Figure S1. Scatterplot matrix of variables included in the kitchen sink PLS. The first variable is log-scale monarch abundance index. The second variable is log-scale annual growth rate. Other variables are shown in the same order as they are listed in Table 1 (see main text). Formatting is identical to Figure 2 (main text).

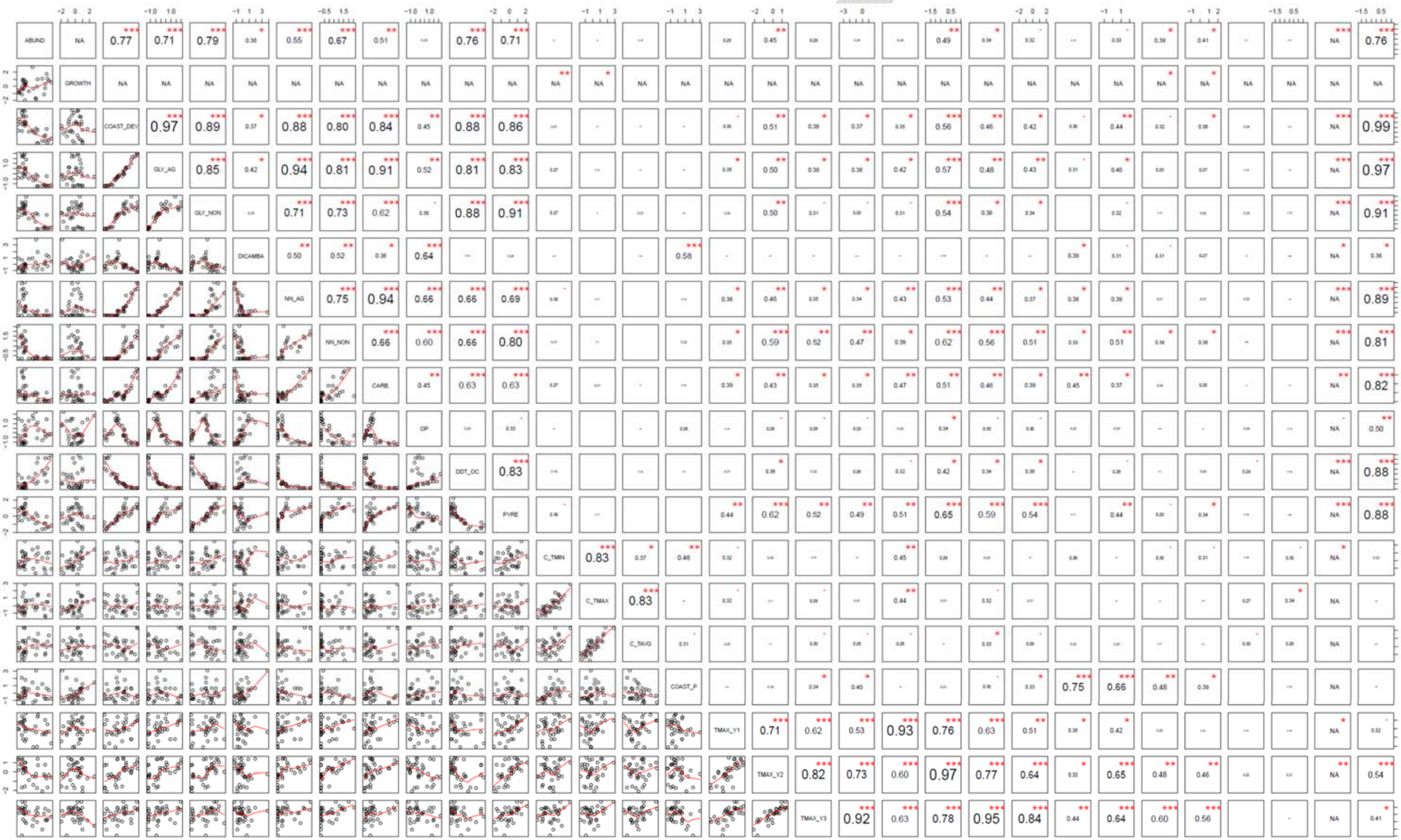

Figure S1 (continued)

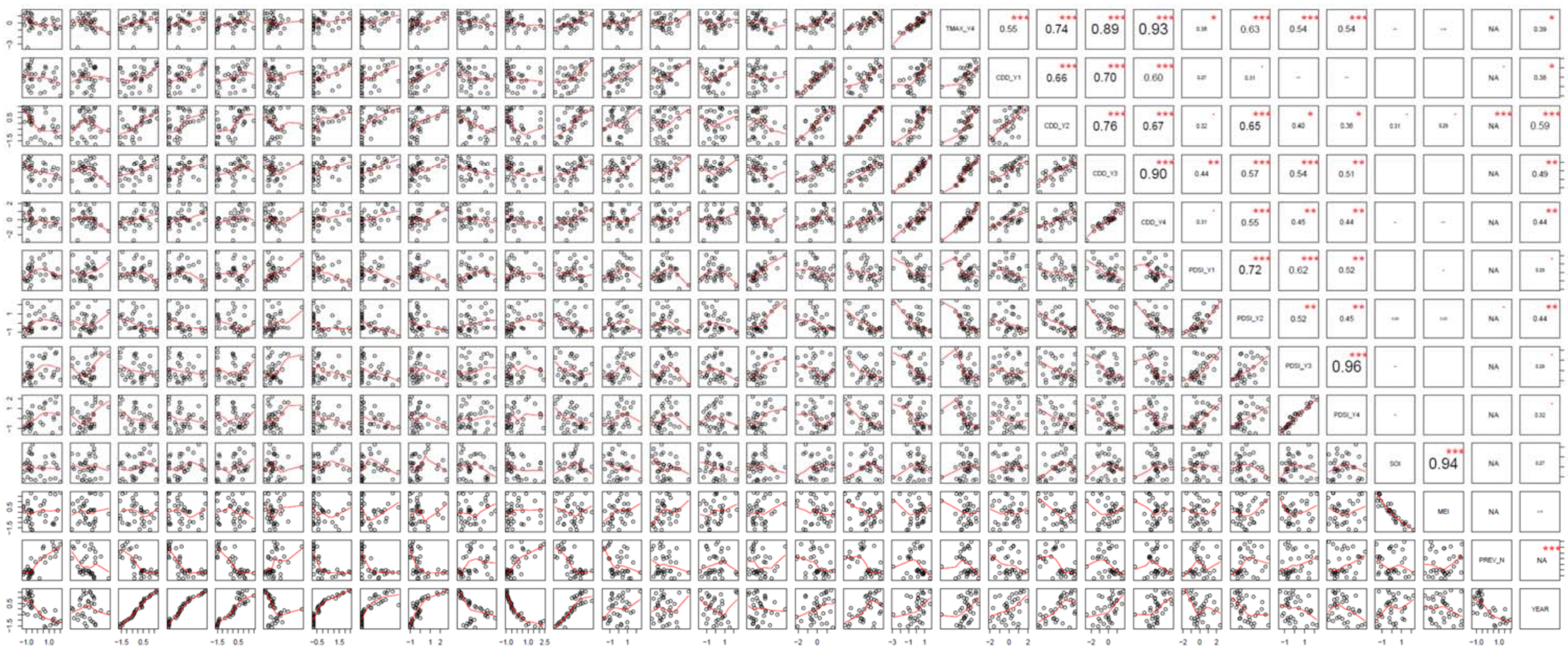

Figure S2. Randomization test for statistical significance of PLSR components from the *a priori* and kitchen sink models. RMSEP = (square) root mean squared error of prediction, calculated for leave-one-out cross-validation. For both models, three components minimized prediction error. Models that did not differ from the minmum at $P < 0.05$ are circled in blue. By convention, the first model that does not differ significantly from the optimum is the number of statistically significant components. Note also that the squared prediction error is consistently lower for the seven-parameter *a priori* model than the 29-parameter kitchen sink model.

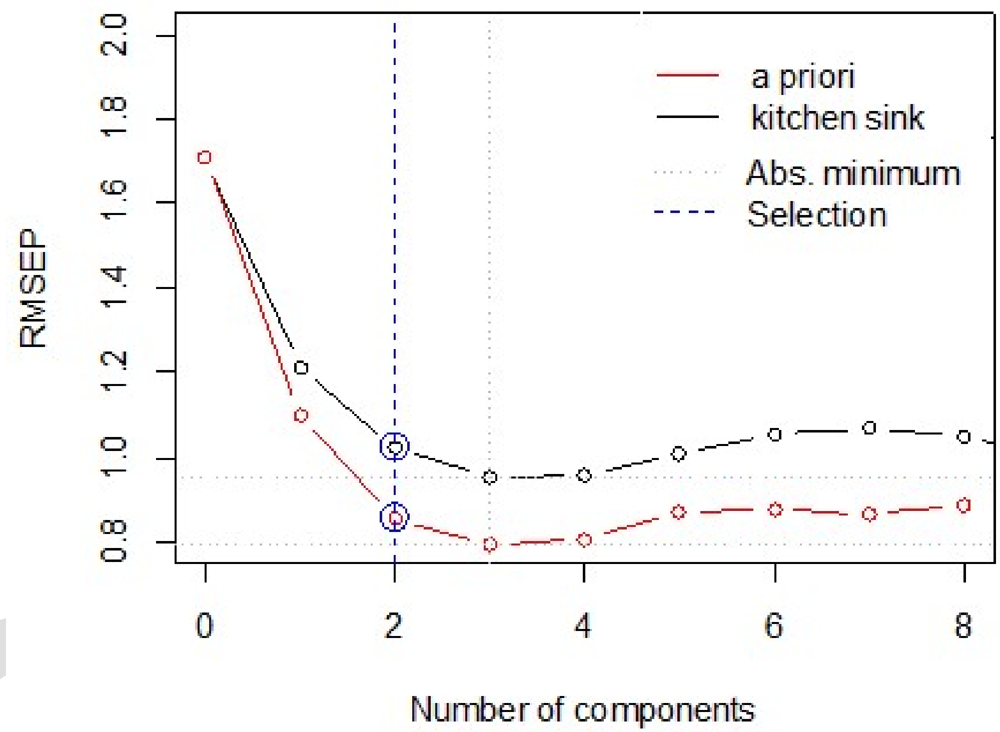

Table S3. Results of model selection across all possible combinations of variables in the a priori model. Variables are described in more detail in the main text

								model selection statistics			
coastal develop-ment	glypho-sate	neonic-otinoids	coastal winter precip.	coastal winter temp.	breeding PDSI	breeding max. temp.	previous monarch abund.	df	log-likeli-hood	DAICc	import-ance, w_i
	-1.30	0.77		0.44			1.10	6	-35.0	0.0	0.11
-1.09		0.58		0.38			1.12	6	-35.2	0.4	0.09
	-1.33	0.88		0.34	0.21		1.06	7	-33.8	0.8	0.07
-0.52				0.44			1.20	5	-37.1	1.2	0.06
	-0.50			0.47			1.22	5	-37.5	2.1	0.04
	-1.28	0.81		0.44		-0.12	1.11	7	-34.6	2.2	0.04
-0.55	-0.77	0.77		0.41			1.08	7	-34.6	2.2	0.04
-0.59			-0.19	0.54			1.17	6	-36.2	2.3	0.04
	-1.15	0.68	-0.20	0.42	0.30		1.06	8	-33.1	2.7	0.03
	-0.48		-0.34	0.51	0.31		1.15	7	-34.8	2.7	0.03
-1.06		0.59		0.38		-0.09	1.13	7	-35.0	3.0	0.02
	-1.26	0.72	-0.05	0.47			1.11	7	-35.0	3.1	0.02
-1.04		0.49	-0.10	0.44			1.12	7	-35.0	3.1	0.02
-1.04		0.57		0.34	0.08		1.12	7	-35.1	3.2	0.02
-0.48			-0.31	0.49	0.25		1.16	7	-35.1	3.2	0.02
	-0.56		-0.18	0.57			1.20	6	-36.7	3.3	0.02
	-1.39	1.04			0.37		0.96	6	-36.8	3.6	0.02
-0.48				0.40	0.08		1.20	6	-37.0	3.9	0.02
-0.49				0.44		-0.07	1.21	6	-37.0	3.9	0.02
-0.52			-0.27	0.59		-0.17	1.19	7	-35.4	4.0	0.02
-0.14	-1.19	0.87		0.34	0.19		1.06	8	-33.8	4.1	0.01
	-0.45			0.41	0.13		1.21	6	-37.1	4.1	0.01
-0.57	0.05			0.44			1.20	6	-37.1	4.2	0.01
	-1.34	0.88		0.33	0.23	0.03	1.06	8	-33.8	4.2	0.01
	-0.46			0.47		-0.08	1.23	6	-37.3	4.6	0.01
	-0.49		-0.27	0.62		-0.19	1.21	7	-35.8	4.7	0.01
-0.47	-0.82	0.80		0.41		-0.11	1.09	8	-34.2	4.9	0.01
	-1.16	0.67	-0.13	0.52		-0.17	1.12	8	-34.2	5.0	0.01
-0.86		0.39	-0.21	0.42	0.19		1.12	8	-34.4	5.2	0.01
-0.94		0.45	-0.17	0.49		-0.15	1.13	8	-34.4	5.3	0.01
	-1.43	1.02			0.48	0.20	0.94	7	-36.1	5.4	0.01
-0.62	0.04		-0.19	0.53			1.17	7	-36.2	5.4	0.01
-0.57	-0.70	0.70	-0.06	0.44			1.08	8	-34.5	5.5	0.01
-1.29		0.79					0.97	5	-39.2	5.5	0.01
-1.10		0.73			0.23		1.01	6	-37.9	5.7	0.01
	-0.48		-0.34	0.52	0.29	-0.03	1.16	8	-34.8	6.1	0.01
0.00	-0.48		-0.34	0.51	0.31		1.15	8	-34.8	6.1	0.01
			-0.30	0.42	0.41		1.45	6	-38.1	6.2	0.01
				0.43			1.58	4	-41.0	6.2	0.01
0.03	-1.18	0.68	-0.20	0.42	0.30		1.06	9	-33.1	6.3	0.01
	-1.15	0.68	-0.20	0.42	0.30	0.00	1.06	9	-33.1	6.3	0.01
				0.33	0.24		1.49	5	-39.7	6.4	0.00

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-1.05	0.59	0.37	0.02	-0.08	1.13	8	-34.9	6.4	0.00

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Table S3., continued

coastal develop-ment	glypho-sate	neonic-otinoids	coastal winter precip.	coastal winter temp.	breeding PDSI	breeding max. temp.	previous monarch abund.	df	log-likeli-hood	DAICc	import-ance, w_i
-0.48			-0.32	0.52	0.20	-0.07	1.17	8	-35.0	6.5	0.00
-0.18	-1.22	1.03			0.35		0.96	7	-36.8	6.7	0.00
	-1.39	1.04	0.00		0.37		0.96	7	-36.8	6.8	0.00
				0.45		-0.20	1.53	5	-39.9	6.9	0.00
		-0.24		0.46			1.44	5	-40.0	7.0	0.00
-0.47				0.42	0.06	-0.03	1.20	7	-36.9	7.0	0.00
		-0.27	-0.38	0.51	0.36		1.32	7	-36.9	7.0	0.00
-0.38	-0.10			0.41	0.09		1.20	7	-36.9	7.0	0.00
-0.52	0.04			0.44		-0.07	1.21	7	-37.0	7.1	0.00
-1.32		0.87	0.15				1.01	6	-38.6	7.2	0.00
	-0.45			0.40	0.14	0.01	1.21	7	-37.1	7.3	0.00
-0.52	0.00		-0.27	0.59		-0.17	1.19	8	-35.4	7.4	0.00
-0.12	-1.21	0.87		0.33	0.20	0.01	1.06	9	-33.8	7.8	0.00
			-0.23	0.57		-0.30	1.53	6	-39.0	7.9	0.00
-0.48	-0.69	0.66	-0.13	0.49		-0.15	1.10	9	-33.9	7.9	0.00
					0.37		1.34	4	-41.9	8.1	0.00
-0.36					0.27		1.09	5	-40.6	8.1	0.00
	-1.38	0.90					0.98	5	-40.6	8.1	0.00
-1.27		0.80				-0.07	0.98	6	-39.1	8.2	0.00
-1.07	-0.32	0.87					0.95	6	-39.2	8.3	0.00
		-0.34	-0.21	0.58			1.41	6	-39.2	8.3	0.00
	-1.57	1.14	0.23				1.00	6	-39.2	8.4	0.00
	-0.32				0.32		1.11	5	-40.7	8.5	0.00
		-0.16		0.37	0.19		1.41	6	-39.3	8.5	0.00
-1.08		0.68			0.30	0.11	1.02	7	-37.7	8.5	0.00
-0.87		0.40	-0.21	0.46	0.12	-0.09	1.13	9	-34.2	8.6	0.00
-0.52							1.05	4	-42.2	8.6	0.00
			-0.08	0.47			1.59	5	-40.8	8.7	0.00

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S4. Supplemental Methods for Environmental Data

Land use change

Overwintering habitat: We assessed coastal development using data from the California Farmland Mapping and Monitoring Program (FMMP; http://www.conservation.ca.gov/dlrp/fmmp). FMMP reports changes in urban and other land cover types from 1984–2014 in two-year intervals. We extracted calculated developed land in each year within a 500m radius around the centroid of each Thanksgiving Count overwintering site. To estimate annual values, we interpolated between bi-annual records in the FMMP dataset. We extrapolated data for 1982-1983 (prior to the start of FMMP) and 2015-2016 (which had not been published yet) using lag-1 autoregressive moving average models (implemented using the nlme function (Pinheiro *et al.* 2018) in R (R_Core_Team 2018).

Breeding habitat: Pesticide use is a general measure of overall agricultural intensification in breeding habitat, and use of glyphosate in particular has been linked to monarch habitat loss in the east (Stenoien *et al.* 2018). We compiled data on commonly used pesticide classes from the California Department of Pesticide Regulation (CDPR) Pesticide Use Reporting database https://www.cdpr.ca.gov/docs/pur/purmain.htm. Data from 1990-2016 are maintained in a searchable database, and 1981-1989 are in CDPR archives. Other states in the West do not maintain comparable systematic annual records, but trends in California pesticide use are parallel to other parts of the West (Sleeter *et al.* 2013; USGS 2016). We compiled CDPR data on annual use of two herbicides (glyphosate and dicamba) and five classes of insecticides (neonicotinoids, carbamates, organophospates, pyrethroids, and organochlorines). Neonicotinoids include the five nitroguanidine neonicotinoid insecticides that are most persistent and prevalent in the West:

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acetamiprid, clothanidin, dinotefuran, imidacloprid, and thiamethoxam (Forister *et al.* 2016; Mogren & Lundgren 2016). CDPR tracks agricultural and non-agricultural use separately, and we kept these differences in our database. The additional four classes of insecticides are the most widely used non-neonicotinoid insecticides and have been included in prior analyses investigating associations between butterfly abundance and pesticide use in California (Forister et al 2016).

Climate variables

Overwintering grounds: For each site in our analysis (Schultz et al. 2017), we averaged climate variables from December – February using data from the PRISM database (http://www.prism.oregonstate.edu). We extracted total monthly precipitation, minimum monthly temperature, mean monthly temperature, and maximum monthly temperature. For each measure, we averaged the values across all overwintering sites each year.

Breeding habitat: We compiled temperature and drought data averaged across the breeding range. We quantified drought using the Palmer Drought Severity Index (PDSI; https://www.ncdc.noaa.gov), averaged from January–September (Stephens and Frey 2010). We quantified temperature using average monthly maximum June–August temperature (Tmax) with temperature data from the NCDC, and cooling degree days (days in which average temperature exceeds 18^{o} C; CDD) in June–August. We first calculated temperature and drought indices separately for four regions defined by their contribution to the western breeding population (Fig. 1, corresponding to hydrogen isotope regions used by Yang et al. (2015) to identify sources of breeding monarchs). Hereafter, we refer to these four regions as: Y1, Y2, Y3, and Y4 (“Y” for

Yang et al. 2015). We also calculated the average of these metrics across the four regions, as a measure of overall conditions (Table 1). We compiled data on two regionwide indices of the El Nino Southern Oscillation that may be associated with butterfly abundance, MEI and SOI (https://www.esrl.noaa.gov/psd/enso/mei/ and https://www.ncdc.noaa.gov/teleconnections/enso/indicators/soi/).

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