gnats). In: Cardé, V.H.R.T. (ed.) *Encyclopedia of insects*. Academic Press, San Diego, CA, USA, pp. 284-297.
- Meyer-Rochow, V., 1972. Eskimos: geschichte und umwelt. *Selecta* 14: 957-960.
- Milne, L.J. and Milne, M.J.G., 1980. *The Audubon society field guide to North American insects and spiders*. The University of California Press, Oakland, CA, USA, 989 pp.
- Muir, J., 1911. *My first summer in the Sierra*. Houghton Mifflin, Boston, MA, USA, 426 pp.
- Naskrecki, P., 2004. Orthoptera (grasshoppers, crickets, and katydids). *Grzimek's animal life encyclopedia*. Gale, Detroit, MI, USA, pp. 201-216.
- Nomland, G.A., 1938. *Bear river ethnography*. *Anthropological records*. Vol. 2. University of California Press, Oakland, CA, USA, pp. 91-126.
- Ogden, P.S., 1950. *Peter Skene Ogden's snake country journals, 1824-25 and 1825-26*. Hudson's Bay Record Society, London, UK, 201 pp.
- Oonincx, D.G.A.B. and De Boer, I.J.M., 2012. Environmental impact of the production of mealworms as a protein source for humans – A life cycle assessment. *PLoS One* 7: e51145.
- Oonincx, D.G.A.B., Van Itterbeeck, J., Heetkamp, M.J., Van den Brand, H., Van Loon, J.J. and Van Huis, A., 2010. An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PLoS One* 5: e14445.
- Oonincx, D.G.A.B., Van Broekhoven, S., Van Huis, A. and Van Loon, J.J.A., 2015. Feed conversion, survival and development, and composition of four insect species on diets composed of food by-products. *PLoS ONE* 10: e0144601.
- Palmer, E., 1871. *Food products of the North American Indians*. Publisher not identified, Place of publication not identified, 24 pp.
- Patterson, J.E., 1929. *The Pandora moth, a periodic pest of Western pine forests*. Technical Bulletin No. 137: 1-19. US Department of Agriculture, Washington, DC, USA.
- Powers, S. and Powell, J.W., 1877. *Tribes of California*. US Government Printing Office, Washington, DC, USA, 639 pp.
- Provancher, L., 1882. *Faune Canadienne. Hymenopteres. Additions et corrections*. *Naturaliste Canadien* 13: 289-311.
- Ramos-Elorduy, J., 1996. Insect consumption as a means of national identity. IV International Congress of Ethnobiology, Lucknow. Deep publications, New Delhi, India, pp. 9-12.
- Reagan, A.B., 1934. *Some notes on the history of the Uintah Basin, in northeastern Utah, to 1850*. Utah Academy, St. George, UT, USA, 10 pp.
- Riddell, F.A., 1960. *Honey Lake Paiute ethnography*. Nevada State Museum, Carson City, NV, USA, 20 pp.
- Riley, C.V. and Howard, L.O., 1893. *Insect life*. US Government Printing Office, Washington, DC, USA, 401 pp.

- Roust, N.L., 1967. Preliminary examination of prehistoric human coprolites from four western Nevada caves. University of California Archaeological Survey Papers on Great Basin Archaeology: 49-88.
- Rozin, P. and Fallon, A.E., 1987. A perspective on disgust. *Psychological review* 94: 23.
- Russell, F., 1898. Explorations in the far north. State University of Iowa, Iowa City, IA, USA, 209 pp.
- Sanborn, A. and Phillips, P., 2013. Biogeography of the cicadas (Hemiptera: Cicadidae) of North America, north of Mexico. *Diversity* 5: 166-239.
- Skinner, A., 1910. The use of insects and other invertebrates as food by the North American Indians. *Journal of the New York Entomological Society* 18: 264-267.
- Steward, J.H., 1941. Culture element distributions XIII Nevada Shoshoni. *University of Anthropological Records* 4(2): 209-359.
- Steward, J.H., 1943. Culture element distributions XXIII Northern and Gosiute Shoshoni. *University of Anthropological Records* 8(3): 263-392.
- Sutton, M.Q., 1985. The California salmon fly as a food source in northeastern California. *Journal of California and Great Basin Anthropology* 7(2): 176-182.
- Sutton, M.Q., 1988. Insects as food: aboriginal entomophagy in the Great Basin. Ballena Press, Menlo Park, CA, USA, 115 pp.
- Van Huis, A., 2003. Insects as food in sub-Saharan Africa. *International Journal of Tropical Insect Science* 23: 163-185.
- Van Huis, A., Van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G. and Vantomme, P., 2013. Edible insects: future prospects for food and feed security. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, FAO Forestry Paper no. 171, 201 pp. Available at: <http://www.fao.org/docrep/018/i3253e/i3253e.pdf>.
- Verbeke, W., 2015. Profiling consumers who are ready to adopt insects as a meat substitute in a Western society. *Food Quality and Preference* 39: 147-155.
- Waugh, F.W., 1916. Iroquois foods and food preparation. Coyote Press, Salinas, CA, USA, 251 pp.
- Wirth, W.W., 1971. The brine flies of the genus *Ephydra* in North America (Diptera: Ephydriidae). *Annals of the Entomological Society of America* 64: 357-377.
- Witherspoon, W.W., 1889. Collection of honey dew by the Nevada Indians. *American Anthropologist* 2. American Anthropological Association, Arlington, VA, USA, pp. 380.
- Wright, W.G., 1884. A naturalist in the desert. *Overland Monthly* 4: 279-284.
- Yhoung-Aree, J. and Viwatpanich, K., 2005. Edible insects in the Laos PDR, Myanmar, Thailand, and Vietnam. In: Paoletti, M.G. (ed.) *Ecological implications of minilivestock: potential of insects, rodents, frogs, and snails*. Science Publishers Inc., Enfield, NH, USA, pp. 415-440.