**Online Resource 1**

# Irrigated agriculture influences selenium levels in an endangered marsh bird

Environmental Monitoring and Assessment

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**Supplementary tables, figures, and raw data related to Yuma Ridgway's rail blood, breast feathers, and head feathers**

**Table 1a** Factors that explain variation in selenium concentrations of Yuma Ridgway's rail blood collected from the Salton Sea, California, USA (2020–2021). Phase 1 includes all models with $\Delta AIC_C \leq 2$, the null model, and the global model (sex*mass + age*mass + (1|year)). Phase 2 includes all models with $\Delta AIC_C \leq 2$, the informed null (top model from phase 1), and the global model (sex + age + water source + velocity*marsh size + (1|year)). $\Delta AIC_C$ = the difference in Akaike Information Criterion for small sample sizes from the best fitting model; $w_i$ = Akaike weight of the model. Potential explanatory variables included: age (juveniles vs adult); water source (spring-fed, river-fed, or ag-fed); velocity (two-week rolling average of the inflow velocity at the time of rail capture); marsh size (total hectares of continuous cattail marsh)

| **Phase 1** | | |
|---|---|---|
| **Model** | **$\Delta AIC_C$** | **$w_i$** |
| sex + age | 0.00 | 0.28 |
| age | 0.09 | 0.27 |
| sex | 0.39 | 0.23 |
| null | 0.51 | 0.22 |
| global | 19.52 | 0.00 |
| **Phase 2** | | |
| sex + age + water source + velocity | 0.00 | 0.97 |
| global | 14.45 | 0.00 |
| informed null | 29.35 | 0.00 |

**Table 1b** Parameter estimates (Beta), standard errors (SE), and 95% confidence intervals for all predictor variables included in the top model (phase 2) to explain variation in selenium concentration of Yuma Ridgway's rail blood collected from the Salton Sea, California, USA (2020–2021). Age (adult [reference category] or juvenile); sex (female [reference category] or male); water source (spring-fed, river-fed, or ag-fed [reference category]); velocity (two-week rolling average of the inflow velocity at the time of rail capture)

| **Parameter** | **Beta** | **SE** | **Lower 95% CI** | **Upper 95% CI** |
|---|---|---|---|---|
| intercept | 14.11 | 1.13 | 11.94 | 16.28 |
| sex | 0.73 | 0.91 | -1.03 | 2.49 |
| age | -1.42 | 1.22 | -3.77 | 0.94 |
| water source: river-fed | -5.15 | 1.02 | -7.11 | -3.20 |
| water source: spring-fed | -6.97 | 2.00 | -10.83 | -3.12 |
| velocity | -9.32 | 4.38 | -17.75 | -0.90 |

**Table 2a** Factors that explain variation in selenium concentration of Yuma Ridgway's rail breast feathers collected from the Salton Sea, California, USA (2020–2021). Phase 1 includes all models with $\Delta AIC_C \leq 2$, the null model, and the global model (sex*mass + age*mass + (1|year)). Phase 2 includes all models with $\Delta AIC_C \leq 2$, the informed null (top model from phase 1), and the global model (age + water source + velocity*marsh size + (1|year)). $\Delta AIC_C$ = the difference in Akaike Information Criterion for small sample sizes from the best fitting model; $w_i$ = Akaike weight of the model. Potential explanatory variables include: age (juvenile vs adult); water source (spring-fed, river-fed, or ag-fed); velocity (two-week rolling average of the inflow velocity at the time of rail capture); marsh size (total hectares of continuous cattail marsh)

| **Phase 1** | | |
|---|---|---|
| **Model** | **$\Delta AIC_C$** | **$w_i$** |
| age | 0.00 | 0.55 |
| sex + age | 0.71 | 0.39 |
| null | 10.44 | 0.00 |
| global | 13.91 | 0.00 |
| **Phase 2** | | |
| age + water source + velocity | 0.00 | 0.42 |
| age + water source + marsh size | 0.49 | 0.33 |
| age + water source | 1.69 | 0.18 |
| global | 3.89 | 0.06 |
| informed null | 14.15 | 0.00 |

**Table 2b** Parameter estimates (Beta), standard errors (SE), and 95% confidence intervals for all predictor variables included in the top model (phase 2) to explain variation in selenium concentration of Yuma Ridgway's rail breast feathers collected from the Salton Sea, California, USA (2020–2021). Age (adult [reference category] or juvenile); water source (spring-fed, river-fed, or ag-fed [reference category]); velocity (two-week rolling average of the inflow velocity at the time of rail capture)

| **Parameter** | **Beta** | **SE** | **Lower 95% CI** | **Upper 95% CI** |
|---|---|---|---|---|
| intercept | 6.44 | 1.58 | 2.78 | 10.10 |
| age | 2.76 | 0.82 | 1.11 | 4.33 |
| water source: river-fed | -1.85 | 0.61 | -3.03 | -0.65 |
| water source: spring-fed | -3.59 | 1.32 | -6.10 | -0.95 |
| velocity | -0.99 | 2.72 | -6.15 | 4.42 |

**Table 3a** Factors that explain variation in selenium concentration of Yuma Ridgway's rail head feathers collected from the Salton Sea, California, USA (2021). Phase 1 includes all models with $\Delta AIC_C \leq 2$, the null model, and the global model (sex*mass + age*mass). Phase 2 includes all models with $\Delta AIC_C \leq 2$, the informed null (top model from phase 1), and the global model (water source + velocity*marsh size). $\Delta AIC_C$ = the difference in Akaike Information Criterion for small sample sizes from the best fitting model; $w_i$ = Akaike weight of the model. Potential explanatory variables include: age (juvenile vs adult); water source (spring-fed, river-fed, or ag-fed); velocity (two-week rolling average of the inflow velocity at the time of rail capture); marsh size (total hectares of continuous cattail marsh)

| Phase 1 | | |
|---|---|---|
| **Model** | **$\Delta AIC_C$** | **$w_i$** |
| null | 0.00 | 0.78 |
| global | 2.58 | 0.22 |
| **Phase 2** | | |
| water source + marsh size | 0.00 | 0.76 |
| global | 2.36 | 0.23 |
| null | 25.04 | 0.00 |

**Table 3b** Parameter estimates (Beta), standard errors (SE), and 95% confidence intervals for all predictor variables included in the top model (phase 2) to explain variation in selenium concentration of Yuma Ridgway's rail head feathers collected from the Salton Sea, California, USA (2021). water source (spring-fed, river-fed, or ag-fed [reference category]); velocity (two-week rolling average of the inflow velocity at the time of rail capture); marsh size (total hectares of continuous cattail marsh)

| Parameter | Beta | SE | Lower 95% CI | Upper 95% CI |
|---|---|---|---|---|
| intercept | 2.93 | 0.15 | 2.63 | 3.23 |
| water source: river-fed | -0.86 | 0.18 | -1.22 | -0.51 |
| water source: spring-fed | -1.50 | 0.28 | -2.06 | -0.93 |
| marsh size | -0.001 | 0.0003 | -0.001 | -0.0004 |

**Table 4** All selenium (Se; ppm dw) and biological data of Yuma Ridgway's rails sampled at the Salton Sea, California, USA (2020–2021). Rail ID plus a number (e.g., "_1") denotes capture and recapture events; BF = breast feathers; HF = head feathers; Inflow velocity = two-week rolling average of the marsh inflow velocity at the time of rail capture

| Year | Rail ID | Blood Se | BF Se | HF Se | Sex | Age | Mass (g) | Water Source | Inflow Velocity ($m^3/s$) | Marsh Size (ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | R1 | 9.91 | 6.62 | - | F | A | 242 | Ag | 0.034 | 48 |
| 2020 | R2 | - | 1.70 | - | F | A | 280 | Ag | 0.199 | 137 |
| 2020 | R3 | - | 4.97 | - | F | A | 280 | Ag | 0.000 | 137 |
| 2020 | R4 | 21.90 | 1.23 | - | F | A | 200 | Ag | 0.000 | 137 |
| 2020 | R5 | 11.90 | 2.83 | - | F | A | 290 | Ag | 0.000 | 137 |
| 2020 | R6 | 16.10 | 4.64 | - | F | A | 260 | Ag | 0.000 | 137 |
| 2020 | R7 | 18.20 | 4.28 | - | F | A | 245 | Ag | 0.242 | 137 |
| 2020 | R8 | - | 2.87 | - | M | A | 263 | Ag | 0.044 | 48 |
| 2020 | R9 | 14.00 | 6.52 | - | M | A | 334 | Ag | 0.039 | 48 |
| 2020 | R10 | 9.42 | 5.09 | - | M | A | 283 | Ag | 0.035 | 48 |
| 2020 | R11 | 13.60 | 7.25 | - | M | A | 298 | Ag | 0.037 | 48 |
| 2020 | R12 | 27.20 | 3.61 | - | M | A | 280 | Ag | 0.168 | 137 |
| 2020 | R13 | 17.80 | 2.97 | - | M | A | 300 | Ag | 0.175 | 137 |
| 2020 | R14 | 23.60 | 3.93 | - | M | A | 260 | Ag | 0.236 | 137 |
| 2020 | R15 | 16.10 | 5.28 | - | M | A | 290 | Ag | 0.236 | 137 |
| 2020 | R16 | 8.29 | 4.10 | - | M | A | 270 | Ag | 0.000 | 137 |
| 2020 | R17 | 11.70 | 6.63 | - | F | J | 228 | Ag | 0.034 | 48 |
| 2020 | R18 | 12.10 | 7.07 | - | F | J | 230 | Ag | 0.043 | 48 |
| 2020 | R19 | 17.20 | 4.45 | - | M | J | 280 | Ag | 0.198 | 137 |
| 2020 | R20 | 11.20 | 10.4 | - | M | J | 150 | Ag | 0.236 | 137 |
| 2020 | R21 | 13.00 | 5.06 | - | M | J | 240 | Ag | 0.242 | 137 |
| 2020 | R22 | 7.83 | 6.81 | - | M | J | 245 | Ag | 0.043 | 48 |
| 2021 | R23 | 6.67 | 3.41 | 6.14 | F | A | 226 | Ag | 0.141 | 856 |
| 2021 | R24 | 8.00 | - | - | F | A | 234 | Ag | 0.284 | 856 |
| 2021 | R25_1 | - | 3.25 | 4.65 | F | A | 222 | Ag | - | 856 |
| 2021 | R25_2 | 7.44 | 2.36 | 4.35 | F | A | 267 | Ag | - | 856 |
| 2021 | R26 | 12.60 | 10.90 | - | F | A | 266 | Ag | 0.008 | 12 |
| 2021 | R27 | 7.81 | 12.20 | 22.90 | F | A | 264 | Ag | - | 6 |
| 2021 | R28 | 11.20 | 10.80 | 19.00 | F | A | 234 | Ag | 0.388 | 137 |
| 2021 | R29 | 13.20 | 7.51 | 15.00 | F | A | 292 | Ag | 0.055 | 48 |
| 2021 | R30 | 5.01 | 5.85 | 7.95 | F | A | 232 | Ag | 0.284 | 856 |
| 2021 | R31 | 10.40 | 15.00 | 29.50 | F | A | 334 | Ag | 0.392 | 137 |
| 2021 | R32 | 6.40 | 3.78 | 5.06 | F | A | 238 | Ag | 0.284 | 856 |
| 2021 | R33 | 21.60 | 14.80 | 42.00 | F | A | 242 | Ag | 0.063 | 856 |
| 2021 | R34 | 13.80 | 4.85 | 7.20 | F | A | 243 | Ag | 0.309 | 856 |
| 2021 | R35 | - | 1.46 | 2.57 | F | A | 201 | Ag | - | 856 |
| 2021 | R36 | 9.78 | 6.63 | 10.90 | F | A | 226 | Ag | 0.373 | 137 |
| 2021 | R37 | 6.94 | 1.72 | 2.50 | F | A | 241 | Ag | 0.273 | 856 |

| Year | Rail ID | Blood Se | BF Se | HF Se | Sex | Age | Mass (g) | Water Source | Inflow Velocity ($m^3/s$) | Marsh Size (ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2021 | R38 | 5.65 | 5.25 | 2.15 | F | A | 245 | Spring | - | 66 |
| 2021 | R39 | 6.59 | 6.66 | 5.40 | F | A | 266 | Spring | - | 66 |
| 2021 | R40 | 18.00 | 8.47 | 38.00 | F | A | 231 | Spring | - | 66 |
| 2021 | R41 | 5.05 | 1.37 | 2.00 | F | A | 276 | Spring | - | 30 |
| 2021 | R42 | 5.13 | 2.46 | 2.50 | M | A | 276 | Spring | - | 66 |
| 2021 | R43 | 5.01 | 1.57 | 1.84 | M | A | 302 | Spring | - | 30 |
| 2021 | R44 | 5.30 | - | - | M | J | - | Spring | - | 66 |
| 2020 | R45 | 5.61 | 1.59 | - | F | A | 211 | River | 0.028 | 11 |
| 2020 | R46 | 4.11 | 1.70 | - | F | A | 214 | River | 0.028 | 11 |
| 2020 | R47 | 7.36 | 6.02 | - | F | A | 243 | River | 0.087 | 42 |
| 2020 | R48 | 5.56 | 2.12 | - | F | A | 249 | River | 0.085 | 42 |
| 2020 | R49 | 2.49 | 1.10 | - | F | A | 221 | River | 0.084 | 42 |
| 2020 | R50 | 9.52 | 2.47 | - | F | A | 240 | River | 0.084 | 42 |
| 2020 | R51 | 24.80 | 8.18 | - | M | A | 268 | River | 0.028 | 11 |
| 2020 | R52 | 8.15 | 2.88 | - | M | A | 289 | River | 0.028 | 11 |
| 2020 | R53 | 11.30 | 8.07 | - | M | A | 284 | River | 0.024 | 4 |
| 2020 | R54 | 5.90 | 3.84 | - | M | A | 290 | River | 0.028 | 11 |
| 2020 | R55 | 7.20 | 4.76 | - | M | A | 279 | River | 0.087 | 42 |
| 2020 | R56 | 6.96 | 5.19 | - | M | A | 279 | River | 0.085 | 42 |
| 2020 | R57 | 2.30 | 1.32 | - | M | A | 253 | River | 0.084 | 42 |
| 2020 | R58 | 9.52 | 4.52 | - | M | A | 278 | River | 0.084 | 42 |
| 2020 | R59 | 4.68 | 1.94 | - | M | A | 281 | River | 0.084 | 42 |
| 2020 | R60 | 7.80 | 3.64 | - | F | J | 225 | River | 0.085 | 42 |
| 2020 | R61 | 9.29 | 8.69 | - | F | J | 208 | River | 0.084 | 42 |
| 2020 | R62 | 7.96 | 4.27 | - | M | J | 325 | River | 0.085 | 42 |
| 2020 | R63 | 8.57 | 9.85 | - | M | J | 269 | River | 0.085 | 42 |
| 2020 | R64_1 | 1.02 | - | - | M | J | 192 | River | 0.084 | 42 |
| 2020 | R65_1 | 7.28 | 6.81 | - | M | J | 303 | River | 0.084 | 42 |
| 2021 | R66 | 6.16 | 7.41 | 13.50 | F | A | 303 | River | 0.062 | 42 |
| 2021 | R67 | 6.36 | 6.57 | 8.84 | F | A | 295 | River | 0.038 | 4 |
| 2021 | R68 | 6.47 | 2.74 | 3.40 | F | A | 254 | River | 0.039 | 11 |
| 2021 | R69 | 27.80 | 5.45 | 11.10 | F | A | 205 | River | 0.056 | 42 |
| 2021 | R70 | 8.43 | 5.59 | 5.20 | F | A | 275 | River | 0.056 | 67 |
| 2021 | R71 | 13.10 | 12.80 | 14.70 | F | A | 236 | River | - | 67 |
| 2021 | R72 | 8.29 | 2.84 | 4.12 | F | A | 329 | River | 0.056 | 191 |
| 2021 | R73 | 10.10 | 2.96 | 3.34 | F | A | 217 | River | 0.028 | 67 |
| 2021 | R74 | 5.00 | 5.21 | 5.71 | F | A | 237 | River | 0.169 | 191 |
| 2021 | R65_2 | 10.10 | 3.96 | 3.91 | M | A | 307 | River | 0.062 | 42 |
| 2021 | R75 | 10.30 | 4.65 | 9.64 | M | A | 308 | River | 0.062 | 42 |
| 2021 | R76 | 5.66 | 13.70 | 22.00 | M | A | 309 | River | 0.062 | 42 |
| 2021 | R77 | 7.63 | 5.37 | 5.66 | M | A | 310 | River | 0.038 | 4 |

| Year | Rail ID | Blood Se | BF Se | HF Se | Sex | Age | Mass (g) | Water Source | Inflow Velocity ($m^3/s$) | Marsh Size (ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2021 | R78 | 12.40 | 9.86 | 25.00 | M | A | 333 | River | 0.035 | 11 |
| 2021 | R79 | 7.25 | 9.54 | 16.60 | M | A | 299 | River | 0.039 | 11 |
| 2021 | R80 | 10.50 | 5.91 | 9.06 | M | A | 346 | River | 0.048 | 42 |
| 2021 | R81 | 12.50 | 7.63 | 12.70 | M | A | 302 | River | 0.056 | 42 |
| 2021 | R82 | 13.30 | 4.17 | 6.19 | M | A | 252 | River | 0.056 | 42 |
| 2021 | R83 | 14.90 | 2.94 | 3.18 | M | A | 281 | River | 0.056 | 42 |
| 2021 | R84 | 9.31 | 2.56 | 4.17 | M | A | 266 | River | 0.049 | 42 |
| 2021 | R85 | 7.68 | 8.18 | 17.30 | M | A | 275 | River | 0.056 | 67 |
| 2021 | R86 | 7.80 | 6.50 | 18.90 | M | A | 324 | River | 0.056 | 67 |
| 2021 | R87 | 14.40 | 14.60 | 27.00 | M | A | 311 | River | - | 67 |
| 2021 | R88 | 9.63 | 4.62 | 8.10 | M | A | 271 | River | 0.169 | 191 |
| 2021 | R89 | 8.04 | 4.40 | 7.50 | M | A | 300 | River | 0.028 | 67 |
| 2021 | R90 | 11.90 | 3.09 | 4.38 | M | A | 298 | River | 0.056 | 191 |
| 2021 | R91 | 8.51 | 9.16 | 9.31 | M | A | 310 | River | 0.056 | 67 |
| 2021 | R92 | 5.49 | 3.06 | 4.05 | M | A | 295 | River | 0.169 | 191 |
| 2021 | R93 | 12.10 | 5.55 | 11.10 | M | A | 276 | River | 0.040 | 42 |
| 2021 | R94 | 5.40 | 4.30 | 4.11 | M | A | 303 | River | 0.040 | 11 |
| 2021 | R95 | 7.67 | 1.99 | 3.71 | M | A | 274 | River | 0.049 | 11 |
| 2021 | R64_2 | 18.70 | 8.23 | 13.00 | M | A | 290 | Ag | 0.063 | 856 |
| 2021 | R96 | 11.80 | - | 10.90 | M | A | 298 | Ag | 0.284 | 856 |
| 2021 | R97 | 10.20 | 10.50 | 20.80 | M | A | 300 | Ag | 0.008 | 12 |
| 2021 | R98 | 9.15 | 11.40 | 16.60 | M | A | 316 | Ag | 0.070 | 48 |
| 2021 | R99 | 9.33 | 11.30 | 15.30 | M | A | 263 | Ag | 0.386 | 137 |
| 2021 | R100 | 9.82 | 10.80 | 16.30 | M | A | 261 | Ag | 0.388 | 137 |
| 2021 | R101 | 12.10 | 11.10 | 25.00 | M | A | 300 | Ag | 0.055 | 48 |
| 2021 | R102 | 9.70 | 5.91 | 10.40 | M | A | 249 | Ag | 0.284 | 856 |
| 2021 | R103 | 8.39 | 5.78 | 9.30 | M | A | 296 | Ag | 0.284 | 856 |
| 2021 | R104_1 | 9.53 | 5.80 | 7.98 | M | A | 277 | Ag | 0.284 | 856 |
| 2021 | R104_2 | 11.80 | 5.62 | 8.23 | M | A | 287 | Ag | 0.309 | 856 |
| 2021 | R105 | 14.40 | 10.70 | 19.70 | M | A | 313 | Ag | 0.065 | 48 |
| 2021 | R106 | 14.20 | 9.37 | 15.10 | M | A | 301 | Ag | 0.392 | 137 |
| 2021 | R107 | 10.40 | 10.80 | 17.60 | M | A | 274 | Ag | 0.392 | 137 |
| 2021 | R108 | 9.03 | 6.30 | 10.10 | M | A | 237 | Ag | 0.315 | 856 |
| 2021 | R109 | 8.19 | 5.27 | 6.95 | M | A | 318 | Ag | 0.094 | 856 |
| 2021 | R110 | 5.03 | 3.09 | 3.79 | M | A | 251 | Ag | - | 856 |
| 2021 | R111 | 23.00 | 8.65 | 23.10 | M | A | 321 | Ag | 0.006 | 12 |
| 2021 | R112 | 13.30 | 5.27 | 9.95 | M | A | 291 | Ag | 0.039 | 48 |
| 2021 | R113 | 18.00 | 11.50 | 21.20 | M | A | 293 | Ag | 0.325 | 137 |
| 2021 | R114 | 16.80 | 7.28 | 15.40 | M | A | 296 | Ag | 0.023 | 48 |
| 2021 | R115 | 10.40 | 5.98 | 9.04 | M | A | 283 | Ag | 0.008 | 39 |
| 2021 | R116 | 18.60 | 15.30 | 20.70 | F | J | 178 | Ag | 0.004 | 12 |

| Year | Rail ID | Blood Se | BF Se | HF Se | Sex | Age | Mass (g) | Water Source | Inflow Velocity ($m^3/s$) | Marsh Size (ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2021 | R117 | 8.02 | 12.70 | 24.70 | F | J | 204 | Ag | 0.004 | 12 |
| 2021 | R118 | 9.64 | 3.77 | 8.92 | M | J | 272 | Ag | 0.243 | 856 |
| 2021 | R119 | 12.40 | 11.60 | 16.30 | M | J | 260 | Ag | 0.266 | 137 |

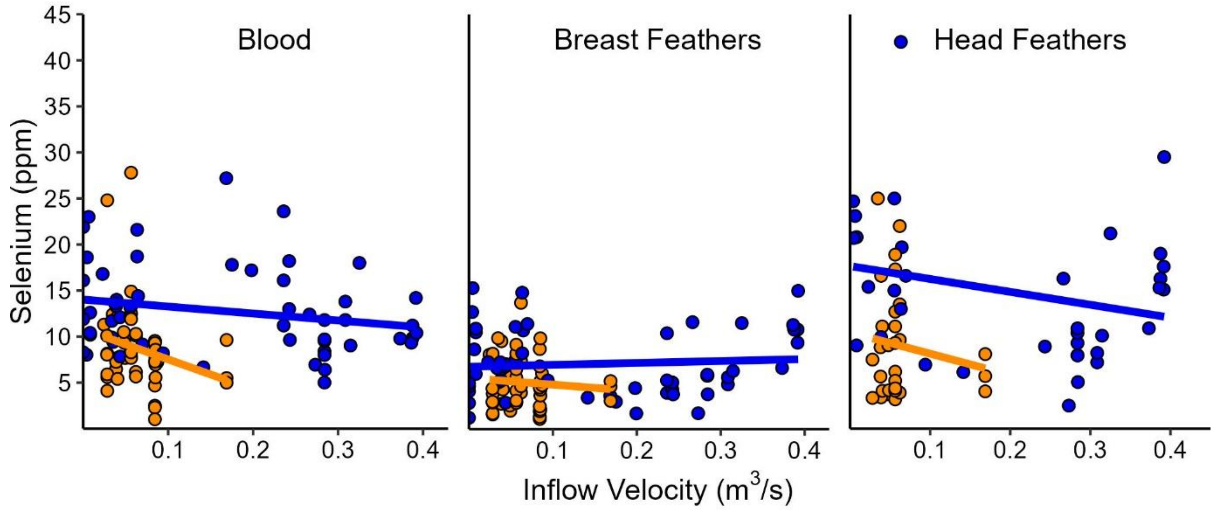


**Fig. 1** Relationship of Yuma Ridgway's rail blood, breast feather, and head feather (2021 only) selenium concentration (ppm dw) to the inflow velocity (two-week rolling average at rail capture date) in river-fed (orange) and ag-fed (blue) marshes at the Salton Sea, California, USA (2020–2021)