Monarch butterfly

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The **monarch butterfly** (*Danaus plexippus*) is a milkweed butterfly (subfamily Danainae) in the family Nymphalidae. It may be the most familiar North American butterfly. Its wings feature an easily recognizable orange and black pattern, with a wingspan of 8.9–10.2 cm (3½–4 in)[3] The viceroy butterfly appears similar in color and pattern, but is markedly smaller and has an extra black stripe across the hind wing.

The eastern North American monarch population is notable for its annual southward late-summer/autumn migration from the United States and southern Canada to Mexico. During the fall migration, it covers thousands of miles, with a corresponding multi-generational return North. The western North American population of monarchs west of the Rocky Mountains most often migrate to sites in California but have been found in overwintering Mexico sites.[4][5] Monarchs were transported to the International Space Station and were bred there.[6]

Monarch butterfly

Female

Male

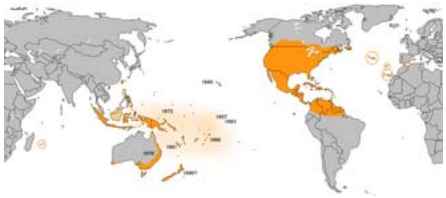
Scientific classification

Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Lepidoptera
Family:	Nymphalidae
Tribe:	Danaini
Genus:	*Danaus* Kluk, 1802
Species:	***D. plexippus***

Binomial name

Danaus plexippus

(Linnaeus, 1758)



Synonyms

Contents

- *Papilio plexippus* Linnaeus, 1758
- *Danaus archippus* (Fabricius, 1793)[1]
- *Danaus menippe* (Hübner, 1816)[2]
- *Anosia plexippus* Dyar, 1903

Description

Commonly and easily mistaken for the similar viceroy butterfly, the monarch's wingspan ranges from 8.9 to 10.2 centimetres (3.5–4.0 in).[3] The upper side of the wings is tawny-orange, the veins and margins are black, and in the margins are two series of small white spots. The forewings also have a few orange spots near the tip. The underside is similar, but the tip of the forewing and hindwing are yellow-brown instead of tawny-orange and the white spots are larger.[7] The shape and color of the wings change at the beginning of the migration and appear redder and more elongated than later migrants.[8] Wings size and shape differ between migratory and non-migratory monarchs. Monarchs from the eastern population of North America have larger and more angular forewings than those in the western population.[6]

Its flight has been described as "slow and sailing".[9]

Adults exhibit sexual dimorphism. The male has a black patch or spot of androconial scales on either hindwing (in some butterflies, these patches disperse pheromones, but are not known to do so in monarchs), and the black veins on its wing are lighter and narrower than those on the female's.[10] The male is also slightly larger.[6][7] One variation has been observed in Australia, New Zealand, Indonesia and the United States termed *nivosus* by lepidopterists. It is grayish-white in all areas of the wings that are normally orange and is only about 1% or less of all monarchs, but populations as high as 10% exist on Oahu in Hawaii.[11]

Like all insects, the monarch has six legs, but uses the four hindlegs as it carries its two front legs against its body.[12]

Range

The range of the western and eastern populations of the monarch butterfly expands and contracts dependent upon the season. The range differs between breeding areas, migration routes and winter roosts.[6]:(p18)

In North America, the monarch ranges from southern Canada to northern South America. It has also been found in Bermuda, Cook Islands,[13] Hawaii, Cuba[14] and other Caribbean islands[6]:(p18) the Solomons, New Caledonia, New Zealand,[15] Papua New Guinea,[16] Australia, New Guinea, Sri Lanka, India, Nepal, the Azores, the Canary Islands Philippines, North Africa[17] and Honolulu.[18][19] It appears in the UK in some years as an acccidental.[20] No genetic differences between monarch populations exist.[21] Reproductive isolation has had no effect in creating sub species.[6]:(p19)

Status

The monarch butterfly is not currently listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) or protected specifically under U.S. domestic laws.[22] On 14 August 2014, the Center for Biological Diversity and the Center for Food Safety filed a legal petition requesting Endangered Species Act protection for the monarch and its habitat.[6]The U.S. Fish and Wildlife Service initiated a Status Review of the Monarch Butterfly under the Endangered Species Act with a due date for information submission of March 3, 2015.

Habitat

Overwintering populations of *D. plexippus* are found in Mexico, California, along the Gulf coast, year-round in Florida, and in Arizona where the habitat provides the specific conditions necessary for their survival.[23][24] The overwintering habitat typically provides access to streams, plenty of sunlight (for body temperatures that allow flight), appropriate vegetation on which to roost, and is relatively free of predators. Overwintering, roosting butterflies have been seen on sumacs, locusts, basswood elm, oak, osage orange, mulberry, pecan, willow, cottonwood, and mesquite.[25] While breeding, its habitat can be found in agricultural fields, pasture land, prairie remnants, urban and suburban residential areas, gardens, trees, and roadsides – anywhere where there is access to larval host plants.[26] Habitat restoration is a primary goal in monarch conservation efforts. Habitat requirements change during migration. During the fall migration, butterflies must have access to nectar-producing plants. During the spring migration, butterflies must have access to larval food plants and nectar plants.

Life cycle

The monarch undergoes the four stages of complete metamorphosis:

Eggs

The eggs are derived from materials ingested as a larvae and from the spermataphores received from males during mating.[27] Eggs are laid singly on the underside of a young leaf of a milkweed plant during the spring and summer months.[28] The eggs are cream-colored or light green, ovate to conical in shape, and about 1.2×0.9 mm in size. The eggs weigh less than 0.5 mg each and have raised ridges that form longitudinally from the point to apex to the base. Though each egg is 1/1000th the mass of the female, she may lay up to her own mass in eggs. Females lay smaller eggs as they age. Larger females lay larger eggs.[27] The number of eggs laid by a female, who may mate several times, ranges from 290 to 1180. [29] Females lay their eggs on milkweed that make their offspring less sick.[30][31] Eggs take 3 to 8 days to develop and hatch into larva or caterpillars.[6]:(p21)Monarchs will lay eggs along the southern migration route.[32]

Larvae

The caterpillar goes through five major, distinct stages of growth and after each one, it molts. Each caterpillar, or instar, that molts is larger than the previous as it eats and store energy in the form of fat and nutrients to carry it through the nonfeeding pupal stage.

The first instar caterpillar that emerges out of the egg is pale green and translucent. It lacks banding coloration or tentacles. The larvae or caterpillar eats its egg case and begins to feed on milkweed. It is during this stage of growth that the caterpillar begins to sequester cardenolides. The circular motion a caterpillar uses while eating milkweed prevents the flow of latex that could entrap it.

The second instar larva develops a characteristic pattern of white, yellow and black transverse bands. It is no longer translucent but is covered in short setae. Pairs of black tentacles (stinkhorns) begin to grow. One pair grows on the thorax and another pair on the abdomen.

The third instar larva has more distinct bands and the two pairs of tentacles become longer. Legs on the thorax differentiate into a smaller pair near the head and larger pairs further back. These third stage caterpillars began to eat along the leaf edges.

The fourth instar has a different banding pattern. It develops white spots on the prolegs near the back of the caterpillar.

The fifth instar larva has a more complex banding pattern and white dots on the prolegs, with front legs that are small and very close to the head.

5th instar with the white spots visible on the prolegs.

At this stage of development, it is relatively large compared to the earlier instars. The caterpillar completes its growth. At this point, it is 25 to 45 mm long and 5 to 8 mm wide. This can be compared to the first instar which was 2 to 6 mm long and 0.5 to 1.5 mm wide. Fifth instar larvae increase 2000 times from first instars. Fifth-stage instar larva chew through the petiole or mid-rev of milkweed leaves and stop the flow of latex. After this, they eat more leaf tissue. Before pupation, larva must consume milkweed to increase their mass prior to pupation. Larva stop feeding and search for a pupation site. The caterpillar attaches itself securely to a horizontal surface, using a silk pad. At this point, it latches on with its hind legs and hangs down. It then molts into an opaque, blue-green chrysalis with small gold dots. At normal summer temperatures, it matures in a few weeks. The cuticle of the chrysalis becomes transparent and the monarch's characteristic orange and black wings become visible. At the end of metamorphosis, the adult emerges from the chrysalis, expands and dries its wings and flies away. Monarch metamorphosis from egg to adult occurs during the warm summer temperatures in as little as 25 days, extending to as many as seven weeks during cool spring conditions. During the development, both larva and their milkweed hosts are vulnerable to weather extremes, predators, parasites and diseases; commonly fewer than 10% of monarch eggs and caterpillars survive.[6]:(pp21-22)

Pupa

In the pupa or chrysalis stage, the caterpillar spins a silk pad on to a horizontal substrate. It then hangs from the pad by the last pair of prolegs upside down, resembling the letter 'J'. It sheds its skin, leaving itself encased in an articulated green exoskeleton. During this pupal stage, the adult butterfly forms inside. The exoskeleton becomes transparent before it ecloses (emerges), and its adult colors can finally be seen.

Adult

The adult butterfly emerges after about two weeks, and hangs until its wings are dry. Fluids are pumped into wings and they expand and stiffen. The monarch expands and retracts its wings, and once conditions allow it then flies to feed on a variety of nectar plants. During the breeding season adults reach sexual maturity in four or five days, however, the migrating generation will not reach maturity until overwintering is complete.[33] Monarchs typically live two to five weeks during the breeding season.[6]:(pp22-23) Larvae growing in high densities are smaller, have lower survival, and weigh less as adults compared to lower densities.[34]

Reproduction

Males that are fit are more likely to mate. Females and males typically mate more than once. Females that mate several times lay more eggs.[35] Mating for the overwintering populations occurs in the spring, prior to dispersion. Mating is less dependent on pheromones than other species in its genus.[36]

Courtship occurs in two phases. During the aerial phase, the male pursues and often forces the female to the ground. During the ground phase, the butterflies copulate and remain attached for about 30 to 60 minutes.[37] Only 30% of mating attempts end in copulation, suggesting that females may be able to avoid mating, though some have more success than others.[38][39] During copulation, the male transfers the spermatophore to the

female. Along with sperm, the spermatophore provides the female with nutrition to aid her in egg-laying. An increase in spermatophore size increases the fecundity of female monarchs. Males that produce larger spermatophores also fertilize more females' eggs.[40]

Monarch butterfly mating

Pictorial lifecycle

egg

caterpillar

beginning pupation

chrysalis

emerging from chrysalis

Mating

Laying eggs

Taxonomy

The name "monarch" may be in honor of King William III of England.[41] The monarch was originally described by Linnaeus in his *Systema Naturae* of 1758 and placed in the genus *Papilio*.[42] In 1780, Jan Krzysztof Kluk used the monarch as the type species for a new genus *Danaus*.

There are three species of Monarch butterflies:

- *D. plexippus*, described by Linnaeus in 1758, is the species known most commonly as the monarch butterfly of North America. Its range actually extends worldwide and can be found in Hawaii, Australia, New Zealand, Spain and on Oceanic Islands.

- *D. erippus*, the southern monarch, was described by Cramer in 1775. This species is found in tropical and subtropical latitudes of South America, mainly in Brazil, Uruguay, Paraguay, Argentina, Bolivia, Chile and southern Peru. The south American monarch and the North American monarch may have been one species at one time. Some researchers believe the southern monarch separated from the monarch's population some 2 mya, at the end of the Pliocene. Sea levels were higher, and the entire Amazonas lowland was a vast expanse of brackish swamp that offered limited butterfly habitat.[43]
- *D. cleophile* Jamaican monarch (Godart in 1819) – ranges from Jamaica to Hispaniola.[44]

White morph of the monarch in Hawaii called White Monarch

Six subspecies and two color morphs of *D. plexippus* have been identified:[45]

- *D. p. plexippus* – nominate subspecies, described by Linnaeus in 1758, is the migratory subspecies known from most of North America.
  - *D. p. p.* form *nivosus*, the white monarch commonly found on Oahu, Hawaii and rarely in other locations.[11]
  - *D. p. p.* (as yet unnamed) – a color morph lacking some wing vein markings.[46]
- *D. p. nigrippus* (Richard Haensch, 1909) – as *forma*: *Danais* [*sic*] *archippus* f. *nigrippus*. Hay-Roe et al. in 2007 identified this taxon as a subspecies:[47]
- *D. p. megalippe* (Jacob Hübner, [1826]) – nonmigratory subspecies, and is found from Florida and Georgia southwards, throughout the Caribbean and Central America to the Amazon River.
- *D. p. leucogyne* (Arthur G. Butler, 1884) − St. Thomas.
- *D. p. portoricensis* A. H. Clark, 1941 − (Puerto Rico).
- *D. p. tobagi* A. H. Clark, 1941 − (Tobago).

The percentage of the white morph in Oahu is nearing 10%. On other Hawaiian islands, the white morph occurs at a relatively low frequency. White Monarchs (nivosus) have been found throughout the world, including Australia, New Zealand, Indonesia, and the United States.[11]

Some taxonomists disagree on these classifications.[43][47]

Monarchs were classified under the family Danaidae, but have been re-classified under Nymphalidae since at least 1958.[48]

Larvae host plants

The host plants used by the monarch caterpillar include:

North America

- *Asclepias nivea* – Caribbean Milkweed
- *Asclepias syriaca* – Common Milkweed
- *Asclepias incarnata* – Swamp Milkweed
- *Asclepias verticillata* – Whorled Milkweed
- *Asclepias tuberosa* – Butterfly Weed
- *Asclepias exaltata* – Poke Milkweed
- *Asclepias viridis* – Green Antelopehorn Milkweed
- *Asclepias asperula* – Antelopehorns Milkweed
- *Asclepias oenotheroide* – Zizotes Milkweed
- *Asclepias variegata* – White Milkweed
- *Asclepias perennis* – Aquatic Milkweed
- *Asclepias humistrata* – Sandhill/Pinewoods Milkweed

- *Asclepias fascicularis* – Mexican Whorled Milkweed
- *Asclepias speciosa* – Showy Milkweed
- *Asclepias subulata* – Rush Milkweed
- *Asclepias erosa* – Desert Milkweed
- *Asclepias californica* – California Milkweed
- *Asclepias cordifolia* – Heartleaf Milkweed
- *Asclepias vestita* – Woolly Milkweed
- *Asclepias eriocarpa* – Woolly Pod Milkweed[49]
- *Sarcostemma clausa* – white vine[18][50]
- *Cynanchum laeve* – Sand vine milkweed[51]

Swamp milkweed, one of many species of *Asclepias* milkweeds used by the monarch

Asclepias curassavica has been planted as an ornamental and naturalized. Its distribution is probably worldwide. Year-round plantings may be the cause of new overwintering sites along the Gulf coast and in Spain.

Adult food sources

Although larvae eat only milkweed, adult monarchs feed on the nectar of many plants including:

- *Apocynum cannabinum* – Indian hemp
- *Asclepias* sp. – milkweeds
- *Aster* sp. – asters
- *Cirsium* sp. – thistles
- *Daucus carota* – wild carrot
- *Dipsacus sylvestris* – teasel
- *Echinacea* sp. – coneflowers
- *Erigeron canadensis* – horseweed
- *Eupatorium maculatum* – spotted joe-pye weed
- *Eupatorium perfoliatum* – common boneset
- *Hesperis matronalis* – dame's rocket
- *Medicago sativa* – alfalfa
- *Solidago* sp. – goldenrod
- *Syringa vulgaris* – lilac
- *Trifolium pratense* – red clover
- *Vernonia altissima* – tall ironweed[24]

Nectaring on purple coneflower *Echinacea purpurea*.

Monarchs obtain moisture and minerals from damp soil and wet gravel, a behavior known as mud-puddling. The monarch has also been noticed puddling at an oil stain on pavement.[24]

Origin of name

Danaus (Greek Δαναός), a great-grandson of Zeus, was a mythical king in Egypt or Libya, who founded Argos; *Plexippus* was one of the 50 sons of Aegyptus, the twin brother of Danaus.

In Homeric Greek *plexippos* (πληξιππος) means "one who urges on horses", i.e. "rider or charioteer". In the 10th edition of *Systema Naturae*, at the bottom of page 467,[52] Linnaeus wrote that the names of the *Danai festivi*, the division of the genus to which *Papilio plexippus* belonged, were derived from the sons of Aegyptus. Linnaeus divided his large genus *Papilio*, containing all known butterfly species, into what we would now call subgenera. The *Danai festivi* formed one of the 'subgenera', containing colourful species, as opposed to the *Danai candidi*, containing species with bright white wings. Linnaeus wrote: *"Danaorum Candidorum nomina a filiabus Danai Aegypti, Festivorum a filiis mutuatus sunt."* (= The names of the *Danai candidi* have been derived from the daughters of Danaus, those of the *Danai festivi* from the sons of Aegyptus).

Robert Michael Pyle suggested *Danaus* is a masculinised version of Danaë (Greek Δανάη), Danaus's great-great-granddaughter, to whom Zeus came as a shower of gold, which seemed to him a more appropriate source for the name of this butterfly.[53] He masculinized the genus name because it had to agree in gender with the species name. If the species-group name is not a noun in apposition, Pyle could have been right and the genus name and specific epithet have to agree in gender, but in that case it is the specific epithet and not the genus name, that is to be altered. In the case of *Danaus plexippus*, however, the specific epithet is a noun in apposition, formed from a personal name in the nominative case, which should not be altered (see ICZN art. 31.1 (http://www.nhm.ac.uk/hosted-sites/iczn/code/includes/page.jsp?article=31&nfv=) and art. 32.3 (http://www.nhm.ac.uk/hosted-sites/iczn/code/includes/page.jsp?nfv=&article=32#3)). If, instead of Danaus, Danaë had been intended, the name would simply have been *Danae plexippus*. Moreover, in *Systema Naturae*, there is a very strong connection of the names with Danaus, and not a single one with Danaë.

Migration

The eastern population migrates both north and south on an annual basis. The population east of the Rocky Mountains migrates to the sanctuaries of the Mariposa Monarca Biosphere Reserve in Mexico. The western population overwinters in various coastal sites in central and southern California. The overwintered population of those east of the Rockies may reach as far north as Texas and Oklahoma during the spring migration. The second, third and fourth generations return to their northern locations in the United States and Canada in the spring.[54] Commercially bred monarchs migrate to overwintering sites in Mexico adding to already existing data of migratory behavior. Not all monarchs in the eastern population migrate to Mexico.[55]

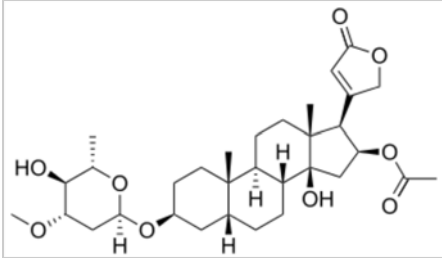
Defense against predators

In both caterpillar and butterfly form, monarchs are aposematic—warding off predators with a bright display of contrasting colors to warn potential predators of their undesirable taste and poisonous characteristics.

Large larvae are able to avoid wasp predation by dropping from the plant or by jerking their bodies.[56]

Aposematism

Monarchs are foul-tasting and poisonous due to the presence of cardenolide aglycones in their bodies, which the caterpillars ingest as they feed on milkweed.[36] By ingesting a large amount of plants in the genus *Asclepias*, primarily milkweed, monarch caterpillars are able to sequester cardiac glycosides, or more specifically cardenolides, which are steroids that act in heart-arresting ways similar to digitalis.[57] It has been found that monarchs are able to sequester cardenolides most effectively from plants of intermediate cardenolide content rather than those of high or low content.[58]



Chemical structure of oleandrin, one of the cardiac glycosides

Additional studies have shown that different species of milkweed have differing effects on growth, virulence, and transmission of parasites.[59] One species, *Asclepias curassavica*, appears to reduce the proportion of monarchs infected by parasites. There are two possible explanations for the positive role of *A. curassavica* on the monarch caterpillar: that it promotes overall monarch health to boost the monarch's immune system; or that chemicals from the plant have a direct negative effect on the parasites.[59]

After the caterpillar becomes a butterfly, the toxin shift to different parts of the body. Since many birds attack the wings of the butterfly, having three times the cardiac glycosides in the wings leaves predators with a very foul taste and may prevent them from ever ingesting the body of the butterfly.[57] In order to combat predators that remove the wings only to ingest the abdomen, monarchs keep the most potent cardiac

glycosides in their abdomens.[60]

Mimicry

Monarchs share the defense of noxious taste with the similar-appearing viceroy butterfly in what is perhaps one of the most well-known examples of mimicry. Though long purported to be an example of Batesian mimicry, the viceroy is actually reportedly more unpalatable than the monarch, making this a case of Müllerian mimicry.[61]

Monarch (left) and viceroy (right) butterflies exhibiting Müllerian mimicry

Human interaction

The monarch is the state insect of Alabama,[62] Idaho,[63] Illinois,[64] Minnesota,[65] Texas,[66] Vermont,[67] and West Virginia.[68] It was nominated in 1990 as the national insect of the United States,[69] but the legislation did not pass.[70]

Monarchs can be attracted by cultivating a butterfly garden with specific milkweed species and nectar plants. Efforts are underway to establish these Monarch Waystations. Monarchs are raised as a hobby and for educational purposes.[71]

An IMAX film *Flight of the Butterflies* describes the story of the Urquharts, Brugger and Trail to then unknown migration to Mexican overwintering areas.[72]

Sanctuaries and reserves have been created at over-wintering locations in Mexico and California to limit habitat destruction. These sites can generate significant tourism revenue.[73]

Organizations and individuals participate in tagging programs. Tagging information is used to study migration patterns.[74]

Monarchs are bred and used in schools, hospices, memorial services and weddings.[75] Memorial services for 9/11 include the release of captive bred monarchs.[76][77][78] Monarchs are used in schools and nature centers for educational purposes.[79]

Threats

There is increasing concern related to the ongoing decline of monarchs; based on a 2014 twenty-year comparison, the population west of the Rocky Mountains has dropped more than 50 percent since 1997 and the numbers east of the Rockies have declined by more than 90 percent since 1995.[6]

Predators

Larva feed exclusively on milkweed and consume protective cardiac glycosides. Toxin levels in Asclepias sp.vary. Not all monarchs are unpalatable, but exhibit Batesian or automimics. Cardiac glycosides levels are higher in the abdomen and wings. Some predators can differentiate between these parts and consume the most palatable ones.[80] Bird predators include brown thrashers, grackles, robins, cardinals, sparrows, scrub jays, pinyon jays,[80]Black-headed Grosbeak, and orioles.[18]

Some mice are able to withstand large doses of the toxin. Overwintering adults become less toxic over time

making them more vulnerable to predators. In Mexico, about 14% of the overwintering monarchs are eaten by birds and mice.[23]

In North America, eggs and first instar larvae of the monarch are eaten by larvae and adults of the introduced Asian lady beetle (*Harmonia axyridis*).[81] The Chinese mantis ("Tenodera sinensis") will consume the larvae once the gut is removed thus avoiding cardenolides.[82] Wasps commonly consume larvae.[83]

Several birds have also adapted various methods that allow them to ingest monarchs without experiencing the ill effects associated with the cardiac glycosides. The oriole is able to eat the monarch through an exaptation of its feeding behavior that gives it the ability to identify cardenolides by taste and reject them.[84] The grosbeak, on the other hand, has adapted the ability an insensitivity to secondary plant poisons which allows it to ingest monarchs without vomiting. As a result, orioles and grosbeaks will periodically have high levels of cardenolides in their bodies, and they will be forced to go on periods of reduced monarch consumption. This cycle of predation effectively reduces the potential predation of monarchs by 50 percent and indicates that monarch aposematism has a legitimate purpose.[84]

On Oahu, a white morph of the monarch has emerged. This is because of the introduction, in 1965 and 1966, of two bulbul species, *Pycnonotus cafer* and *Pycnonotus jocosus*. They are now the most common insectivore birds, and probably the only ones preying on insects as large as the monarch. Monarchs in Hawaii are known to have low cardiac glycoside levels, but the birds may also be tolerant of the chemical. The two species hunt the larvae and some pupae from the branches and undersides of leaves in milkweed bushes. The bulbuls also eat resting and ovipositing adults, but rarely flying ones. Because of its colour, the white morph has a higher survival rate than the orange one. This is either because of apostatic selection (i.e. the birds have learned the orange monarchs can be eaten), because of camouflage (the white morph matches the white pubescence of milkweed or the patches of light shining through foliage), or because the white morph does not fit the bird's search image of a typical monarch, so is thus avoided.[85]

Parasites

Parasites include the tachinid flies *Sturmia convergens*[86] and *Lespesia archippivora*. *Lesperia*-parasitized butterfly larvae complete the formation of their crysalid but die before they emerge as an adult. Before pupation is complete, one white maggot comes out of the chrysalid. The maggot forms a brown pupa on the ground then emerges as an adult.[87]

The bacterium *Micrococcus flacidifex danai* also infects larvae. Just before pupation, the larvae migrate to a horizontal surface and die a few hours later, attached only by one pair of prolegs, with the thorax and abdomen hanging limp. The body turns black shortly after. The bacterium *Pseudomonas aeruginosa* has no invasive powers, but causes secondary infections in weakened insects. It is a common cause of death in laboratory-reared insects.[87]

The protozoan *Ophryocystis elektroscirrha* is another parasite of the monarch. It infects the subcutaneous tissues and propagates by spores formed during the pupal stage. The spores are found over all of the body of infected butterflies, with the greatest number on the abdomen. These spores are passed, from female to caterpillar, when spores rub off during egg-laying and are then ingested by caterpillars. Severely infected individuals are weak, unable to expand their wings, or unable to eclose, and have shortened lifespans, but parasite levels variy in populations. This is not the case in laboratory rearing, where after a few generations, all individuals can be infected.[88] Infection with this parasite creates an effect known as culling whereby migrating monarchs that are infected are less likely to complete the migration. This results in overwintering populations with lower parasite loads.[89] The control of the parasite can be controlled in commercial breeding operations.[90]

Confusion of host plants

The black swallow-wort (*Cynanchum louiseae*) and pale swallow-wort (*Cynanchum rossicum*) plants are problematic for monarchs in North America. Monarchs lay their eggs on these relatives of native vining milkweed (*Cynanchum laeve*) because they produce stimuli similar to milkweed. Once the eggs hatch, the caterpillars are poisoned by the toxicity of this invasive plant from Europe.[91]

Habitat loss due to herbicide use

Conservationists attribute the disappearance of mikweed speices to agricultural practices in the Midwest, where genetically modified seeds are bred to resist herbicides that eliminate milkweed nearby. Growers eliminate milkweed that previously grew between the rows of food crops. Corn and soybeans are resistant to the effect of the herbicide glyphosate. The increased use of these crop strains is correlated with the decline in Monarch populations between 1999 and 2010.[92][93] Chip Taylor, director of Monarch Watch at the University of Kansas, said the Midwest milkweed habitat "is virtually gone" with 120–150 million acres lost.[94][95] To help fight this problem, Monarch Watch encourages the planting of "Monarch Waystations".[71]

Loss of overwintering habitat

The area of forest occupied has been declining and reached its lowest level in two decades in 2013. The decline is continuing but is expected to increase during the 2013–2014 season. Mexican environmental authorities continue to monitor illegal logging of the oyamel trees. The Oyamel is a major species of evergreen on which the overwintering butterflies spend a significant time during their winter diapause, or suspended development.[96]

A 2014 study acknowledged that while "the protection of overwintering habitat has no doubt gone a long way towards conserving monarchs that breed throughout eastern North America", their research indicates that habitat loss on breeding grounds in the United States is the main cause of both recent and projected population declines.[97]

Climate

Climate variations during the fall and summer affect butterfly reproduction. Rainfall, and freezing temperatures affect milkweed growth. Omar Vidal, director general of WWF-Mexico, said "The monarch's lifecycle depends on the climatic conditions in the places where they breed. Eggs, larvae and pupae develop more quickly in milder conditions. Temperatures above 95°F can be lethal for larvae, and eggs dry out in hot, arid conditions, causing a drastic decrease in hatch rate." [98]

Genome

The monarch was the first butterfly to have its genome sequenced.[6]:(p12) The 273-million base pair draft sequence includes a set of 16,866 protein-coding genes. The genome provides researchers insights into migratory behavior, the circadian clock, juvenile hormone pathways and microRNAs that are differentially expressed between summer and migratory monarchs.[99][100][101] More recently, the genetic basis of monarch migration and warning coloration has been described.[102]

There is no genetic differentiation between the migratory populations of eastern and western North America.[6]:(p16) Recent research has identified the specific areas in the genome of the monarch that regulate migration. There appears to be no genetic difference between a migrating and nonmigrating monarch but the gene is expressed in migrating monarchs but not expressed in nonmigrating monarchs.[21]

Conservation

The Center for Biological Diversity, The Center for Food Safety, The Xerces Society and Lincoln Brower have filed a petition to the United States Department of the Interior to protect the monarch by having it declared an endangered species.[6]

Conservationists are lobbying transportation departments and utilities to reduce their use of herbicides and specifically encourage milkweed to grow along roadways and power lines. Reducing roadside mowing and application of herbicides during the butterfly breeding season will encourage milkweed growth. Conservationists lobby agriculture companies to set aside areas that remain unsprayed to allow the butterflies to breed.[93] Butterfly gardening is thought to increase the populations of butterflies.[103]

See also

- Monarch butterfly migration

- Lepidoptera migration
- Monarch Butterfly Biosphere Reserve
- Peninsula Point Light, Michigan
- Butterfly house (conservatory)
- Lepidoptera
- Butterflies
- Viceroy butterfly

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External links

- Monarch Butterfly Migration of 1973 Roosting Behavior on Martha's Vineyard (http://mvgazette.com/news/2014/02/13/great-monarch-migration-still-flies-high-film?k=vg53c317f5c29bd&r=1)
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- Monarch Joint Venture (http://www.monarchjointventure.org) – Partnering Across the U.S. to Conserve the Monarch Butterfly Migration
- Wild for Monarchs (http://www.wildones.org/learn/wild-for-monarchs/) – Wild Ones campaign to help people create monarch habitat
- Monarch website of The Reppert Laboratory (http://www.reppertlab.org) at the University of Massachusetts Medical School.
- Australian Museum fact sheet on Monarch butterflies (http://australianmuseum.net.au/Wanderer-Butterfly/)
- Monarch Migration Maps (http://www.learner.org/jnorth/monarch/)
- USGS description of Monarch butterfly (http://www.butterfliesandmoths.org/species?l=1892)
- Monarch Health (http://www.monarchparasites.org/)
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- Monarch, Canadian Biodiversity Information Facility (http://www.cbif.gc.ca/spp_pages/butterflies/species/Monarch_e.php)
- PBS NOVA Documentary "The Incredible Journey of the Butterflies" (http://www.pbs.org/wgbh/nova/butterflies/)
- Watch a Monarch egg hatch (http://www.pbase.com/10kzoomfz/wild_monarch_07proj_egg)
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- Monarch Butterfly in Australia - How it Arrived in Australia (http://panique.com.au/trishansoz/animals/monarch-butterfly.html)

Categories: Danaus (genus) | Lepidoptera of North America | Butterflies of Canada | Butterflies of the United States | Insects of Mexico | Insects of Hawaii | Fauna of the California chaparral and woodlands | Animal migration | Plants and pollinators | Pollinators | Aposematic species | Lepidoptera of Europe | Symbols of West Virginia | Insects described in 1758 | Endangered fauna of California | Insects with sequenced genomes

Monarch butterfly migration

From Wikipedia, the free encyclopedia

Monarch butterflies (*Danaus plexippus*) perform annual migrations across North America.

Eastern/northeastern populations migrate from southern Canada and the United states to overwintering sites in central Mexico. Similarly, the western population migrate seasonally from regions between the Rocky Mountains and the coast of California. Monarchs also perform small distance migrations in Australia and New Zealand.

Contents

Extinction

The range of the monarch is worldwide and while monarch butterflies are not endangered as a species, the migration of the eastern north american population may be an endangered phenomenon.[1] The media consistently reports that the monarch is endangered of becoming extinct and have been criticized for exaggerating.[2][3][4] Reports of the monarch becoming extinct by the media have been criticized by scientists. "Monarchs are not in danger of extinction," states Lincoln Brower, a monarch conservation researcher.[5][6]

Range of the migration

The eastern population of monarch butterflies migrates both north and south annually. But no individual makes the entire round trip. Female monarchs lay eggs for the next generation during the northward migration.[7] The western population overwinters in various coastal sites in central and southern California, United States, notably in Pacific Grove, Santa Cruz, and Grover Beach. Western monarchs also overwinter in Baja, California's central valley, and the Sierra Nevada foothills.[8]

Not all monarchs migrate. Migrating populations and non-migrating populations coexist in many areas.[9] Monarchs are year-round residents in Florida and monarchs migrate to Florida and Gulf coast areas, and can often continue to breed and survive the winter.[10] The monarch population in Florida, a may be a result from migratory butterflies that do not to migrate north in the spring.[11][9] These locations provide access to nectar plants. If there is a hard frost in these areas they do not survive. *Asclepias curassavica*, an introduced annual

ornamental, provides larval food if native species are unavailable. Year-round breeding of resident monarch populations exist in the Caribbean, and in Mexico as far south as the Yucatán peninsula. Surprisingly, monarchs do not migrate over most of their global range. Tagging records demonstrate that the eastern and western populations are not entirely separate. Arizona butterflies have been captured at overwintering sites in both California and Michoacan, Mexico.[12] In some instances monarchs from Arizona and New Mexico were found overwintering in California and in Mexico.[12][13]

Fall-migrating monarchs are not the same ones that migrated northward approximately five months before. Instead the northern-migrating butterflies are at least five generations removed from overwintering sites. The eastern population migrates up to 4830 miles to overwintering sites in Mexico.[14] One researcher calls it “one of the most spectacular natural phenomena in the world".[15] Other insects show migratory behavior but not nearly for as long distances. The exception would be the desert locust, Schistocerca gregaria which was reported once in 1950 individual that swarms were seen migrating from the Arabian peninsula to over 5000 km to the west coast of Africa in seven weeks.[16]

Overwintering monarchs cluster on oyamel trees in a preserve outside of Angangueo, Michoacan, Mexico; one tree is completely covered in butterflies.

Habitats

Ideal habitats have a profound effect on the migration of large numbers of monarchs. The single most influential factor is the weather. Ideal habitats promote the migration of large numbers of migrating monarchs.

roosting, overwintering butterflies in Pacific Grove, California

Summer

The ideal summer breeding habitat will provide ample nectaring plants for the adults and abundant, healthy larval plants. Low populations of predators and parasites will also allow for more monarchs surviving into adulthood. A low prevalence of disease will improve the survival. Monarchs breed the fastest within a specific temperature range. An increase of the range of the breeding population is another indicator that the habitat is conductive to reproductive success.

Monarchs roosting during fall in central Texas

Fall

In North American the ideal breeding habitat changes in late summer. The migration begins and the ideal habitat required for successful migration changes to a ‘corridor’ (to Mexico) of available nectaring plants, optimal temperatures, tailwinds and low precipitation. The butterflies must also remain hydrated. An early frost will kill migrating butterflies.

Winter

The ideal habitat for monarchs in winter exists in their overwintering sites. The factors influencing the habitat include, the condition of the forest canopy, precipitation, predation, availability of suitable trees on which to roost, sources of water, the ideal temperature range, sunlight, lack of rain and ice and human activity near the sites.[17] Roosting butterflies have been observed to roost in sumacs, locusts, basswood elm, oak, osage orange, mulberry, pecan, willow, cottonwood, and mesquite.[18] If conditions are too hot in the

overwintering sites, the butterflies will use up their fat reserves and not survive until spring. High temperatures initiate reproductive behavior with the possibility of the butterflies leaving the overwintering areas to early while it is still too cold in the north to stimulate the emergence of food plants and nectar plants[11]

Spring

The ideal habitat for monarchs migrating north from Mexico sites to Texas and Oklahoma is less studied. Presumably, tailwinds assist the migration north. Rainfall is critical in creating the ideal habitat for the returning monarchs which must have abundant, lush and healthy foodplants available for larvae. Ideal growth of larval plants that emerge in succession as the breeding butterflies migrate north, is also critical. Drought is a big factor influencing the emergence of food plants.

If any of these habitats is less than ideal, the population of monarchs will be negatively affected though ideal conditions in the other habitats monarchs encounter make up for the 'losses'.

Historical accounts

Before 1975

As late as 1951, monarchs were thought to overwinter in northern latitudes as adults or pupae. Roosts of thousands were observed in southern regions of North America.[19]

Migrating western populations of *D. plexippus* and their overwintering sites were known long before the winter sites in Mexico were located by Canadian and American researchers in the 1970s. Pre-Hispanic native Americans, the Purépecha and Otomi once occupied this area and tied the harvest of corn to the arrival of the butterflies. Monarchs appear in legends of the people that live near overwintering areas. In the areas surrounding the overwintering sites in Mexico, local residents were quite aware of the overwintering behavior of monarch butterflies long before 1975. The local people, called the Mazahua, have lived near the overwintering sites for centuries. The arrival of the monarchs is closely tied to the traditional the Day of the Dead celebrations. Local residents today easily recall seeing the migrating butterflies prior to 1975.[20] [21][22][23]

For at least a century, monarchs were observed overwintering in California in the fog belt.[24] Historical records of lepidopterists do not mention the existence of monarchs in their current western range that extends northward through Washington, Oregon and Canada possibly because milkweed was not available until human disturbance expanded its range.[25]

After 1975

Formal studies began when Fred Urquhart graduated from the University of Toronto in 1935 and accepted a graduate fellowship in the field of entomology. In 1937, Fred began to plot the route taken by the migrating butterflies. He was the first to record that monarchs move S/SW in the fall and that these movements were coorelated to high pressure systems. He began the first successful tagging program which returned data. He and his volunteers recognized the existence of roosting behavior.[26]:290–296, 305, 306, 310

The search for overwintering sites was initiated by Fred Urquhart when he advertised for 'interested persons' in the Mexican press. Catalina Trail and Ken C. Brugger responded to the ad and in January 1975 discovered one of the major overwintering sites. Urquhart, William Calvert, John Christian, and Lincoln P. Brewer cooperated to put together the details in this discovery of a major overwintering site of monarchs in 1976.[27] [28][29] At first, information on the discovery of the first major overwintering was suppressed due to the concerns that public knowledge might lead to endangerment of the butterflies.[30] Since 1976 multiple

overwintering sites have been identified and their locations are public knowledge.[31]

Southern migration

By the end of October, the population of monarchs east of the Rocky Mountains migrates to the sanctuaries of the Mariposa Monarca Biosphere Reserve within the Trans-Mexican Volcanic Belt pine-oak forests in the Mexican states of Michoacán and México. They also overwinter in areas that are privately owned. Monarchs migrate to other locations such as Cuba and Florida in the fall.[32] Two migratory fly ways exist through North America. One in the Central states leads to the Mexican overwintering areas and a smaller flyway along the eastern North American seaboard. The timing of the eastern flyway lags behind the more central flyway. Monarchs migrating along the coast are less likely of being recovered in Mexico. This suggests that butterflies migrating along the eastern seaboard are migrating to locations other than the Mexico, or they have a higher rate of mortality than those migrating inland.[33] A few exceptions exist to the generally observed yearly S-SW migration routes. In 1998:

A tagged monarch in Cabell Geneva KY was recovered in Lindsborg KS a distance of 9 8miles in 2 0 days

A tagged monarch in Hartford CT was recovered in Camp Hill PA 9 8 miles in 5 days

A tagged monarch in Lincoln NE was recovered in Paullina IA Gehlsen MO 158miles in 18 days[34]

Initiation

Monarchs respond to different cues that promote the fall season, southern migration. These include the angle of light coming from the sun, the senescence of larval host plants, the decreasing day period and temperature drop.[35] The migration begins at the northernmost summer range approximately in August. Migrating monarchs are thought to rely heavily on the nectar of fall flower composites that lie along the migration path.[15][36]

Monarchs in diapause

Diapause is a physiological state found most often in arthropods, especially insects, and in embryos of fish that allows survival when conditions become harsh. Diapause is not only induced in an organism by specific stimuli or conditions, but once initiated, only certain other stimuli are capable of bringing the organism out of diapause.[35][37] The latter feature is essential in distinguishing diapause as a different phenomenon from other forms of dormancy such as stratification, and hibernation.[20][38][39][40]

When the adult monarch begins its southern migration, it enters diapause. Where other species in diapause remain fairly immobile, monarchs remain active. When diapause is initiated the butterflies accumulate and store lipids, proteins and carbohydrates.[36] Monarchs migrating to Mexico accumulate more lipids than those migrating to California. [41] Fats and lipids reduce water to provide energy reserves and prevent desiccation.[42] These substances are used to maintain the insect throughout diapause and to provide fuel for development following diapause termination. It occurs at a genetically occurs well in advance of environmental stress.[37] This considered a type of animal dormancy. It is a state resulting in the cessation of high-metabolic activities including reduced oxygen use.[43][43]

Monarchs in diapause of the fall migrating population are physiologically distinct from those in active reproduction behavior in the spring and summer. In diapause, the measurement of fats and lipids levels a can be as high as 34%. The fat storage organ is substantially larger in migrating and overwintering monarchs compared to the summer generations. Samples of tissue excluding the fat body also show higher levels of free lipids in the hemeolymph. Females in diapause show little evidence of mature eggs. Mating is repressed and only occasionally observed among overwintering monarchs. This is thought to increase the survivability

of winter populations and maintain fat reserves that will promote spring northward migration. At one site, the population stayed in diapause until the middle to the end of January. By the beginning of February the day length increases to just over 11 hours, the point at which monarchs come out of diapause.[37] In addition to the required day length, monarchs in diapause must also have temperatures that promote the formation of eggs. When these two conditions are met, mating occurs and females migrate northward. While migrating, the a monarch in diapause uses nectar along its migration to create a significant increase in its fat reserves. There are reports of monarchs laying eggs while traveling southward to overwintering sites. Eggs and larvae are killed by freezing temperatures. Migration ends at the first frost.

Diapause has distinct phases. While diapause varies considerably from one taxon of insects to another, these phases are characterized by series of metabolic processes and responsiveness of the insect environmental stimuli.[37]

Decreasing day period and dropping temperatures have been found to initiate the production of juvenile hormone. This represses the development of gonadal activity, mating behaviors, and egg-laying. While in diapause new behaviors emerge such as the development of social nectaring groups and late afternoon formation of night-time clusters or roosts.[44] Roosting reduces water loss, probably due to decreased surface area to volume ratios reducing evaporative water loss.[45]

Other physiological changes

Migrating monarchs tend to have darker and larger wings.[46] Monarchs that migrate often exhibit changes in the shape of their wings. They are larger, weigh more and contain more fat than monarchs that are not migrating. In females the production of eggs ceases. Mating behavior is not observed presumably due to changing levels of hormones that promote breeding.

Colony dispersal and northern migration

Northern migration

There is a northward migration in the spring.[47] Female monarchs lay eggs for the next generation during these migrations.[7] Northward migration from Florida normally occurs from mid-March to mid-May and the initial wave of the migration may be the offspring of monarchs that have overwintered in Florida and along the northern Gulf Coast, not in central Mexico. Tagged monarchs from Tallahassee were recovered in Virginia and Georgia.[48]

The distance and length of these journeys exceeds the normal lifespan of monarchs, which is less than two months for butterflies born in early summer. The first generation leaving the overwintering sites only migrates as far north as Texas and Oklahoma. The second, third and fourth generations return to their northern breeding locations in the United States and Canada in the spring.

Initiation

As with the initiation of the southern migration, a variety of cues trigger the cessation of diapause, the beginning of breeding activity and the movement north. In the case of the western population, the dispersal proceeds in a westerly and northwesterly direction. During this process, roosting sites sometimes move and the monarchs move to lower elevations. Rising temperatures and increasing daylengths influence the initiation of the northward migration. Temperature also has an effect. Mated females leave the overwintering sites before the males. Monarchs travelling north do not form roosts.[12]

Rates of recolonization

Rates of recolonization have remained steady between 1997 and 2011. The recolonization of the breeding grounds in the United States and Canada is a two generation process. The pattern of recolonization of the northern breeding areas has not changed since monitoring began in 1997. The timetables of the re-colonization range is not correlated to the censuses of overwintering monarchs in Mexico.[33]

Migration routes

Generally speaking, the eastern population migrates from southern Canada and the Midwest United States almost directly south toward Mexico. Monarchs from the Northeast tend to migrate in a southwesterly direction. Monarchs transplanted from the midwest to the east coast began migrating directly south but then reoriented their path to the southwest in one study. Geographical features affect the migration route.[49]

In general, the western population of monarchs migrates from areas west of the Rocky Mountains including northern Canada to California. Australian monarchs that migrate travel from the west to eastern regions closer to the Pacific.

Roosting sites

During the migration, the eastern and western populations tend to group together during the migration and then at the overwintering sites. These roosts form along the migration routes. Prior to the discovery of the overwintering sites in Mexico, Fred Urquhart observed roosting behavior in south-migrating butterflies in Mexico and Michoacan. He documented 1500 monarchs roosting at lighthouse point Florida.[26]:88, 305–306 In California, monarchs have been observed roosting in a wide variety of locations: Fremont, Natural Bridges Beach, golf courses, suburban areas. California roosts differ from those in Mexico. Roosts are observed on in inland areas and on non-native tree species.[50]

Overwintering sites

Overwintering sites in California, Northwestern Mexico, Arizona, the Gulf Coast, central Mexico and Florida share the same habitat characteristics: a moderating climatic conditions (thermally stable and frost free), are relatively humid, allow access to drinking water and have the availability of trees on which to roost and avoid predation. California has more than 200 overwintering sites.[51]:2 Overwintering sites have also been observed in coastal South Carolina along with ovapositing females.[33]

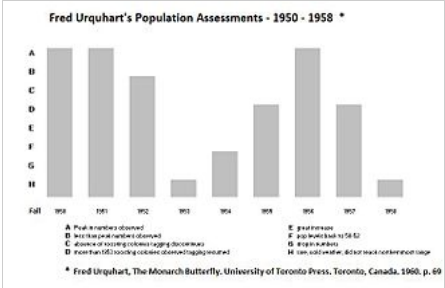
At least twenty colonies exist in Mexico.[51]:1

California overwintering sites exist in areas that are developed and are not considered especially forest-like. These sites have been referred to as having a uniform vegetation population of either Montery pine or eucalyptus trees and are sometimes present in urban areas. Over wintering sites are dynamic in that tagged butterflies are observed in different roosts throughout the winter. [52] Monarchs overwintering along the Gulf Coast and in Florida do not enter diapause and breed year-round.

Population and migratory study methods

Population counts "dramatically" vary year to year.[53] The cause of the variations are attributed to natural occurrences, [41] Different methods are used to count migrating butterflies,[33] and man-made changes to the habitat. The validity of the population census at overwintering sites in North America is questioned. The discrepancy between migrating populations and populations present at the overwintering sites suggests a significant adult mortality during the migration.[54] The Commission for Environmental Cooperation has determined that population variations require a long-term and large scale monitoring effort[53] Population

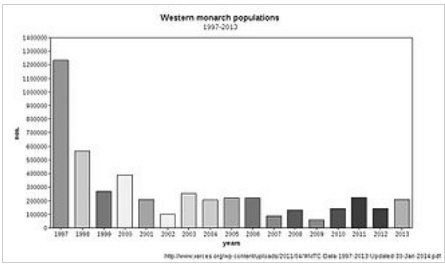
estimates of adults, or of eggs and larva, and milkweed abundance, should correlate with the censuses at the overwintering sites. Data are currently unavailable at this time to determine these censuses but a current study by The Monarch Larva Monitoring Project is designed to determine whether or not population. Censuses in Mexico match the populationc censuses in the Midwestern United States and Canada.[55]



Urquharts population assessments

Mark and recapture

This is the technique whereby a sample of the population is captured, tagged, and returned to the original location. After the tagged monarchs are released they are later re-captured. This procedure allows the determination of the total populations since the recaptured monarchs are directly proportional to the number in the whole population. An estimate of the total population size can be obtained by dividing the number of marked individuals by the proportion of marked individuals in the second sample. This method of population determination is useful because it is not practical to count all the individuals in the population. Other names for this method, or closely related methods, include capture-recapture, capture-mark-recapture, mark-recapture, sight-resight, mark-release-recapture, multiple systems estimation, band recovery, the Petersen method and the Lincoln method.[56] has been used to estimate the number of butterflies remigrating to Florida in the spring and overwintering in California.[57][58]



Western monarch populations 1997-2013 from Xerces data

These are tags used to attach to the wings of monarch butterflies to study their migration. The circular tags are presently used (2014) and the green tags were used in the past by Monarch Watch - the University of Kansas

Butterfly counts

Monarch butterfly counts can be compared to bird counts. During a butterfly count, individuals and organized groups count the numbers of butterflies that they observe during a discrete time period and within a predetermined area. The western population of mnonarchs are counted during their 'Thanksgiving Butterfly Count'.[59] Methods differ but can include consistent observations of butterflies traversing areas within predetermined limits, presumably along the migratory route measured in butterflies/hour sometimes with recording vectors. Data collected are likely to be accurate and become more accurate with the increasing number of samples.[11] Concentrations of migrating monarchs are consistently monitored by Cape May Bird Observatory,[60] Peninsula Point Light, Michigan, and Point Pelee National Park, Ontario, Canada.

Butterfly counts of monarchs serve many purposes. The results of the counts allow the determination of the range of the monarch. This includes what is known as 'accidental sightings'; sightings that occur out of the normally established range. Determining the range will reveal the expansion or contraction of the butterfly's normal range. The range of the monarch does vary year. Another result that is obtained during the butterfly count of the monarch is an estimate of the butterflies population. Butterfly counts of the monarch reflect effects of weather on the range and populations. Habitat change can impact a count; many assess habitat changes in the range of the monarch based upon the counts. The ratio of monarchs to other spiecies observed during a count provides information about habitat changes. Publicized butterfly counts can generate interest.[61][62]

Monarch butterfly counts from 1979-1990 revealed fluctuations. Some of these are attributed to severe weather effects, El Nino Southern Oscillation and volcanic eruption.[61]

Migrating monarchs tend to congregate and form roosts on peninsulas that point south. Monitoring programs count the number of monarchs in roosts that develop along the migration route. Monitoring data from multiple sites correlate.[63]

Protocols used to conduct the censuses include:

- Driving Census
- Walking Census
- Roosting Counts
- Hawk-watch Observations[64]

Aerial and satellite observations

The condition of the Mexican forest habitats and progression of deforestation of overwintering roosts can be observable via satellite imagery. These images show the changes in and around the overwintering areas. Efforts to visual the satellite images for actual presence of the roosts of butterflies have not been successful. Small aircraft were used in one study, allowing views of the colonies. Aerial assessments of the areas surrounding the colonies revealed the presence of potential areas of colonization. After these efforts the costs out-weighed the benefits of high-altitude aerial photography. It was determined to be time-consuming and expensive and did not allow a reliable method for identifying or conducting a census of the colonies.[62][65]

Direct observations

Direct observation was the primary method used when monarch migration studies began.[66] These past sightings and recovery of tagged butterflies is information cited in publications even up to 2014. Direct observations are performed by laypeople, scientists and those residing close to overwintering sites.

Types of data collected

Direct observation usually means that an observer records data while the butterfly is one stage of its migration. This can include:

- Historical accounts.[20]
- flight vectors
- densities
- appearance in the northern breeding range
- appearance in overwintering sites
- location of overwintering sites
- wing condition
- sex
- size
- roosts
- butterfly counts (butterfly sightings/minute)
- emergence of host plants
- local frosts
- estimations of populations and densities
- wind direction
- cloud cover
- parasite loads
- latitude/longitude

Use of data and availability

Recorded, anecdotal information is most often submitted to the sponsoring organization. Data has significantly accumulated over the years and is used by researchers. Scientific observations are sometimes treated like proprietary information and are not available to the public or other researchers.[53][46][67] Observers have begun to record their sightings via Google maps.[68]

Observers

Most observers are laypersons (trained and untrained), individuals identified with the term ‘citizen scientist’ but also called "amateur naturalists".[69] Anecdotal information by observers has been criticized and labelled as not "good science" and "not science at all".[69] Conservation organizations and scientists use observations in their research. Those who participate in organized butterfly counts also provide valid observations. Some regions in Texas are located in the flight path during the migration and the patterns, distributions, and populations are recorded by observers there.[70]

Tagging

Tagging was done as early as 1796 on silk moths by Indian silk producers. It was discovered that the moths would migrate up to 100 miles. Prior to the tagging activity of Fred Urquart, other methods of monarch tagging included wing incisions, spots arrangements, colored spots, spraying with dyes, painted letters and numbers. The reason these methods resulted in no information about the migration was because there were no instructions to return or at least record the recovery.[26]:279Many organizations currently use tagging to study migration.[71][72][73]

Monarch tagging is a popular educational project for students.[74] Captive/commercially bred monarchs migrate to overwintering sites in Mexico. [75]

Reciprocal transfers of tagged monarchs have demonstrated that monarchs from east of the Rocky mountains will migrate south if transferred west, in the range of the western population (rather than SW). Monarchs transferred from Nebraska to Oregon will also migrate South.[74]

New methods of studying the migration include the use of VHF transmitters and commercial aircraft.[76] Isotopic tagging has been employed.[77][78]

Migratory theory mechanisms

Theories that explain monarch migration are many. "Science has not yet offered a sufficient explanation for how that [the migration] happens."[79] Researchers often propose that multiple migratory mechanisms play a role. Not all who study monarch migration agree on the mechanisms that allow the migrating butterflies to

find overwintering sites.

Instinct

It is proposed that the ability to find overwintering sites in California and Mexico is an inherited trait. It has also been called a genetic memory.[80] The possibility of an inherited map has been posited suggesting that the butterflies may follow streams and recognize landmarks.[81][82][83] Other studies provide evidence against the theory of an inherited map.[84]

Geographical features, chemical markers

Migration theories take into account the terrain monarchs encounter during their migration. Mountains, rivers, lakes and oceans are credited with influencing the migration. [41] Large roosts of migrating monarchs are often formed at a locations that act as obstacles impeding their movement S/SW. Roosting butterflies are thought to form these roosts to wait for ideal weather conditions that will aid them in crossing these landforms, such as lack of rain, temperature, tailwinds, and sunlight. Some years the roosting sites form predictably and consistently year to year. In other instances, roosting sites form in new areas on a transient basis. A roost of migrating monarchs can contain as few as four and as many as thousands. Other geographic features such as the Appalachian Mountains and the Sierra Madres in Mexico 'funnel' the migration, orienting it to the S/SW.[49][84] One monarch tagged in Ontario was recovered on a oil rig 100 miles south of Galveston, Texas.[85]

One recent hypothesis suggests that is that monarchs may be chemically marking certain trees, using an unknown substance and so orienting themselves when they return the following winter.[86]

Chemical markers

One recent hypothesis suggests that is that monarchs may be chemically marking certain trees, using an unknown substance and so orienting themselves when they return the following winter.[86]

Position of the sun

The migratory patterns may be based on a the position of the sun in the sky including its angle and spectrum changes that occur near the end of the summer breeding season.[87][88] The proposed Sun compass depends upon a circadian clock based in their antennae.[89][90] The antennae contain cryptochrome, a photoreceptor protein sensitive to the violet-blue part of the light spectrum. In the presence of violet or blue light, it can function as a chemical compass.[91][92]

Other theories

The Colombus Hypothesis is another theory that accounts for the phenomena of the mass migration of the eastern population of the monarch by examining historical records. This theory discusses how many butterflies engage in mass movements to expand their range[93] or relieve pressure on their habitat.[24] According to this theory, the eastern population did not have such an extensive range and did not migrate. Historical observations of animal life during the colonial period in America make no mention of monarch butterflies. Observations of monarchs began and seemed to be related to the deforestation of the Northeast. Monarchs were presumably residents of subtropical and tropical areas but began to move north to breed on the increased numbers of larval host plants that replaced the deforested areas.[94] Populations found in other regions do not migrate over such long distances (in Australia, for example) This may suggest that the migratory behavior of the eastern population of the monarch butterfly developed after other populations of monarchs had become established in other regions.[95]

Another theory denies the existence of the mass migration, but instead explains the movements of monarchs in the fall to **weather conditions**:

> In the fall, monarch adults in Canada and the upper Midwest likely receive an environmental trigger (change in photoperiod or seasonal cold snap) and cease egg laying. When the main jets stream moves south out of Canada, high and low pressure cells become carried across extreme southern Canada and later across the US. At that time, monarchs need merely rise on thermals during clearing conditions and become carried toward the South out of the region in which they were reared. If they have reached sufficient altitude in their ride on thermals, the north winds can carry some of them considerable distance towards Mexico." *Adrian Werner, professor emeritus of natural history at the University of California, Santa Barbara*[69]

Werner goes on to say that monarchs were found in Mexico in the winter simply because people expected they would be there. He contends that monarchs may be in other places, but just haven't been found yet.

Conservation

Monitoring and conservation organizations can be organized by their efforts directed to each of the four stages in the monarch lifecycle.[96]

> “We have a lot of habitat in this country but we are losing it at a rapid pace. Development is consuming 6,000 acres a day, a loss of 2.2 million acres per year. Further, the overuse of herbicides along roadsides and elsewhere is turning diverse areas that support monarchs, pollinators, and other wildlife into grass-filled landscapes that support few species. The adoption of genetically modified soybeans and corn have further reduced monarch habitat. If these trends continue, monarchs are certain to decline, threatening the very existence of their magnificent migration.” *O.R. Taylor* [97]

The winter roosts in both Mexico and California were declared to be threatened phenomena by the International Union for the Conservation of Nature and Natural Resources (IUCN) in the IUCN Invertebrate Red Data Book.[98]

Historical conservation regulations began when the residents of Pacific Grove, CA passed an ordinance prohibiting the disturbance of the "peaceful occupation of the Monarch butterflies".[26]

Adult mortality

Unknown factors that impact the numbers of migrating monarchs requires more research. Culling may occur during the migration due to high counts of infection with the parasite 'Ophryocystis elektroscirrha.[99]

Overwintering sites

Work to protect the overwintering sites in Mexico began before 1975 and were initiated by local residents. Populations of overwintering monarchs in Mexico have been declining. It is expected that the numbers of monarchs will increase this winter (2014–15) due to favorable conditions that existed during the early spring migration and throughout the summer.[100]

Gulf Coast areas and Florida

Overwintering sites exist along the Gulf Coast states and in Florida.

Mexico

Periodic disasters at the Mexican overwintering sites are the main reason for the population decline. Some sites have experienced losses of 30% to 90% during storms.[98][101] Conservation efforts in and around the overwintering sites include the planting of native tree species on which the monarchs prefer to roost.[102]

California

Overwintering monarchs in California have shown to have a slight preference to roost on native species but will also consistently choose introduced eucalyptus species, even when native species are present.,[103] roosting sites in California are typically located close to the coastline, though some have been found further inland.

Reductions in milkweed and agricultural regions of the United States

167 million acres of monarch habitat has been lost since 1996.[104] The reduction in milkweed habitat in agricultural regions of North America has been cited as a major cause of population declines.[105][106] Prior to the introduction of genetically altered corn and soybeans, milkweed was common in the crop fields. Conservationists cite the use of pesticides and herbicides as a cause of population decline. Public criticism of GMO crops continues of corn and soybeans which have *Bacillus therigenes* genes as part of their DNA, (pollen from these crops is thought to increase monarch mortality).[101] that produce pollen that can fall onto larval host plants negatively impacts the survival of larvae. More acres of GMO crops are planted yearly, partly in demand for the ethanol that is required in gasoline, the so-called ethanol mandate, the Clean Energy Act of 2007[107][108] The of a connection between the use of GMO crops and the decline in population has been called 'suggestive but not conclusive'.[109] Milkweed habitat is also destroyed by the expansion of urban and suburban areas.[110]

Conservationists also call attention to the decreased habitat that allows the growth of nectaring plants.[101][111][112][113]

Man-made obstacles

Man-made obstacles include vehicular traffic near larval food plants and adult nectaring plants.[101][114] One study suggests that the planting of non-native milkweed, Ascleepias curassavica in South Carolina has the potential to pull monarchs out of the migratory pool.[33]

Other threats

Factors that have a negative effect on the migration are extreme weather, including colder winters in central Mexico, droughts in Texas, invasive (non—milkweed)flora on which monarchs lay eggs and the increased use of synthetic insecticides that are less biodegradable.[115]

Conservation programs

There are many organizations and programs existing to promote the preservation of the monarch and its migration.

- **Health monitoring** contributes to conservation by studying the health of butterflies in all or various stages of its life cycle.
- **Habitat restoration** contributes to conservation by planting larval food plants, nectaring plants and

overwinter plants necessary for winter survival.

- **Policy** contributes to the conservation by coordination of efforts across governmental and non-governmental organizations
- **Reserves** protect habitat for the butterfly.
- **Education** contributes to the conservation of the monarch by raising awareness and participation in conservation activities.
- **Censuses** of the monarch provide information regarding the migration routes, relative population comparisons between different populations.
- **Grants** are given and received to help foster new conservation programs and to fund research.
- **Research** provides information regarding the butterfly and its migration.
- **Citizen Science Participation** involves activities by lay-persons to promote conservation.
- **Tagging** and then recapturing monarchs provides information useful to provide information on migration.
- **Regulations** exit to protect the butterfly and its habitat
- **Economic development** promotes the development of alternative sources of income around Mexican overwintering sites to prevent the harvesting of trees used by overwintering butterflies
- **Repository** is the accumulated data produced by scientists and citizen scientists.
- **Available to public** indicates whether this data are shared freely to the public.

Organization or political entitie
Monarch Watch (http://www.monarchwatch.org)
Monarch Joint Venture (http://www.monarchjointventure.org/)
Association for butterflies (http://afbeducation.org/butterfly-research/)
Project Monarch Health (http://www.monarchparasites.org/)
Pollinator Partnership (http://www.pollinator.org/monarchs.htm)
UNESCO[116]
La Naturaleza Nos Llama (http://www.lanaturalezanosllama.com/)
National Park System
Executive Order - Presidental Memorandum [118]
Xerces
Volunteer Match (http://www.volunteermatch.org/search/org678953.jsp)
Iowa Department of Natural Resources Iowa Prairie Resource Center
California State Park system
City ordinance of Capitola, California
The Coastal Zone Management Act, California[119]
Assessment and Status Report, Canada
Monarch Butterfly Fund
Forest For Monarchs (http://www.forestsformonarchs.org/)
Larson Juhl (https://https://www.larsonjuhl.com/global-releaf.aspx)
Monarch Ecology Fund (http://www.ecologyfund.com/ecology/info_plant_tree.html#monarch)
Plantit (http://www.plantit2020.org/)
Global Climate Summit California Environmental Protection Agency (http://www.calepa.ca.gov/Search/d q=Monarch+butterfly&sa=Search&cof=FORID%3A11& siteurl=www.calepa.ca.gov%2Fsearch%2Fdefault.aspx%3Fq%3DMonarch%26cx%3D016697183436188 8&ref=www.calepa.ca.gov%2F&ss=574j190276j3)
USDA
Medio Ambiente y Recursos Naturales (http://www.mimorelia.com/noticias/michoacan/destinan-110-mdp /153293)
Texas Milkweeds and Monarchs (http://www.inaturalist.org/projects/texas-milkweeds-and-monarchs)
Wild Ones Wild for Monarchs (http://www.wildones.org/learn/wild-for-monarchs/)

Proposed policies to conserve the migration

Much discussion exists concerning what actions may benefit the migration. Efforts to preserve this

phenomenon include:

- continued discussion via the Trilateral Committee for Wildlife and Ecosystem Conservation and Management Summit to organize continent wide conservation actions[121]
- Reforestation of overwintering habitat in Mexico.[122]
- Promote the Farm Service Agency Conservation Reserve Program in which enrolled farmers receive yearly payments for removing environmentally sensitive areas from production and to promote species of plants that improve habitat.[123]
- the formation of specific organizations to educate the public about the migration and monarch biology[124]
- the study of the effects of diseases, parasites and predators on populations [125]
- limiting activities at the overwintering sites (logging, tourism),[49][126]
- payments to local residents to monitor forest habitats[49]
- mass planting of milkweed and nectar plants. Concerned individuals governmental agencies, and organizations have made efforts to restore milkweed habitats to provide nectar and foodplants.[127][128][129][130][131][132]
- studies that involve the participation of citizen-scientists who monitor and apply tags to migrating monarchs
- the lobbying of lawmakers, corporations, highway departments, utilities and policy-makers to preserve habitat[133][134][135]
- the creation of media (websites, magazine articles, art, newspapers, movies, children's books, documentaries, educational curricula) that provides information about monarch migration.

Economic influences related to the migration phenomena

Tourism around the overwintering sites in Mexico and California provides income for those who provide such services.[136]

Residents near the overwintering sites are concerned that their children do not have enough to eat so they are forced to continue illegal logging. Other residents take advantage of the months butterflies overwinter near their homes. Though they consider themselves quite poor, it is possible for them to generate enough income to last them through the year acting as guides, providing lodging and meals, selling crafts and souvenirs.

Overwintering monarchs roost in trees on privately owned land. Laws and regulations regarding the protection of the overwintering sites and habitat override the interests of land owners, farmer' cooperatives and local governing bodies.

In 1986, Mexico created sanctuaries for the winter months. Sections of the forest were closed to the local people who depended on lumber for their income. Small-scale logging operations continued though illegal. Conservation organizations pay residents to patrol the forest.[49]

Contributions are solicited to fund programs that support monarch conservation efforts.[137][138] Some donations to conservation programs are directed toward fundraising for the organization.[139]

Politics

The scientific and conservation efforts require the involvement of the United States, Canada and Mexico. This has resulted in the formation of the North American Monarch Conservation plan. Conservation plans in Mexico have been suggested to be deficient.[140]

> Conservation has both practical and theoretical components, with the former often having little to do with science or biology. Education shapes attitudes, a sympathetic populace lobbies government, regulations are instituted, and where possible, land is set aside as reserves. *Joel Berger, University of Nevada*[141]

Affected people groups

Indigenous people groups, residents, farmers and landowners surrounding the overwintering sites have made statements about their dissatisfaction with the involvement of Canadian and American conservationists concerning the enforcement of restricting the use of lands in and around preserves. Sustainable development in the areas surrounding overwintering colonies has been identified as a major factor in conservation efforts. It refers to the substitution of economic activities that have a negative effect on conservation efforts with economic opportunities that have a positive effect on conservation goals. Mexican communities have expressed concern with the limitations placed on their use of land and resources. Conservation proposals are met with 'little enthusiasm' if not inclusive of local interests.[51][142][143][144]

> Sustainable development and conservation today is a problem of marketing and financing, with real numbers and real mechanisms-not of good intentions. - *Roberto Solis, Instituto Nacional de Ecologia, Mexico* [51]:11

Animal research in conservation has a role but it has little significance unless sociological, economic and political issues are satisfactorily resolved.[141]

Access to overwintering colonies is tightly controlled by Mexico and monitored by Profepa, Universidad Nacional Autonoma de Mexico (UNAM), Instituto Politécnico Nacional (IPN), Monarch Butterfly Biosphere Reserve (MBBR), local and international volunteers.[145] The world Wildlife Fund pays for the salaries of enforcement officers.[49]

Presidential memorandum

President Obama recently directed his agencies via a presidential memorandum, to "Promote the Health of Honey Bees and Other Pollinators". The monarch butterfly was specifically mentioned in the memorandum.[118]

Petition to designate the monarch endangered

The Center for Biological Diversity, The Center for Food Safety, The Xerces Society and Lincoln Brower have filed a petition to the Interior Department (USA) to protect the monarch by having it declared as an endangered species.[146] The environmental activist Robert Kennedy has endorsed the petition but has said the designation should be 'threatened', not 'endangered'. Critics state monarchs are not threatened and do not need Federal protection. Listing the monarch could divert funding take attention away from rarer species at greater risk of extinction.Critics also are concerned about what the petition does not say.

> ...it could create a backlash. Fear of regulation, he said, could make landowners into opponents. He pointed out the petition calls for the “designation of critical habitat” via the powers of the act, but doesn’t spell out what that means. *Chip Taylor, Monarch Watch*[147]

Scientific community

Not all researchers are in consensus regarding lobbying for federal government intervention, population censuses,[55] steps to take to conserve the migration, and the possible endangered status of the monarch. They have been critical of the data generated by citizen scientists calling it 'inappropriate'. Differences in opinions by researchers are common.[55] Some researchers have been critical of each other for not making their data available to the public and to each other.[148][54][53] Like all scientic research, opinions are voiced, sometimes explicitly. One scientistist is critical of the first tagging efforts by Fred Urquhart calling it an "amateurish self-serving approach to biology that isn't science".[69] Another researcher denies that the monarch migrates but instead is greatly affected by weather conditions to head south.[69]

Local governments

Local governments are considering legislation to provide habitat for migrating monarchs.[149]

See also

- Conservation biology
- Lepidoptera migration
- Monarch Butterfly Biosphere Reserve
- Peninsula Point Light, Michigan
- Catalina Trail

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- Journey North (http://www.learner.org/jnorth/)
- Forests For Monarchs, Mexico (http://www.forestsformonarchs.org/)

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Categories: Animal migration | Danaus (genus) | Lepidoptera | Insects of North America

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