Conservation Matters:
Contributions from the Conservation Committee

Are Butterflies in Trouble? If So, Why?

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> I sometimes think of the story of P eter Bamm, who was on a lovely island where he met all kinds of people, good and bad. He dreamt in a nightmare that a bomb might come and destroy everything, and the first thing that occurred to him was what a pity it would be for the butterflies.
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> Dietrich Bonhoeffer ,
> *Letters and Papers from Prison*

I've been hearing the same mantra all my adult life: "There were more butterflies when I was a kid." And for most of those years, in my capacity as a butterfly guru to the public and the media, I've pooh-poohed the idea. I certainly didn't see it happening—and if anyone should see it I should, since I'm in the field at least 200 days a year looking at butterflies. The ubiquity of the perception, from New York to San Francisco to Buenos Aires, led me to hypothesize that its roots were psychological. Butterflies, I reasoned, are more prominent objects in a little kid's landscape than in an adult's. As we get bigger and older we notice them less, not because there are fewer of them but because they are smaller relative to us…and we get preoccupied with other sorts of things, like football and consumer electronics and sex. A neat explanation; perhaps even a correct one.

Of course, I knew butterflies can go downhill. My experience in this regard is anything but unique: I watched the butterfly fauna of my childhood neighborhood in Philadelphia, West Oak Lane, shrink as the city encroached farther and farther into what had been woodlots and old fields. Down the road from my house was the ancient Cedar Park Inn, with its hand-painted sign picturing eastern Red Cedar (*Juniperus virginiana*). The tree had once been common here; now it was extinct in Philadelphia County, and with it the Olive Hairstreak (*Mitoura gryneus*), which I had to go deep into the country to find. Even in the seemingly intact cool woodsiness of the Wissahickon Ravine, which seemed as if it could not have changed appreciably since Ben Franklin's day, the Falcate Orange-Tip (*Anthocharis midea*) and Bates' Crescent (*Phyciodes batesii*) vanished on my watch. (The latter seems to be extinct in most of its historic range.) As a senior at the University of Pennsylvania I used this history as my term paper in Jack McCormick's community ecology class. He gave me an "A" and said with a little tweaking it might be publishable. (One specific tweak: to drop the expression "to go extinct," which he regarded as slangy. It is normal in the scientific literature today.) But I never tweaked it. It's a pity; it was 40 years ahead of its time – not dissimilar, if more mature, papers are appearing all the time now. In 1965 Geographic Information Systems hadn't been invented yet and aerial photointerpretation was still largely a specialty of military intelligence. I relied on city planning documents to track the course of urbanization. Even that was ahead of its time. The first papers of this sort that I know about appeared decades later!

But those losses were local, their cause was transparent – habitat loss due to development – and I regarded such losses as regrettable but inevitable, and I wasn't thinking on larger scales. And at the same time, in southwest Philly, the Eastwick urban-renewal project had leveled many blocks of run-down housing, creating an exuberant swath of old-field succession that was absolute butterfly heaven. (There were outbreak populations of the Checkered White, *Pontia protodice*, there; it is reputed to be extinct in Pennsylvania now.) So losses might be reversible, at least in part: the bulldozer taketh away, but it also giveth. And yet…I had the 19th- and early 20th-Century records of Henry Skinner, Eugene Aaron, Frank Haimbach, Philip Laurent, J .U.D. Pleasants…; I knew that the Mulberry Wing (*Poanes massasoit*) and the Silver-Bordered Fritillary (*Boloria selene myrina*) had once occurred in Fairmount Park, and now they were gone. I saw one of the last Regal

Fritillaries (*Speyeria idalia*) recorded in southeastern Pennsylvania with my own eyes (near Devon, Chester County, in 1966; David Wright says the very last was in 1975— at least until 1990 and 1992, also in Chester County!). Despite all that, I remained an optimist. I also headed West.

Now I know better. I don't *think* butterflies are in trouble. I *know* it. But I didn't in 1971.

When I was hired at the University of California, Davis, I finally had the opportunity to do what I had been dreaming of doing: I wanted to monitor a butterfly fauna and use multivariate statistical methods to identify what environmental variables exerted the most influence on its seasonality (phenology). My undergrad adviser had been Robert MacArthur, the great ecologist, and he had encouraged me to think of life-history phenomena as "adaptive strategies" fashioned by Darwinian evolution. My project was conceived as running about five years. In a Mediterranean climate, with high interyear variance, that should be enough to give meaningful statistics. Besides, it was the time frame for learning whether or not I'd get tenure; I might have to move on after that.

I did get tenure, and the data were so exciting that the project just kept going. It's now in year 39. It expanded to ten sites (and ten faunas) from sea level to tree line, embracing both slopes of the Sierra Nevada and 159 species and subspecies of butterflies (so far). The only comparably large butterfly database is in the United Kingdom, and is of similar age but very differently organized. I collect all my own data (that's why I'm afield 200 days a year); the British use a network of many cooperative observers who monitor their local faunas. They have fewer than 60 species in the entire country, and substantially less topographic and climatic diversity than exists on my transect. The two projects are complementary, and both are designed for data mining. And they are being mined.

When I initiated my project in 1972, no one was talking about global warming. In fact, some were talking about global *cooling*, and the possibility that we were heading for a new Ice Age. My goals were short-term. To use some applied-math jargon, I was not looking for a signal; I was trying to identify biotic responses to noise—the short-term weather fluctuations that a 5-year study would focus on. The data were not collected to identify biotic consequences of any long-term trend. But when we had about 30 years' worth the mere amount of data was daunting, and my research group, led by then-doctoral student Matt Forister, convinced me that it was high time we started analyzing the data. (I had tried to get money from the National Science Foundation years before to do this. They were willing to fund data collection, but not the analysis unless I could explain in some detail the statistical methods to be used. I couldn't, because some of them hadn't been invented yet! When we did get funded, that was one of our highest priorities—to figure out how to do what we needed to do. They teach you in grad school that all research should be designed with the analytical procedures fully-defined in advance. They rarely teach you that the idiosyncrasies of real-world research routinely trump such notions. They do.)

So we took all those data and began taking them apart and asking questions whose answers were by and large inapparent on inspection but could be teased out with statistical analyses. You have probably read about our results in the press. The study came out in mid-January 2010 and is the first of several projected papers in various stages of completion. Now, by 2010 some things were glaringly apparent on the Philadelphia model—that is, visible to the naked eye—, but other things were not. Here is a summary of what we found.Keep in mind as you read this that we had no axe to grind; we were letting the data tell us their own story. Keep in mind also that the data and the inferences from them apply strictly only to our transect across north-central California. The degree to which they can be generalized elsewhere remains to be seen. They are, however, broadly consistent with data on other taxonomic groups and on butterflies in other places, as I'll discuss a bit later.

1. Butterfly faunas near sea level are deteriorating rapidly, especially in the last decade. But the deterioration is not adequately explained by climate change. The most important factor appears to be habitat loss (as documented by land-use statistics at the County level, a more-refined use of the same technique I applied in 1965!). We suspect that more sophisticated analysis using Geographic Information Systems will reveal that loss of habitat connectivity is more important than absolute habitat area.

2. Butterfly faunas at mid-elevation on both slopes of the Sierra Nevada are either holding their own or deteriorating slowly. Here there has been no significant habitat loss, and changes, such as they are, are inferred to be climate-driven.

3. At our highest (tree-line) site, overall butterfly richness is *increasing*, as more and more lower-elevation species follow warming uphill. However, most of them cannot establish as breeding residents because their essential resources, especially larval host plants, are not available; plants, which cannot fly, respond to climate change much more slowly than butterflies, which can. At the same time, 3 of the 4 most characteristic butterfly species of the alpine zone at Castle Peak (not necessarily globally) are becoming less common.

4. The most surprising finding—we were totally unprepared for this!—was that the common ruderal ("weedy"), multiple-brooded species, which some collectors take for granted and sometimes refer to derisively as "junk species," are actually declining *faster* than the ecological specialists. These species regularly colonize upslope in summer but cannot overwinter at high elevations. We expected to find them

becoming more common as the climate warmed, but in fact the reverse is happening! This is apparently due to loss of their preferred weedy habitats at low elevations (as they are replaced by sterile residential subdivisions, business parks and such), which reduces their populations and thus the number of individuals available to disperse and colonize upslope. (One "junk species" that is not declining is the European Cabbage Butterfly, *Pieris rapae*, which has benefitted from the spread of the invasive weed Perennial Peppergrass (*Lepidium latifolium*) at low elevations. This weed is now marching upslope, is established at 5000' and starting to show up at 7000'.)

In the Philadelphia of my youth, the Common Sooty Wing (*Pholisora catullus*) was a "junk species." When I came to California, it was one here too; I could find larvae within ten minutes' walk from my lab, and I had it in my garden every year. Now it is approaching regional extinction; I know one active population in my county (Yolo) and one in adjacent Sacramento County. It breeds on Amaranth pigweeds—not exactly endangered plants. The Large Marble (*Euchloe ausonides*) was common throughout this region in the 1970s, breeding on naturalized mustards (*Brassica*) and wild radish (*Raphanus*). Now it appears to be regionally extinct. Also on a regional basis, the entire macrolepidopteran fauna of willows (*Salix*) in riparian habitat is in dire straits on the floor of the Sacramento Valley for no obvious reason—Lorquin's Admiral (*Limenitis lorquini*), the Mourning Cloak (*Nymphalis antiopa*), the Sylvan Hairstreak (*Satyrium sylvinus*) and the once-abundant diurnal Sheep Moth (*Hemileuca eglanterina*), all extinct in many former localities and hanging on perilously only here and there. The habitats of these species appear unchanged; we infer that the cause of the declines is on a larger-than-local scale. Most of the changes are less striking and more subtle—but none the less real.

Let me qualify all of this: I know that folks who are concerned about pesticides, air pollution, genetically-modified organisms, introduced biological-control agents, and so forth are going to ask how we can be so sure their particular *bête noire* isn't involved in these declines. (They always do.) The answer in a nutshell is that we *can't*. For some of these factors no useful data is available. For others—pesticides—*too much* data is available, and we have no idea how to prioritize them for analysis. Agriculture in the Central Valley is a remarkably complex spatio-temporal mosaic. The crops planted and the pesticides used on them within the relevant geographic areas change constantly, particularly as a consequence of yearly variance in rainfall, economics, and the actions of regulatory agencies. The observed patterns of butterfly decline do not by and large suggest pesticides as an important factor, but as of now we just don't know. (And even in "eco-conscious" Davis a fair number of people have their lawns chemically treated for weeds and pests, but that hasn't dented the abundance of the ubiquitous Fiery Skipper (*Hylephila phyleus*) – at least not yet. Nor have garden pesticides prevented the spectacular recrudescence of the Gulf Fritillary, *Agraulis vanillae*, in this region in the past few years after a 40-year absence, an event that has drawn lots of media attention. Of course, both of these almost completely urban species are of subtropical origin… Last year the Western Tiger Swallowtail, *Papilio rutulus*, which unaccountably went extinct in Davis—but not elsewhere in the region—a decade before, reappeared all over the city in extraordinary numbers. There's a lot we don't understand.)

There is no doubt that climate is changing. Climate is always changing. At UC Davis I teach about paleoclimates and paleovegetation. I tell the students that our imaginations are hamstrung by the temporal scale of a human life. Let's harken back to my hypothesis about why people think there are fewer butterflies than there used to be. We tend to think of whatever we grew up with as "normal." Within our own threescore and ten, we see change as something alarming, something deviant. But Nature as we see it is a freeze-frame from a very long movie. Change is the *normal* state of affairs: it's stasis that is abnormal and requires explanation. There is controversy over whether human activity is driving the current episode of climate change; there is no controversy that the change is happening. There is also no controversy that land-use change, which is apparently driving our low-elevation butterfly decline in California, is human-caused!

So when some geezer my age says to me "There were a lot more butterflies when I was a kid," I'm a lot more willing than I used to be to take him seriously .

WANT TO LEARN MORE?

There's a lot of professional literature on butterfly declines, climate change and related subjects. By and large it is unknown to amateurs because it appears in scientific journals not focused on Lepidoptera per se. Here is some suggested reading. *This is NOT an attempt at an exhaustive bibliography!*

THE GRINNELL PROJECT is an attempt to resurvey the altitudinal distributions of mammals studied in detail by Berkeley zoologist Joseph Grinnell a century ago. Because his notes and voucher specimens and site photographs are lovingly preserved at the Museum of Vertebrate Zoology, UC Berkeley, it is possible to revisit nearly all of his collection sites and see how much the distributions have changed. You can read about the project at http://mvz.berkeley.edu/Grinnell/index.html and from it you can download the major publication to emerge thus far: C. Moritz et al., 2008. Impact of a century of climate change on small-mammal communities in Yosemite National Park, USA. *Science 322*: 261-264. The mammalian patterns the Berkeley crew is finding are quite similar to ours in butterflies.

BIOTIC RESPONSES TO CLIMATE CHANGE are documented in hundreds of papers, with more coming out weekly—as an on-line search will quickly show! Here are a few important ones.

Bale,J.S. et al. 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global Change Biology* 8:1-16.

Hickling,R. et al. 2006. The distributions of a wide range of taxonomic groups are expanding polewards. *Global Change Biology* 12:450-455.

Menendez, R. et al. 2006. Species richness changes lag behind climate change. *Proceedings of the Royal Society B (Biological Sciences)* 273:1465-1470.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution and Systematics* 37:637-669.

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate-change impacts across natural systems. *Nature 421*:37-42.

Root, T.R. 2003. Fingerprints of global warming on wild animals and plants. *Nature 398*:611-615.

Walther, G.R. et al. 2002. Ecological responses to recent climate change. *Nature 416*:389-395.

Wilson,R.J. et al. 2005. Changes to the elevational limits and extent of species range associated with climate change. *Ecology Letters* 8:1138-1146.

IMPACTS ON LEPIDOPTERA are documented in a few dozen papers so far, many of them from Europe and the British Isles, some from the Tropics! Examples:

Altermatt, F. 2009. Climatic warming increases voltinism in European butterflies and moths. *Proceedings of the Royal Society B (Biological Sciences)*: DOI: 10.1098/rspb.2009.1910

Chen, I.C. et al. 2009. Elevation increases in moth assemblages over 42 years on a tropical mountain. *Proceedings of the National Academy of Sciences of the USA 106*:1479-1483.

Conrad, K.F. et al. 2006. Rapid declines of common, widespread British moths provide evidence of an insect biodiversity crisis. *Biological Conservation 132*:279-291.

Dennis, R.L.H. and T.H. Sparks. 2007. Climate signals are reflected in an 89-year series of British Lepidoptera records. *European Journal of Entomology 104*:763-767.

Morecroft,M.D. et al.2009. The UK Environmental Change Network: Emerging trends in the composition of plant and animal communities and the physical environment. *Biological Conservation 142*:2814-2832.

Parmesan, C. et al. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature 399*:579-583.

Pollard,E. and B.C.Eversham. 1995. Butterfly monitoring 2—interpreting the changes. In A.Pullin, ed. *Ecology and Conservation of Butterflies*. Chapman & Hall. Pp.23-26.

Poyry,J. et al. 2009. Species traits explain recent range shifts in Finnish butterflies. *Global Change Biology 15*:732-743.

Roy, D.B. and T.H. Sparks. 2000. Phenology of British butterflies and climate change. *Global Change Biology* 6:407-416.

IMPACTS OF LAND USE AND INTERACTIONS WITH CLIMATE are increasingly well-documented, sometimes with Leps, e.g.:

Brook, B.W., N.S. Sodhi and C.J.A.Bradshaw. 2008. Synergies among extinction drivers under global change. *Trends in Ecology and Evolution 23*:453-460.

Clark, P.J., J.M. Reed and F.S. Chew. 2007. Effects of urbanization on butterfly species richness, guild structure, and rarity. *Urban Ecosystems 10*:321-337.

Jetz,W., D.S. Wilcove and A.P.Dobson.2007. Projected impacts of climate and land-use change on the global diversity of birds. *PLoS Biology 5*:1211-1219.

Opdam,P. and D. Wascher. 2004. Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. *Biological Conservation 117*:285-297.

vanDyck,H. et al. 2009. Declines in common, widespread butterflies in a landscape under intense human use. *Conservation Biology 23*:957-965.

vanSwaay,C., M. Warren and G. Lois.2006. Biotope use and trends of European butterflies. *Journal of Insect Conservation* 10:189-209.

Warren, M.S. et al. 2001. Rapid responses of British butterflies to opposing forces of climate and habitat change. *Nature 414*:65-69.

White, P. and J.T.Kerr.2006. Contrasting spatial and temporal global change impacts on butterfly species richness during the 20th Century. *Ecography 29*:908-918.

One of the first papers spotlighting urban butterfly ecology was by Bob (R.M.) Pyle, 1983: Urbanization and endangered insect populations, Ch.15 in G.Frankie and C.S.Koehler, eds., *Urban Entomology: Interdisciplinary Perspectives*, pp. 367-394. Praeger Scientific, New York. This paper was far enough ahead of its time that even I forgot about it for years, and it is hard to find. It should be reprinted accessibly for Lepidopterists.

…and finally, our own paper is

Forister, M.L. et al. 2010. Compounded effects of climate change and habitat alteration shift patterns of butterfly diversity.*Proceedings of the National Academy of Sciences of the USA*. DOI: 10.1073/pnas.0909686107.

And our Web site, with details on our project and summary data, is http://butterfly.ucdavis.edu. Come visit us!

Are Butterflies in Trouble?

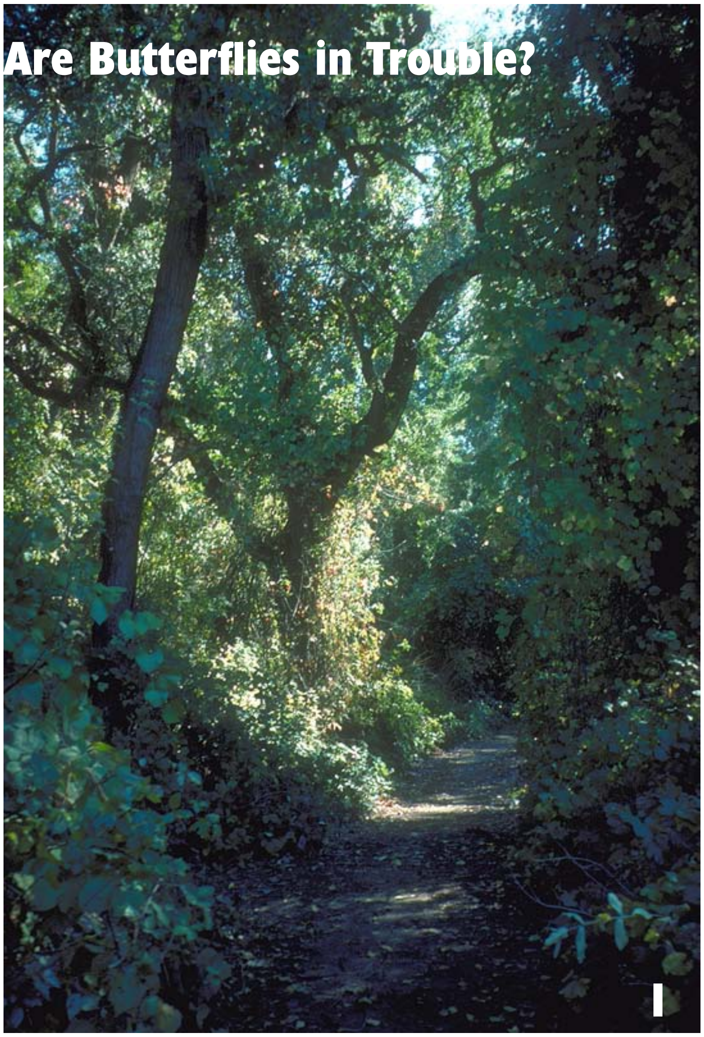

Fig.1) Riparian habitat in the Sacramento Valley looks fine, though reduced by an estimated 99-95% since the 19th Century. It is losing species faster than any other habitat type on our transect. This is a scene in the North Sacramento study site. **Fig.2)** The Mourning Cloak, *Nymphalis antiopa*, shown here visiting Rabbitbrush, *Chrysothamnus nauseosus*, at Donner Pass in the Sierra Nevada, has undergone a catastrophic decline near sea level on our transect in the past ten years, but its troubles may be related to its rhythm of annual altitudinal migration. **Fig. 3)** The familiar Acmon Blue, *Plebejus acmon*, shown on a Smartweed (*Polygonum*) flower in a drainage ditch at our West Sacramento site, is one of the "weedy" species that seem to be suffering from loss of habitat at low elevations—leading to a decrease in occurrence in the mountains, where it is an immigrant. **Fig. 4)** Here at tree-line on Castle Peak in the Sierra Nevada, more and more lower-elevation species are turning up as strays. Meanwhile, the true high-altitude species, such as the Ivallda Arctic (*Oeneis chryxus ivallda)*, found in this rubble-strewn rock garden, appear to be in decline.