Supplementary Online Material

Appendix 1

*Model selection process and results for single-species occupancy models.—* We adopted a sequential approach to identify factors influencing trout habitat use and detection probabilities. First, using a global habitat use structure, ψ(time + DO + temp + veg + depth + size \* veg + size \* depth), we determined the most parsimonious structure for detection probability, *p*, or the frequency of use by trout. Given the small plot size and clarity of water, the probability of a seeing a trout given that it was in the plot during a survey should be close to one, thus detection probability likely reflects the “frequency of use” or the probability that a trout would use a plot during a 5-minute survey, given that the plot was used by trout at any point during the 30-45 minute season. We considered four structures where detection probability varied by trout size class, vegetation density, both size class and vegetation density (additive structure), or was constant across all plots and surveys. Retaining the best supported detection structure using information-theoretic model selection (Burnham and Anderson, 2002), we explored covariates hypothesized to influence trout habitat use (ψ). Specifically, we fit all possible models that considered univariate structures for all uncorrelated covariates, additive effects of size and habitat covariates, and size\*depth and size\*vegetation density interactions (Table A1.1). There was a high degree of correlation between the covariates of water depth, strata, and connectivity (Pearson’s correlation coefficients ≥ 0.70). Accordingly, we excluded strata and connectivity, leaving water depth, vegetation density, temperature, dissolved oxygen and size class as covariates in our analysis of trout habitat use. We used Program MARK (White and Burnham, 1999) to fit all models, setting the effective sample size as the number of sampled plots.

Model selection results suggested that trout detection probability was constant across plots and size classes (*p*(.); AICc weight, *w* = 0.45). Using this constant detection probability structure, we fit 105 occupancy structures to the trout detection data (Table A1.1). Trout habitat use was most influenced by trout size class, depth, and vegetation density. The cumulative weights for each of these covariates was near 1 and less than 0.50 for all other covariates.

Appendix 2

*Model selection process and results for two-species occupancy models.* —We used a sequential approach to model building and selection. We examined factors influencing model parameters in the following order: (1) trout detection probability (frequency of use), (2) tadpole detection probability, (3) trout probability of use, and (4) tadpole probability of use.

Specifically, we fit 16 trout detection probability (frequency of use) structures including all possible additive effects of four covariates (vegetation density, water temperature, cloud presence, and wind presence, Table A2.1).

Using the top model of trout detection probability (frequency of use), we tested all possible additive effects of four covariates (vegetation density, water temperature, cloud presence, and wind presence) on tadpole detection probability (frequency of use; 16 total models). In each of these models we included an additive effect of trout presence and trout detection on tadpole detection. The top model included no covariates (Table A2.2). We then tested a model in which tadpole detection depended on trout presence but not trout detection and one in which tadpole detection did not depend on trout presence (Table A2.3). The top model included an effect of trout presence but not detection.

Using our top models of trout and tadpole detection probability (frequency of use), we tested all possible additive effects of depth and vegetation density on trout use, resulting in four possible models. The top model included an effect of depth but not of vegetation density (Table A2.4).

Using our top model of trout detection probability and habitat use and tadpole detection probability, we tested all possible additive effects of depth, vegetation density, and trout effects on tadpole habitat use, resulting in eight possible models. The top model included an effect of vegetation density (Table 1).

Table A1.1. Model selection results for the analysis of greenback cutthroat trout habitat use around a boreal toad egg deposition area at Spruce Lake in Rocky Mountain National Park. We only present the top models (*w* > 0.01) of the 105 models that were fit to the trout habitat use data. Interactions between trout size classes (large and small) and vegetation density or depth are indicated with a star (\*) and separated within parentheses, additive effects are indicated with a plus sign (+). The best supported detection probability structure, constant detection probability, p(.), was used in all models. The columns present the model notation, Akaike‘s information criterion values adjusted for sample size (AICc), the difference between the model’s AICc value and that of the top model (ΔAICc), AICc weights (*w*), number of parameters (*K*), and the deviance of the model. “Size” indicates an effect of trout size class, “Depth” an effect of plot depth, “Veg” an effect of vegetation density, “Time” an effect of the time of day, “DO” an effect of dissolved oxygen, and “Temp” an effect of water temperature.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model | AICc | ΔAICc | *w* | *K* | Deviance |
| Size+Depth+Veg+Temp | 314.41 | 0.00 | 0.10 | 6 | 301.33 |
| Size+Depth+Veg | 314.44 | 0.03 | 0.09 | 5 | 303.68 |
| (Size\*Veg)+Depth+Temp | 315.10 | 0.69 | 0.07 | 7 | 299.64 |
| (Size\*Depth)+Veg+Temp | 315.13 | 0.72 | 0.07 | 7 | 299.68 |
| Size+Depth+Veg+Time | 315.37 | 0.96 | 0.06 | 6 | 302.29 |
| (Size\*Veg)+Depth | 315.63 | 1.22 | 0.05 | 6 | 302.55 |
| Size+Depth+Veg+DO | 315.75 | 1.34 | 0.05 | 6 | 302.67 |
| (Size\*Depth)+Veg | 315.96 | 1.55 | 0.04 | 6 | 302.88 |
| (Size\*Veg)+(Size\*Depth)+Temp | 316.51 | 2.10 | 0.03 | 8 | 298.61 |
| (Size\*Veg)+Depth+Time | 316.51 | 2.10 | 0.03 | 7 | 301.06 |
| Size+Depth+Veg+Time+Temp | 316.56 | 2.15 | 0.03 | 7 | 301.11 |
| Size+Depth+Veg+DO+Temp | 316.65 | 2.24 | 0.03 | 7 | 301.19 |
| (Size\*Depth)+Veg+Time | 316.75 | 2.34 | 0.03 | 7 | 301.30 |
| (Size\*Depth)+Veg+Time+Temp | 316.91 | 2.50 | 0.03 | 8 | 299.01 |
| (Size\*Veg)+Depth+Time+Temp | 316.98 | 2.57 | 0.03 | 8 | 299.08 |
| (Size\*Veg)+Depth+DO | 317.10 | 2.69 | 0.02 | 7 | 301.64 |
| (Size\*Depth)+Veg+DO | 317.39 | 2.98 | 0.02 | 7 | 301.94 |
| (Size\*Veg)+Depth+DO+Temp | 317.50 | 3.09 | 0.02 | 8 | 299.61 |
| Size+Depth+Veg+Time+DO | 317.51 | 3.09 | 0.02 | 7 | 302.05 |
| (Size\*Depth)+Veg+DO+Temp | 317.52 | 3.11 | 0.02 | 8 | 299.63 |
| (Size\*Veg)+(Size\*Depth) | 317.64 | 3.23 | 0.02 | 7 | 302.19 |
| (Size\*Veg)+(Size\*Depth)+Time+Temp | 318.00 | 3.59 | 0.02 | 9 | 297.60 |

Table A1.1 continued

Table A2.1 Model selection results for trout detection (*p*A= *r*A) in a two species (greenback cutthroat trout and boreal toad tadpole) occupancy study at a boreal toad breeding area in Rocky Mountain National Park. All models had the global structure for tadpole detection (*p*B/*r*B; Veg + Cloud + Wind + Temp + trout use + trout detection), trout use (ψA; depth + Veg), and tadpole use (ψB; depth + Veg + trout use). “.” indicates a model in which trout detection probability was constant across all plots and surveys. The columns present the model notation, Akaike’s information criterion values adjusted for small sample size (AICc), the difference between the model’s AICc value and that of the top model (ΔAICc), AICc weights (*w*), number of parameters (*K*), and the deviance of the model. “Wind” indicates an effect of wind greater than 10 mph, “Cloud” an effect of clouds obscuring the sun, “Depth” an effect of plot depth, “Veg” an effect of vegetation density, and “Temp” an effect of water temperature.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Trout detection model | AICc | ΔAICc | *w* | *K* | Deviance |
| Veg + Temp | 238.11 | 0.00 | 0.73 | 17 | 177.50 |
| Veg + Cloud + Temp | 241.25 | 3.14 | 0.15 | 18 | 174.16 |
| Veg + Cloud | 243.00 | 4.89 | 0.06 | 17 | 182.39 |
| Veg + Wind + Temp | 244.47 | 6.36 | 0.03 | 18 | 177.37 |
| Veg | 246.25 | 8.14 | 0.01 | 16 | 191.58 |
| Veg + Cloud + Wind + Temp | 248.20 | 10.09 | 0.00 | 19 | 174.01 |
| Temp | 248.64 | 10.54 | 0.00 | 16 | 193.98 |
| Veg + Cloud + Wind | 249.10 | 10.99 | 0.00 | 18 | 182.01 |
| Veg +Wind | 250.73 | 12.62 | 0.00 | 17 | 190.12 |
| . | 252.65 | 14.54 | 0.00 | 15 | 203.45 |
| Cloud + Temp | 253.04 | 14.93 | 0.00 | 17 | 192.43 |
| Cloud | 253.12 | 15.01 | 0.00 | 16 | 198.46 |
| Wind + Temp | 254.56 | 16.45 | 0.00 | 17 | 193.95 |
| Wind | 256.56 | 18.45 | 0.00 | 16 | 201.89 |
| Cloud + Wind | 258.32 | 20.21 | 0.00 | 17 | 197.71 |
| Cloud + Wind + Temp | 259.52 | 21.41 | 0.00 | 18 | 192.42 |

Table A2.1 continued

Table A2.2 Model selection results for covariate models of tadpole detection (*p*B/*r*B) in a two species (greenback cutthroat trout and boreal toad tadpole) occupancy study at a boreal toad breeding area in Rocky Mountain National Park. All models had the best supported structure for trout detection (*p*A= *r*A; Veg + Temp) and the global structure for trout use (ψA; Depth + Veg), and tadpole use (ψB; Depth + Veg + trout use). “.” indicates a model in which tadpole detection probability was constant across all plots and surveys. All models included additive effects of trout use and detection on tadpole detection. The columns present the model notation, Akaike’s information criterion values adjusted for sample size (AICc), the difference between the model’s AICc value and that of the top model (ΔAICc), AICc weights (*w*), number of parameters (*K*), and the deviance of the model. “Wind” indicates an effect of wind greater than 10 mph, “Cloud” an effect of clouds obscuring the sun, “Depth” an effect of plot depth, “Veg” an effect of vegetation density, and “Temp” an effect of water temperature.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Tadpole detection model | AICc | ΔAICc | *w* | *K* | Deviance |
| . | 219.99 | 0.00 | 0.74 | 13 | 180.51 |
| Wind | 223.00 | 3.00 | 0.16 | 14 | 178.84 |
| Cloud + Wind | 226.97 | 6.97 | 0.02 | 15 | 177.77 |
| Wind + Temp | 227.67 | 7.68 | 0.02 | 15 | 178.47 |
| Cloud + Temp | 227.72 | 7.73 | 0.02 | 15 | 178.52 |
| Veg + Wind | 227.97 | 7.98 | 0.01 | 15 | 178.77 |
| Veg + Temp | 228.40 | 8.41 | 0.01 | 15 | 179.20 |
| Cloud | 229.26 | 9.27 | 0.01 | 14 | 185.11 |
| Temp | 229.66 | 9.66 | 0.01 | 14 | 185.50 |
| Veg | 230.40 | 10.40 | 0.00 | 14 | 186.24 |
| Cloud + Wind + Temp | 232.31 | 12.32 | 0.00 | 16 | 177.65 |
| Veg + Cloud + Temp | 232.94 | 12.95 | 0.00 | 16 | 178.28 |
| Veg + Temp | 235.28 | 15.28 | 0.00 | 15 | 186.08 |
| Veg + Cloud + Wind + Temp | 238.11 | 18.11 | 0.00 | 17 | 177.50 |
| Veg + Cloud + Wind | 238.54 | 18.54 | 0.00 | 16 | 183.87 |
| Veg + Wind + Temp | 239.63 | 19.64 | 0.00 | 16 | 184.97 |

Table A2.2 continued

Table A2.3 Model selection results for effects of trout use and detection on tadpole detection (frequency of use, *p*B/*r*B) in a two species (greenback cutthroat trout and tadpole) occupancy study at a boreal toad breeding area in Rocky Mountain National Park. All models had the best supported structure for trout detection probability (*p*A= *r*A; Veg + Temp) and the global structure for trout use (ψA; Depth + Veg), and tadpole use (ψB; Depth + Veg + trout use). The columns present the model notation, Akaike’s information criterion values adjusted for sample size (AICc), the difference between the model’s AICc value and that of the top model (ΔAICc), AICc weights (*w*), number of parameters (*K*), and the deviance of the model.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Tadpole detection model | AICc | ΔAICc | *w* | *K* | Deviance |
| Effect of trout use but not trout detection  (*pB≠ rBA=rBa*) | 215.75 | 0.00 | 0.71 | 12 | 180.60 |
| No effect of trout use or detection  *(pB= rBA=rBa)* | 217.53 | 1.78 | 0.29 | 11 | 186.42 |
| Effect of trout use and detection  (*pB≠ rBA≠ rBa*) | 226.4 | 10.65 | 0.00 | 13 | 186.91 |

Table A2.4 Model selection results for trout occupancy (ψA) in a two species (greenback cutthroat trout and tadpole) occupancy study at a boreal toad breeding area in Rocky Mountain National Park. All models had the best supported structure for trout detection (*p*A= *r*A; Veg + Temp), tadpole detection probability (*p*B/*r*B; trout use), and tadpole use (ψB; Depth + Veg +trout use). “.” indicates a model in which trout use was constant across all plots. The columns present the model notation, Akaike’s information criterion values adjusted for sample size (AICc), the difference between the model’s AICc value and that of the top model (ΔAICc), AICc weights (*w*), number of parameters (*K*), and the deviance of the model. “Depth” indicates an effect of plot depth and “Veg” an effect of vegetation density.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Trout habitat use model | AICc | ΔAICc | *w* | *K* | Deviance |
| Depth | 215.60 | 0.00 | 0.52 | 11 | 184.49 |
| Depth + Veg | 215.75 | 0.15 | 0.48 | 12 | 180.60 |
| . | 225.95 | 10.36 | 0.00 | 10 | 198.62 |
| Veg | 230.78 | 15.18 | 0.00 | 11 | 199.67 |