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SUPPLEMENTARY INFORMATION

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Climate-driven changes in northeastern US butterfly communities

Data and Analytical Details

Data were collected and organized by a statewide network of volunteer observers associated with the Massachusetts Butterfly Club (MBC). From 1992-2010, observations were made by club members in both organized and opportunistic outings and species and number of individuals observed recorded. These observations were posted to a moderated email listserv daily. Postings were reviewed and vetted for quality before being entered into a formal database. In practice, nearly every day on which the weather was warm and/or sunny produced 3-5 lists and weekend days with good weather often produced 10 to 15 lists during spring and summer months. Most summers produced between 1000 and 1300 lists with good spatial coverage across the state (Table S-1).

Table S-1: Number of reports by Massachusetts Butterfly Club members by year and region. The mean number of species per report is shown in parenthesis.

Year	State-wide	Region 1	Region 2	Region 3	Region 4	Region 5
1992	307 (4.1)	76 (3.2)	78 (4.7)	94 (6.3)	58 (1.7)	9 (7.9)
1993	559 (4.2)	76 (3.4)	315 (4.4)	88 (6.4)	31 (1.2)	43 (3.2)
1994	952 (5.3)	192 (4.5)	490 (5.4)	130 (9.7)	137 (4.1)	51 (6.5)
1995	1025 (5.5)	168 (5.6)	494 (5.5)	174 (6.4)	196 (4.4)	21 (13.0)
1996	730 (6.3)	54 (5.5)	471 (5.9)	121 (10.4)	85 (5.0)	29 (5.7)
1997	536 (2.2)	141 (2.3)	167 (2.0)	125 (2.2)	77 (1.7)	36 (3.8)
1998	1320 (5.6)	324 (6.5)	378 (6.5)	262 (7.8)	337 (3.2)	72 (4.6)
1999	1415 (6.0)	269 (6.0)	562 (6.5)	295 (9.4)	301 (3.6)	56 (6.1)
2000	1155 (5.7)	275 (5.1)	409 (7.0)	219 (8.5)	255 (3.2)	45 (4.8)
2001	1349 (5.4)	379 (5.1)	544 (5.5)	199 (8.6)	223 (4.1)	42 (5.3)
2002	1141 (4.8)	312 (4.5)	471 (5.1)	155 (6.0)	190 (3.9)	48 (5.5)
2003	1180 (5.9)	263 (5.4)	511 (5.7)	205 (8.2)	206 (5.0)	41 (9.7)
2004	1060 (6.2)	176 (4.8)	400 (6.5)	175 (9.2)	279 (5.1)	56 (9.9)
2005	1055 (5.7)	207 (5.0)	441 (6.1)	173 (6.3)	220 (5.6)	35 (10.0)
2006	1262 (5.3)	229 (5.0)	558 (5.5)	213 (6.6)	266 (4.2)	27 (12.5)
2007	1233 (6.2)	152 (7.5)	581 (5.5)	199 (8.2)	300 (5.9)	37 (10.7)
2008	1277 (5.5)	216 (5.7)	693 (5.2)	175 (7.2)	195 (4.7)	31 (10.0)
2009	1099 (6.1)	215 (6.0)	492 (6.0)	193 (8.9)	208 (4.6)	32 (7.5)
2010	1142 (6.2)	181 (6.8)	441 (6.4)	259 (7.4)	250 (4.9)	29 (7.8)
Total	19779 (5.6)	3905 (5.3)	8496 (5.7)	3454 (7.6)	3814 (4.3)	740 (7.1)

Massachusetts is a small state and is composed of 351 townships, each approximately 100 km^2. Township was reported for each list when it was submitted, allowing relatively precise georeferencing of observations. Trends were estimated at the state level and enough observations were available to estimate trends in five regions defined by ecology and climate (1) (Figs. 2 and S-4). These regions included: 1) The Cape Cod and Islands Terminal Moraines and Bristol Lowlands, 2) Metro Boston, 3) Worcester Plateau, 4) Connecticut River Valley, and 5) Berkshire Mountains (Fig. 2).

We excluded some species due to taxonomic realignments or changes in how the MBC reported certain taxa, the most notable were the tiger swallowtails (*Papillio glacus, P. canadiensis*, and *P. appalachiensis*) and ecotypes / subspecies of *Limenitis arthemis.* Two species, the Milbert's tortoiseshell (*Aglais milberti*) and little yellow (*Pyrisitia lisa*), were excluded because their populations exhibited major outbreaks in the middle of the time-series not reflective of overall population trends. Most excluded species were simply observed too rarely to reliably estimate population trends (Table S-2).

Life history traits for all species in the MBC database were gathered and cross checked from multiple published accounts (2; 3; 4). Species were considered northerly if more than 50% of their published range was north of the City of Boston (41.78° N 70.50° W), and were considered southerly if more than 50% of their published range was south of that line (Fig. S-1). Ranges that were approximately half on either side were considered "core". In very wide ranging species, range area west of the Mississippi River was not considered because Western climates differ greatly from Eastern climates in North America. In addition, we drew upon records from the 1986-1990 Massachusetts Butterfly Atlas (MBA), a 5 year intensive survey program, to identify species that had recently invaded the state (5).

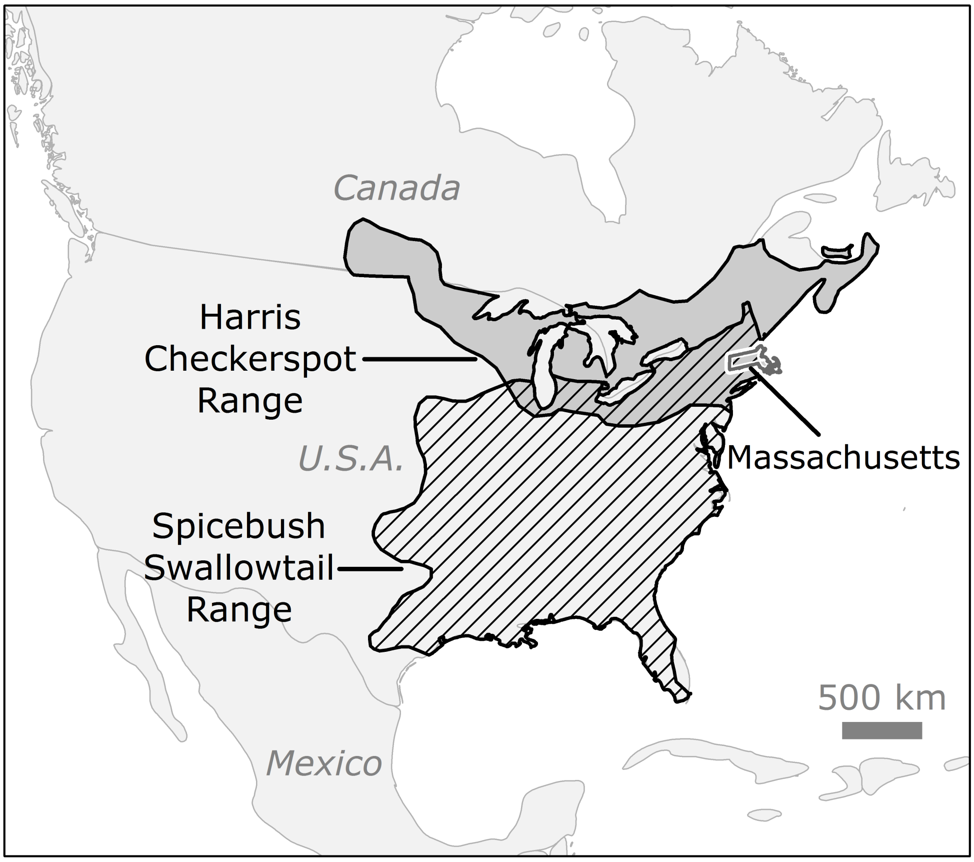

Fig S-1: Example ranges of two species commonly found in Massachusetts, one with a northerly range (Harris' Checkerspot) and another with a southerly range (Spicebush Swallowtail).

List-length models

The statistical method we used to analyze the Massachusetts Butterfly Club data is relatively new (6; 7), but is far more robust to the kinds of effort variation common in citizen science data than more established methods. The method makes the simple assumption that the more species reported in a particular outing, the greater the observation effort, and therefore the appearance of any one species in a list of observations will be related to the list's length. Thus, adding a parameter that relates list-length to the observed occurrence effectively controls for effort. In actual fact, it controls for all conditions that may prevent the observation of a species when it is present. For butterflies, which can be cryptic, have varying phenologies, and be very sensitive to weather, the number of species observed, the so called "list-length," may be a better control for effort than more formal measures such as person hours or person miles walked while surveying. For example, if observers work in groups, effort is typically not independent, and although additional group members may count more individuals, they do not greatly change the probability of detection of a given species, shape of the discovery curve, or time until all species present are detected. Group size might correspond to effort if members are highly trained and have a highly systematic search and survey plan, but that is not the case with most citizen science data. The list-length method does have limitations. It is not suitable for comparing the population sizes of different species because the unique behaviour, color, and size of each species impart a unique baseline detection probability, with large, gaudy butterflies such as swallowtails much more detectable than small cryptic species like skippers. The opportunistic nature of the data also does not permit quantitative estimation of population size. However, the method and data are extremely well suited for detecting changes in abundance and distribution through time. Though the analysis may not be able to estimate exact population size, citizen scientist observations can be extremely numerous, and list-length analysis can produce very robust estimates of change in population size through time.

The list-length model we fit is a simple 3 parameter logistic regression:

$$\text{logit}[P(obs)] = a_1 + a_2\log(L) + a_3\text{yr} \tag{1}$$

where $P(obs)$ is the probability of detection, L is the number of species observed that day, and yr is year. The vector of coefficients, $\boldsymbol{a}$, are assumed to be normally distributed; so that a_1 is the intercept and is the relative detectability of a species, a_2 is the effect of list-length, and a_3 is the change in detectability through time. The a_2 term is required or relative changes in population would be confounded with changes in reporting effort. As noted, L accounts for all factors that might limit the number of species detected on a given outing. These include person hours, poor weather, observer skill, and season. With a_1 and a_2 accounted for, the parameter of primary interest, a_3 (change in detectability through time), can be estimated. The model was fit in a Bayesian framework using the free software package WinBUGS. The model was run in two independent chains, updated 20000 times, used a burn-in of 10000, a thin of 5, and used vague priors. All diagnostics, including Rhat values, pD, and chain mixing, indicate good convergence for all species we report.

To ensure rarity did not affect population trend estimates, we plotted a_1 against a_2 (Fig. S-8). In Fig. S-8, the initial slope was negative. When the 6 fastest growing species were removed, nearly all recent invaders from the south and since they were not detected in the first half of the time-series they had very small baseline detectability, the relationship disappears. This suggests effort was well controlled and rarity did not affect population trend estimates.

To assess the impact of life history traits, we ranked species based on their estimated population trajectory, then used simple permutation tests (1000000 permutations) to see if particular traits were clumped in a higher-than-random chance in increasing or decreasing population trajectories.

Detectability and data quality. Butterflies are extremely well suited for observation by citizen scientists. In most temperate areas, including Massachusetts, this group is a relatively small, manageable number of species with which most interested citizen scientists can quickly become familiar. This property allows trained observers to report all species they see. Observers may not detect all butterfly species present, but because butterflies are so tractable, species that are detected can be identified which allows them to be recorded and included on a species list. Observer skill and effort do play a role in detection and identification. MBC members who regularly make reports are, on balance, highly skilled at identifying butterflies. There are less skilled observers, but in practice, observers with lower identification abilities tended not to make reports because they were not confident of their skills. Reports from less skilled observers tended to be shorter lists because the observers omitted species they could not identify. So, in effect, list-length also considers skill level as another factor affecting effort with long lists only created by the most skilled observers. Finally, butterflies are frequently observed in the field that cannot be identified because they could not be approached closely enough to observe distinguishing features. The MBC reporting protocol for uncertain observations is to record down to the taxonomic level that can be identified, typically family or genus. For this analysis, such uncertain records were excluded.

In the MBC data, we noticed a tendency for some gaudy or rare species to be reported by themselves. This problem is discussed at length in (6; 7), so we excluded all trips that reported fewer than 4 species (9229 trips reported at least 4 species). One species in particular, the very impressive Giant Swallowtail (*Papilio cresphontes*), was always reported in list lengths of 1, so we could not estimate population trends. However, others have reported this species to be increasing markedly and it is now probably breeding in the state (Table S-2, reference 8).

Effect of phenology on population trend estimates. A standard practice for modelling population trends in butterfly populations is to include a non-linear term (quadratic) (e.g. 9) or GAM spline (e.g. 10) that accounts for the phenologic flight times of butterflies. However, we already include list-length as an explanatory variable. List-length is intended to control for effort, but it also carries a clear phenological signal (Fig. S-2) and controls for all factors that limit detectability, including weather, observer effort, observer skill, and phenology. List-lengths are short in the spring and fall because there are few butterflies on the wing, increase and peak in spring, peak a second time in mid summer, and have a long decay into the autumn, so phenology is directly reflected in list-length. Because this is the case, we choose to let list-length explain detectability rather than include additional parameters to separately account for phenology as these parameters are likely to covary with list-length.

A somewhat less elegant, but simpler approach to account for phenology is to exclude from the analysis observation trips that occur before and after a species' earliest and latest day-of-year observation dates. This allowed us to keep from introducing the additional parameters needed for a quadratic or polynomial effect and may be as effective at controlling for phenology, particularly for species with very short flights. The results of this alternate analysis are shown in Fig. S-3, and indicate some minor differences from the original analysis which used all the data. Almost all species have very similar population trend estimates in both analyses and the community level impression and interpretation is essentially identical. This suggests that list-length controls for phenology reasonably well.

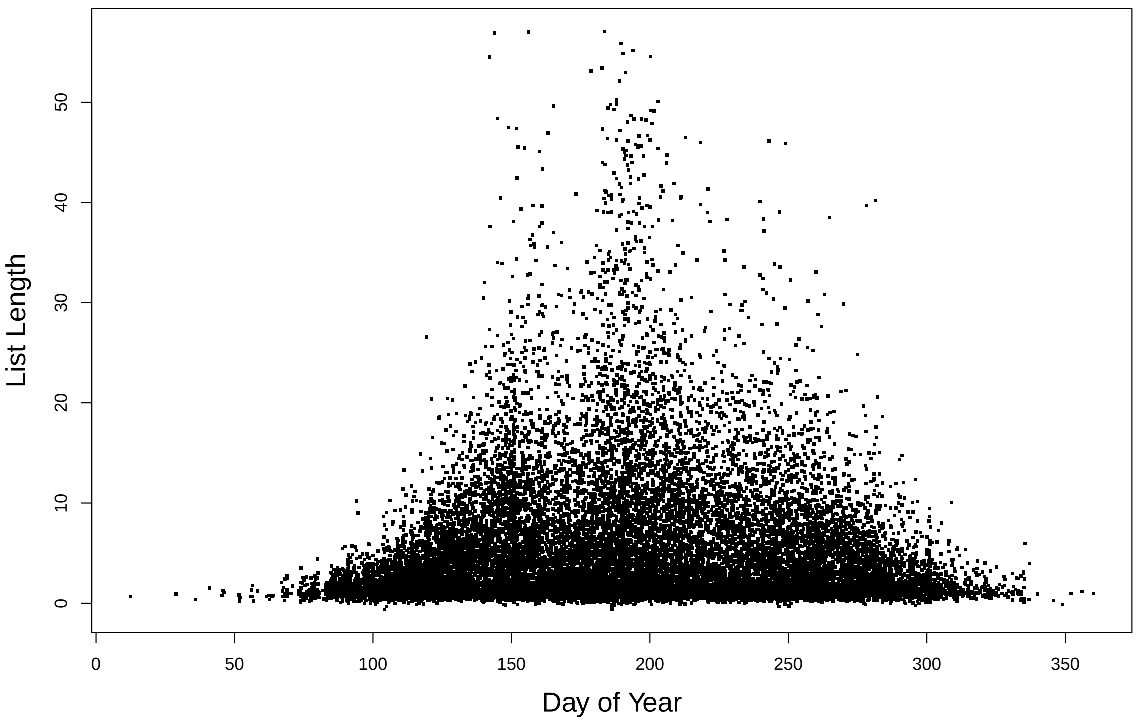

Fig S-2: List-length vs. day of year for all observations in the MBC database. Points have been jittered slightly to show overlapping observations as both x and y axes are discrete variables. Two distinct modes are apparent in late spring (day 150) and midsummer (day 190). A third more diffuse and less obvious mode is apparent in mid- to late autumn (day 255). This pattern suggests list-length should strongly control for phenological / seasonal effects of detection as well as effort.

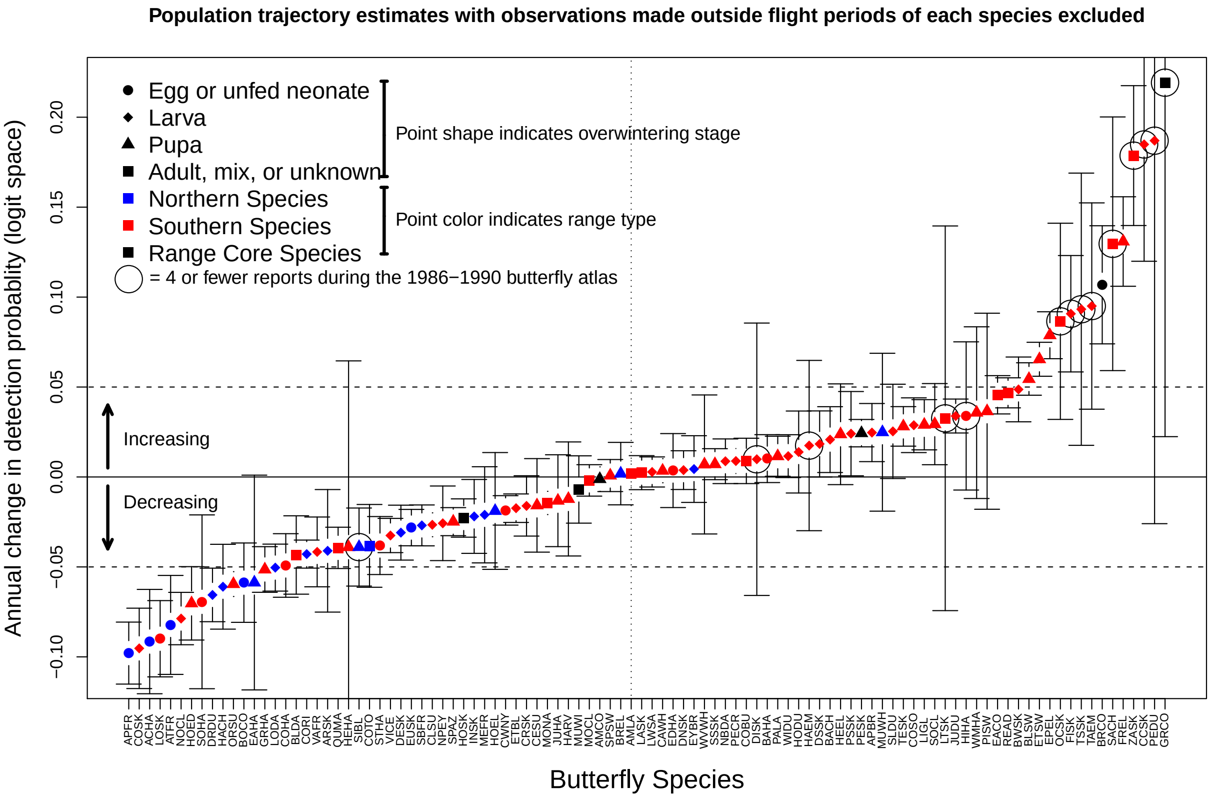

Fig S-3: Population trajectories as shown in Fig. 1, except estimated using only observations that were made during the phenological window of adult flight for each species. This resulted in a slight change in the population trajectories of some species, especially species with short flights, but the community level pattern is unchanged.

Massachusetts as a Eularian point for detecting range changes in Eastern North America butterfly populations.

Although geographically small, Massachusetts has a unique geographic position straddling the Temperate Transition Zone and represents a wide range of climactic conditions in Eastern North America (Fig. S-4). In addition, it is positioned within only a few hundred kilometers of Carolinian subtropical ecoregions to the south and observations of subtropical butterflies in Massachusetts occur regularly. Boreal and high temperate conditions persist in the western areas of the state where mountains of approach 1200 meters. These mountains are connected contiguously to alpine and arctic conditions on higher peaks in the Appalachians and populations of arctic and boreal butterflies such as Harris' checkerspot, bog copper, and arctic skipper persist in the state. In the east, extremely mild winters influenced by the Gulf Stream persist over Cape Cod, Nantucket, and Martha's Vineyard. The proximity to tropical and boreal climates, the diversity of climates within a small area, and the small overall size allow our results to be interpreted in a Eulerian framework that considers Massachusetts a point that populations move through. In this framework, butterfly populations can be thought of as concentrations of fluids, where the concentration should be expected to be lower at the edges of a species' geographic range and higher near the center of mass of its geographic range (11; 12). In this framework, we can assume that increasing populations are indicative of Massachusetts becoming closer to the core of a species' range as it shifts and this indicates conditions are becoming more favorable in Massachusetts. Declining populations suggest the geographic center is moving farther away from Massachusetts, and conditions are become less favorable.

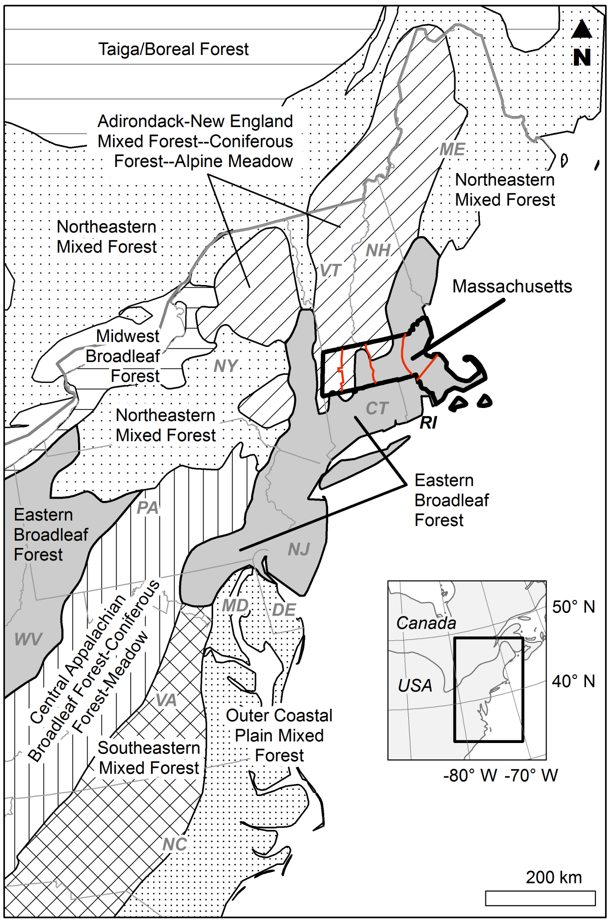

Fig S-4: Butterfly population trends reported here are from the state of Massachusetts, which is juxtaposed between warm and cold ecoregions in Eastern North America (13). The state is dominated by temperate eastern broadleaf forests, but includes northern coniferous and mixed forests and is only a few hundred km from warm ecoregions. Red lines show subregions of the regional analysis (detailed in Fig. 2).

Table S-2: Species codes, common name, Latin name, rational for exclusion (if applicable), and number of 1986-1990 Massachusetts Butterfly Atlas reports for all butterfly species recorded by the Massachusetts Butterfly Club.

Code	Common Name	Latin Name	Why Excluded?	1986-90 Atlas Reports
ACHA	Acadian Hairstreak	*Satyrium acadica*	Included	32
AMCO	American Copper	*Lycaena phlaeas*	Included	158
AMLA	American Painted Lady	*Vanessa virginiensis*	Included	170
AMSN	American Snout	*Libytheana carinenta*	Too few observations	0
APFR	Aphrodite Fritillary	*Speyeria aphrodite*	Included	68
APBR	Appalachian Brown	*Satyrodes appalachia*	Included	49
ARSK	Arctic Skipper	*Carterocephalus palaemon*	Included	30
ATFR	Atlantis Fritillary	*Speyeria atlantis*	Included	20
BACH	Baltimore Checkerspot	*Euphydryas phaeton*	Included	100
BAHA	Banded Hairstreak	*Satyrium calanus*	Included	92
BLDA	Black Dash	*Euphyes conspicua*	Included	98
BLSW	Black Swallowtail	*Papilio polyxenes*	Included	117
BOCO	Bog Copper	*Lycaena epixanthe*	Included	27
BOEL	Bog Elfin	*Callophrys lanoraieensis*	Too few observations	0
BWSK	Broad-winged Skipper	*Poanes viator*	Included	44
BRCO	Bronze Copper	*Lycaena hyllus*	Included	10
BREL	Brown Elfin	*Callophrys augustinus*	Included	68
CAWH	Cabbage White	*Pieris rapae*	Included	186
CGAZ	Cherry Gall Azure	*Celastrina serotina*	Taxonomic realignment	NA
CTSW	Canadian Tiger Swallowtail	*Papilio canadensis*	Cryptic Species	NA
CHWH	Checkered White	*Pontia protodice*	Too few observations	0
CLSU	Clouded Sulpher	*Colias philodice*	Included	171
CESU	Cloudless Sulphur	*Phoebis sennae*	Included	5
COSK	Cobweb Skipper	*Hesperia metea*	Included	33
COBU	Common Buckeye	*Junonia coenia*	Included	59
CCSK	Common Checkered-Skipper	*Pyrgus communis*	Included	2
CORI	Common Ringlet	*Coenonympha tullia*	Included	157
ROSK	Common Roadside-Skipper	*Amblyscirtes vialis*	Too few observations	10
COSO	Common Sootywing	*Pholisora catullus*	Included	69
CWNY	Common Wood-Nymph	*Cercyonis pegala*	Included	79
COTO	Compton's Tortoiseshell	*Nymphalis vaualbum*	Included	50
COHA	Coral Hairstreak	*Satyrium titus*	Included	65
CRSK	Crossline Skipper	*Polites origenes*	Included	66
DESK	Delaware Skipper	*Anatrytone logan*	Included	110
DISK	Dion Skipper	*Euphyes dion*	Included	1
DRDU	Dreamy Duskywing	*Erynnis icelus*	Included	91
DNSK	Dun Skipper	*Euphyes vestris*	Included	141
DSSK	Dusted Skipper	*Atrytonopsis hianna*	Included	86
EAHA	Early Hairstreak	*Erora laeta*	Included	5
EACO	Eastern Comma	*Polygonia comma*	Included	69
EPEL	Eastern Pine Elfin	*Callophrys niphon*	Included	103
ETBL	Eastern Tailed Blue	*Cupido comyntas*	Included	160
ETSW	Eastern Tiger Swallowtail	*Papilio glaucus*	Cryptic species	NA
EDHA	Edwards Hairstreak	*Satyrium edwardsii*	Included	55
EUSK	European Skipper	*Thymelicus lineola*	Included	55
EYBR	Eyed Brown	*Satyrodes eurydice*	Included	78
FISK	Fiery Skipper	*Hylephila phyleus*	Included	1
FREL	Frosted Elfin	*Callophrys irus*	Included	12
GISW	Giant Swallowtail	*Papilio cresphontes*	Too few observations	0
GSFR	Great Spangled Fritillary	*Speyeria cybele*	Included	110
GRCO	Grey Comma	*Polygonia progne*	Included	4
GRHA	Grey Hairstreak	*Strymon melinus*	Included	66
GUFR	Gulf Fritillary	*Agraulis vanillae*	Too few observations	0
HAEM	Hackberry Emperor	*Asterocampa celtis*	Included	1
HACH	Harris' Checkerspot	*Chlosyne harrisii*	Included	24
HARV	Harvester	*Feniseca tarquinius*	Included	37
HEEL	Henry's Elfin	*Callophrys henrici*	Included	28

Continued from Table S-2.

Code	Common Name	Latin Name	Why Excluded?	1986-90 Atlas Reports
HEHA	Hessel's Hairstreak	*Callophrys hesseli*	Included	11
HIHA	Hickory Hairstreak	*Satyrium caryaevorus*	Included	0
HOED	Hoary Edge	*Achalarus lyciades*	Included	27
HOEL	Hoary Elfin	*Callophrys polios*	Included	5
HOSK	Hobomok Skipper	*Poanes hobomok*	Included	151
HODU	Horace's Duskywing	*Erynnis horatius*	Included	34
INSK	Indian Skipper	*Hesperia sassacus*	Included	47
JUHA	Juniper Hairstreak	*Callophrys gryneus*	Included	36
JUDU	Juvenal's Duskywing	*Erynnis juvenalis*	Included	147
LASK	Least Skipper	*Ancyloxypha numitor*	Included	156
LODA	Long Dash	*Polites mystic*	Included	118
LOSK	Leonard's Skipper	*Hesperia leonardus*	Included	32
LIGL	Little Glassywing	*Pompeius verna*	Included	100
LWSA	Little Wood-Satyr	*Megisto cymela*	Included	156
LIYE	Little Yellow	*Pyrisitia lisa*	Single year outbreak	1
LTSK	Long-tailed Skipper	*Urbanus proteus*	Included	1
MEFR	Meadow Fritillary	*Boloria bellona*	Included	30
MITO	Milbert's Tortoiseshell	*Aglais milberti*	3 year outbreak	29
MONA	Monarch	*Danaus plexippus*	Included	155
MOCL	Mourning Cloak	*Nymphalis antiopa*	Included	132
MUWI	Mulberry Wing	*Poanes massasoit*	Included	53
MUWH	Mustard White	*Pieris oleracea*	Included	5
NBDA	Northern Broken-Dash	*Wallengrenia egeremet*	Included	91
NOCL	Northern Cloudywing	*Thorybes pylades*	Included	82
NPEY	Northern Pearly-eye	*Enodia anthedon*	Included	71
SOHA	Oak Hairstreak	*Satyrium favonius*	Included	9
OCSK	Ocola Skipper	*Panoquina ocola*	Included	0
ORSU	Orange Sulphur	*Colias eurytheme*	Included	162
PALA	Painted Lady	*Vanessa cardui*	Included	23
PECR	Pearl Crescent	*Phyciodes tharos*	Included	192
PESK	Pecks Skipper	*Polites peckius*	Included	157
PSSK	Pepper and Salt Skipper	*Amblyscirtes hegon*	Included	41
PEDU	Persius Duskywing	*Erynnis persius*	Included	0
PISW	Pipevine Swallowtail	*Battus philenor*	Included	11
QUMA	Question Mark	*Polygonia interrogationis*	Included	94
READ	Red Admiral	*Vanessa atalanta*	Included	32
RSPU	Red Spotted Purple	*Limenitis arthemis astyanax*	Taxonmic realignment	136
RSAD	Red-spotted Admiral	*Limenitis arthemis*	Taxonmic realignment	NA
SACH	Sachem	*Atalopedes campestris*	Included	2
SBFR	Silver Bordered Fritillary	*Boloria selene*	Included	89
SIBL	Silvery Blue	*Glaucopsyche lygdamus*	Included	0
SLDU	Sleepy Duskywing	*Erynnis brizo*	Included	26
SSSK	Sliver-Spotted Skipper	*Epargyreus clarus*	Included	179
SOCL	Southern Cloudywing	*Thorybes bathyllus*	Included	19
SPSW	Spicebush Swallowtail	*Papilio troilus*	Included	100
SPAZ	Spring Azure	*Celastrina ladon*	Included	78
STHA	Striped Hairstreak	*Satyrium liparops*	Inlcluded	97
SUAZ	Summer Azure	*Celastrina neglecta*	Change in reporting	NA
TAEM	Tawny Emperor	*Asterocampa clyton*	Included	0
TESK	Tawny-edged Skipper	*Polites themistocles*	Included	77
TISW	Tiger Swallowtail	*Papilio glaucus*	Cryptic species	NA
TSSK	Two-spotted Skipper	*Euphyes bimacula*	Included	3
VAFR	Variegated Fritillary	*Euptoieta claudia*	Included	23
VICE	Viceroy	*Limenitis archippus*	Included	145
WVWH	West Virginia White	*Pieris virginiensis*	Included	28
WHAD	White Admerial	*Limenitis arthemis arthemis*	Taxanomic realignment	48
WMHA	White-M Hairstreak	*Parrhasius m album*	Included	6
WIDU	Wild Indigo Duskywing	*Erynnis baptisiae*	Included	54
ZASK	Zabulon Skipper	*Poanes zabulon*	Included	2

Table S-3: Percent population change since 1992 calculated from parameter estimates including upper and lower 90% confidence intervals. Species are listed in the order they appear in Fig. 1.

Code	lower	% Change	upper	Code	lower	% Change	upper
APFR	-89.3	-85.4	-79.9	LASK	-16.2	-1.9	14.5
ACHA	-90.0	-82.9	-70.9	SSSK	-13.1	-0.3	14.0
ATFR	-89.0	-81.8	-69.8	NBDA	-19.6	0.1	24.3
LOSK	-85.6	-79.4	-70.6	AMLA	-6.5	2.5	11.8
NOCL	-80.5	-74.6	-66.9	DISK	-73.5	6.1	324.6
SOHA	-88.5	-73.3	-38.2	CAWH	-2.2	2.2	6.5
HOED	-80.2	-71.1	-57.6	LWSA	-6.6	5.8	19.4
BOCO	-80.2	-70.3	-55.5	HAEM	-54.8	8.5	159.7
COSK	-77.4	-67.1	-52.1	COBU	-10.8	11.0	37.5
EAHA	-89.4	-67.3	0.8	PECR	1.2	9.5	18.0
ORSU	-59.7	-55.0	-49.9	HOEL	-34.9	17.5	111.2
HACH	-77.9	-65.7	-46.7	WIDU	-1.8	21.0	48.7
COHA	-74.5	-65.0	-52.1	PALA	-0.1	20.7	45.3
LODA	-71.9	-64.2	-54.6	HODU	-18.9	23.6	87.8
BLDA	-74.4	-61.6	-42.4	APBR	-5.5	26.1	67.9
GRHA	-67.6	-59.2	-48.7	BACH	-8.1	27.9	77.5
STHA	-69.9	-59.9	-46.7	GSFR	8.7	23.9	40.7
VAFR	-71.0	-58.5	-40.8	PESK	11.8	23.8	36.6
ARSK	-75.7	-54.3	-14.0	LTSK	-80.6	33.7	817.2
DRDU	-63.6	-53.1	-39.7	LIGL	6.5	36.1	73.5
CORI	-54.5	-48.1	-40.9	TESK	20.5	44.9	73.6
DESK	-63.6	-51.9	-36.5	DSSK	9.7	50.2	104.9
EUSK	-56.7	-48.4	-38.5	HIHA	-28.8	52.4	225.7
QUMA	-58.4	-48.9	-37.4	MUWH	-31.7	53.0	241.2
COTO	-66.8	-49.3	-22.7	PSSK	-0.4	52.6	132.8
VICE	-52.7	-44.2	-34.4	SOCL	2.8	55.1	133.3
CWNY	-48.9	-41.7	-33.6	PISW	-42.3	55.8	318.2
NPEY	-62.2	-45.1	-20.2	COSO	18.7	55.5	102.9
SBFR	-52.7	-41.9	-28.9	BREL	15.1	55.9	110.1
CRSK	-57.1	-41.8	-21.2	WVWH	-9.7	85.3	277.7
SIBL	-60.4	-41.0	-12.2	WMHA	-21.6	88.3	350.3
CLSU	-29.5	-23.7	-17.6	BWSK	36.7	87.1	155.0
CESU	-61.0	-37.7	-0.8	JUDU	52.4	74.3	98.3
SPAZ	-39.3	-31.3	-22.4	SLDU	27.7	104.7	226.0
HOSK	-44.3	-33.0	-19.5	EACO	73.3	104.4	139.6
MEFR	-60.1	-34.8	6.3	READ	69.8	88.8	108.8
HEHA	-90.2	-34.1	342.9	BLSW	90.9	115.4	141.6
INSK	-53.0	-32.3	-2.5	HEEL	66.1	174.7	350.3
MUWI	-51.0	-30.9	-2.8	OCSK	35.6	250.5	794.8
ETBL	-31.7	-22.7	-12.8	FISK	105.4	259.8	522.8
MONA	-22.5	-15.7	-8.7	TAEM	58.1	353.3	1183.2
HARV	-56.3	-22.1	38.7	EPEL	209.5	273.5	345.9
JUHA	-49.7	-19.0	30.1	TSSK	19.4	371.7	1736.9
EDHA	-41.9	-16.0	21.4	BRCO	195.0	418.1	795.1
EYBR	-39.6	-15.1	19.1	SACH	123.9	691.2	2625.8
DNSK	-25.8	-10.7	7.2	FREL	657.2	1013.5	1484.7
BAHA	-27.9	-9.0	14.6	CCSK	450.8	1629.5	4990.4
SPSW	-16.9	-4.0	10.5	ZASK	904.9	1809.0	3314.2
MOCL	-15.5	-2.9	11.3	GRCO	10.7	3763.3	119245.9
AMCO	-9.7	-1.4	7.2	PEDU	-21.8	4302.6	212911.1

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Additional Supporting Figures and Results

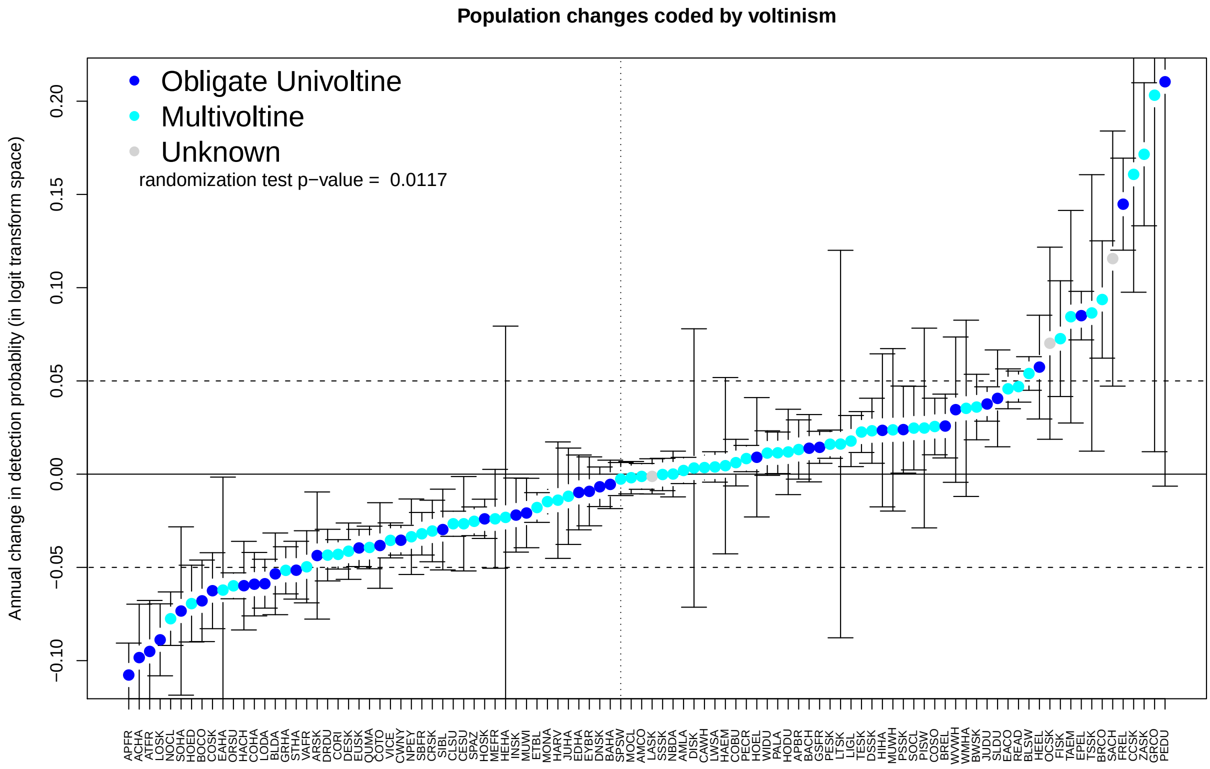

Fig S-5: Population trajectories coded by voltinism. Obligate univoltinism is significantly overrepresented in declining species.

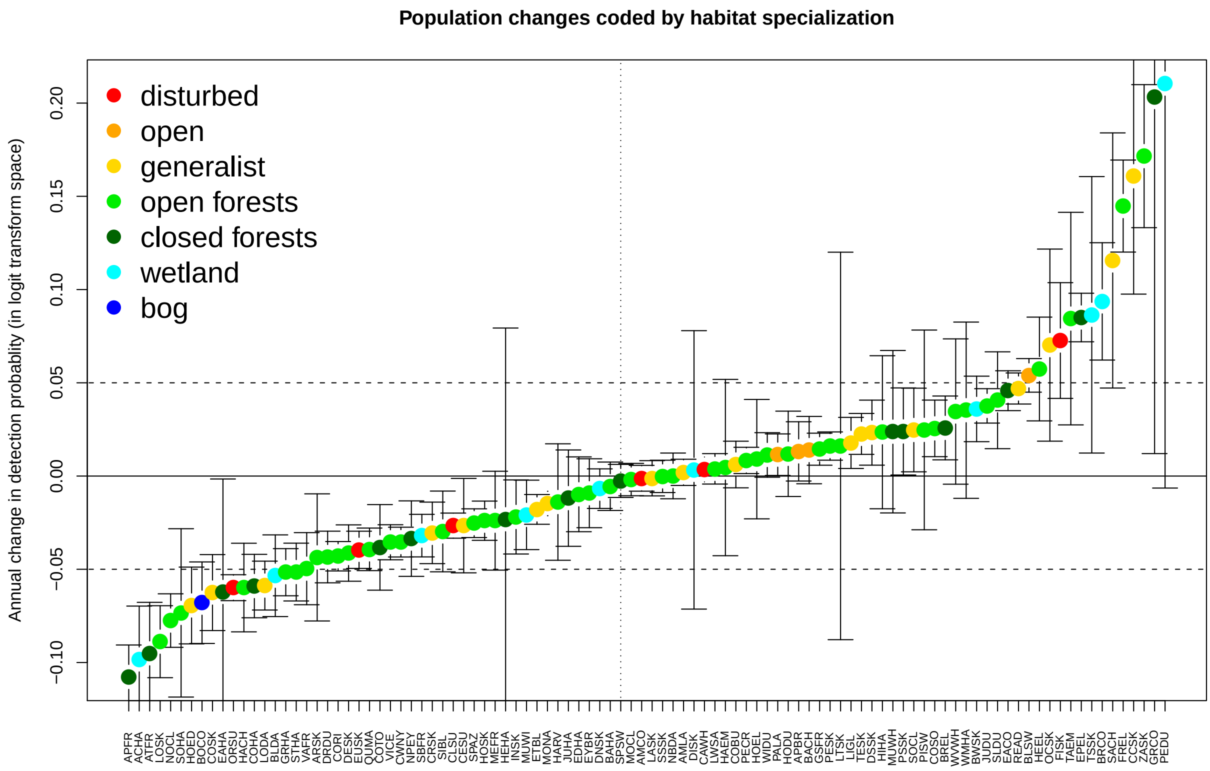

Fig S-6: Population trajectories coded by habitat preference. No significant patterns with respect to habitat preference are present.

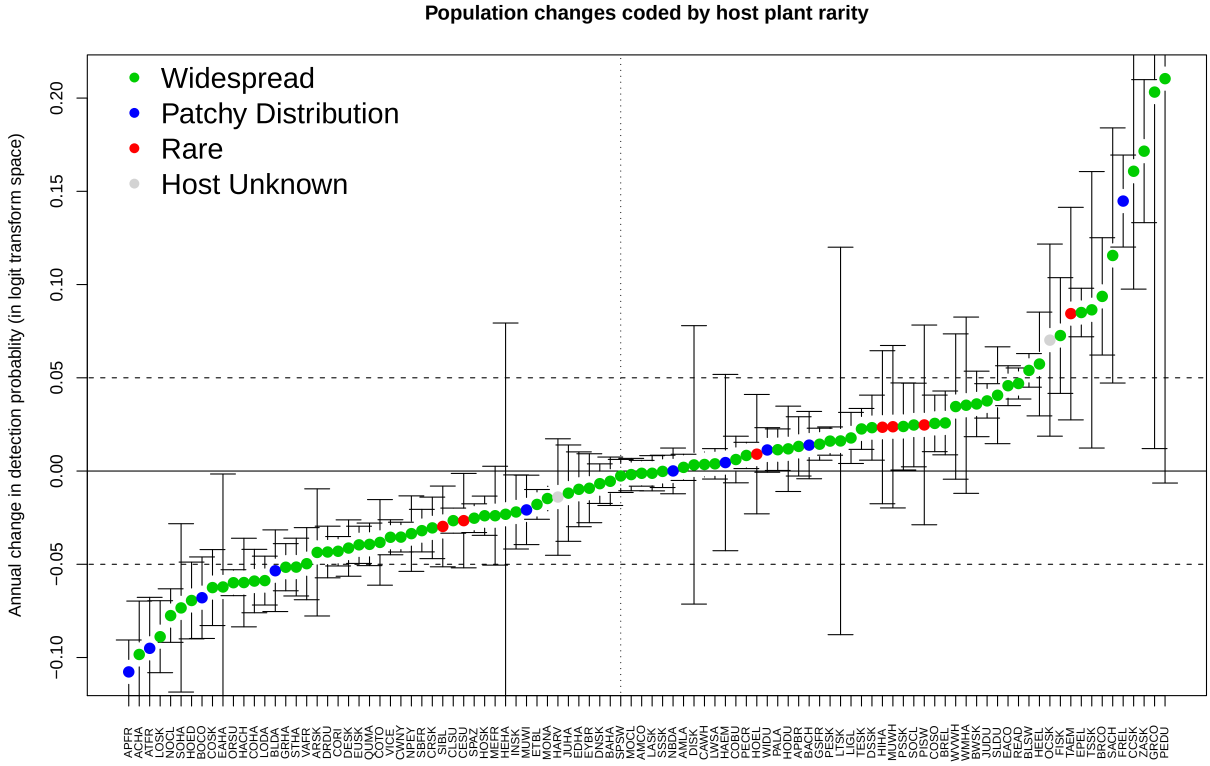

Fig S-7: Population trajectories coded by host plant rarity. No significant patterns with respect to host plant rarity are present.

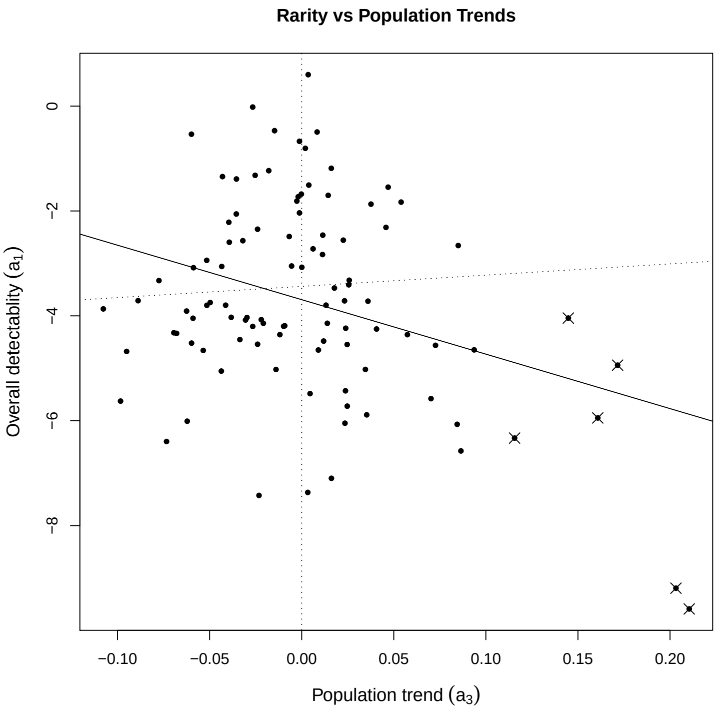

Fig S-8: Overall detectability vs population trend. When all populations are included, there is a negative relationship between rarity and population trend (solid line - rare species tend to be increasing). When the 6 most rapidly increasing populations are excluded, which are mostly invading from the south and are estimated as rare because they were not present during the beginning of the time-series, the relationship disappears (dotted line).

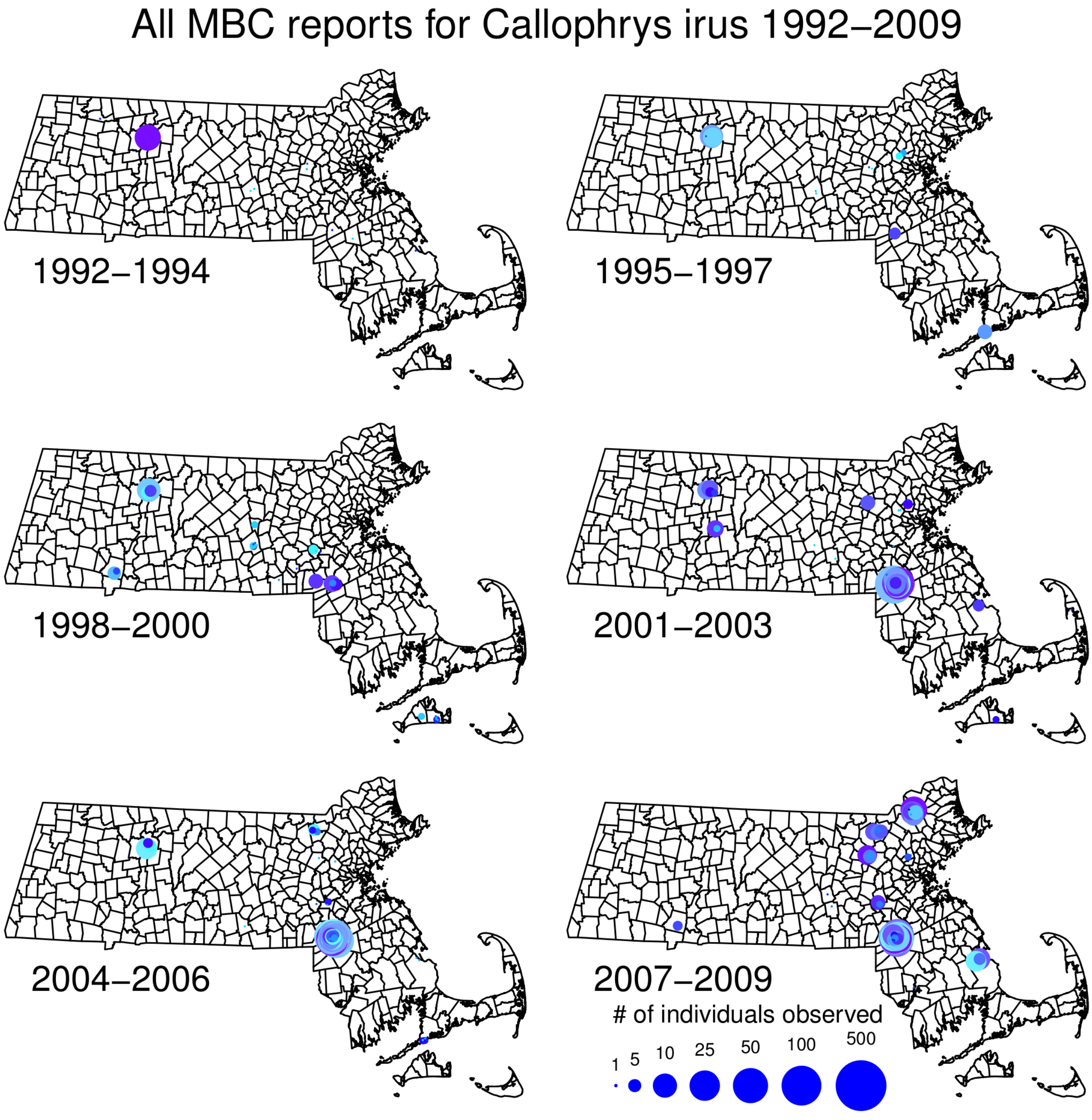

Fig S-9: Raw MBC reports for the Frosted Elfin (*Callophrys irus*). Hue of each report is randomly offset so that overlapping reports are more visible, and the size of the circles represents the number of individuals reported that day. Circle size is log scaled so that large reports do not overwhelm the map.

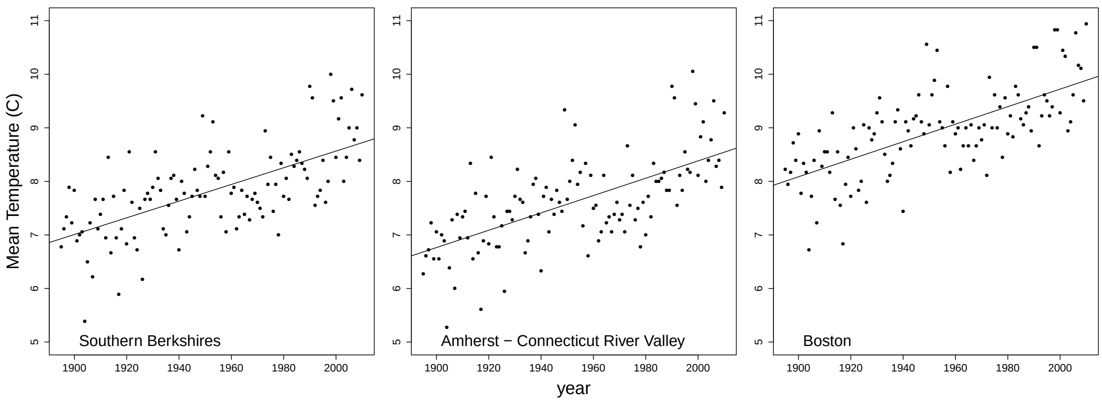

Fig S-10: Increase in annual average temperature in Southern Berkshire County (Region 5), Amherst (Region 4), and Boston (Region 2), since 1900. (Data source: 14).