Supplementary material

**The foraging ecology of invasive black rats (*Rattus rattus*) differs in two nearby islands in a dry tropical archipelago in Brazil**

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**Table S1** Isotopic values of potential food items used as sources in stable isotope mixing models to estimate the diet of black rats (*Rattus rattus*) in the Abrolhos archipelago, Brazil

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Source-type | *n* | Taxonomic ID | Island | *δ*13C (‰) | SD | *δ*15N (‰) | SD |
| Seabirds | 13 | *Sula dactylatra* | Santa Bárbara and Siriba | -18.23 | 0.35 | 9.78 | 0.81 |
| Seabirds | 10 | *Sula leucogaster* | Santa Bárbara and Siriba | -17.29 | 0.32 | 11.01 | 1.99 |
| Seabirds | 10 | *Phaethon aethereus* | Santa Bárbara and Siriba | -17.31 | 0.39 | 10.79 | 1.10 |
| C3 Plant | 18 | *Sida cordifolia* | Santa Bárbara | -27.39 | 1.62 | 18.69 | 1.53 |
| C4 Plant | 17 | *Cyperus* sp. | Santa Bárbara | -13.33 | 0.44 | 17.6 | 2.58 |
| Carnivorous invertebrate | 16 | Theraphosidae | Santa Bárbara and Siriba | -16.62 | 2.15 | 24.29 | 3.47 |
| Herbivorous invertebrate | 18 | Orthoptera | Santa Bárbara | -14.88 | 2.4 | 24.36 | 2.31 |
| C3 Plant | 14 | *Ipomea pes-caprae* | Siriba | -25.57 | 1.13 | 15.98 | 3.09 |
| C4 Plant | 23 | *Cyperus* sp. | Siriba | -12.64 | 0.3 | 17.29 | 2.54 |
| Herbivorous invertebrate | 23 | Orthoptera | Siriba | -13.56 | 0.35 | 22.18 | 1.74 |
| Lizards | 15 | *Tropidurus torquatus* | Siriba | -13.11 | 1.03 | 20.71 | 2.29 |
| Lizards | 14 | *Tropidurus torquatus* | Santa Bárbara | -16.44 | 2.25 | 19.57 | 4.19 |

**Table S2** Candidate sets of trophic discrimination factors (TDF) of carbon (ΔC) and nitrogen (ΔN) stable isotopes tested by the mixing polygon approach (Smith et al. 2013) to compose Bayesian mixing models for the diet of black rats (*Rattus rattus*) in the Abrolhos archipelago, Brazil

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TDF set | Source | Rat tissue | Island | Estimation | Animal model used in experiments | ΔC (‰) | SD | ΔN (‰) | SD | Reference |
| 1 | Seabirds | Liver | Santa Bárbara and Siriba | Regression | *Rattus rattus* | -1.1 | 1 | 1.5 | 1 | Caut et al. 2008 |
| 1 | C3 plants | Liver | Siriba | Regression | *Rattus rattus* | 1.8 | 1 | 0.0 | 1 | Caut et al. 2008 |
| 1 | C4 plants | Liver | Siriba | Regression | *Rattus rattus* | -2.9 | 1 | -0.3 | 1 | Caut et al. 2008 |
| 1 | Spiders | Liver | Santa Bárbara and Siriba | Regression | *Rattus rattus* | -1.4 | 1 | -2.2 | 1 | Caut et al. 2008 |
| 1 | Insects | Liver | Siriba | Regression | *Rattus rattus* | -2.5 | 1 | -1.6 | 1 | Caut et al. 2008 |
|  | Lizards | Liver | Siriba | Regression | *Rattus rattus* | -2.7 | 1 | -1.3 | 1 | Caut et al. 2008 |
| 1 | Seabirds | Muscle | Santa Bárbara and Siriba | Regression | *Rattus rattus* | -2.6 | 1 | 1.3 | 1 | Caut et al. 2008 |
| 1 | C3 plants | Muscle | Siriba | Regression | *Rattus rattus* | -3.6 | 1 | 2.4 | 1 | Caut et al. 2008 |
| 1 | C4 plants | Muscle | Siriba | Regression | *Rattus rattus* | -5.2 | 1 | 2.9 | 1 | Caut et al. 2008 |
| 1 | Spiders | Muscle | Santa Bárbara and Siriba | Regression | *Rattus rattus* | -2.9 | 1 | 7.4 | 1 | Caut et al. 2008 |
| 1 | Insects | Muscle | Siriba | Regression | *Rattus rattus* | -4.5 | 1 | 5.7 | 1 | Caut et al. 2008 |
|  | Lizards | Muscle | Siriba | Regression | *Rattus rattus* | -4.8 | 1 | 4.7 | 1 | Caut et al. 2008 |
| 1 | C3 plants | Liver | Santa Bárbara | Regression | *Rattus rattus* | 2.4 | 1 | -0.7 | 1 | Caut et al. 2008 |
| 1 | C4 plants | Liver | Santa Bárbara | Regression | *Rattus rattus* | -2.6 | 1 | -0.4 | 1 | Caut et al. 2008 |
| 1 | Insects | Liver | Santa Bárbara | Regression | *Rattus rattus* | -2.1 | 1 | -2.2 | 1 | Caut et al. 2008 |
|  | Lizards | Liver | Santa Bárbara | Regression | *Rattus rattus* | -1.5 | 1 | -0.9 | 1 | Caut et al. 2008 |
| 1 | C3 plants | Muscle | Santa Bárbara | Regression | *Rattus rattus* | -4.8 | 1 | 3.6 | 1 | Caut et al. 2008 |
| 1 | C4 plants | Muscle | Santa Bárbara | Regression | *Rattus rattus* | -4.7 | 1 | 3.0 | 1 | Caut et al. 2008 |
| 1 | Insects | Muscle | Santa Bárbara | Regression | *Rattus rattus* | -3.7 | 1 | 7.5 | 1 | Caut et al. 2008 |
|  | Lizards | Muscle | Santa Bárbara | Regression | *Rattus rattus* | -3.0 | 1 | 4.0 | 1 | Caut et al. 2008 |
| 2 | Vegetal sources | Muscle | Santa Bárbara and Siriba | Diet type C | *Rattus rattus* | -0.4 | 1 | 4.6 | 1 | Caut et al. 2008 |
| 2 | Animal sources | Muscle | Santa Bárbara and Siriba | Diet type A | *Rattus rattus* | -1.69 | 1 | 1.39 | 1 | Caut et al. 2008 |
| 2 | Vegetal sources | Liver | Santa Bárbara and Siriba | Diet type C | *Rattus rattus* | 0.64 | 1 | 4.55 | 1 | Caut et al. 2008 |
| 2 | Animal sources | Liver | Santa Bárbara and Siriba | Diet type A | *Rattus rattus* | -1.65 | 1 | 1.12 | 1 | Caut et al. 2008 |
| 3 | All sources | Muscle | Santa Bárbara and Siriba | Experimental diet 2 | *Mus musculus* | -2.10 | 0.5 | 2.00 | 0.5 | Arneson and MacAvoy 2005 |
| 3 | All sources | Liver | Sbar and Siriba | Experimental diet 2 | *Mus musculus* | -2.20 | 0.4 | 3.80 | 0.3 | Arneson and MacAvoy 2005 |

**Table S3** Black rat individuals collected on Santa Bárbara and Siriba islands in the Abrolhos archipelago in 2019 and 2021 and the carbon and nitrogen isotope ratios in their liver and muscle. Individual ID is the same as reported in the main text Fig. 2

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | Liver | | Muscle | |
| Individual ID | Island | Area | Sex | Year | *δ*13C (‰) | *δ*15N (‰) | *δ*13C (‰) | *δ*15N (‰) |
| CO-1 | Santa Bárbara | colony | female | 2021 | -16.4 | 15.4 | -17.6 | 15.0 |
| CO-2 | Santa Bárbara | colony | female | 2021 | -17.5 | 16.2 | -16.7 | 16.8 |
| CO-3 | Santa Bárbara | colony | female | 2021 | -18.1 | 15.2 | -17.6 | 15.9 |
| CO-4 | Santa Bárbara | colony | male | 2021 | -16.1 | 17.1 | -17.0 | 19.0 |
| CO-5 | Santa Bárbara | colony | male | 2021 | -15.9 | 15.6 | -16.7 | 16.9 |
| CO-6 | Santa Bárbara | colony | male | 2021 | -16.3 | 15.6 | -17.1 | 15.6 |
| CO-7 | Santa Bárbara | colony | male | 2021 | -16.5 | 15.1 | -16.5 | 16.4 |
| GR-8 | Santa Bárbara | grassland | female | 2019 | -22.4 | 11.6 | -21.7 | 12.7 |
| GR-9 | Santa Bárbara | grassland | female | 2019 | -13.6 | 19.3 | -15.5 | 19.2 |
| GR-10 | Santa Bárbara | grassland | male | 2019 | -20.2 | 15.8 | -20.5 | 15.0 |
| GR-11 | Santa Bárbara | grassland | male | 2019 | -16.3 | 19.8 | -15.6 | 19.8 |
| GR-12 | Santa Bárbara | grassland | male | 2019 | -15.8 | 14.4 | -16.5 | 16.8 |
| GR-13 | Santa Bárbara | grassland | male | 2019 | -19.8 | 16.5 | -20.9 | 16.0 |
| GR-14 | Santa Bárbara | grassland | female | 2021 | -16.2 | 25.9 | -18.2 | 22.6 |
| GR-15 | Santa Bárbara | grassland | female | 2021 | -18.6 | 22.5 | -20.6 | 19.4 |
| GR-16 | Santa Bárbara | grassland | female | 2021 | -22.4 | 14.9 | -22.2 | 13.3 |
| GR-17 | Santa Bárbara | grassland | female | 2021 | -18.7 | 19.7 | -19.6 | 19.2 |
| GR-18 | Santa Bárbara | grassland | male | 2021 | -19.6 | 20.5 | -19.4 | 18.2 |
| GR-19 | Santa Bárbara | grassland | male | 2021 | -15.9 | 15.2 | -18.0 | 15.3 |
| GR-20 | Santa Bárbara | grassland | male | 2021 | -22.9 | 15.1 | -22.5 | 14.5 |
| GR-21 | Santa Bárbara | grassland | male | 2021 | -21.3 | 16.3 | -21.7 | 18.5 |
| HO-22 | Santa Bárbara | houses | female | 2019 | -20.6 | 20.7 | -21.7 | 21.0 |
| HO-23 | Santa Bárbara | houses | male | 2019 | -18.5 | 17.2 | -19.8 | 16.4 |
| HO-24 | Santa Bárbara | houses | male | 2019 | -17.8 | 22.3 | -16.8 | 21.8 |
| CO-25 | Siriba | colony | female | 2021 | -16.3 | 16.4 | -16.0 | 15.9 |
| CO-26 | Siriba | colony | female | 2021 | -16.1 | 16.3 | -17.2 | 16.9 |
| CO-27 | Siriba | colony | female | 2021 | -16.7 | 16.2 | -17.2 | 15.4 |
| CO-28 | Siriba | colony | female | 2021 | -13.0 | 23.1 | -12.6 | 21.9 |
| CO-29 | Siriba | colony | female | 2021 | -14.7 | 16.2 | -15.7 | 15.9 |
| CO-30 | Siriba | colony | male | 2021 | -15.5 | 14.9 | -14.0 | 17.3 |
| CO-31 | Siriba | colony | male | 2021 | -13.6 | 15.5 | -13.9 | 16.7 |
| CO-32 | Siriba | colony | male | 2021 | -13.0 | 18.5 | -13.6 | 17.6 |
| GR-33 | Siriba | grassland | female | 2021 | -15.6 | 24.7 | -14.2 | 25.0 |
| GR-34 | Siriba | grassland | female | 2021 | -16.6 | 24.3 | -14.3 | 24.8 |
| GR-35 | Siriba | grassland | female | 2021 | -14.6 | 22.3 | -14.5 | 21.4 |
| GR-36 | Siriba | grassland | female | 2021 | -15.9 | 25.2 | -14.2 | 24.7 |
| GR-37 | Siriba | grassland | male | 2021 | -15.3 | 23.9 | -14.0 | 22.7 |
| GR-38 | Siriba | grassland | male | 2021 | -18.0 | 22.4 | -17.0 | 20.5 |
| IN-39 | Siriba | intermediate | female | 2019 | -19.0 | 20.6 | -17.0 | 21.5 |
| IN-40 | Siriba | intermediate | female | 2019 | -17.2 | 20.9 | -17.9 | 19.2 |
| IN-41 | Siriba | intermediate | male | 2019 | -17.5 | 21.8 | -16.7 | 22.3 |
| IN-42 | Siriba | intermediate | male | 2019 | -20.3 | 23.4 | -20.9 | 21.6 |
| IN-43 | Siriba | intermediate | male | 2019 | -17.4 | 20.2 | -19.4 | 18.8 |

**Table S4** Kruskal-Wallis values testing differences in the body mass and length of black rats (*Rattus rattus*) sampled in the Abrolhos archipelago, Brazil, between islands (Santa Bárbara and Siriba) and areas (seabird colonies and grassland habitat). Significant differences are shown in bold

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Difference tested | Kruskal-Wallis’  Chi-square | df | p-value |
| Body mass (g) | Island | 0.22 | 1.00 | 0.639 |
|  | **Area** | **4.08** | **1.00** | **0.043** |
| Body length (cm) | Island | 2.26 | 1.00 | 0.133 |
|  | **Area** | **7.61** | **1.00** | **0.006** |

**Table S5** Analysis of variance of selected Generalized Linear Models, with computed percentage of the null deviance explained by each variable. Significant variables (*p* <0.05) are displayed with bold *p-*values

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Parameter | % explained | Deviance  residuals | df | Residual deviance | *F* | *p*-value |
| **Liver** |  |  |  |  |  |  |  |
| *δ*15N | Null |  |  | 42 | 557.13 |  |  |
|  | Island | 16.47 | 91.77 | 41 | 465.36 | 13.05 | **0.0009** |
|  | Habitat | 26.48 | 147.53 | 40 | 317.82 | 20.98 | **<0.0001** |
|  | Mass | 3.80 | 21.16 | 39 | 296.66 | 3.01 | 0.0909 |
|  | Island:Habitat | 5.29 | 29.46 | 38 | 267.20 | 4.19 | **0.0476** |
|  | Total explained | 52.04 | 289.92 |  |  |  |  |
| *δ*13C | Null |  |  | 42 | 255.39 |  |  |
|  | Island | 18.23 | 46.56 | 41 | 208.82 | 11.42 | **0.0016** |
|  | Habitat | 17.89 | 45.69 | 40 | 163.13 | 11.20 | **0.0017** |
|  | Total explained | 36.12 | 92.25 |  |  |  |  |
| **Muscle** |  |  |  |  |  |  |  |
| *δ*15N | Null |  |  | 42 | 414.39 |  |  |
|  | Island | 18.62 | 77.15 | 41 | 337.24 | 14.26 | **0.0005** |
|  | Habitat | 19.81 | 82.11 | 40 | 255.13 | 15.18 | **0.0004** |
|  | Mass | 2.85 | 11.80 | 39 | 243.33 | 2.18 | 0.1480 |
|  | Island:Habitat | 9.10 | 37.73 | 38 | 205.60 | 6.97 | **0.0119** |
|  | Total explained | 50.38 | 208.79 |  |  |  |  |
| *δ*13C | Null |  |  | 42 | 297.16 |  |  |
|  | Island | 31.46 | 93.48 | 41 | 203.68 | 22.24 | **<0.0001** |
|  | Habitat | 11.96 | 35.55 | 40 | 168.13 | 8.46 | **0.0059** |
|  | Total explained | 43.42 | 129.03 |  |  |  |  |

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**Fig. S1** Isospace showing the mean ± 95% CI values in liver (left) and muscle (right) of rats captured in different habitats in Santa Bárbara and Siriba islands in the Abrolhos archipelago, Brazil

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**Fig. S2** Simulated stable isotope mixing polygons for the diet of black rats (*Rattus rattus*) in the Abrolhos archipelago, Brazil, using three different sets of trophic discrimination factors (TDFs) for correcting isotopic values of food sources. The left, centre and right panels refer to TDF Sets 1, 2 and 3, respectively, described in Table S2. The first panel line set shows mixing polygons for the liver of rats from Santa Bárbara Island; the second for the liver of rats from Siriba Island; the third for the muscle of rats from Santa Bárbara; and the fourth for the muscle of rats from Siriba. The position of rats (black dots) and the average source signatures (white crosses) are shown. Probability contours (black lines) are at the 5% level (outermost line) and at every 10% level

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**Fig. S3** Isospace showing values in liver (above) and muscle (below) of individual rats from Santa Bárbara (A) and Siriba (B) islands in the Abrolhos archipelago, Brazil, and the mean ± SD of potential food sources. Source values were corrected with the Set 2 of trophic discrimination factors (TDFs) described in Table S2, measured by Caut et al. (2008)

**References**

Arneson LS, MacAvoy SE (2005) Carbon, nitrogen, and sulfur diet–tissue discrimination in mouse tissues. Can J Zool 83:989–995. https://doi.org/10.1139/z05-083

Caut S, Angulo E, Courchamp F (2008) Discrimination factors (Δ15N and Δ13C) in an omnivorous consumer: effect of diet isotopic ratio. Funct Ecol 22:255–263. https://doi.org/10.1111/j.1365-2435.2007.01360.x

Smith JA, Mazumder D, Suthers IM, Taylor MD (2013) To fit or not to fit: evaluating stable isotope mixing models using simulated mixing polygons. Methods Ecol Evol 4:612–618. https://doi.org/10.1111/2041-210X.12048