BLOSSOMING TREASURES OF BIODIVERSITY

49. Milkweeds – a sustainable resource for humans and butterflies

Ernest Small*

Science and Technology Branch, Agriculture and Agri-Food Canada, Ottawa, Ontario K1A 0C6, Canada

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Introduction

Calling all butterflies of every race
From source unknown but from no special place
They ever will return to all their lives,
The milkweed brings up to my very door
The theme of wanton waste in peace and war
As it has never been to me before…

Where have those flowers and butterflies all gone
That science may have staked the future on?
He seems to say the reason why so much
Should come to nothing must be faced.

– Extract from Pod of the Milkweed
by Robert Frost (1874–1963)

Limiting human destruction of biodiversity requires compromise between two polar perspectives. On the one hand, biodiversity can be viewed primarily as a resource to be exploited for economic purposes. On the other, biodiversity can be conceived as intrinsically valuable, to be respected and admired for aesthetic and philosophical reasons. While this is a false dichotomy (both humans and all other living things will thrive only if we moderate our degradation of the planet’s ecosystems), it remains true that the survival of many wild creatures is determined by a contest between people intent only on profit and those who have championed biological conservation. This contribution discusses a prominent example of this struggle, which is particularly instructive because survival of the species in question depends not on saving it only in zoos and tiny wildlife preserves, but over a vast international, indeed intercontinental territory.

Almost everyone is familiar with the subjects of this review – the Monarch Butterfly (Danana plexippus; Figure 1) and its obligate food source, milkweeds (species of Asclepias). Various factors have contributed to Monarchs becoming charismatic champions of the cause of conservation: (1) their beauty and athleticism (Robert Frost called butterflies ‘flowers that fly’); (2) their charm, innocence and harmlessness; (3) the astonishing phenomenon of such tiny organisms, no heavier than paperclips, conducting round trips over vast distances between southern Canada and Mexico; (4) once ubiquitous in very large numbers, Monarchs are rapidly becoming alarmingly rare, and while it is all too easy to ignore the plight of most wildlife, the most beautiful jewels of the insect world demand sympathetic concern. Just as a dying Canary in a coal mine signals that an environment is dangerous to life, dying butterflies raise fear that we humans are poisoning our planet so seriously that our own welfare is threatened. The Monarch Butterfly story has become a teaching tool to educate schoolchildren (Figure 2) not just about science but about the values of the natural world and how to preserve it.

Schoolchildren and indeed the general public have been persuaded that the solution to preserving Monarchs is simply to plant milkweeds in the butterfly’s breeding and migrating areas but, as detailed in this review, the following factors need to be considered. (1) Several milkweed species are, consistent with their name, significant weeds, harmful to important agricultural crops and poisonous to livestock. (2) Some ornamental garden milkweeds planted in certain locations can actually be detrimental to Monarch Butterflies. (3) Milkweeds are currently under examination as new, profitable agricultural crops for useful products. Establishing such crops potentially has both good and bad consequences for Monarchs. (4) Additional developments influence the welfare of wild Monarch Butterflies and their milkweed hosts, such as climate change, the commercial trade in butterflies, and government programmes which either help or hurt biodiversity.

The plants

The milkweed genus Asclepias contains about 130 species, most native to the Americas, the majority in

*Email: Ernie.Small@agr.gc.ca

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tropical regions. Milkweeds are named for their milky, latex-containing sap, which makes the plants unpalatable to most animals. The most important chemicals in the sap are cardenolides, which are steroids of the cardiac glycoside category. The plants are herbaceous perennials, some of the species spreading vigorously by underground branching rhizomes. A few species are evergreen, but most have deciduous foliage. Milkweeds occur in a variety of habitats, including open wetlands, dry sandy areas, short- and tall-grass prairie, river banks, bogs, irrigation ditches and arid valleys, but several important species particularly grow in disturbed environments such as farmlands, along roadsides and in ditches.

Milkweeds have an unusual flower structure and pollination mechanism (Figure 3), found only in the Apocynaceae family (in which Milkweeds belong) and Orchidaceae (Orchids). The pollen is packaged into waxy masses or sacs of hundreds of pollen grains. Each tear-shaped sac is called a pollinium, and these are held together in pairs (a single pair is called a pollinarium) by arms attached to a pad (technically a ‘corpusculum’), the entire structure resembling a miniature saddle-bag. The specially designed flowers have slits between the anthers. These slits trap the legs (sometimes the mouthparts) of foraging insects and, while retrieving the leg, a groove in the pad often clasps the leg, attaching the pollinarium to the leg. When the insect visits the flower of another milkweed plant, a leg carrying a pollinarium again becomes trapped in a slit of the flower, but this time the pollinarium is deposited and serves to fertilise the flower. Because the pollinia have many pollen grains, the resulting fruit (Figure 4) may have many ovules fertilised and so each pod can develop numerous seeds (200–300 or so in some species). Milkweeds are pollinated mostly by Lepidoptera (butterflies and moths) and Hymenoptera (ants, bees and wasps). Large wasps are the most effective pollinators. The abundant nectar also attracts beetles and other insects, as well as hummingbirds, which are unlikely to be significant as pollinators.

The fruits of milkweeds (technically called follicles although usually referred to as pods) split at a suture when they are mature, releasing the seeds. The seeds bear a cluster of white, silky hairs. These tufts of hollow, fluffy seed fibres serve as parachutes or sails to take advantage of wind for seed dispersal.

The values of milkweed fibre

Milkweed stem fibre

Many plants are sources of natural fibre. Commercial natural plant fibres are especially obtained (1) from fibre attached to seeds (Cotton is an example), which serve to

Figure 1. Monarch Butterflies (Danaus plexippus) feeding on Swamp Milkweed (Asclepias incarnata). (a) Adult. Photo by Derek Ramsey (GDFL). (b) Caterpillar. Photo by Andrew C (CC BY 2.0).
distribute the seeds by wind, or (2) from stems (so-called ‘bast fibre’), where the fibre adds strength and flexibility. Indigenous people occasionally employed milkweed stem fibre for nets (Figure 5), cordage and coarsely woven textiles. In the past there has also been interest expressed in harvesting the stem fibre for paper and other modern products. However, as pointed out in the following, the seed fibre of milkweed plants, not the stem fibre, is the principal milkweed fibre of commercial interest today, particularly for bedding and insulated clothing.

Bedding
Milkweed seed fibres are durable, hypoallergenic, very soft, and cottony in appearance, all considerations desirable in pillows and comforters. Milkweed in combination with cotton is employed today for these products, albeit on a small scale.

Insulated clothing
Milkweed fluff is currently under consideration for use as a loose fill in insulated winter clothing and sleeping bags. Down is a better product for such purposes, but is much more expensive. A combination of down and other feathers with milkweed fluff is significantly cheaper than down, and represents a promising product.

Oil spill absorbents
In the province of Quebec, the Protec Company is growing several hundred ha of Milkweed to produce an oil spill absorbent for use in Canada’s national parks. The milkweed fibres are enclosed in floating tubes, and are able to absorb considerably more oil than polypropylene, the material currently widely used to clean up spills.

Textiles
Milkweed fluff is a difficult fibre to process for textile purposes, but blends with cotton have proven to have merit. Considerable research has been conducted to clarify textile applications of milkweed fibre. The market for textiles is dominated by synthetic fibres and cotton, so this sector is very competitive and it is difficult for new fibres to become established.

Filters
Milkweed seed fluff has been employed experimentally in filters employed to prevent leakage from two-stroke outboard motors, and has proven to be quite effective.

Flotation devices
The fluff attached to milkweed seeds is made up of individual fibres, which are hollow, buoyant, wax-covered (and therefore water-resistant), and so were once used to fill life jackets (also known as life vests). In recent times, synthetic preparations are employed for flotation, but in the past, kapok from the seed fibres of the tropical Kapok Tree (Ceiba pentandra) was the chief stuffing for life vests. During the Second World War, supplies of kapok, cultivated chiefly in the rainforests of Asia, became unavailable to the Allies, and milkweed fluff (from the Common Milkweed, A. syriaca) was widely substituted. US navy tests showed that 1 lb of milkweed fluff could keep a 150 lb sailor afloat for 40 h. About 20 lb of ripe milkweed pods had to be collected to provide enough fibre for a single life jacket, and school children were enlisted in milkweed fluff collection drives.

The values of milkweed seed oil
Most seeds (reminiscent of eggs) are a combination of an embryo and food reserves provided to give the seedling a boost in growth while it develops leaves for photosynthesis and roots to absorb water and minerals from the soil. Plants usually provide a specific form of food reserve — starch, oil (fat) or protein. Milkweed seeds contain 20–30% oil. Humans use the seeds of many species for food and other purposes, and in recent times the oil of Milkweeds has become a candidate for several applications.

Cosmetics and sunscreens
A cosmetic beauty product known as ‘Ingram’s milkweed cream’ (Figure 6) was widely sold in the early part of the twentieth century. Recently, chemical derivatives of components of milkweed seed oil are being marketed as base
materials for cosmetics, skin- and hair-care products, moisturisers, conditioners and sunscreens. Chemically transformed components of milkweed oil have been shown to be effective blockers of skin-damaging ultraviolet light. Processed milkweed oil holds water effectively and is therefore a good moisturiser. Cosmetic applications represent the most important economic usage of milkweed oil at present.

**Industrial chemicals**

Oilseeds are rich in hydrocarbons, and these are often valuable as industrial chemicals. Milkweed has not yet proven to be an economic source, but this is an area deserving considerable research effort as several milkweed compounds might be quite profitable. Polyphenols such as occur in milkweeds have potential for wood laminating resins, plywood glues, particleboard adhesives, fortifiers for starch adhesives, oil well drilling muds, clay floculants and plastics. Oil components that are present could be used in a wide variety of chemical intermediates. Other extracts might be usable as high value lubricants or coatings.

**Food and dietary extracts**

The oil in milkweed seeds is rich in unsaturated fatty acids, and is potentially usable as human food. The lipids (particularly the fatty acids and sterols) have potential as health-promoting extracts (‘nutraceuticals’). The oilseed sector is dominated by established crops, several of which are currently marketed for their healthful oil and extracts, and the productivity of milkweed would have to be raised considerably to penetrate this market sector.

**Biodiesel**

Oilseeds can be used to prepare biodiesel fuels, and it is conceivable that milkweed could be a candidate for this application. However, Soybean, Rapeseed and tropical oilseeds are very much more productive than milkweed, and are unlikely to be displaced. There was some interest in researching the possible biodiesel use of milkweed oil in the last decades of the twentieth century, but interest has since waned.

**The values of milkweed nectar**

Milkweeds are valued for high quality honey production. Common Milkweed (*A. syriaca*) produces nectar both during the day and at night, and is visited by pollinators 24 h a day. A large Honey Bee colony can gather 6–7.7 kg (13–17 lb) of nectar from Common Milkweed in 1 day. Honey Bees are known to produce as much as 50 kg of honey per ha (45 lb per acre) from milkweeds.

Figure 3. Milkweed pollinaria (paired sacs of pollen grains) attached to pollinators. (a) A Bumble Bee on Swamp Milkweed (*Asclepias incarnata*), with pollinaria attached to the front legs. Photo by Rodger Evans (CC BY ND 2.0). (b) Pollinaria attached to the leg of a Long-horned Bee (*Melissodes trinodis*). Photo by Sam Droege (CC BY 2.0).
Miscellaneous uses of Milkweeds

Milkweed latex was employed during World War II as a source of rubber, but with quite limited success, particularly because the content of rubber is low. The latex has been used as glue and even as chewing gum, but all of these usages were very minor and are obsolete.

The seed meal remaining after oil is extracted from the seeds is high in protein, unsuitable for food because it is high in the toxic cardenolides mentioned earlier. However, the protein has potential as a chemical feedstock for industrial purposes. The seed meal has been shown to kill nematodes, and to act as a pesticide against Fall Army Worms, suggesting possible use in plant protectants.

Pet litter and fireplace logs have been prepared from milkweed pods. Such usages are very minor, but if a major milkweed industry becomes established, leftover ‘waste’ products such as pods offer the possibility of salvage for secondary products.

Indigenous peoples made wide use of milkweeds for medicine, treating dozens of disease conditions. The young shoots, stems, roots, flower buds and young fruits of some species were also boiled and eaten as a vegetable or used as a flavouring by American Indians, but the more toxic species required several changes in boiling water. (There is controversy over whether the widespread *A. syriaca* requires such treatment to make it edible.) The copious nectar from milkweed flowers is high in sugar and Indigenous People as well as voyageurs used it as a sweetener. In general it is unwise to take milkweeds internally (although seed extracts, as noted above, have some culinary potential).

Agricultural cultivation of Milkweed

Weeds are notorious for their ability to grow without human care, and so it is surprising that when humans learn that certain weeds have properties so useful that they deserve to be cultivated, they often prove very difficult to cultivate. Ironically, one of the problems is that they suffer from other weeds, and this is certainly the case when one attempts to grow milkweeds. Also ironically, some growers of milkweeds, for the purpose of generating seeds to establish plants to conserve Monarch Butterflies, have used glyphosate herbicide to control weeds – the very herbicide, as described later, that has been associated with widespread destruction of milkweeds. Diseases and pests (including Monarchs) are also significant problems. As noted later, using pesticides to control pests of milkweed could pose a serious problem for Monarchs, indeed for several butterflies. Monarch Butterflies are voracious feeders on milkweed foliage, and are capable of defoliating plants grown for industrial purposes, so they may need to be controlled. Also, other insects may need to be eliminated, and in doing so any visiting Monarchs are likely to be harmed. Because of the economic possibilities for producing various products, a number of researchers have examined methods of cultivating milkweeds, and these are described in the literature cited at the end of this review. Borders and

Figure 4. Milkweed fruits and seeds. (a) A mature pod of Common Milkweed (*Asclepias syriaca*) split open along a suture to reveal the seeds. Photo by Mdf (CC BY 3.0). (b) A milkweed pod releasing seeds. Photo by Harry Alverson CC BY 2.0).
The populations of numerous native plants are being reduced because of the spread of civilisation, and milkweed is one of the casualties. While there is sympathy for the survival of several of the rare milkweed species, in the context of butterfly conservation the main concern is for the common species that are hosts for most butterflies. Reduction of the dominant milkweed species has been attributed especially to (1) agricultural practices, particularly the establishment of crop monocultures which simply exclude all other plants from a region, and (2) the use of herbicides. The US Midwest is the world’s most productive location for Monarch Butterflies, especially the Corn Belt region, where Monarch breeding is greater than anywhere else. In the Midwestern US, as much as 70% of milkweeds occur in agricultural lands. Mowing and application of herbicides to roadsides and weedy lands has been especially responsible for reducing milkweed populations.

Curiously, Common Milkweed (*A. syriaca*; Figure 7) actually seems to have increased in areas of the US in the late twentieth century because it was resistant to the principal herbicides of the time. Today, however, ‘Round-Up Ready’ transgenic crops are being sprayed with powerful glyphosate herbicide, killing the milkweed and other weeds, while sparing the crops which have been genetically modified to tolerate the herbicide. This problem should not be confused with another issue related to engineered crops: in the past, the pollen of Bt-transformed crops (particularly Corn, i.e. Maize) was thought to rain down on milkweeds in sufficient quantities to poison Monarchs. While Bt toxins are widely believed to be selectively toxic to certain insects, including some Lepidopteran larvae, current majority opinion is that Monarchs are not significantly affected (Minorsky 2001). Milkweed was once widespread in The Corn Belt of the US. Today, herbicide-resistant Corn and Soybean predominate there, and milkweeds are quite rare in the cultivated fields. Oddly, and reflecting an attempt to please everyone, the US government supports the questionable corn ethanol programme, which has greatly increased American corn production, thereby harming Monarch Butterflies, while at the same time engaging in admirable programmes to preserve Monarchs.

The corresponding plight of Monarch Butterflies

The name ‘Monarch Butterfly’ generally refers to the species *Danaus plexippus*, although some specialists also use it for some other butterflies. This species is occasionally found as an introduction in locations around the world, but primarily ranges from North America to northern South America (Figure 8). The Monarch is famous for its north-south migrations in North America. Although it is a tropical insect, it ‘vacations’ as far north as southern...
Canada. However, Monarchs are incapable of surviving temperate-zone winters (even as eggs or pupae).

Monarch Butterflies east of the Rocky Mountains mostly exhibit the following pattern. In the autumn, a large group (tens of millions) of adults migrates (Figure 9) south from southern Canada and the northern US to overwinter in very small areas in the mountains of central Mexico, in high-altitude forests of Oyamel Fir (Abies religiosa). In the spring (February and March) these same individuals migrate to northern Mexico and the southern US, where they lay eggs. The new generation migrates northwards until they occupy the Midwestern and northeastern US and southern Canada from May to August, where they pass through two or more generations over the summer before migrating southwards in late August. One of the fascinating aspects of this cycle is that no individual completes the entire circuit, sometimes as long as 3200 km (2000 miles) between Canada and Mexico. Butterflies that reach Mexico may be the great-great-grandchildren of the butterflies that left the country the previous spring, and it is a mystery how they find their way back to the same roosting locations occupied by their great-great-grandparents, sometimes even the same trees. Most individual adults only live for 4 to 6 weeks, but the late summer generation which overwinters in Mexico lives 6 to 7 months.

West of the Rocky Mountains, a relatively small group (several hundred thousand) of Monarchs migrates from southern Canada and the western US to overwinter in the southern California coast, and occasionally in Mexico. Whether in Mexico or California, butterflies are also widely used to limit vegetation from encroaching on railways and power line corridors, although this is basically to control shrubs and trees. Milkweeds are innocent victims of such spraying, and accordingly so are Monarch Butterflies, which is unfortunate since milkweeds not just for habitat and food but also for protective chemicals.

As noted previously, habitat destruction and herbicide application in cultivated fields and along roadsides have reduced milkweed availability to Monarchs. Herbicides are also widely used to limit vegetation from encroaching on railways and power line corridors, although this is basically to control shrubs and trees. Milkweeds are innocent victims of such spraying, and accordingly so are Monarch Butterflies, which is unfortunate since railways and power lines provide very long routes that are often ideal for migration.

Habitat destruction by logging and by excessive ecotourism has endangered the refugia in Mexico where most migrating Monarchs overwinter. However, efforts have been made to protect designated areas.

American biologist Paul Ehrlich (author of The Population Bomb) may have exaggerated in stating ‘The fluttering of a butterfly’s wings can effect climate changes on the other side of the planet’, but climate change is thought to be exerting detrimental effects on Monarch Butterflies. A frightening scenario concerns the future climate of the very small Mexican highland sites where the insects overwinter (averaging only 6 ha or 16 acres): it has been suggested that the climate there could change so significantly that most of the world’s Monarchs could vanish.
The release of butterflies to celebrate events such as weddings (where a dozen butterflies can cost $100.00) or associated with classroom activities (monarch/milkweed educational kits generally sell for around $40.00) and butterfly display houses is controversial. Some fear (with variable levels of justification) that certain releases or escapes of butterflies could spread diseases, result in harmful hybridisation, disrupt scientific analysis of natural geographical distributions, introduce invasive species, and endanger rare species of plants (particularly endangered milkweeds). Butterflies are a significant cash crop, and there are dozens of ‘butterfly farms’ in North America, distributing over 10 million insects annually, mostly Monarchs and Painted Ladies (Vanessa subgenus Cynthia). There is also a global butterfly house industry supplying butterfly pupae as a cash crop, largely conducted by privately-owned butterfly farms in tropical countries, particularly Central America and Southeast Asia. Unfortunately at upwards of $10.00 for a Monarch Butterfly, there is also poaching from the wild. Trade in butterflies is regulated, particularly with respect to shipping from one location to distant places. A widespread recommendation is that butterflies should only be released if collected in a local region and released there.

Monarchs are charismatic, attracting widespread sympathy for conservation of habitats, which benefits not just the butterflies but also a host of other species. The Monarch Butterfly migration has been designated ‘an endangered biological phenomenon’, although the species is not considered to be at risk of extinction at present. There is extensive encouragement to plant personal milkweed gardens to provide foliage as fodder for monarch caterpillars, preferably using local native milkweed species. As well, nectar-producing plants are desirable to feed the adults, which unlike the larvae are able to utilise a wide range of nectar-bearing plants.

**Harmful aspects of Asclepias species**

Milkweeds are usually very minor, but sometimes quite significant agricultural weeds of crops grown in rows (such as Corn and Soybean). Some cereal farmers in the eastern US have been so frustrated with Common Milkweed (A. syriaca) that they have referred to it as ‘the Wheat Farmer’s Nightmare’.

Most milkweed species have toxic agents, including alkaloids, in the milky latex for which the plants are named. However, cardenolides (which are cardiac glycosides capable of seriously depressing heart function) are the primary poisons of milkweeds. These toxic agents protect the plants from being eaten by various herbivores, although Monarch Butterflies are very resistant to the levels of cardenolides in most milkweed species. As noted previously, adult Monarchs contain considerable cardenolides acquired from the plants, and use these as chemical warfare weapons against predators. Similarly, native people of South America and Africa also used milkweed latex as a poison by coating their arrowheads to improve hunting. Milkweeds occur in pastures, and can contaminate the resulting hay. Some milkweeds are toxic to livestock, and indeed sometimes are fatal. Sheep and goats are most susceptible because of their habit of browsing. Cattle and sometimes horses have also been poisoned by milkweed, and poultry are also sensitive. Consumption of as little as 0.2% (fresh weight) of Western Whorled Milkweed (A. subverticillata) is known to cause death in livestock. However, most vertebrates are not attracted to the plants, although some mammals...
such as Jackrabbits can appreciably damage milkweeds. Poisoning usually occurs when livestock are penned in a small area with little choice except milkweed, or when fed fodder contaminated with milkweed.

Cultivating milkweeds as garden ornamentals and for promoting Monarch Butterflies

Nurseries now frequently offer milkweed stock for gardeners and conservationists. Local native plant societies also often provide seeds for planting. Tips for establishing milkweed plants are available on the Web, as well as in several of the references cited later.

Many species of *Asclepias*, especially *A. incarnata* (Swamp Milkweed) and *A. tuberosa* (Butterfly Weed; Figure 11), are planted in gardens for their beautiful flowers. Butterfly Weed should not be confused with ‘Butterfly Bush’, any of more than 100 species of *Buddleja* (*Buddleia*), especially *B. davidii*, a beautiful garden ornamental known for attracting butterflies. This species is an excellent nectar source, but completely unsuitable for butterfly larvae. It is also so invasive in some regions that it is banned. Tropical Milkweed (*Asclepias curassavica*; Figure 12) is perhaps the most beautiful and frequently grown species. Many attractive cultivars of Tropical Milkweed are available, and the species has become dominant among garden milkweeds. This native of the tropical Americas is often grown as an annual in northern regions, and has become naturalised in some US states. Although very attractive to Monarchs, cultivating this species is somewhat controversial as some specialists have raised the possibility that it induces the butterflies to linger in some regions (particularly the southern US) rather than flying south. Remaining too long in a given location may increase the prevalence of butterfly diseases, especially the protozoan parasite *Ophryocystis elektroscirrha*.

About 30 species of milkweeds have been documented to be hosts for Monarch Butterflies, although probably almost all species can be utilised. Conservation specialists strongly recommend planting native milkweed species to promote butterfly welfare. The US Department of Agriculture’s PLANTS Database (USDA 2014) provides distribution maps for 74 species of *Asclepias* native to the US, some extending into Canada, and these maps are helpful in knowing what species are adapted to local regions. Many milkweed species are important food plants for Monarchs but, in the eastern range, Common Milkweed (*A. syriaca*) is the most important. Because seeds of only a few species of *Asclepias*, known to be good food plants of Monarchs, are available from commercial and conservation sources, it is necessary to do some research to learn what species are best locally in North America. The online document USDA (2015) is helpful in this regard.

It may seem unlikely that personal milkweed gardens can significantly assist Monarchs. However, planting small, scattered stands of milkweeds has been said to be better than establishing large stands, because the latter attract concentrations of predators of the plants and parasites of the butterflies. Indeed, the agricultural growth of milkweed monocultures is known to suffer from such problems. ‘Butterfly gardens’ are usually established, like birdfeeders, so that the gardeners can attract beautiful and entertaining animals. Probably some people who maintain milkweeds for Monarch consumption think that their primary purpose is to provide nectar for the attractive adult butterflies, rather than for the less attractive caterpillars, and are disappointed when they find the larvae consuming their plants.

Milkweeds could be employed as naturalising plants for highway beautification, landscaping, habitat restoration and erosion control (in fact they are sometime included in wildflower mixtures intended for these purposes). Such usages could be extremely helpful for providing food for Monarch Butterflies along their flyways.

Summary and recommendations

Cultivated milkweed is a multi-purpose, quite minor industrial crop with several economic applications at pre-
sent (Table 1). It is possible that the floss and oil associated with the seeds will prove to have greater commercial uses in the future, which would justify substantial cultivation in the same ways that agricultural crops are grown. Generally, such speciality crops are cultivated on a relatively small scale and so are welcome additions to crop diversification – far less damaging to ecosystems than the major large-scale monocultures. Unfortunately, commercial fields of milkweed grown for industrial purposes could well be subjected to pesticides to control insects, including Monarch Butterfly caterpillars, and this would be a most unwelcome development. Further, cultivation of milkweeds in southern areas of the natural distribution range of Monarch Butterflies could cause them to tarry or even become residents there, with the accompanying worsening of diseases, as has been demonstrated to occur in such circumstances. The milkweed industries are in their infancy, but it is to be hoped that codes of ethics respecting the Monarch Butterfly will be developed. It may be noted that cultivating milkweeds on an industrial basis in countries outside of the native distribution in the Americas would not endanger the butterflies.

Milkweeds grown as ornamentals are generally very helpful in providing food for Monarch caterpillars, although as noted earlier, in southern areas the butterflies can be induced to remain instead of migrating, to their detriment. Some milkweed species can become invasive, harming natural ecosystems, and care needs to be exercised in this regard. To avoid this, environmentally-conscious gardeners are being urged to plant local milkweed species, but seed supplies from nurseries and local nature organisations need to be expanded considerably.

Wild milkweeds growing in native habitats have been significantly diminished because of reduction of habitat and the use of powerful herbicides paired with genetically engineered crops resistant to these chemicals. These are the greatest threats to the continuing welfare of Monarch Butterflies. From a governmental viewpoint, the most effective way of compensating for the reduction of flyway habitats essential for Monarchs during their perilous journeys is to utilise seeds of locally adapted milkweeds for vegetating roadsides and revegetating degraded landscapes, in conjunction with limiting the use of pesticides on lands where the butterflies occur.

The widespread use of Monarch Butterflies to educate children about the need to conserve nature is one of the most encouraging developments with respect to limiting harm to biodiversity and ecosystems. While the humble milkweed may in time be developed into a significant agricultural crop for mankind, its indispensable role in supporting butterflies will always remain its most important purpose.

Believe it or not

- American Indians used milkweed floss as a soft, warm, non-allergenic lining for the cradles of infants. (For anyone considering this, note that the floss is highly flammable.)
- As noted in the description of the pollination mechanism of milkweed species, sacs of pollen grains are attached to insect legs unintentionally inserted into slits between the anthers of the flowers. Retrieving the leg out of the slit requires an insect large enough to have the strength to do so. Insects too small and weak to remove their trapped leg often die attached to the flower. Among the
casualties are flies, which sometimes tear off a trapped leg in order to escape. Honey Bees also sometimes die trapped in milkweed flowers, and occasionally when they return to their hive, so covered with pollinia that they cannot fly well, the other bees consider them to be inefficient and reject them from the colony.

- In 2009, Monarchs were bred in the International Space Station as part of an educational experiment for teachers and students. The complete life cycle of the butterflies was examined as they ate, grew and underwent metamorphosis in space in the absence of gravity.
- Although the toxic cardenolides that the larvae of Monarch Butterflies acquire while eating milkweed foliage makes the insects so bitter-tasting and toxic that they are protected from carnivores, too much of the toxin can be poisonous even to the normally resistant caterpillars. To limit consumption of the latex, the caterpillars bite into a vein near the base of the leaf, and allow the latex to ooze out like blood from an animal vein. Then they eat a portion of the leaf which normally would have been supplied by the vein’s latex, so their consumption of toxins is reduced.
- Milkweed Bugs are true bugs (order Hemiptera; Figure 13), specialising on seeds, including those of Milkweeds. Like Monarch Butterflies, some species absorb toxic constituents from milkweed latex, which protects them from predators, and also like...
Monarchs they are brightly coloured to warn their enemies that they are distasteful and poisonous.

- In the past, accumulated masses of Monarch Butterflies overwintering on fir trees in Mexico were so heavy that they caused entire branches to break off. Very recent surveys show that Monarch populations in Mexico have been reduced by over 90% compared to former years.

Figure 11. Butterfly Weed (*Asclepias tuberosa*). (a) Photo by H. Zell (CC BY 3.0). (b) Drawing. From Witte and Wendel (1869). Photo placed online by Swallowtail Garden Seeds (CC BY 2.0).

Figure 12. (a) Tropical Milkweed (*Asclepias curassavica*). Photo by Dohduhdah (released into the public domain). (b) Monarch (*Danaus plexippus*) caterpillars feeding on Tropical Milkweed. Photo by Engeser (CC BY 3.0).
Several invasive European species of Vincetoxicum (often placed in Cynanchum), attract Monarch Butterflies to lay eggs on them. Unfortunately the emerging caterpillars starve to death because the plants are insufficiently nutritious.

Monarch Butterflies are not the only insects to travel remarkable distances. Some dragonfly species have been reported to conduct a round trip migration of 14,000 to 18,000 km (7000–11,000 miles) across the sea from southern India to Africa (Walker 2009). By comparison, the Monarch Butterfly covers only a maximum of about 7000 km (4300 miles) in an annual round trip from Mexico to southern Canada. (On average, it requires four generations of butterflies and dragonflies to complete these round-trip journeys). A tagged male Monarch released in Canada was recaptured the next year in Texas (it could not have survived the cold there and presumably wintered in Mexico), so it travelled at least 4635 km (2880 miles). The desert locust Schistocerca gregaria of the Caribbean and South America has been recorded as travelling a distance of 4500 km (2800 miles).

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**Recommended literature**

Adams, R. P., M. F. Balandrin, and J. R. Martineau. 1984. “The Showy Milkweed, Asclepias speciosa: a Potential New Semi-Arid Land Crop for Energy and Chemicals.” *Biomass* 4: 81–104.

Berkman, B. 1949. “Milkweed—A War Strategic Material and a Potential Industrial Crop for Sub-Marginal Lands in the United States.” *Economic Botany* 3: 223–239.
Bhowmik, P. C., and J. D. Bandeen. 1976. “The Biology of Canadian Weeds: 19. Asclepias syriaca L.” Canadian Journal of Plant Science 56: 579–589.

Boppré, M., and R. I. Vane-Wright. 2012. “The Butterfly House Industry: Conservation Risks and Education Opportunities.” Conservation & Society 10: 285–303.

Borders, B., and E. Lee-Máder 2014. “Milkweeds: A Conservation Practitioner’s Guide. Plant Ecology, Seed Production Methods, and Habitat Restoration Opportunities.” Portland, OR: The Xerces Society for Invertebrate Conservation. www.xerces.org/milkweeds-a-conservation-practitioners-guide.

Campbell, T. A., and K. A. Grasse. 1986. “Effect of Stage of Development on Chemical Yields in Common Milkweed, Asclepias syriaca.” Biomass 9: 239–246.

Castelli, C. “Using Asclepias syriaca Seed Fibers to Prevent Oil Spills from Two-Stroke Outboard Motors.” Student research paper. http://www.scientiareview.org/pdfs/405.pdf.

Commission for Environmental Cooperation. 2008. North American Monarch Conservation Plan. Montreal, Canada: Commission for Environmental Cooperation. http://www3.cec.org/islandora/en/item/2350-north-american-monarch-conservation-plan-en.pdf.

Crews, P. C., S. A. Sievert, and L. T. Woeppel. 1991. “Evaluation of Milkweed Floss as an Insulative Fill Material.” Textile Research Journal 61: 203–210.

Emon, J. Van, and J. N. Seiber. 1985. “Chemical Constituents and Energy Content of Two Milkweeds, Asclepias speciosa and A. curassavica.” Economic Botany 39: 47–55.

Gaertner, E. E. 1979. “The History and Use of Milkweed (Asclepias syriaca L.).” Economic Botany 33: 119–123.

Harry-O’kuro, R. E, H. Mojathed, S. F. Vaughn, P. F. Dowd, G. S. Santo, R. A. Holser, and T. P. Abbott. 1999. “Milkweed Seedmeal: a Control for Meloidogyne chitwoodii on Potatoes.” Industrial Crops and Products 9: 145–150.

Hartlzer, R. G. 2010. “Reduction in Common Milkweed (Asclepias syriaca) Occurrence in Iowa Cropland from 1999 to 2009.” Crop Protection 29: 1542–1544.

Hojilla-Evangelista, M. P., and R. L. Evangelista. 2009. “Effects of Cooking and Screw-Pressing on Functional Properties of Protein in Milkweed (Asclepias spp.) Seed Meals and Press Cakes.” Industrial Crops and Products 29: 615–621.

Holser, R. A. 2003. “Properties of Refined Milkweed Press Oil.” Industrial Crops and Products 18: 133–138.

Jepsen, S., D. F. Schweitzer, B. Young, N. Sears, M. Ormes, and S. H. Black. 2015. Conservation Status and Ecology of the Monarch Butterfly in the United States. Arlington, VA: NatureServe. Portland, OR: The Xerces Society for Invertebrate Conservation. http://www.xerces.org/wp-content/uploads/2015/03/NatureServe-Xerces_monarchs_USFS-final.pdf.

Judd, W. W. 1968. “Insects Trapped by the Pollinial Apparatus of Milkweed, Asclepias syriaca L., in Dunn Township, Ontario.” Canadian Journal of Zoology 46: 475–479.

Knudsen, H. D., and R. Y. Sayler. 1992. “Milkweed: the Worth of a Weed.” In New Crops, New Uses and New Markets, 1992 Yearbook of Agriculture, 118–123. Washington: United States Department of Agriculture.

Landis, T. D. 2014. “Monarch Waystations: Propagating Native Plants to Create Travel Corridors for Migrating Monarch Butterflies.” Native Plants 15: 5–16.

Lemoine, N. P. 2015. “Climate Change May Alter Breeding Ground Distributions of Eastern Migratory Monarchs (Danaus Plexippus) via Range Expansion of Asclepias Host Plants.” PLoS ONE. doi:10.1371/journal.pone.0118614.

Louis, G. L., and B. A. K. Andrews. 1987. “Cotton/Milkweed Blends: a Novel Textile Product.” Textile Research Journal 57: 339–345.

Luna, T., and R. K. Dumroese. 2013. “Monarchs (Danausplexippus) and Milkweeds (Asclepias Species).” Native Plants 14: 5–16.

McCarty, M. K., and C. J. Scifres. 1968. “Western Whorled Milkweed and Its Control.” Weed Science 16: 4–7.

Minorsky, P. V. 2001. “The Monarch Butterfly Controversy.” Plant Physiology 127: 709–710.

Phippen, W. B. 2007. “Production Variables Affecting Follicle and Biomass Development in Common Milkweed.” In Issues in New Crops and New Uses, edited by J. Janick and A. Whipkey, 82–88. Alexandria, VA: ASHS Press.

Pollinator Health Task Force. 2015. “National Strategy to Promote the Health of Honey Bees and Other Pollinators.” https://www.whitehouse.gov/sites/default/files/microsites/ostp/Pollinator%20Health%20Strategy%202015.pdf.

Roșu, A., S. Danaila-Guidea, R. Dobrinioiu, F. Toma, D. T. Roșu, N. Sava, and C. Manolache. 2011. “Asclepias syriaca L. – An Undersupplied Industrial Crop for Energy and Chemical Feedstock.” Romanian Biotechnological Letters 16(6, Suppl.): 131–138.

Schlegel, V., R. Zbaskin, T. Gries, B. H. Lee, T. Carr, J.-Y. Lee, C. Weller, and S. Cupp. 2009. “Characterisation of Potential Health Promoting Lipids in the Co-Products of De-Flossed Milkweed.” Food Chemistry 126: 15–20.

Stevens, O. A. 1945. “Cultivation of Milkweed.” Bulletin (North Dakota Agricultural Experiment Station (Fargo)) no. 333.

USDA. 2014. “PLANTS Database.” Natural Resources Conservation Service, United States Department of Agriculture. http://plants.usda.gov.

USDA. 2015. “Conservation and Management of Monarch Butterflies: a Strategic Framework.” http://www.fs.fed.us/wildflowers/pollinators/monarch_butterfly/documents/ConservationManagementMonarchButterflies.pdf.

Van Emon, J., and J. N. Seiber. 1985. “Chemical Constituents and Energy Content of Two Milkweeds, Asclepias speciosa and A. curassavica.” Economic Botany 39: 47–55.

Walker, M. 2009. “Longest Insect Migration Revealed.” http://news.bbc.co.uk/1/hi/earth/earth_news/newsid_8149000/8149714.stm.

Witt, J. D., and H. D. Knudson. 1993. “Milkweed Cultivation for Floss Production.” In New Crops, edited by J. Janick and J. E. Simon, 428–431. New York: Wiley.
Witt, M. D., and L. A. Nelson. 1992. “Milkweed as a New Cultivated Row Crop.” *Journal of Production Agriculture* 5: 167–171.

Witte, H., and A. J. Wendel. 1868. *Flora. Afbeeldingen en beschrijvingen van boomen, heesters, éénjarige planten, enz., voorkomende in de Nederlandsche tuinen* [Pictures and Descriptions of Trees, Shrubs, Annuals, etc. Occurring in Dutch Gardens]. Amsterdam, The Netherlands: Groninger – J.B. Wolters.

Wyatt, R. 1994. “Ecology and Evolution of Reproduction in Milkweeds.” *Annual Review of Ecology and Systematics* 25: 423–441.