Linking North American Demographic Trends to Mexican Non-Breeding Grounds in a Migratory Warbler

Dileka Kariyawasam[1,4,5], Ian Becker[1], Evan Farese[1], José Luis Alcantara Carbajal[2], Mark H. Conway[3] and Andrea Contina[1]

[1]The University of Texas Rio Grande Valley, School of Integrative Biological and Chemical Sciences, Brownsville, USA; [2]Colegio de Postgraduados, Área de Fauna Silvestre PREGP-Ganadería, Campus Montecillo, Texcoco, Mexico; [3]Lower Rio Grande Valley Avian Research, Harlingen, USA; [4]Ecology and Evolutionary Biology Program, Texas A&M University, College Station, USA; [5]Department of Ecology and Conservation Biology, Texas A&M University, College Station, USA

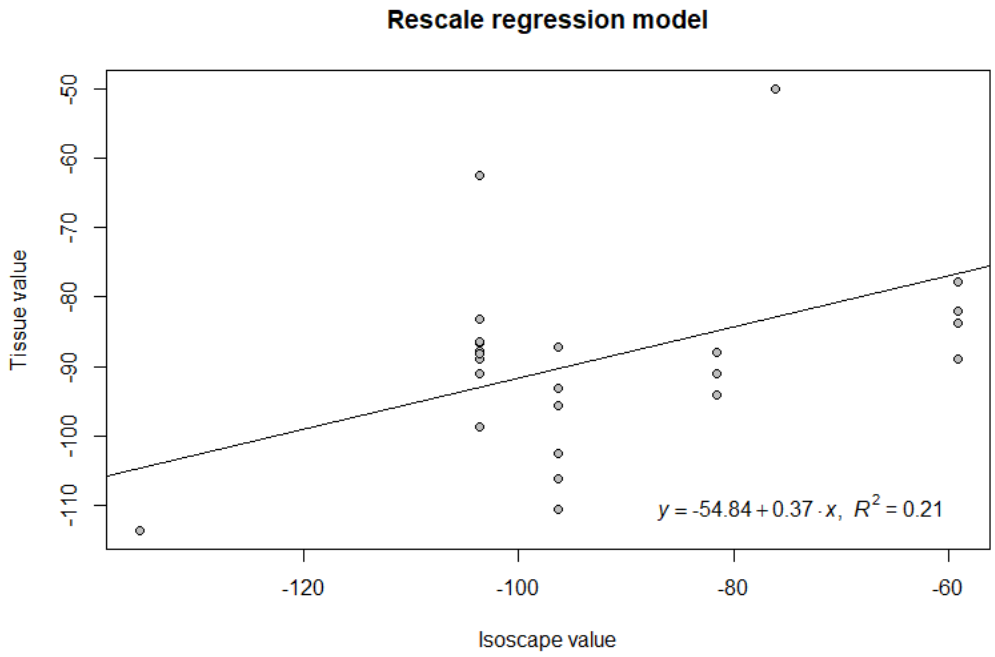


Figure S1: Linear regression model relating measured tissue δ²H and predicted isoscape δ²H. The model was significant ($F_{1,22}$ = 5.79, p = 0.025) and explained approximately 21% of the variation in tissue δ²H (adjusted R^2 = 0.21).

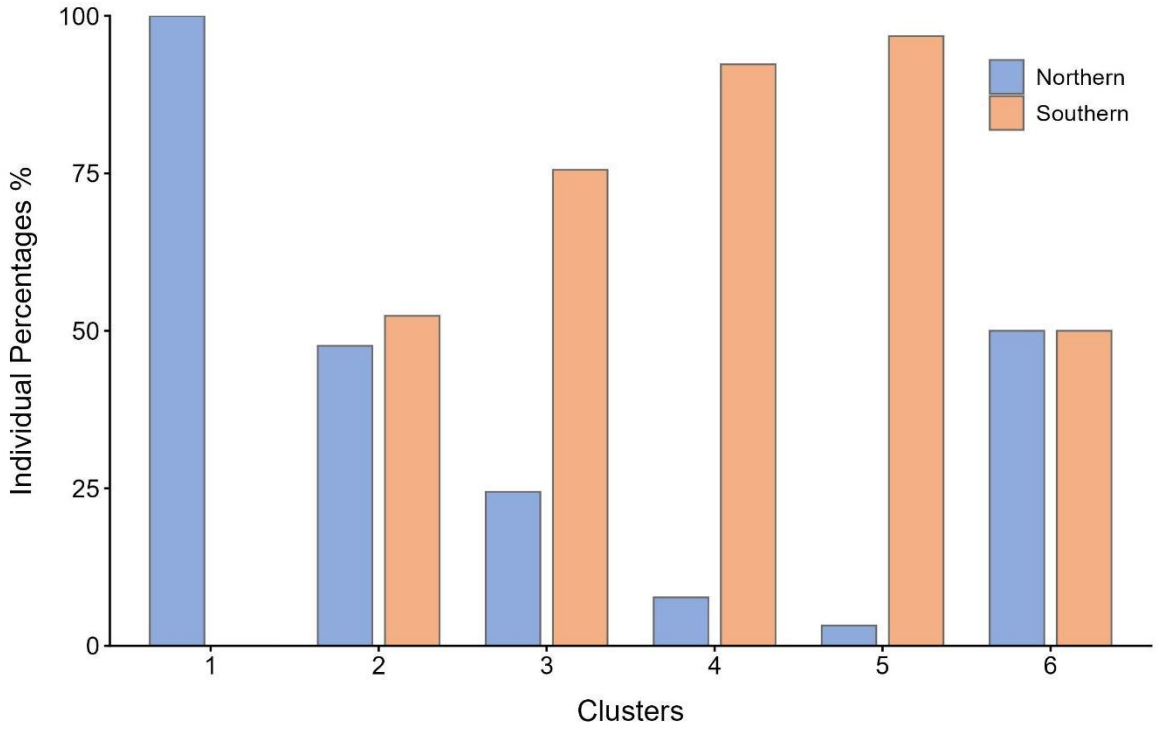


Figure S2. Geographic distribution of individual Orange-crowned Warblers across six isotopic breeding clusters relative to non-breeding capture latitudes in Mexico. The bar chart shows the relative percentages of individuals within each cluster whose assigned non-breeding location of capture was in the Northern group (subtropical, above the Tropic of Cancer ~23°26′ N, blue bars), comprising sites TAMQ, CABA, PICH, and PATO, versus the Southern group (tropical, below ~23°26′ N, orange bars), comprising sites ACPF, ESJC, FLOR, ROCA, and ARCO (refer to Table S1 for full site names). Cluster 1 shows high linkage to the northern sites (100% North), while Clusters 4 and 5 demonstrate strong linkage to the southern sites (>90% South). Clusters 2 and 6 exhibit the highest degree of latitudinal mixing, with individuals distributed in nearly equal proportions across both northern and southern non-breeding groups.

Table S1: Mean transition probabilities (ψ) of Orange-crowned Warbler probable breeding clusters to non-breeding ecoregions. Transition probabilities were weak (ψ

< 0.25), with some moderate transitions (ψ = 0.26–0.40) observed for central and western breeding populations (e.g., Clusters 1 and 2) to the Western Sierra Madre and Western Pacific Coastal Plain.

Eco-region	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Eastern Sierra Madre	0.10	0.16	0.18	0.19	0.29	0.09
Sierra and Plains of El Cabo	0.22	0.26	0.16	0.14	0.18	0.04
Tamaulipas-Texas Semiarid Plain	0.80	0.17	0.02	0.01	0.00	0.00
Transversal Neo-Volcanic System	0.14	0.22	0.22	0.19	0.19	0.04
Western Pacific Coastal Plain, Hills and Canyons	0.40	0.30	0.13	0.08	0.07	0.02
Western Sierra Madre	0.32	0.35	0.20	0.08	0.05	0.00

Table S2: List of Orange-crowned Warbler individual samples. This table shows stable isotope values, age, sex, cluster, and group allocations: northern group above ~23°26′ N and a southern group below ~23°26′ N and Pacific or Gulf group based on

their position relative to the Sierra Madre Occidental. Sex: F = Female and M = Male; Age categories: HY = Hatch-year (young birds born during the current calendar year), AHY = After-hatch-year (adult birds), SY = Second-year (born the previous year), U = Unknown (the birds for which it is difficult to determine the category).

Individual _ID	Site_ID	δ^2H	Sex	Age	Cluster	Tropic of Cancer ~23°26′ N	Sierra Madre Occidental
OCWA-1	ESJC_01	-111.714	F	AHY	4	Southern	Pacific
OCWA-2	ESJC_02	-125.847	M	SY	3	Southern	Pacific
OCWA-3	ESJC_03	-125.205	F	AHY	3	Southern	Pacific
OCWA-4	ESJC_04	-112.273	M	AHY	4	Southern	Pacific
OCWA-5	ESJC_05	-138.945	M	U	2	Southern	Pacific
OCWA-6	ESJC_06	-129.317	M	U	3	Southern	Pacific
OCWA-7	ESJC_07	-129.92	M	U	3	Southern	Pacific
OCWA-8	ESJC_08	-107.112	M	AHY	4	Southern	Pacific
OCWA-9	ESJC_09	-137.259	F	AHY	2	Southern	Pacific
OCWA-10	ESJC_10	-83.0365	U	AHY	5	Southern	Pacific
OCWA-11	ESJC_11	-132.917	M	U	3	Southern	Pacific
OCWA-12	ESJC_12	-128.115	F	U	3	Southern	Pacific
OCWA-13	ESJC_13	-123.141	M	U	3	Southern	Pacific
OCWA-14	ESJC_14	-84.3589	M	U	5	Southern	Pacific
OCWA-15	ESJC_15	-77.4641	F	U	5	Southern	Pacific
OCWA-16	ESJC_16	-143.699	F	SY	2	Southern	Pacific
OCWA-17	ESJC_17	-69.7813	F	SY	5	Southern	Pacific
OCWA-18	ESJC_18	-81.5348	M	SY	5	Southern	Pacific
OCWA-19	ESJC_19	-79.646	F	AHY	5	Southern	Pacific

OCWA-20	ESJC_20	-80.3948	M	U	5	Southern	Pacific
OCWA-21	ESJC_21	-132.613	F	AHY	3	Southern	Pacific
OCWA-22	ESJC_22	-88.14	M	SY	5	Northern	Pacific
OCWA-23	PATO_01	-105.661	F	AHY	4	Northern	Pacific
OCWA-24	PATO_02	-144.547	M	AHY	2	Northern	Pacific
OCWA-25	PATO_03	-157.997	F	AHY	2	Northern	Pacific
OCWA-26	PATO_04	-128.881	F	AHY	3	Northern	Pacific
OCWA-27	PATO_05	-148.893	F	AHY	2	Northern	Pacific
OCWA-28	PATO_06	-134.341	F	AHY	3	Northern	Pacific
OCWA-29	PATO_07	-132.395	M	AHY	3	Northern	Pacific
OCWA-30	PATO_08	-144.185	F	AHY	2	Northern	Pacific
OCWA-31	PATO_09	-113.812	M	AHY	4	Northern	Pacific
OCWA-32	PATO_10	-131.16	F	AHY	3	Northern	Pacific
OCWA-33	PATO_11	-154.951	M	AHY	2	Northern	Pacific
OCWA-34	PATO_12	-144.643	M	AHY	2	Northern	Pacific
OCWA-35	PATO_13	-87.1902	M	AHY	5	Northern	Pacific
OCWA-36	PICH_01	-151.097	F	AHY	2	Northern	Pacific
OCWA-37	PICH_02	-127.017	M	AHY	3	Northern	Pacific
OCWA-38	PICH_03	-79.0765	M	AHY	5	Northern	Pacific
OCWA-39	PICH_04	-111.228	F	AHY	4	Northern	Pacific
OCWA-40	PICH_05	-63.5076	F	AHY	6	Northern	Pacific
OCWA-41	PICH_06	-132.043	M	AHY	3	Northern	Pacific
OCWA-42	PICH_07	-127.869	M	AHY	3	Northern	Pacific
OCWA-43	PICH_08	-139.633	F	AHY	2	Northern	Pacific
OCWA-44	PICH_09	-136.437	M	AHY	3	Northern	Pacific
OCWA-45	PICH_10	-122.088	M	AHY	3	Northern	Pacific
OCWA-46	PICH_11	-149.382	M	AHY	2	Northern	Pacific

OCWA-47	CABA_01	-107.808	U	AHY	4	Northern	Pacific
OCWA-48	CABA_02	-144.268	F	AHY	2	Northern	Pacific
OCWA-49	CABA_03	-118.641	U	AHY	3	Northern	Pacific
OCWA-50	FLOR_01	-86.2788	NA	NA	5	Southern	Pacific
OCWA-51	FLOR_02	-74.8993	F	SY	5	Southern	Pacific
OCWA-52	FLOR_03	-143.621	NA	NA	2	Southern	Pacific
OCWA-53	FLOR_04	-95.4327	NA	NA	5	Southern	Pacific
OCWA-54	FLOR_05	-104.908	NA	NA	4	Southern	Pacific
OCWA-55	FLOR_06	-86.1383	NA	NA	5	Southern	Pacific
OCWA-56	FLOR_07	-82.947	M	U	5	Southern	Pacific
OCWA-57	FLOR_08	-103.04	M	U	4	Southern	Pacific
OCWA-58	FLOR_09	-71.9154	F	SY	5	Southern	Pacific
OCWA-59	FLOR_10	-81.7421	NA	NA	5	Southern	Pacific
OCWA-60	FLOR_11	-154.572	NA	NA	2	Southern	Pacific
OCWA-61	FLOR_12	-140.133	NA	NA	2	Southern	Pacific
OCWA-62	FLOR_13	-110.9	M	SY	4	Southern	Pacific
OCWA-63	FLOR_14	-80.849	M	NA	5	Southern	Pacific
OCWA-64	FLOR_15	-67.596	M	SY	5	Southern	Pacific
OCWA-65	FLOR_16	-84.3719	F	SY	5	Southern	Pacific
OCWA-66	FLOR_17	-112.432	M	NA	4	Southern	Pacific
OCWA-67	FLOR_18	-90.8875	NA	NA	5	Southern	Pacific
OCWA-68	FLOR_19	-82.0902	NA	NA	5	Southern	Pacific
OCWA-69	FLOR_20	-113.245	F	SY	4	Southern	Pacific
OCWA-70	FLOR_21	-83.0732	NA	NA	5	Southern	Pacific
OCWA-71	FLOR_22	-71.2417	M	U	5	Southern	Pacific
OCWA-72	FLOR_23	-91.1147	M	U	5	Southern	Pacific
OCWA-73	FLOR_24	-99.7262	M	U	4	Southern	Pacific

OCWA-74	FLOR_25	-144.434	F	SY	2	Southern	Pacific
OCWA-75	FLOR_26	-80.3275	F	NA	5	Southern	Pacific
OCWA-76	FLOR_27	-81.5889	F	SY	5	Southern	Pacific
OCWA-77	FLOR_28	-99.4242	F	SY	4	Southern	Pacific
OCWA-78	FLOR_29	-90.6822	NA	NA	5	Southern	Pacific
OCWA-79	ARCO_17	-115.348	M	AHY	4	Southern	Gulf
OCWA-80	ARCO_18	-81.7947	F	AHY	5	Southern	Gulf
OCWA-81	ARCO_19	-106.173	M	AHY	4	Southern	Gulf
OCWA-82	ARCO_20	-121.785	M	AHY	3	Southern	Gulf
OCWA-83	ARCO_21	-107.699	F	AHY	4	Southern	Gulf
OCWA-84	ARCO_22	-94.31	M	AHY	5	Southern	Gulf
OCWA-85	ARCO_23	-113.955	U	AHY	4	Southern	Gulf
OCWA-86	ARCO_24	-141.421	M	AHY	2	Southern	Gulf
OCWA-87	ARCO_25	-110.55	M	AHY	4	Southern	Gulf
OCWA-88	ARCO_26	-108.15	F	AHY	4	Southern	Gulf
OCWA-89	ARCO_27	-102.852	U	AHY	4	Southern	Gulf
OCWA-90	ARCO_28	-109.055	F	AHY	4	Southern	Gulf
OCWA-91	ARCO_29	-134.155	M	AHY	3	Southern	Gulf
OCWA-92	ARCO_30	-134.403	U	AHY	3	Southern	Gulf
OCWA-93	ARCO_31	-122.081	U	AHY	3	Southern	Gulf
OCWA-94	ARCO_32	-89.8978	U	AHY	5	Southern	Gulf
OCWA-95	ARCO_01	-106.727	U	U	4	Southern	Gulf
OCWA-96	ARCO_02	-105.717	M	U	4	Southern	Gulf
OCWA-97	ARCO_03	-131.061	F	NA	3	Southern	Gulf
OCWA-98	ARCO_04	-109.707	M	U	4	Southern	Gulf
OCWA-99	ARCO_05	-101.341	M	U	4	Southern	Gulf

OCWA-100	ARCO_06	-110.01	F	U	4	Southern	Gulf
OCWA-101	ARCO_07	-103.561	F	SY	4	Southern	Gulf
OCWA-102	ARCO_08	-109.654	U	AHY	4	Southern	Gulf
OCWA-103	ARCO_09	-101.825	U	AHY	4	Southern	Gulf
OCWA-104	ARCO_10	-138.309	U	AHY	2	Southern	Gulf
OCWA-105	ARCO_11	-116.324	U	AHY	4	Southern	Gulf
OCWA-106	ARCO_12	-121.205	U	AHY	3	Southern	Gulf
OCWA-107	ARCO_13	-83.8083	U	HY	5	Southern	Gulf
OCWA-108	ARCO_14	-93.5225	U	HY	5	Southern	Gulf
OCWA-109	ARCO_15	-99.3931	U	U	4	Southern	Gulf
OCWA-110	ARCO_16	-66.5176	U	AHY	5	Southern	Gulf
OCWA-111	ACPF_09	-112.094	NA	NA	4	Southern	Gulf
OCWA-112	ACPF_10	-84.0441	NA	NA	5	Southern	Gulf
OCWA-113	ACPF_11	-73.8161	NA	NA	5	Southern	Gulf
OCWA-114	ACPF_12	-133.57	NA	NA	3	Southern	Gulf
OCWA-115	ACPF_13	-86.3306	NA	NA	5	Southern	Gulf
OCWA-116	ACPF_14	-81.1668	NA	NA	5	Southern	Gulf

OCWA-117	ACPF_15	-99.843	NA	NA	4	Southern	Gulf
OCWA-118	ROCA_01	-154.654	M	AHY	2	Southern	Gulf
OCWA-119	ROCA_02	-100.881	F	SY	4	Southern	Gulf
OCWA-120	ROCA_03	-88.5267	F	AHY	5	Southern	Gulf
OCWA-121	ROCA_04	-94.5092	F	AHY	5	Southern	Gulf
OCWA-122	ROCA_05	-113.723	F	AHY	4	Southern	Gulf
OCWA-123	ROCA_06	-100.221	F	AHY	4	Southern	Gulf
OCWA-124	ROCA_07	-91.7209	F	AHY	5	Southern	Gulf
OCWA-125	ROCA_08	-105.848	F	AHY	4	Southern	Gulf
OCWA-126	ROCA_09	-105.647	F	AHY	4	Southern	Gulf
OCWA-127	ROCA_10	-81.8845	F	AHY	5	Southern	Gulf
OCWA-128	ROCA_11	-126.734	U	AHY	3	Southern	Gulf
OCWA-129	ROCA_12	-89.8603	U	AHY	5	Southern	Gulf
OCWA-130	ROCA_13	-111.795	U	AHY	4	Southern	Gulf
OCWA-131	ROCA_14	-107.624	F	AHY	4	Southern	Gulf
OCWA-132	ROCA_15	-106.075	F	AHY	4	Southern	Gulf
OCWA-133	ROCA_16	-121.413	U	AHY	3	Southern	Gulf

OCWA-134	ROCA_17	-86.9393	F	AHY	5	Southern	Gulf
OCWA-135	ROCA_18	-104.683	F	AHY	4	Southern	Gulf
OCWA-136	ROCA_19	-90.0287	F	AHY	5	Southern	Gulf
OCWA-137	ROCA_20	-127.108	F	AHY	3	Southern	Gulf
OCWA-138	ROCA_21	-112.516	F	AHY	4	Southern	Gulf
OCWA-139	ROCA_22	-70.6333	U	SY	5	Southern	Gulf
OCWA-140	ROCA_23	-90.627	U	SY	5	Southern	Gulf
OCWA-141	ROCA_24	-94.8861	U	AHY	5	Southern	Gulf
OCWA-142	ROCA_25	-91.8357	F	AHY	5	Southern	Gulf
OCWA-143	ROCA_26	-133.961	M	SY	3	Southern	Gulf
OCWA-144	ROCA_27	-120.625	F	SY	3	Southern	Gulf
OCWA-145	ROCA_28	-120.014	F	AHY	3	Southern	Gulf
OCWA-146	ROCA_29	-155.637	U	AHY	2	Southern	Gulf
OCWA-147	ROCA_30	-119.012	U	AHY	3	Southern	Gulf
OCWA-148	ROCA_31	-75.8603	U	AHY	5	Southern	Gulf
OCWA-149	ROCA_32	-81.8141	U	AHY	5	Southern	Gulf
OCWA-150	ROCA_33	-86.7205	U	AHY	5	Southern	Gulf

OCWA-151	ROCA_34	-122.324	F	AHY	3	Southern	Gulf
OCWA-152	ROCA_35	-77.6967	M	AHY	5	Southern	Gulf
OCWA-153	ROCA_36	-125.797	M	AHY	3	Southern	Gulf
OCWA-154	ROCA_37	-120.602	M	AHY	3	Southern	Gulf
OCWA-155	ROCA_38	-130.278	F	AHY	3	Southern	Gulf
OCWA-156	ROCA_39	-130.051	U	AHY	3	Southern	Gulf
OCWA-157	ROCA_40	-122.306	M	AHY	3	Southern	Gulf
OCWA-158	ROCA_41	-123	F	AHY	3	Southern	Gulf
OCWA-159	ROCA_42	-118.182	U	AHY	3	Southern	Gulf
OCWA-160	ROCA_43	-123.345	F	AHY	3	Southern	Gulf
OCWA-161	ROCA_44	-88.6087	F	AHY	5	Southern	Gulf
OCWA-162	ROCA_45	-104.768	F	AHY	4	Southern	Gulf
OCWA-163	ROCA_46	-111.699	M	AHY	4	Southern	Gulf
OCWA-164	ROCA_47	-92.8445	F	AHY	5	Southern	Gulf
OCWA-165	ROCA_48	-93.0209	F	AHY	5	Southern	Gulf
OCWA-166	ROCA_49	-85.9213	M	HY	5	Southern	Gulf
OCWA-167	ROCA_50	-103.69	U	AHY	4	Southern	Gulf

OCWA-168	ROCA_51	-109.805	F	AHY	4	Southern	Gulf
OCWA-169	ROCA_52	-98.6146	F	AHY	4	Southern	Gulf
OCWA-170	ROCA_53	-81.0921	F	AHY	5	Southern	Gulf
OCWA-171	ROCA_54	-106.333	F	HY	4	Southern	Gulf
OCWA-172	ROCA_55	-120.983	M	AHY	3	Southern	Gulf
OCWA-173	ROCA_56	-113.172	M	AHY	4	Southern	Gulf
OCWA-174	ACPF_01	-86.4418	NA	NA	5	Southern	Gulf
OCWA-175	ACPF_02	-97.0139	NA	NA	5	Southern	Gulf
OCWA-176	ACPF_03	-105.493	NA	NA	4	Southern	Gulf
OCWA-177	ACPF_04	-68.6694	NA	NA	5	Southern	Gulf
OCWA-178	ACPF_05	-57.8915	NA	NA	6	Southern	Gulf
OCWA-179	ACPF_06	-125.313	NA	NA	3	Southern	Gulf
OCWA-180	ACPF_07	-132.683	NA	NA	3	Southern	Gulf
OCWA-181	ACPF_08	-88.8898	NA	NA	5	Southern	Gulf
OCWA-182	TAMQ_01	-173.472	U	SY	1	Northern	Gulf
OCWA-183	TAMQ_02	-167.982	M	SY	1	Northern	Gulf
OCWA-184	TAMQ_03	-171.234	F	SY	1	Northern	Gulf

OCWA-185	TAMQ_04	-165.321	F	SY	1	Northern	Gulf
OCWA-186	TAMQ_05	-165.382	M	SY	1	Northern	Gulf
OCWA-187	TAMQ_06	-130.254	F	U	3	Northern	Gulf
OCWA-188	TAMQ_07	-168.093	M	NA	1	Northern	Gulf
OCWA-189	TAMQ_08	-181.671	F	SY	1	Northern	Gulf