Deer movement and resource selection during Hurricane Irma - Implications for Extreme Climatic Events and Wildlife

H.N. Abernathy, D.A. Crawford, E.P. Garrison[[1]](#footnote-1), R.B. Chandler, M.L. Conner, K.V. Miller, and M.J. Cherry

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Appendix 1.

Table S1. Land cover classification data and reclassification schematic. The data classification scheme presented here is derived from the Florida Natural Area Inventory (FNAI) cooperative land cover, version 3.2 site-level land cover data. Land cover classifications are grouped into a land cover reclassification types used in this study. These cover types were classified using unsupervised classification following the FNAI Classification System. A subset of land cover reclassification types were used in our generalized linear mixed models (GLMMs) with individual animal specific intercept term treated as a random effect.

|  |  |  |
| --- | --- | --- |
| Original Site Land Cover Name | Spectral Class | Land Cover Reclassification Name |
| Rural Open Forested | 18311 | Agriculture |
| Orchards/Groves | 18332 | Agriculture |
| Vineyard and Nurseries | 18334 | Agriculture |
| Other Agriculture | 18335 | Agriculture |
| Row Crops | 183311 | Agriculture |
| Field Crops | 183312 | Agriculture |
| Improved Pasture | 183313 | Agriculture |
| Citrus | 183321 | Agriculture |
| Ornamentals | 183343 | Agriculture |
| Fallow Cropland | 1833151 | Agriculture |
| Mesic Hammock | 1120 | Hardwood Hammock |
| Cabbage Palm | 1125 | Hardwood Hammock |
| Rockland Hammock | 1130 | Hardwood Hammock |
| Mixed Hardwood-Coniferous | 1400 | Hardwood Hammock |
| Successional Hardwood Forest | 1410 | Hardwood Hammock |
| Hydric Hammock | 2232 | Hardwood Hammock |
| Prairie Hydric Hammock | 22322 | Hardwood Hammock |
| Cabbage Palm Hammock | 22323 | Hardwood Hammock |
| Oak-Cabbage Palm Forests | 183111 | Hardwood Hammock |
| Unimproved/Woodland Pasture | 183314 | Hardwood Hammock |
| Cypress/Tupelo(incl Cy/Tu mixed) | 2210 | Hardwood Swamp |
| Cypress | 2211 | Hardwood Swamp |
| Isolated Freshwater Swamp | 2213 | Hardwood Swamp |
| Strand Swamp | 2214 | Hardwood Swamp |
| Other Coniferous Wetlands | 2220 | Hardwood Swamp |
| Other Hardwood Wetlands | 2230 | Hardwood Swamp |
| Mixed Wetland Hardwoods | 2233 | Hardwood Swamp |
| Other Wetland Forested Mixed | 2240 | Hardwood Swamp |
| Cypress/Hardwood Swamps | 2241 | Hardwood Swamp |
| Cypress/Pine/Cabbage Palm | 2242 | Hardwood Swamp |
| Dome Swamp | 22131 | Hardwood Swamp |
| South Florida Bayhead | 22312 | Hardwood Swamp |
| Marshes | 2120 | Marshes |
| Isolated Freshwater Marsh | 2121 | Marshes |
| Glades Marsh | 2125 | Marshes |
| Sawgrass | 2131 | Marshes |
| Floating/Emergent Aquatic Vegetation | 2140 | Marshes |
| Cultural - Palustrine | 2400 | Marshes |
| Depression Marsh | 21211 | Marshes |
| Lacustrine | 3000 | Open Water |
| Natural Lakes and Ponds | 3100 | Open Water |
| Cultural - Lacustrine | 3200 | Open Water |
| Artificial/Farm Pond | 3210 | Open Water |
| Artificial Impoundment/Reservoir | 3220 | Open Water |
| Quarry Pond | 3230 | Open Water |
| Canal | 4210 | Open Water |
| Ditch/Artificial Intermittent Stream | 4220 | Open Water |
| Mesic Flatwoods | 1311 | Pine Forests |
| Scrubby Flatwoods | 1312 | Pine Forests |
| Wet Flatwoods | 2221 | Pine Forests |
| Hydric Pine Flatwoods | 22211 | Pine Forests |
| Hydric Pine Savanna | 22212 | Pine Forests |
| Cabbage Palm Flatwoods | 222112 | Pine Forests |
| Palmetto Prairie | 1340 | Prairie |
| Prairies and Bogs | 2110 | Prairie |
| Wet Prairie | 2111 | Prairie |
| Mixed Scrub-Shrub Wetland | 2112 | Prairie |
| Marl Prairie | 2113 | Prairie |
| Highway Rights of Way | 1812 | Roads |
| Transportation | 1840 | Roads |
| Shrub and Brushland | 1500 | Shrub |
| Rural Open | 1831 | Shrub |
| Vegetative Berm | 1811 | Urban |
| Low Intensity Urban | 1821 | Urban |
| Rural Structures | 1832 | Urban |
| Communication | 1850 | Urban |
| Utilities | 1860 | Urban |
| Extractive | 1870 | Urban |
| Sand & Gravel Pits | 1872 | Urban |
| Oil & Gas Fields | 1874 | Urban |
| Urban Open Land | 18211 | Urban |
| Residential, Low Density | 18212 | Urban |
| Commercial and Services | 18223 | Urban |
| Industrial | 18224 | Urban |
| Urban Open Forested | 182111 | Urban |
| Melaleuca | 7200 | NoData |
| Brazilian Pepper | 7300 | NoData |
| Exotic Wetland Hardwoods | 7400 | NoData |

|  |  |
| --- | --- |
| Model Name | Model Description |
| Null  | ~1 + cluster(Deer Identification Number) + strata(Paired Real and Random GPS Points) |
| Global  | Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods + Hurricane + Sex +Hurricane\*(Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods + Sex) + Sex\*(Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods + Hurricane) + Hurricane\*Sex\*(Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods) + cluster(Deer Identification Number) + strata(Paired Real and Random GPS Points) |
| Model 1  | Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods + Hurricane + Sex + cluster(Deer Identification Number) + strata(Paired Real and Random GPS Points) |
| Model 2 | Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods + Hurricane + cluster(Deer Identification Number) + strata(Paired Real and Random GPS Points) |
| Model 3  | Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods + Sex + cluster(Deer Identification Number) + strata(Paired Real and Random GPS Points) |
| Model 4 | Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods + Hurricane + Sex + Hurricane\*(Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods + Sex) + cluster(Deer Identification Number) + strata(Paired Real and Random GPS Points) |
| Model 5 | Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods + Hurricane + Sex + Sex\*(Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods) + cluster(Deer Identification Number) + strata(Paired Real and Random GPS Points) |
| Model 6 | Shrub + Elevation + Hardwood Hammock + Marsh + Cypress + Prairie + Pine Flatwoods + Hurricane + Sex + Sex\*Hurricane + cluster(Deer Identification Number) + strata(Paired Real and Random GPS Points)  |

**Table S2.** **Competitive model descriptions**. Competitive model descriptions for each conditional logistic regression model used to examine habitat selection of deer in Florida Panther National Wildlife Refuge and Big Cypress National Preserve during Hurricane Irma, September 10, 2017.

**Table S3.** **Percentage of collared deer GPS locations in each land cover type.** Percentage of collared deer GPS locations found in different habitat types in Florida Panther National Wildlife Refuge and Big Cypress National Preserve during the pre-storm wet season, May 1 – Sep 9, 2017, and Hurricane Irma, September 10, 2017.

|  |  |
| --- | --- |
|   | Percentage of Locations  |
| Habitat Type | Pre-Irma | Hurricane Irma |
| Agriculture | 1.25% | 2.14% |
| Hardwood Hammock | 1.64% | 2.50% |
| Hardwood Swamp | 19.35% | 16.79% |
| Marshes | 29.81% | 8.93% |
| Open Water | 0.09% | 0.00% |
| Pine Forests | 24.44% | 52.14% |
| Prairie | 18.93% | 15.71% |
| Roads | 1.07% | 0.36% |
| Shrub | 3.40% | 1.43% |
| Urban | 0.02% | 2.14% |

**Table S4.** **Competitive model AIC table.** Competitive models, the log-likelihood (L), the number of parameters in the model (K), the relative difference in AIC values compared to the top-ranked model (ΔAIC), and the AIC model weights (W) of the model-selection procedure examining habitat selection during the wet season (May 1 - September 9, 2017) and Hurricane Irma (September 10, 2017) in the Florida Panther National Wildlife Refuge and Big Cypress National Preserve. Conditional logit regression model with unique deer identification number as a cluster variable were used to determine habitat selection. Model considered are outlined in Table S5.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Competitive Models | L | K | ΔAIC | W |
| Global | -132757 | 31 | 0.00 | 1.00 |
| Model 5 | -132783 | 16 | 21.69 | 1.00 |
| Model 4 | -132809 | 17 | 74.43 | 1.00 |
| Model 2 | -132824 | 8 | 87.59 | 1.00 |
| Model 1 | -132824 | 9 | 89.59 | 1.00 |
| Model 6 | -132824 | 10 | 91.59 | 1.00 |
| Null | -133062 | 0 | 547.27 | 1.00 |

**Table S5.** **Top model coefficients.** Beta coefficients (β), standard errors (SE), z-values, and p-values from the top conditional logit regression model with unique deer identification number as a cluster variable. The conditional logit regression model examines deer habitat selection during the wet season (May 1 - September 9, 2017) and Hurricane Irma (September 10, 2017) in the Florida Panther National Wildlife Refuge and Big Cypress National Preserve. For all habitat types, negative beta coefficients indicate a positive association with habitat selection and positive beta coefficients indicate avoidance; for elevation, positive beta coefficients indicate a positive association with habitat use and negative beta coefficients indicate avoidance.

|  |  |  |  |
| --- | --- | --- | --- |
| Habitat Type | β (SE) | Z-value | P-value |
| Shrub | -0.31 | -2.06 | 0.04 |
| Elevation | -0.01 | -0.24 | 0.81 |
| Hardwood Hammock | 0.05 | 0.21 | 0.83 |
| Marsh  | -0.24 | -2.16 | 0.03 |
| Cypress | 0.15 | 2.02 | 0.04 |
| Prairie | -0.03 | -0.38 | 0.70 |
| Pine Forests | -0.14 | -1.57 | 0.12 |
| Hurricane | NA | NA | NA |
| Sex(M) | NA | NA | NA |
| Shrub\*Hurricane | 1.39 | 3.57 | 0.00 |
| Elevation\*Hurricane | 0.43 | 2.14 | 0.03 |
| Hardwood Hammock\*Hurricane | -1.44 | -1.58 | 0.11 |
| Marsh\*Hurricane | 0.86 | 2.99 | 0.00 |
| Cypress\*Hurricane | -0.43 | -2.04 | 0.04 |
| Prairie\*Hurricane | 0.06 | 0.35 | 0.73 |
| Pine Forests\*Hurricane | -0.97 | -3.70 | 0.00 |
| Hardwood Hammock\*Sex(m) | NA | NA | NA |
| Shrub\*Sex(m) | 0.47 | 2.65 | 0.01 |
| Elevation\*Sex(m) | -0.01 | -0.33 | 0.74 |
| Hardwood Hammock\*Sex(m) | -0.16 | -0.56 | 0.57 |
| Marsh\*Sex(m) | 0.03 | 0.21 | 0.83 |
| Cypress\*Sex(m) | -0.09 | -0.97 | 0.33 |
| Prairie\*Sex(m) | -0.03 | -0.36 | 0.72 |
| Pine Forests\*Sex(m) | 0.00 | -0.02 | 0.99 |
| Shrub\*Sex(m)\*Hurricane | -2.22 | -2.52 | 0.01 |
| Elevation\*Sex(m)\*Hurricane | -0.31 | -1.02 | 0.31 |
| Hardwood Hammock\*Sex(m)\*Hurricane | 2.71 | 1.19 | 0.23 |
| Marsh\*Sex(m)\*Hurricane | -0.59 | -1.47 | 0.14 |
| Cypress\*Sex(m)\*Hurricane | 0.40 | 0.91 | 0.36 |
| Prairie\*Sex(m)\*Hurricane | -0.15 | -0.37 | 0.71 |
| Pine Forests\*Sex(m)\*Hurricane | 0.92 | 1.24 | 0.21 |

**Table S6. Distances traveled by each deer from the home range boundary during Hurricane Irma.** The straight-line distance from each deer’s 95% utilization distribution (i.e., home range) to GPS locations during Hurricane Irma (September 10, 2017) in Florida Panther National Wildlife Refuge and Big Cypress National Preserve.

|  |  |  |  |
| --- | --- | --- | --- |
| Deer ID | Sex | Maximum Distance (m) | Approximate Age  |
| 236 | f | 0 | 5 |
| 258 | m | 0 | 2 |
| 262 | f | 0 | 5.5 |
| 265 | m | 0 | 2.5 |
| 266 | m | 0 | 3 |
| 274 | f | 0 | 6.5 |
| 277 | f | 0 | 4.5 |
| 278 | f | 0 | 2.5 |
| 302 | f | 0 | 5.5 |
| 307 | f | 0 | 6.5 |
| 322 | m | 0 | 3.5 |
| 400 | m | 0 | 5 |
| 402 | m | 0 | 3 |
| 405 | m | 0 | 5 |
| 406 | m | 0 | 5 |
| 408 | f | 0 | 4 |
| 413 | f | 0 | 3.5 |
| 418 | f | 0 | 2.5 |
| 428 | m | 0 | 2.5 |
| 435 | m | 0 | 3 |
| 437 | f | 0 | 5.5 |
| 440 | f | 0 | 3 |
| 441 | m | 0 | 2.5 |
| 453 | f | 0 | 4 |
| 461 | m | 0 | 1.5 |
| 462 | m | 0 | 3 |
| 463 | f | 0 | 3.5 |
| 465 | f | 0 | 5 |
| 276 | f | 8.61 | 5.5 |
| 444 | f | 9.63 | 5 |
| 305 | f | 12.73 | 4.5 |
| 213 | f | 27.53 | 4 |
| 280 | f | 30.91 | 4.5 |
| 423 | m | 33.07 | 3 |
| 426 | f | 33.78 | 3.5 |
| 211 | f | 34.64 | 5 |
| 300 | f | 50.44 | 4.5 |
| 449 | m | 67.71 | 3 |
| 442 | f | 72.55 | 2 |
| 417 | f | 75.14 | 3 |
| 414 | f | 104.78 | 6 |
| 331 | m | 141.67 | 4.5 |
| 433 | m | 232.52 | 2.5 |
| 244 | f | 241.59 | 5 |
| 457 | f | 256.31 | 3.5 |
| 459 | f | 258.30 | 4 |
| 425 | f | 264.14 | 3.5 |
| 242 | f | 281.81 | 5.5 |
| 234 | f | 324.74 | 3 |
| 466 | m | 339.66 | 1.5 |
| 458 | f | 348.43 | 4 |
| 430 | m | 512.29 | 4.5 |
| 431 | f | 594.61 | 3 |
| 248 | f | 753.57 | 5.5 |
| 239 | f | 775.91 | 4 |
| 460 | f | 857.90 | 5.5 |
| 268 | f | 1088.52 | 5.5 |
| 456 | f | 1670.35 | 4 |
| 240 | f | 1870.69 | 5 |

**Table S7. Competing models for deer leaving its seasonal home range.** Competitive models, the log-likelihood (L), the number of parameters in the model (K), the AIC values (AIC), the relative difference in AIC values compared to the top-ranked model (ΔAIC), and the AIC model weights (W) of the model-selection procedure examining utilization distribution (i.e., seasonal home range) characteristics and if those characteristics determined if an individual deer left its home range during Hurricane Irma (September 10th, 2017) in Florida Panther National Wildlife Refuge and Big Cypress National Preserve. We used generalized linear models (GLMs) to examine the characteristics of deer home ranges which might cause individuals to leave their home range during Irma: maximum elevation (E), the proportion of pine forest (Pf), sex (S), and seasonal home range area (UD).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Competitive models | K | L | AIC | ΔAIC | W |
| UD | 1 | -36.92 | 77.80 | 0.00 | 0.22 |
| Pf + UD | 2 | -35.96 | 77.90 | 0.07 | 0.21 |
| E + Pf + UD | 3 | -35.79 | 79.60 | 1.74 | 0.09 |
| E + UD | 2 | -36.86 | 79.70 | 1.88 | 0.09 |
| S + UD | 2 | -36.92 | 79.80 | 2.00 | 0.08 |
| Pf + S + UD | 3 | -35.92 | 79.80 | 2.00 | 0.08 |
| S | 1 | -38.31 | 80.60 | 2.79 | 0.05 |
| Pf | 2 | -37.62 | 81.20 | 3.40 | 0.04 |
| E + Pf + S + UD | 4 | -35.76 | 81.50 | 3.69 | 0.04 |
| E + S + UD | 3 | -36.85 | 81.70 | 3.87 | 0.03 |
| E + S  | 2 | -38.27 | 82.50 | 4.70 | 0.02 |
| E + Pf + S  | 3 | -37.53 | 83.10 | 5.22 | 0.02 |
| Null | 0 | -40.82 | 83.60 | 5.80 | 0.01 |
| Pf | 1 | -39.97 | 83.90 | 6.09 | 0.01 |
| E | 1 | -40.45 | 84.90 | 7.07 | 0.01 |
| E + Pf | 2 | -39.95 | 85.90 | 8.07 | 0.00 |

**Table S8. Top model coefficients for deer altering movement rates during Hurricane Irma.** Model covariates,Beta coefficients (β), standard errors (SE), t-values, and p-values from a linear mixed model (LMER) with individual animal specific intercept term treated as a random effect quantifying the impact of Hurricane Irma on sex-specific deer movement one week before, the day of, and after Hurricane Irma (September 3 - 9, 10, and 11 - 17, 2017, respectively) in the Florida Panther National Wildlife Refuge and Big Cypress National Preserve.

|  |  |  |  |
| --- | --- | --- | --- |
| Model Covariates  | β (SE) | t-value | P-value |
| Intercept  | 3.06 (+0.08) |  38.15 | <0.001 |
| Day of Storm | 0.31 (+0.10) | 3.12 | 0.002 |
| Sex  | 0.43 (+0.14) | 3.01 | 0.004 |
| Day of Storm\*Sex  | -0.23 (+0.18) |  -1.26 | 0.21 |

1. Elina.Garrison@myfwc.com [↑](#footnote-ref-1)