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Monarch Butterflies May Be Threatened in Their North American Range

Introduction:

At the end of each summer millions of monarch butterflies fly from eastern North America to a dozen small patches of forest in central Mexico where they spend the winter. In the spring the butterflies fly north moving into areas as their food plant, milkweed, comes back. In the summer an individual monarch butterfly lives one or two months. That means that the butterflies that fly to Mexico in the fall are as much as five generations removed from the animals that left Mexico the previous spring. How they get to Mexico when their great great grandparents were the most recent generation to make the trip is a long standing mystery. Recent work suggests that monarchs use the sun to orient and navigate.

Professor Lincoln Brower explained in the June 1994 issue of *Environmental Review* the threat to monarch winter habitat in Mexico posed by increasing deforestation. A recent paper reports that most of the monarchs collected from overwintering sites in Mexico were born in the most intensively farmed parts of the U.S. Midwest. American-style intensive agriculture using new insecticides and herbicides and bioengineered seeds may well pose another threat to the eastern monarch migration[1].

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We spoke with Chip Taylor, acting chair of the Department of Entomology at the University of Kansas, about monarch butterflies and conservation efforts on their behalf.

ER: Professor Taylor, what is your training?

CT: I have been at the University of Kansas since 1969. Previous to that I had been at the University of Connecticut where I obtained my Ph.D.; while working on my Ph.D. I evolved from being an evolutionary biologist to an insect ecologist. Besides working on butterflies, I've been working with African bees — the so-called killer bee — that has been moving north through the tropics and subtropics of the Americas since 1957. We're still doing some work on those bees and their hybridization with different subspecies as well as their relative susceptibility to Varroa mites, the mite that is devastating European bees all around the world.

ER: Can you describe the trip the monarch butterflies make each year?

CT: Sure. In March the butterflies break from their winter roosting areas in Mexico and begin to fly northwards, moving through the mountains in Mexico, eventually coming into Texas some 500 miles later. By the first of March we see a few butterflies entering Texas, but the mass of them leave the roosts around the 15th of March, and we see most of the butterflies moving across the southern states from about the 20th to the 30th of March. They lay eggs all along the way wherever there's milkweed, primarily in Texas but basically all across the southern states. As they sweep across the southeastern U.S. wherever milkweeds grow, monarchs will move in and lay eggs on the plants. It's the adults that develop from these eggs

that disperse farther north to the limits of their distribution, which is limit of the milkweed distribution.

ER: Does the milkweed plant confer some protection to the butterfly?

CT: The milkweeds contain toxins, cardiac glycosides, and as the butterfly larvae eat the leaves they sequester these toxic compounds. In the adult butterflies the highest concentrations of these toxins are found in the exoskeleton, particularly the wings. The amounts of these toxins in the adult butterflies are highly variable and depend on the species of milkweeds fed upon by the larvae and several other factors. Due to the toxins some insectivorous birds are unable to eat monarchs, but there are two bird species in Mexico that eat large numbers of monarchs, in one case because the birds have learned to selectively eat only the contents of the abdomen which are low in toxins.


Photo by Paul B. Southerland

ER: Do they keep moving all summer?

CT: It's not clear yet how long the butterflies keep moving, but in midsummer there is relatively little migratory movement. If you mark and recapture summer residents, you find that not many of them are going anywhere, they're all pretty much resident.

The butterflies migrating to Mexico are three to five generations removed from the butterflies that flew north the previous spring.

ER: You see same behavior with neotropical migrant birds: they go north, find a place they like and stay there.

CT: Right, exactly. Then about the 15th of August, say at the latitude of St. Paul, Minnesota or even farther north the new butterflies that emerge are asexual. They mill around, they may hang around in trees and feed on flowers for as long as two weeks.

ER: Asexual being just not interested, or not developed?

CT: They are male and female, but they are turned off reproductively. They stay in this nonreproductive condition, and they mill around for some time and they accumulate fat, and then around the last three or four days of August the butterflies begin to move south. As this migration sweeps south it picks up newly emerged butterflies all along the way.

It takes the monarchs about two months to get into Mexico. They start arriving at the roost sites about the first of November, and it takes most of the month of November for them to finish their arrival. By the first of December most of the butterflies have arrived.

ER: This migration is mind boggling.

CT: Their migration is the longest distance insect migration that we know of. The butterflies return to the same mountainsides and even the same sites on those mountainsides every year. The question is, since they've

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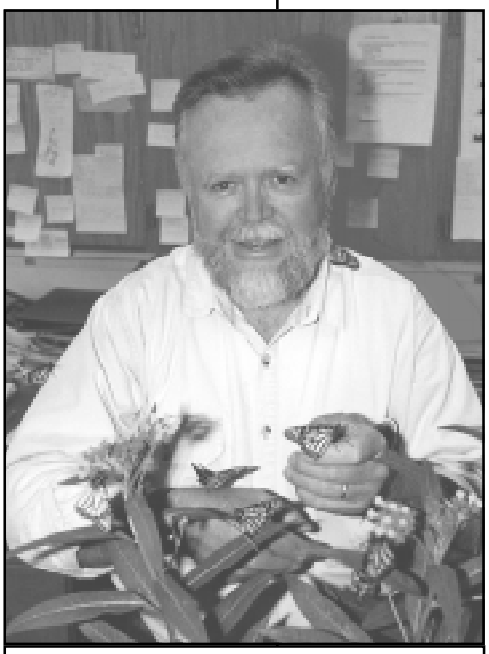
never been to those mountains before, how do they do that? The butterflies migrating to Mexico are three to five generations removed from the butterflies that flew north the previous spring. They converge on these same sites of a few hectares, the same locations year after year. They start on the ridge tops and they move around from place to place and eventually they form these dense masses of butterflies, usually on southwesterly slopes. As the winter progresses, the butterflies will move off of these roosts in good weather and fly downslope. So, the whole group of butterflies moves downhill progressively over a two or three month period.

ER: They are sexually inactive during the migration south. Do they perk up when they get to Mexico?

CT: They remain nonreproductive until the last two weeks of February when they become sexually active. At this time there's a lot of mate seeking going on, and the pairs of butterflies just fall out of the sky in tremendous numbers.

One of the curious things about this mating frenzy is that the males that do most of the mating, at the early part of this at least, are the small, extremely worn males. One way to explain this is what's called the last-chance hypothesis; that is, these butterflies are in poor condition and they generally have relatively depleted fat bodies, and their chance of being able to survive and to move north is not good. So the theory is that they're becoming active because they're going to die soon.

But there is a plausible and easy way to explain what happens with the individuals with smaller mass. It may be that when their juvenile hormone kicks in, it perfuses through those worn butterflies a bit faster because they have smaller mass, and the hormone turns development on sooner than in butterflies that have large fat bodies. So, the answer here may be fairly simple: it may be just a mass-related response to juvenile hormone. This is an hypothesis that can be tested.



Professor O.R. (Chip) Taylor and friends.
All images courtesy of Monarch Watch

Another curious aspect about this mating pattern is that these smaller males tend to mate with females that are among the biggest and most beautiful in the population, and that confuses people. They say, How do these little runts get to mate with all those big, beautiful females?

We did some cage tests, and we got exactly the same results in the cages: the small butterflies became sexually active sooner, and they mated disproportionately with the large females. We suspect that the small-size females are more maneuverable and can get away from these randy males more effectively. That may explain what's going on in the field: it may be just a matter of the big females not being maneuverable enough to get away from these small males.

ER: Assuming they want to.

CT: Well yes, that's assuming they want to. But females put the males to the test, let's put it that way. They do put up a fuss and they do struggle to get away from these males most of the time, so the males have to work hard to persuade the females to be receptive to them.

ER: Does the weather affect the migration?

CT: How they spread in the spring depends upon the weather patterns. In some years the weather patterns in the Midwest shut them down, and migratory butterflies out of Mexico just don't make it even back to Kansas. In other years when we've had warm springs we'll see a lot of butterflies come through Kansas as early as April.

One of the fascinating things about this migration is that the spring behavior is so different from that in the fall. In the fall monarchs are low key, they are nonsexual, they are moving around from flower to flower, they are roosting a lot. The butterflies in the fall are flying fairly

high off the ground because they are using thermals and they are using wind patterns; in some cases they're using the laminar flow. If conditions are favorable, they can attain an altitude with a favorable temperature of fifteen degrees Celsius where they are at a physiological temperature optimum. These butterflies have been seen up to 5,000 feet by glider pilots, and commercial airline pilots have told me they've seen them up to 10,000 feet.

ER: How far can they travel in a day?

CT: During the migration they are moving on an average of fifty to seventy-five miles a day depending on the physical conditions. There are days when they don't move at all if the weather is unfavorable, but we're talking average, so that means that on some days when the winds are right they may be moving over one hundred miles in a day.

In contrast, in the spring, they're moving distinctly to a northeasterly direction, inches above the ground. We see mostly females and aside from a stop here and there to feed, they are on a direct line to the northeast laying eggs all the way. A female that arrives in southern Iowa has probably laid eggs for 1,500 miles.

ER: Is that from a mating that happened in Mexico?

CT: Possibly, although they do mate along the way as well. But by the time they get that far north there are few males left.

ER: What happens in the summertime?

CT: During the summer monarchs undergo three to five generations of reproduction. One year we saw five generations in Kansas. As you go farther north the number of generations is less. The butterflies virtually disappear during the summer from the southern area where they produced the first generation (Texas, Louisiana, Alabama, Mississippi, Georgia, up through to South Carolina and even into parts of North Carolina). The milkweed dies back, so they lose a host plant as the summer progresses in the south, and the best resource is ahead of them to the north and to the northeast.

> Their migration is the longest distance insect migration we know of. The butterflies return to the same mountainsides and even the same sites on those mountainsides every year.

ER: When did you start Monarch Watch?

CT: We started monarch Watch in 1992. I was very fond of these butterflies, and I'd been using them for classroom teaching and I'd been interested in them since I was a kid.

We decided to get involved with monarchs because while working with African bees in Mexico in 1992 few monarchs were seen coming north. I was curious about the low numbers, so I called Lincoln Brower and we discussed this. Subsequently, there was a little blurb that appeared in *Science* which basically begged the question, What's happening to the monarchs? Where are they? What does this foretell about at least the short-term future of the monarchs?

A few months later, I had some conversations with a colleague of mine, a high school teacher by the name of Brad Williamson; he came over one day and we discussed the monarch situation. I thought it might be good to get some tagging going on with these butterflies now that the population was low. With low populations maybe we'd learn more than what's been found with earlier tagging programs. Brad thought this was a good idea, but that we ought to get high school kids involved.

In early Sept 1992, we sent out a couple of news releases asking for volunteers to tag monarchs. The response was just extraordinary, and that was the birth of Monarch Watch; and it has evolved into an outreach program. Presently we are interacting with about 2,000 schools and 100,000 kids. Last fall we issued approximately 220,000 tags. The monarch population was low in 1998 and it was not a good tagging year. Nevertheless, about 65,000 butterflies were tagged, and of these ninety-six have been recovered in Mexico through mid February. This is the highest number to be recovered in one year and there should be many more tags recovered before the season ends in March.

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ER: It sounds like Monarch Watch is about more than tagging.

CT: A large part of the Monarch Watch program involves tagging butterflies, but we are also trying to involve the students and other participants in numerous scientific projects. There is little money for large-scale research projects, and even with money a scientist can only be one place at a time. To conduct continent-wide research our solution has been to recruit many people who have an interest in science and in these butterflies and to train them, mostly through our web site and our literature, to obtain useful data.

ER: What's the point of the tagging?

CT: A similar tagging program was started by Fred and Nora Urquhart to find out where the monarchs went in the winter. Subsequently, the idea was to learn the pathways the monarchs took and how they navigated across the continent.

Unfortunately, Fred and Nora never analyzed their data for this question. And, you can see why analysis seems impossible when you look at the data. Analysis is difficult because some of the monarchs are blown off course. For example, monarchs that are tagged in Kansas might be recovered in Alabama. This is confusing because they're going the wrong way, and there are many wrong-way recoveries.

We solved the problem by systematically sorting through the data for each region of the country. This analysis gives us a mean vector for each region and this has given us a clear picture of how the monarchs are moving across the country.

Our objective with this analysis was to identify the major flight paths taken by monarchs as they cross the US. The recoveries in Mexico are interesting, but they are not the most important part of the data. The most valuable information comes from butterflies that are recaptured within the United States because they give us directions or vectors of movement. We also have people involved in studies of vanishing bearings and body headings.

Butterfly tagging kits being assembled for distribution to more than 2,000 schools.

ER: Vanishing bearings?

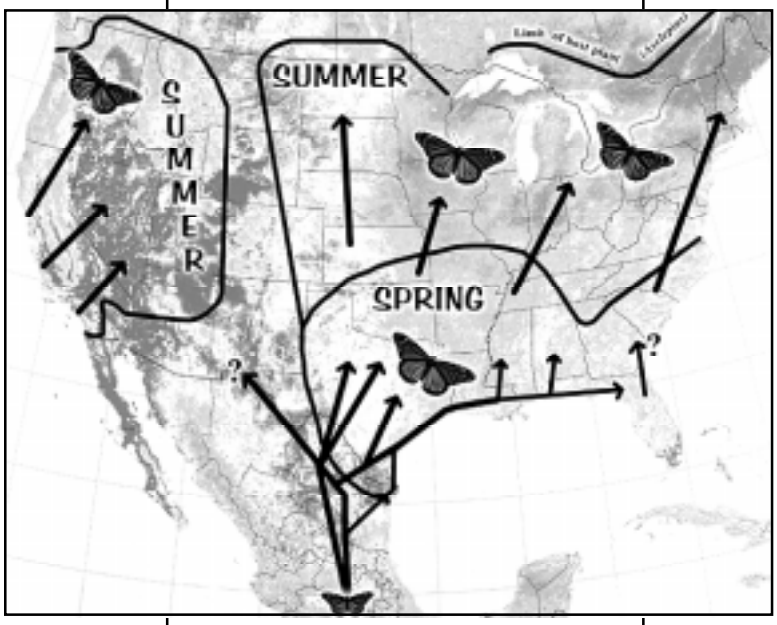
CT: A vanishing bearing is simply the compass direction recorded as the butterfly disappears on the horizon. These data can be useful if there's no wind. If there's wind the vanishing bearings are compromised by the wind, so you get some combination of what the butterfly wants to do and what the wind is allowing it to do.

The more useful data comes from body headings, which are bearings that we take off the long axis of the butterfly. A butterfly might be sideslipping with the wind, but if you can get directly behind the butterfly you can measure the compass direction that it's heading. Usually this is different from the vanishing bearing. So, a butterfly might be sideslipping and going 160 degrees when in fact it's trying to go 220. It's like a sailboat: you point the sailboat one way and you're sideslipping another. You can see airplanes doing the same thing in strong crosswinds.

We've been using these kinds of data to measure of what the butterfly is attempting to do. We are trying to get at the underlying cause by looking for patterns. These patterns will be compared to those predicted, if for example, monarchs were using the earth's magnetic field to navigate.

ER: So how do they navigate?

CT: We recently published the first paper in a series on monarch orientation and navigation. In the first paper, we were able to show that the butterflies use a sun compass. That is, they use the sun as a way of marking what time of day it is, and in positioning themselves relative to where they should go at that particular time of day.



We have another paper coming out that's the first in a series to determine whether they use a magnetic field for orientation. In this study, we treated the butterflies with a strong magnetic pulse to see whether this disturbed their orientation. The monarchs were very disoriented by this treatment, and as a group, they were random in their orientation. Some of them spiraled upwards in behavioral displays that we hadn't seen before, and a few others got up and flew and then crashed into the ground and then got up and flew and crashed into the ground again, suggesting that their orientation sense was markedly disturbed by the magnetic pulse. We have other, as yet unpublished data, and all I can say is that we're getting close to resolving the issue of how monarchs orient and navigate as they move across country.

ER: Are the monarchs endangered?

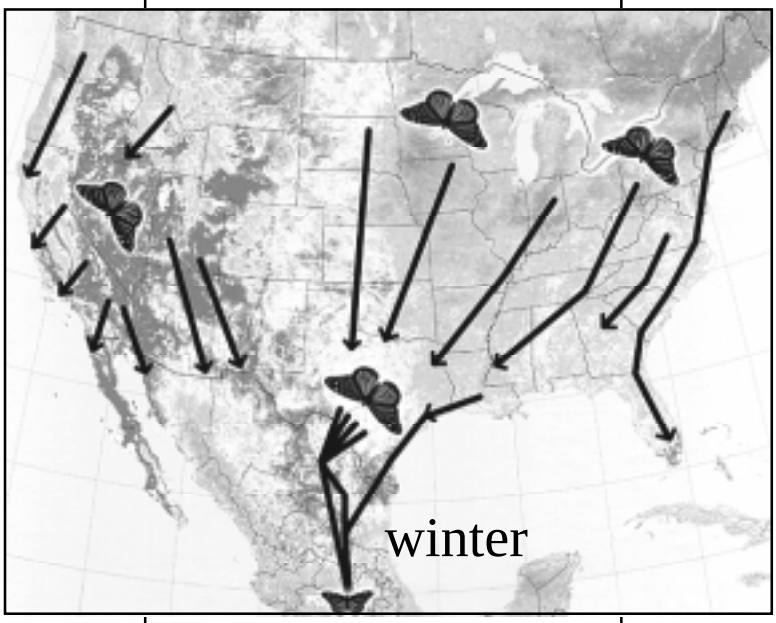
CT: The issue we're all concerned about is the long-term persistence of this eastern migratory population because it does appear to be threatened. The monarchs overwinter in fir forests on just a few mountain tops in a relatively small area, with a high-density human population, in the transvolcanic mountains west of Mexico City. The forests on these mountains are a source of income for the local people and even though the forests are protected, there is poaching of trees within the Monarch Reserve each year. The forests are rapidly disappearing from the unprotected areas nearby and soon the fir forests in the Reserve will be some of the last sources of lumber in Central Mexico. Once this occurs the pressure on the Reserve will be even more intense.

There's a good possibility that unless meaningful programs are put into place that make these forests valuable to the local people, we will lose them and the butterflies. We can't put a fence around these places. We're never going to keep the people out. We have to make the butterflies and the people compatible with each other. One way to do that is to make the living forest valuable to the local people. We haven't succeeded in figuring out how to do this, and until we do, this migration is going to be threatened because the trees are valuable. They have a value today, a tangible value. The value of the butterflies to the local people is less obvious. These are people that need money, they need food, they need resources, and these trees are their resources.

The local communities are organized into ejidos. Ejidos are communally held lands. With the establishment of the Monarch Reserve, the local ejido residents were told, yes, you own the land and

you own the forests, but no, you can't use them. It would be like saying to any of us, You can have title to your house, but you can't use it. That's the position that they are in, and many local people resent it strongly. And who can blame them?

We need a solution. We need to move toward sustainability in this region but how can this be accomplished? There many issues that need to be resolved and some of the solutions might be nothing more than slippery slopes that could have untoward consequences. We need to be cautious but we do need progress on these issues, and soon. The local people are becoming increasingly impatient with all the talk and promises. Mexico, Canada and the United States have to work together on monarch conservation. There is movement in this direction but it is slow, very slow.



ER: Ecotourism isn't the answer?

CT: It's not adequate because it doesn't necessarily benefit everybody in the community. Some of these communities want to have the ecotourism and they want to harvest the forest at the same time. They don't see why they can't because if you look at the forests they are pretty extensive, and to the casual observer, the butterflies only appear to use part of the area. So, naturally, they want to do both.

The sad thing about this situation in Mexico is that unless they maintain the forests for another reason, they are going to lose something else very important. These forests protect their watersheds. The forests collect moisture and provide runoff for these communities; they are essentially the aquifer for these areas. And, if they remove these forests, as they have in so many other places in Mexico, the communities will become impoverished because water is their most important resource.

ER: What about the monarch's summer range being centered in our farm belt?

CT: In the middle of our Monarch Watch development we got a call from Len Wassenaar and Keith Hobson of Saskatoon wanting to know if we would be willing to collaborate in a project to characterize the monarchs of North America for isotopes of carbon and hydrogen.

Hobson and Wassenaar had been using natural isotopic variation as a way of tracking birds. Their idea was that we may be able to establish the origins of monarchs that arrive in Mexico if we could characterize the North American continent for the natural distribution of hydrogen and carbon isotopes.

They asked if we could help them by generating, first of all, a control study and secondly by having people rear monarchs all over the country, and this is what we did. In the course of two years we sent out about 130 rearing kits containing monarch eggs around the country. The rearing kits specified that the monarchs were to be reared on naturally occurring milkweed. When the participants finished the project, they sent us back six monarchs and some pressed leaves from the milkweeds they had used to feed them.

After the season, we sent the monarchs and leaves to Wassenaar and Hobson and they analyzed them to determine the correspondence between the isotopic ratios in the plants, and the ratios in the butterflies that ate the plants. In our control experiments we had a good fit: the isotopes matched the water, the plants, and the butterflies. All the samples were analyzed from five Canadian provinces as well as some thirty states, and Wassenaar and Hobson mapped the monarch breeding area for isoclines of isotopic

ratios. A paper based on these findings will be published in February.

Subsequently, Wassenaar and Hobson collected dead monarchs at the overwintering sites in Mexico and brought them back for analysis for these isotopes. Based on the isoclines of isotopic ratios all our volunteers had helped establish, they could look at a map of North America and match the ratios in the butterflies to the general area from which each butterfly originated.

The result was rather startling because they showed that 50 percent of the monarchs come out of a relatively small area from eastern Nebraska to western Pennsylvania. That placed an origin of monarchs smack dab in the middle of some of our most intensive agriculture in the United States. This is our most intensively managed land for corn and soybeans. We had long suspected, based on heresay evidence, that many monarchs were being reared in corn and soybean fields on the milkweeds, particularly a viney milkweed, that is often abundant in these fields. This species is relatively difficult to get rid of, as are some of the other milkweeds in crop fields.

This result sent up a warning flag because there could be a lot of monarchs coming out of these fields. If they're not originating from these fields, they must be coming from the pastures and roadsides. However, if you fly over this region, it doesn't look like there's enough marginal acreage out there to produce the monarch numbers we are talking about. So, it's probable that a large number of monarchs are coming out of these agriculture sites.

There are two things that concern us, both involve transgenic plants. The two principal ones here are Roundup-ready corn and soybeans, and then BT (*Bacillus thuringiensis*) transgenic corn. Although they've established transgenic BT in a number of other crop plants such as potatoes, the acreages are relatively small in the areas where monarchs breed.

The BT transgenic corn is of interest because there's a potential biocide involved here. If the BT toxin gets into the pollen, and I say if, because that has not been established experimentally yet, it could be a biocide for any susceptible species. Corn pollen is windblown and it ends up on leaf surfaces of plants within and adjacent to the cornfields. Monarchs, and other susceptible species, could die from eating BT-toxified leaf material.

Fifty percent of the monarchs in Mexico come out of a relatively small area from eastern Nebraska to western Pennsylvania... smack dab in the middle of some of our most intensive agriculture.

The other technology that we're concerned about is the Roundup-ready corn and soybeans, because these are designed to target weeds in corn and soybean fields. The idea here is that crop plants are genetically engineered to be resistant to the herbicide Roundup. The farmer puts these seeds in, the plants come up, then they can apply Roundup for weed control. Use of the transgenic

crops cuts down the tillage, reduces the competition for water and nutrients, and the result is supposed to be a higher yielding crop.

Milkweeds are one of the weed groups targeted by Roundup. Therefore, the use of Roundup-ready varieties will probably lead to a decline in milkweed abundance in these fields. If this happens, monarchs , which are dependent on milkweeds, are certain to decline as well.

The use of Roundup-ready corn and soybeans is increasing rapidly. These varieties were introduced only three or four years ago but the estimates are that 19 percent of the corn and 30 percent of the soybeans planted last year were Roundup- ready. We're trying to obtain grant support for surveys to determine what, if any, effect the use of these transgenic crops will have on monarch populations. I suspect there could be one and it could be significant.

ER: What can be done?

CT: What can be done to save the eastern monarch population? I'm not sure. The situation is a very complex mix of social, political, economic, biological and cultural issues. I doubt that any of the scientists or other interested parties is sufficiently knowledgeable to comprehend all the nuances of these issues or wise enough to weave a fabric of compromise that will serve the interests of all the people as well as the butterflies.

We need a collective effort, one which involves all three countries. We need to bring the local residents, monarch specialists, hydrologists, agricultural specialists, foresters, sociologists and politicians to the table to work out a sustainable development plan for the region. I favor a forty-year management plan for the forests, one which incorporates knowledge of productivity, promotes reforestation, manages diseases and pests. But, the plan must be more comprehensive than simply forest management. Ultimately, it's the politicians who make the decisions on conservation issues such as these. Collectively we can work out an excellent plan but unless we have the support from the politicians and the financial backing of the three governments, non governmental organizations and international development agencies, we are not likely to succeed to saving the monarchs. Our job is therefore twofold, to devise a sound long-term plan and to convince the politicians to support it.

> During the migration on some days when the winds are right they may be moving over one hundred miles in a day.

Showy milkweed (*Asclepias speciosa*)

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The Monarch Watch website address is www.MonarchWatch.org

Further readings:

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Tracking Migratory Birds Using Isotopes

Introduction:

Most birds in North America fly south for the winter. Some species like robbins may migrate relatively few miles, other species like swallows may migrate thousands of miles each year. Migratory birds need to have suitable habitat in their summer breeding grounds, their winter residences, and along the flyways in between. It is difficult to know if populations of migratory birds are stable or declining because their numbers fluctuate from year to year, they move north and south every year, and they also may change the places they use as the landscape changes.

How do habitat changes affect migratory birds? If they are forced to use degraded habitat do they have fewer young or do they lose weight? Scientists have had a difficult time answering these most basic questions because there has been no reliable way to follow birds from their winter to summer ranges. Peter Marra used the same isotope technique described in the preceeding monarch butterfly article to study migratory birds in their winter range. Good winter habitat for American redstarts is dominated by plants with one isotopic signature while less desireable habitat has a different signature. He found that birds that had to live in marginal habitats lost weight over the winter and had higher levels of stress hormone.

Good winter habitat is limiting for at least some neotropical migratory birds. Meanwhile natural areas throughout the region are under continuous and increasing pressure from human development.

We spoke with Peter about his work and its implications for migratory birds.

ER: Dr. Marra, what is your position in the academic food web?

PM: I have a masters degree from Louisiana State University with Van Remsen studying tropical birds in Peru and temperate birds in Louisiana, a tropical-temperate comparison, looking at the factors that maintain species diversity in the tropics. From there I went to Dartmouth College, where I worked for four years with Dr. Richard Holmes, my eventual Ph.D. advisor, and I ran his temperate and tropical research programs on migratory birds. In 1992 I entered the Dartmouth College Ph.D. program and began the research that was published in *Science*. I am now working at the Smithsonian Migratory Bird Center in Washington D.C.

What are the consequences for birds of occupying a particular habitat?

ER: Can you give us a little background information about neotropical migratory birds?

PM: Most birds that breed in the temperate zone migrate south in the winter. Neotropical migratory birds spend up to four months on the breeding grounds in the U.S. and Canada where males and females pair up and defend a territory and build one and sometimes two nests. In some cases they'll double brood, or in some cases the males will have two females, but in most cases they'll just have one. The birds will raise their young and the young will fledge, and then they will start their fall migration down to the wintering grounds.

When they get down to the wintering grounds migrant birds aren't paired any more. At the end of the breeding season the pairs break up, as far as we know. When they arrive at their wintering sites many birds select territories and defend them. So males will have their territories and females will have territories exclusive of the males, and they'll defend them over the winter by themselves. Then when spring rolls around, before they fly north these birds will put on fat. Most migratory birds fly just at night and land at stopover sites during the day to rest and refuel for the next evening's flight. Eventually they arrive at the breeding grounds where males and females will pair up and start the cycle again.

ER: How long does the migratory flight take?

PM: We think anywhere from three to five weeks, but it is difficult to say.

ER: Why can't you follow them?

PM: Well, any time you study an animal that moves as much as a migratory bird or a whale or a sea turtle, you can't follow them from place to place. Actually we now have transmitters that can track whales and sea turtles by satellite, but we can't do that with small migratory birds, the transmitters and batteries aren't small enough.

ER: Bird populations fluctuate from year to year don't they?

PM: Yes. If you were to go to the breeding grounds say at the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire every year for ten years and count birds, you would see that their numbers change from year to year, some years are high, some years are low. I want to understand what causes those fluctuations. This question is important because some of these neotropical migrant species are declining and we want to figure out why.

This is a tough problem because the birds spend different parts of the year in different places. So we need to look at all the significant events that are occurring say, on the breeding grounds at Hubbard Brook, and what happens during migration and what happens to the birds during the wintering period in the Caribbean, Central America, or in South America, which is actually the majority of the annual cycle, sometimes up to seven or eight months of the year.

ER: Why is it a tough problem?

PM: We can look at these different places and figure out what's going on with the birds' habitat but we're doing it with different populations of the same species of bird. We don't know where the birds in their breeding grounds at Hubbard Brook spend their winters, and we don't know where the birds wintering in Jamaica spend their summers. So linking the different parts of the annual cycle, figuring out for instance, how what happens to the birds during the winter influences their performance during the summer was next to impossible. How do conditions during the winter influence the numbers of birds that arrive on the breeding grounds in the summer?

Yellow rumped warbler.
All images courtesy of Marcus G. Martin

People have thought that the breeding grounds are important since this is after all, where the birds are actually reproducing. So the majority of work on migratory birds has focused on breeding ground events. Most of the work during the winter has been looking mainly at the distribution of birds across habitat types or looking at densities of birds. There's been very little work trying to characterize and quantify how different habitats affect the condition of these birds. In other words, what are the consequences of occupying a particular habitat? That question is easier to answer during the breeding period because we can look at their reproductive success by finding nests and counting the number of young fledged. But in the winter it's a much more challenging problem.

ER: What did you do when you got to Jamaica?

PM: One of the first things I wanted to do in Jamaica was to look at the consequences for the birds of occupying different habitat types on the wintering grounds. First, males and females are not paired during the winter. Males and females each defend there own territories. When you look at the territories of males and females across several habitat types on the wintering grounds in Jamaica — that's where I did my work — you see that some habitats are occupied mainly by males, and some habitats are occupied mainly by females, so the habitat types are male-biased or female-biased.

This pattern of male-biased and female-biased habitats is pretty common in migratory birds in both the New World and the Old World, and it's termed sexual habitat segregation. I wanted to know what causes the pattern and then what the consequences of it were on birds. That was the focus of my research.

ER: What birds go to Jamaica for the winter?

PM: The species I worked on was the American redstart, but you see the same pattern in other warblers like the black and white warbler, black-throated blue warbler, Magnolia warbler, ovenbirds, and the Parula warbler. Many species show this segregation of the sexes.

ER: How are the male and female-type habitats different?

PM: The habitats that are female biased are typically dry scrub-type habitat with less to eat. The male-biased habitats are typically the tall, wet forest, black mangrove swamp habitats. Habitat segregation is caused by older, slightly larger male birds excluding females into the poorer, scrubby-type habitat.

ER: That's not very chivalrous.

PM: Not at all. Chivalry is dead in migratory birds. Males are excluding females from the best habitat. There are a few females that can persist in the better habitat, and those females that live in the mangrove-type habitat do better than the males and females in the scrub-type habitat, so it doesn't matter if the bird is male or female, if it can get into the good habitat, it's going to do well.

Magnolia warbler

ER: How do you determine if a bird is doing well?

PM: When the birds first arrive in Jamaica in September and October, I catch them then and band them so I can recognize individuals later, and I map their territories and figure out the size of the area they will be in for the winter. When I weigh the birds I collect a blood sample and I measure the blood levels of a hormone called corticosterone, which is a type of stress hormone. If you were to restrict the amount of food you gave a bird, it would secrete more corticosterone, and would increase its activity level. It's thought to be an adaptation to get a stressed animal to increase its foraging, a mechanism that helps animals respond to periods of low food availability.

ER: What volume of blood do you need to be able to pick up that signal?

PM: Not much at all, about the size of a small drop of water.

ER: What did you expect to find out from the blood samples?

PM: I predicted that in the fall corticosterone levels would be similar between birds as they moved into the different winter habitats. When I came back in the spring and recaptured these birds, I weighed them again and I sampled their blood to look at corticosterone levels.

To test the idea that habitat type is important I predicted that the corticosterone levels of the birds in the scrub habitat would be higher than the corticosteroid levels of the birds in the mangrove habitat, regardless of whether or not they're male or female. And that's what I found: birds in the scrub habitat at the end of the winter period had cort levels that were twice that of birds in the mangrove habitat whose corticosterone levels had stayed the same.

Furthermore, birds in the man grove maintained the same body mass over the winter periods whereas birds in the scrub habitat lost up to 11 percent of their body mass. So there were serious consequences to being excluded out into this poor habitat. This didn't necessarily cause birds to die but it did influence when they could depart for the spring migration and when they

would get back to the breeding grounds.

That is significant because birds getting back first are in better condition compared to birds that are getting back later, they get the best territories and they have the highest reproductive success. It had been observed that in most migratory birds the males arrive in the breeding grounds before the females, and no one has known why. My data suggest that this pattern is possibly related to events occurring on the wintering grounds. But how do we link these two different periods of the annual cycle?

northern Parula

ER: Were you able to follow birds from Jamaica to the breeding grounds?

PM: No, that's the point. We don't know where our Jamaica birds are spending the summer, or where our birds in the summer are spending their winters. So I decided to try a technique using isotopes as a habitat-specific marker to link the birds to their different habitat types in the winter.

ER: How did you use isotopes to connect the birds to different habitats?

PM: Elements like carbon and hydrogen and oxygen each occur in a variety of slightly different forms or weights called isotopes. So you can have different weights of carbon atoms like carbon 12 or carbon 13. Different isotopes can occur in different places in nature, for instance, there can be different amounts of carbon 13 or carbon 12 in plants depending upon the type of plant and depending upon how wet or dry a place is. Plants in wetter habits retain less carbon 13 relative to carbon 12 while dry habitat plants; for instance, the various grasses, retain more carbon 13.

This means that plants in drier habitat tend to have tissues that are enriched in carbon 13, whereas plants in the wetter-type habitats tend to be depleted in carbon 13. When insects eat the plant leaves they pick up these isotopes; and when the birds eat the insects they also pick up that isotope signal. If a bird is in a particular habitat for awhile, it should pick up that signal, and nothing to do with its condition should effect that. So then there's a marker in these birds that they retain for six to eight weeks, that can track them back to wet or dry habitats.

I was able to figure out what these signals were in Jamaica. And then I went to Honduras and found that the signals were pretty much the same: they were different according to the different habitats the birds were in, and the wetter habitats were different from the drier habitats in Honduras in the same way they were different in Jamaica.

ER: How does that connect to the birds' summer habitat?

PM: To look at the connection between winter and summer habitats, I predicted that birds getting back to the breeding grounds early should have carbon isotope values similar to birds in wet habitats from Jamaica and Honduras; and birds getting back late should have carbon isotope values similar to birds from the dry areas. And that's exactly what I found, which suggests that events during the winter influence events in the breeding grounds.

ER: What do your results mean to conservation efforts?

PM: It suggests that the best winter habitats are probably limiting these birds' reproduction in the summer. There doesn't appear to be enough suitable winter habitats for redstarts out there. We haven't been able to get a handle on what's going on at the population level with these birds because redstarts occur over such a wide range.

But if there were suitable habitats out there, then there shouldn't have been any delay in the arrival time. We wouldn't have seen a gradual increase in the enrichment of carbon 13 if all the birds had been able to spend their time in wet habitat. So it suggests that optimal

winter habitats in the winter are saturated and limiting. I'm suggesting that the condition of the wintering grounds is deteriorating and causing some birds to arrive north later.

ER: How does this play out in the summer breeding grounds? Do you follow redstarts say, at Hubbard Brook?

PM: We didn't these past few years, but we have done that in the past. Tom Sherry of Tulane University, a colleague of mine, was following them for about ten years looking at reproductive success.

ER: Are redstarts declining?

PM: No. Redstarts are pretty much holding their own, and it's not clear how many species are declining. It depends on the region in the U.S. you look at and the years that you look at, so we don't know. There are some species that are definitely declining; but redstarts seem to be holding their own.

ER: Are you familiar with John Terborg's book called, *Where Have All the Birds Gone*?

PM: Yes. It was a useful book in many ways. I think it got people thinking about the issue a bit more, and perhaps treating the data that were available in more rigorous ways. And when we did that we found out that understanding population declines wasn't a simple issue. We needed to break it up by region, we needed to do different statistical analyses on the data, so in some ways the book was premature, at least the title was premature.

There are definitely some migratory species out there that are declining, but we need to be careful about the conclusions we draw. I think some scientists were cautious of his approach because we didn't want the "cry wolf" syndrome to take effect because the data that these declines are based on are not real solid. The breeding bird surveys are the best data we have, but there definitely are some problems associated with them.

Virginia's warbler

ER: Many people have seen familiar birds disappear from their backyards. How do you explain that?

PM: It's true that some people see species declining in their back yards, but it may be that same species is increasing someplace else. Forests go through a variety of stages, and birds are specialized on different successional stages. And because they are declining in someone's back yard doesn't mean they are not increasing someplace else. Habitats change. It's difficult to get a handle on such a thing. We now know that events that occur during the winter period are linked to what happens in the summer breeding grounds.

Therefore the reproductive success we see in the breeding grounds might be directly related to what happens in Jamaica. So somebody who's looking at a bird reproducing in their back yard in Virginia may think that how it succeeds there is due entirely to their surrounding areas, but it may have little to do with that and more to do with where it spent its previous winter.

ER: What needs to be done?

PM: I would love to see people begin thinking about the big picture, we can't just think about the breeding grounds and we can't just think about the wintering grounds and we can't just think about stopover sites. We need to think about all these different periods and how these different periods of the annual cycle interact. It doesn't matter how much conservation work we do in the breeding grounds, if we don't conserve areas in the wintering grounds. These different periods are inextricably linked. Natural selection has acted to put these birds in a particular habitat with different life history strategies to adapt to changing conditions.

ER: Are the birds losing habitat?

PM: There's no question. The most suitable habitat types, these tall, wet

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rainforests and these black mangrove swamps, are some of the most threatened habitats in the world, certainly in the Caribbean and Central America. The only tall wet forests remaining in places other than Belize and Costa Rica where they've had enough foresight to put in reserves, are on mountainsides and areas that can't be cut down for agriculture. And even on the mountainsides in a lot of places those areas we once though were safe are now coffee farms.

The amount of forest that is being cut down is just unbelievable. Look at Honduras and Nicaragua. Not only are there effects on wild-life, there are effects on people when you have a natural event like a hurricane moving through and there's nothing to hold the soil; you have landslides.

Black mangroves are also being destroyed at alarming rates and that's due not only to local peoples but also large companies that move into these areas for shrimp farming. They just rip apart these mangroves so they can farm shrimp at inexpensive costs. Then the shrimp farms are abandoned and the mangrove swamps are gone. These mangroves are not just important for birds, but they are important for many marine fisheries, the larval stages of many marine fishes and shrimp depend on mangroves for their nursery grounds.

NEXT MONTH

WILDFIRE IN THE YELLOWSTONE ECOSYSTEM: LINDA WALLACE GRANT MEYER

WARMING AND GRASSLAND COMMUNITY STRUCTURE: RICHARD ALWARD

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