SNOW FLIES

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Editor: JOHN RICHARD SCHROCK
Editorial Committee: DAVID EDDS, TOM EDDY, GAYLEN NEUFELD
Editors Emeritus: ROBERT BOLES, JOHN BREUKELMAN, ROBERT F. CLARKE
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EDITORIAL NOTE: This issue of the Kansas School Naturalist tells the story of the little wingless snow crane flies of the genus Chionea. This is a simplification of the definitive work on these unusual flies published by Dr. George Byers, professor and curator emeritus of entomology at the Snow Entomological Museum at the University of Kansas in Lawrence. Teachers and students who wish to read further about these fascinating insects should refer to his "The Crane Fly Genus Chionea in North America," The University of Kansas Science Bulletin, Vol. 52: 59-195, March 1983. All illustrations are from his work and used by permission; additional thanks are due to Dr. Byers for reading the text and offering suggestions. However, any errors of generalization and content are mine.

--J.R. Schrock

Cover Figure 1. A male snow fly, species Chionea alexandrialla Garrett, as viewed from above (the body is approximately 7 mm long). Such line drawings illustrate the art skills useful to an entomologist.

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"Insects" KSN Vol. 10, No. 2 (out-of-print, photocopy available for $1.00)
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INSECTS IN WINTER?

We don't expect to find insects active outdoors during our leafless, chilly winters (although fleas, cockroaches and other insect pests may join us in our warm homes). Nevertheless, nearly all insects find some way of enduring this cold spell. Many overwinter in an inactive pupal stage in a cocoon or as eggs hidden beneath bark or soil. However, some are active in winter and even find the cold season to be the best time for adults to reproduce and disperse. One of these unexpected winter insects is the "snow fly," a long-legged, virtually wingless crane fly that surprises outdoorsmen when it is spotted walking across the snow on a mild winter day. Entomologists, the biologists who study insects, see many new and unusual invertebrates in their daily work. Observing and collecting these strange insects was the first step in unraveling the life history of the snow fly.

WHY BE A WINTER FLY?

"By attaining the adult stage in winter," says entomologist George Byers of K.U., "Chionea escapes many of the common warm weather predators that take a heavy toll of winged crane flies . . . " Snow flies thus avoid capture by spiders, dragonflies, ants, frogs, toads and salamanders. And many kinds of insect-eating birds have flown south for the winter. Byers notes that winter birds would probably pick up these flies on the snow surface if they are as conspicuous to birds as they are to humans.

Some other insects have taken advantage of this release from predators to become more common in winter as well. Tiny springtails become very numerous and some are called "snow-fleas." Some winter stoneflies are wingless or short-winged, but others are fully winged and fly about on warmer winter days. Many fly fishermen are familiar with midges that emerge in the winter. A few other flies, wasps and even non-insect spiders can sometimes manage in near-frigid conditions. But since these invertebrates are not "warm-blooded," it takes a special physiology to be active when it is cold.

HOW DO INSECTS SURVIVE IN WINTER?

To survive as an insect in winter, there are two things to understand: the microclimate of the ground in winter and the special adjustment these "cold-blooded" insects can make.

When we wander out on a cold January day, we readily feel the bitter below-zero winds that blow around our 5-6 foot tall frames. But several feet below the soil surface, the ground is not frozen--that is why we place our outside plumbing below the "freeze line." And when a layer of snow is added, we have a blanket that lies upon this "warm" soil and shelters it from the bitter cold air and winds above. In 1930, an entomologist named Mail found the temperature just below the soil surface varied from -1 to +3 degrees C over the month of January, while the air temperature above fluctuated from -2 to -23 C. Other workers discovered the blanket of snow evened out the extremes of day and night. Since the warm earth beneath the snow often melts away the bottom of the snow blanket (which remains propped up by grasses and litter), a thin open space between snow
and soil offers a mild mini-world where some insects and small mammals are sheltered from the outside world. This is called the **subnivean environment**.

**HOW DO SNOW FLIES REMAIN ACTIVE AT VERY COOL TEMPERATURES?**

Many insects cannot survive near-freezing temperatures. Most of our body processes involve enzyme reactions (a type of chemistry) that work best within a range of temperatures. Snow flies therefore must have developed different enzyme systems that allow them to carry on the chemistry for body processes at cooler temperatures.

Actual "freezing" poses a particularly difficult challenge. First, if tissues freeze solid, the fluid cellular and organ functions come to a halt—nothing can move. More disastrous is the fact that when ice crystals form, the sharp ice crystal points rupture cells and tissues and destroy the structure, as anyone who has frozen and thawed lettuce knows.

Snow flies are cold hardy as adults for several reasons. Since adults probably do not eat solid food, food particles cannot provide the nucleus to start ice crystals growing. In addition, the electrolytes in the haemolymph (that is
Figure 3. Internal anatomy of the adult male (top) and female (bottom) snow fly, *Chionea alexandriana*, drawn by Dr. George Byers. Obviously there is as much complexity packed inside a small insect's body as in our larger anatomy. Muscles are labelled with "m" and a number. The other structures include: acg--accessory gland, at--aorta and cedv--cardiac enlargement of dorsal vessel (acts as "heart"), covd--common or median oviduct, cp--crop, dv-dorsal vessel, fp-fat pad, fspth--functional spermatheac, gc--genital chamber, agn5--abdominal ganglion of fifth segment, hg--hindgut or intestine, mpt--malpighian tubule (acts as "kidney"), oes--oesophagus, sgl--salivary gland, vn--ventriculus.

the chemicals in the clear "blood") lower the natural freezing point (similar to how gasoline doesn't freeze as soon as water). However, some insects, including the snow fly, are able to remain active and undamaged at below-freezing temperatures. The entomologist Hagvar found snow flies active down to -6 C and most common at temperatures between -4 and -5 C. Others confirmed these flies operate in a narrow range, mainly between 0 and -4 C. Whatever enzyme systems allow it to live in cool temperatures don't function at higher "normal" temperatures. So you need not go looking for snow flies on snow on warm winter days when the snow is rapidly melting—it would be too hot for their system.

Exactly how do winter insects keep their blood liquid at below-freezing temperatures? One known mechanism is the production of glycerol, a chemical similar to anti-freeze, that increases the viscosity of its body fluids and prevents molecules from travelling to align as a crystal. And there is still unknown biochemistry to be learned about being a cold-loving snow fly!
Figure 4. Muscles of the hind leg of a snow fly, *Chionea alexandriana*, drawn by Dr. George Byers. Each numbered muscle has a base, or "origin", and an "insertion" point where it is attached and moves when the muscle shortens. This illustrates more of the fabulous complexity that is packed inside an insect.

**HOW DO WE KNOW THEY BELONG TO THE CRANE FAMILY?**

There are many families of flies in the order Diptera. The family Tipulidae contains a large number of species of long-legged crane flies that somewhat resemble large mosquitoes and nearly all of which are active adults during the warm seasons. Crane flies also have a V-shaped suture on the back of the thorax. Since snow flies lack both wings and this V-shaped suture, why are they grouped with crane flies rather than with midges or mosquitoes? Indeed, some entomologists in the 1800s gave snow flies a separate family name. But in 1869, the diplomat and dipterist C. R. Osten Sacken showed this group belonged among the crane flies.

How can Dr. Byers and other entomologists be so certain these strange wingless snow flies belong in the midst of a large family of flying crane flies? The work of grouping evolutionarily related organisms (called systematics) requires comparison of very many structures. Dr. Byers knows the snow fly genus *Chionea* is in the tribe Eriopterini in the subfamily Limoniinae of the crane fly family Tipulidae because of comparisons of many body parts as well as life history and behavior. This includes the structures of mouthparts (maxillary palps), the egg-layer (ovipositor), hairless eyes, many leg structures, etc. Indeed, because insects have a complex surface armor or exoskeleton, an entomologist may have more surface-structure names to learn for an insect that a medical student has to learn for the human body!
WHY ARE THEY CALLED "FLIES" IF THEY LACK WINGS?

Some insects such as the silverfish or the numerous soil springtails evolved from ancestors that never had wings. We know this because they lack the infolded seams that strengthen the thorax and provide a ridge to anchor wing muscles. But other modern wingless insects, such as the snow fly and the cat flea, did have ancestors with wings. Although these species have evolutionarily "lost" their wings, their anatomy still includes rudimentary structures showing they once had wings.

Most adult winged insects have two pairs or four wings attached to the thorax. But the order of true flies has only one pair of wings, hence the order name "Diptera" for "two-wings." The hind pair of wings in flies are reduced to club-like "halteres" that are easily seen on both the Cover Figure 1 and Figure 2. These halteres help to sense position during flight (pitch, roll, yaw). Although snow flies have lost their front wings, the presence of halteres is one of many features that tell entomologists that the wingless snow fly nevertheless belongs to the order of two-winged flies.

WHEN ARE ADULT SNOW FLIES FOUND?

Byers found collection records for snow flies "... for every month from September through May, with peaks of abundance of adults coming generally in October-November and February-March." Although many collectors did not note the time of day they found the insect, Byers suggests looking for them in the late afternoon. They are easiest to see on snow. But to expand our knowledge of their life history, the avid collector could consider the other clues in this article and hunt for them under logs, in mouse nests, and in leaf litter.

HOW LONG DO THEY LIVE?

Compared to winged summer crane flies that may live up to a week to ten days, snow flies are very long-lived. Byers suspects "two months will not be found uncommon" for North American adults. Long adult life may not just reflect a slow metabolism in a cold environment, but also may be an adaptation to variations in weather--it allows an adult to postpone mating and dispersal when weather is severe. However, the snow fly must make it through the rest of the year in some stage and it is the egg, larval and pupal stages where the life history is least known.

WHY WANDER ON THE SNOW?

One explanation given has been that males can find females easier on the surface of snow. However, noting their poor vision and the disadvantage of seeing the world from a few millimeters above the snow, Byers disputes this theory. Instead, he says, "I regard the appearance of Chionea on snow as partly, at least, a means of effecting genetic recombination." He notes that the flies' living in isolated clusters in underground burrows increases the problem of inbreeding. Getting up on the snow surface and walking straight for some distance is a "device for bringing about a mixing of genes." How do they get topside? Experienced in the field, Byers points out the many leeward cavities in snow that give access to the surface, as well as stems that vibrate in the wind and pry vertical shafts that are roadways to the surface. Once on the surface, Chionea is known to be a strong walker. By picking-them-up and putting-them-down, the spider-like fly can stomp its way across considerable distances at the breakneck speed of four feet a minute!
THE STRANGE CASE OF THE FLY THAT WEARS A NECKLACE!

It looked like an abnormality. Dr. Byers had extracted a preserved specimen from an alcohol vial and oriented it under his stereo microscope. At first glance, it appeared the fly had a swollen neck membrane. Upon closer inspection, the ring was definitely not part of the insect's body. He had seen something similar to this earlier in two dried, pinned specimens—such specimens are shriveled and easily broken—and had suspected the head had broken off and the ring was a bead of dried glue where a collector had reattached it. But this was a "wet" specimen, and he soon found more just like it. He gave the collars a much closer inspection. Probing with needle and forceps, he found the ring could be loosened and "rotated on the neck by the tip of a needle, yet it fits very closely and cannot be slipped off over the head."

This was very puzzling. With careful microscope work, he described the several cases of "...a ring-like capsule around the neck, thin walled and somewhat the shape of an inner tube of an automobile tire." It was obviously not a product of the snow fly itself and with time, additional cases began to shed light on the unusual collars. Within some capsules he could discern "a large number of immature nematodes, which after a time rupture the capsule wall and emerge. He did not have living rings that showed this, but among his preserved specimens he could find collars showing "various stages of increasing development of the nematodes within the capsule and then of their leaving it."

Now nematodes are not insects but are small roundworms that are even more...
devoid of identification features than some insect larvae. Therefore it is an animal group where many species are yet to be identified and where there are few specialists available. Through communication with nematologist Dr. May Belle Chitwood, Byers learned these nematodes from the snow fly collar were closely related to *Rhabditis*, some species of which utilize insects to hitch-a-ride from place to place. Searching through the literature, Byers found another expert who described parasitic nematodes that depended upon coprophagous (feces-eating) insects to transport them from host-to-host.

After much work, Byers concluded: "It is possible that *Chionea* is used by the nematode as a means of travelling from one mouse burrow to another in order to parasitize the rodents. Or the *Chionea* may be merely a device for providing the nematode a generally more widespread distribution, if it is a free-living form. In any event, the female nematode probably places her egg capsule (which may be a more solid, gelatinous ring at the outset) around the fly's neck at the time of its emergence from the pupal skin, for it is at that time that the fly is least mobile and least able to avoid such treatment. I have speculated freely in the interpretation of these nematode capsules, but whatever the true story, it must be a very interesting one."

To investigate such a diverse problem takes a broadly-trained and experienced biologist with insight into the life history and behavior of a wide range of organisms. In this era of specialization, not many researchers could have solved this much of the puzzle of a fly that wore a necklace.
LIFE CYCLE
Researchers have collected live gravid females that have then laid eggs in laboratory cages. So we know that some female snow flies carry up to 194 eggs and lay them singly on or in the moist paper surfaces provided by entomologists. Eggs take from eight days to three weeks to hatch but, not knowing what their food sources are, our knowledge of the young snow flies consists of snapshots of collected larvae. Similar to other fly larvae, the softer bag-like body is far less adorned with identification features, compared to adults. However, the mouthparts have to deal with food gathering and are more hardened; the head capsule provides identification features. Between the summer larval stages and the adult is the autumnal pupa (Figure 6). Here the details of the adult-to-be begin to emerge, very much like a pupa in a cocoon from which a moth soon emerges.

WHY ARE THERE SO MANY DIFFERENT SPECIES OF SNOW CRANE FLIES?
Sixteen species of *Chionea* snow flies are now recognized as occurring in North America. Most have ranges somewhat distinct from each other. This reflects, in part, biologists' belief that these different species diverged over time from common ancestors. For this to occur, the fly populations had to spread out, and then peripheral populations became separated from the parent population by geographical distance and accumulation of random mutations. In time and in response to different selection pressures, local populations of snow flies became so unlike their parent stock that the two were no longer able to interbreed. This process is called speciation and probably requires long periods of time.

Figure 6. Pupa of the snow fly, *Chionea alexandriana*. This is the stage where the active feeding larva converts into an adult insect. There are fewer detailed structures labelled: cc—cephalic crest, h—haltere, mxp—sheath of maxillary palp, pn—pronotum, numerals indicate abdominal segments. Drawn by Dr. George Byers.
WHAT DO SNOW FLIES EAT?

Nobody knows. Byers has kept an adult fly alive for 19 days; the record is 62 days. But adults do not appear to feed on solid foods. It is the larvae that feed heavily and grow and "I have failed at every attempt to rear the insects," reports Byers. Indirect evidence suggests that those living in rodent burrows feed on the rodents' feces. Immatures have been described, "... but no details of the life history of any species have been made known." Those species found in caves would likely live on some organic debris, he believes. One clue comes from distantly-related flies whose larvae live on the fungus that grows on bat guano.

WHAT EATS SNOW FLIES?

Not much. Remember that one advantage to being a winter insect is that harsh winters greatly reduce the kinds of animals that might feed on you. As already mentioned, during the time a snow fly is actually outside walking across the snow, it may be relatively vulnerable to winter birds. But the majority of its time is spent in burrows and amid litter, where it probably has only two types of predators to worry about.

"Rock-crawlers" are strange primitive insects found on the mountains of western North America. They too are active in winter, clambering about among snow-laced rocks. Entomologists have actually witnessed these wingless cricket-like insects eat snow flies in their laboratory. They also recovered fragments of snow flies from the guts of 23 dissected rock-crawlers.

Although it has never been witnessed, we also know snow flies are at least occasionally eaten by mice. The proof of this is indirect. Tapeworms are common in mice and rats. These tapeworms produce eggs that are deposited with feces on the floor of rodent burrows. These eggs are then eaten by insect larvae such as beetle grubs, moth caterpillars, and flea larvae. Inside an intermediate insect host, a tapeworm forms its cysticercoid stage and waits to be eaten by a rodent. It is absolutely necessary for the tapeworm to alternate back-and-forth between being a cysticercoid in an insect body and a tapeworm in a rodent. Since Byers found cysticercoids in two out of three specimens of Chionea stoneana he collected in eastern Kansas, he knows some are eaten by mice in order to keep this parasite cycle going.
WHERE DO SNOW FLIES OCCUR?

Snow flies in the genus *Chionea* range through both Eurasia (Europe across to Japan) and North America. *C. albertensis* was first described from Alberta, Canada, and occurs down to Oregon. *C. wilsoni* is found in mountainous northeastern Alabama and *C. scita* occurs along the Appalachians. In the prairie states, *C. stoneana* extends into Kansas, Oklahoma, Iowa, Minnesota, Wisconsin, Missouri, Illinois and Indiana. Most widespread is *Chionea valga* which occurs from Alberta to Labrador and down to Minnesota and Virginia.

Although it is common to pinpoint all of the collection sites for a species on a map and then draw a boundary to enclose them, defining the insect's "range," Dr. Byers only notes the collection localities. In addition to those he personally collected, he checked all the specimens that could be located in U.S. museums—he could find only 1100 adult specimens for all species together. Compared to the more than 123,470,000 insects in U.S. museums, 1100 is a very small number indeed. Until more are collected, Byers is reluctant to fill in a defined range. As with much scientific research, his monograph is a temporary assessment of what is presently known, which he hopes "... will serve to stimulate further interest in these flies, which may some day lead to a more complete treatment of them."

WHY DO SNOW FLIES OCCUR WHERE THEY DO?

Although *Chionea* ranges across 2000 miles of the U.S. east-to-west and 1500 miles north-to-south, Byers finds they occur in two general regions. The western flies follow the mountain ranges. The eastern flies mostly follow the forests west to the edge of the plains. A large part of this eastern range was glaciated, some of it as recently as 10,000 years ago. Since the biology of the flies shows they couldn't exist on the Ice Age glaciers, the Wisconsin Age ice pushed such species as *Chionea valga* southward. Now that we are in an interglacial period, Byers calculates that his wingless fly may have walked 1200 miles to regain its present northern range. "This sounds impressive but actually amounts to somewhat more than 195 m (210 yards) per year, probably not an unusual distance for an individual *Chionea* in its lifetime."

An effort to explain current ranges of the 16 North American species involves the correct discernment of species, extensive collections to define exact ranges, careful studies of the insects' habitat needs and tolerance limits, and insight into the complex ancient history of the area. Such studies of the biogeography of snow flies may eventually complete the puzzle of why they live where they are today.

EXACTLY WHERE CAN YOU COLLECT SNOW FLIES?

"Most of what we know about these flies is based on their occurrence on the surface of the snow," says Dr. Byers. Yet this may only reflect how noticeable this highly contrasting insect is when it is stomping across the snow. The majority of its time is probably spent amid dried leaves, the debris of rotten logs or in small animal tunnels. And some species have been surprisingly abundant on the floor of caves, well inside the border of total darkness. Perhaps you can go out next winter on a mild day and look for them on the snow in the appropriate habitat: "... environments that are to some extent forested."
WHY DID THEY LOSE THEIR WINGS?

For an insect to fly requires sufficient warmth for muscles to move rapidly. Perhaps you have seen cool butterflies in the morning, spreading their wings to intercept sunlight so they could warm up enough to fly. For this insect to survive in winter, it must remain near the mild snow blanket; flying up into cold air would require warmth this insect could never generate.

But when this fly walks around subnivean caverns or rodent burrows, wings would get in the way. There would likely be heavy selection against such useless projections (similar to the loss of wings on early "fleas" that were also derived from early flies).

However (and unlike the fleas), snow flies have maintained well-developed halteres. "It is problematical why, in a dipteran that is altogether flightless, the halteres should be so well developed," says Byers, "but neither observation of the living flies nor microscopic examination of the structures of the halteres has led to an explanation." Because each haltere has a noticeable nerve leading to it and what appear to be sensory pegs at its base, he suspects the halteres have a sensory function, but it will be up to future researchers to investigate this.

Another advantage to losing wings is that the space normally taken by muscles to flap the wings can now be used for developing eggs (see Figure 8). This is rather unusual because eggs are usually confined to the last body section, the abdomen.

Figure 8. Side view of the head and thorax of a female snow fly, *Chionea nivicola*, drawn by Dr. Byers. Normally, a winged insect has a thorax full of muscles that power the wings, and eggs are confined to the abdominal cavity. This shows eight eggs stored in the thorax in the space left by the "missing" flight muscles.
Figure 9. A female (left) and male (right) snow fly, *Chionea scita*, mating. The male is mostly supported by the hind legs. This is an unusual mating posture for flies.

**ROMANCE IN THE TUNNELS?**

Rare and cold-weather insects do not have the luxury of being choosy about mates. The several entomologists who have captured live snow flies agree that when placed in the same container, males and females immediately mate, even though it is several degrees below freezing. Mating takes 30 to 70 minutes. While winged crane flies face opposite directions during mating, these wing-less flies take the position shown in Figure 9. This requires the elaborate male copulatory structures to be inverted 180 degrees to match the female's abdomen and probably relates to the enlarged hind femora of males.

**STRANGE BEHAVIOR OF A STRANGE FLY**

When caged with no place to hide, snow flies assume the crouch shown in Figure 11 and spend long periods of time perfectly still. They may raise and lower their bodies slowly and rhythmically, similar to fingertip push-ups. And when moderately alarmed, the fly draws its legs in close against the body and perhaps looks more like a chip of bark than a sprawled tasty insect. And male snow flies can jump! Byers describes how an unprovoked male "... suddenly leaped from the edge of a dish to the front of my shirt as I was watching its movements."
SNOW SCORPIONFLIES
This is a completely separate group of insects that has also evolved winter species that look very much like snow flies, and they can also be found walking across snow in the wintertime.

Most scorpionflies are warm-weather insects with four wings as adults. They are mostly forest hunters.

Scorpionflies are not closely related to snow flies. They have their own order, Mecoptera. The ancestors of present scorpionflies were also ancestors to flies and fleas, but scorpionflies never developed hind wings into halteres. Therefore the scorpionflies are not "true flies" and we do not separate out the word "fly" as we do for insects in the order Diptera.

The evolution of winter forms with greatly-reduced wings may have involved natural selection pressures similar to what is described for snow flies. This tendency for organisms from different ancestry to evolve similar traits when in a similar environment is called convergent evolution.

Most scorpionflies feed on dead insects, but the larval and adult snow scorpionflies feed on mosses. There are thirteen species of snow scorpionflies found in the United States.

Dr. Byers not only specializes on the study of crane flies, including our snow flies, but is also one of the few authorities on scorpionflies. The Snow Entomological Museum at the University of Kansas has, by far, the world's largest collection of scorpionflies.
"WHAT GOOD ARE THEY?"

Why study such insignificant and rarely seen flies? "What good are they?" is a particularly common American question nowadays. Sadly, we often feel obliged to appeal to the possibility that remote and undescribed plants and animals may have beneficial uses as drugs or may be unknown vectors for human diseases. But by far most of them are not particularly useful or harmful to us, nor are they keystone species supporting critical food webs. Nor are they unique indicator species monitoring the health of the environment in any precise way. Most are, in a sense, merely small fibers in the enormous fabric of the knowledge we are developing about our natural world. A society that supports the pursuit of such knowledge that has no immediate direct return, nevertheless gains a growing depth of wisdom that flavors how it views the future.

It is certainly as exciting to work toward these mental discoveries as it is to physically strive for Olympic medals, and the accomplishments are far more lasting. Although Dr. Byers solved a lot of interesting puzzles about snow flies, he also exposed many new challenging problems yet unaddressed. Perhaps one of our young readers will pick them up.

Figure 11. Chionea scita, resting posture, drawn by Dr. George Byers.