***Supplementary material***

Ecological trap for seabirds due to the contamination caused by the Fundão dam collapse, Brazil

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Table S1. Parameters used for the prob\_algorithm function of the probGLS R package dedicated to trajectory simulation from GLS data (Merkel et al., 2016). Numerous parameters were fixed following Merkel et al. (2016), as they were relevant for migratory seabirds such as range of the solar angles (range.solar), the structure of twilight detection error (sunrise.sd & sunset.sd), and structure of temperature measurement errors (sst.sd & max.sst.diff).

|  |  |  |
| --- | --- | --- |
| **Model parameters** | **Description** | **Value used** |
| particle.number | number of particles computed for each point cloud | 1000 |
| iteration.number | number of track iterations | 100 |
| sunrise.sd & sunset.sd | shape, scale and delay values describing the assumed assumed uncertainty structure for each twilight event following a log normal distribution | 2.49/ 0.94/ 0 |
| range.solar | range of solar angles used | -7° to -1° |
| boundary.box | the range of longitudes and latitudes likely to be used by tracked individuals | 70 W to 0 W 40 S to 50 N |
| speed.dry | fastest most likely speed, speed standard deviation (sd) and maximum speed allowed when the logger is not submerged in sea water | 20 / 10 / 50 (m.s-1) |
| speed.wet | fastest most likely speed, speed standard deviation (sd) and maximum speed allowed when the logger is submerged in sea water | 1 / 1.3 / 5 (m.s-1) |
| sst.sd | logger-derived sea surface temperature (SST) sd | 0.5°C |
| max.sst.diff | maximum tolerance in SST variation | 3°C |

Table S2. Concentrations of trace elements arsenic (As), cadmium (Ca), chromium (Cr), iron (Fe), mercury (Hg), and lead (Pb) in blood and feather samples of brown bobby *Sula leucogaster* from before and after impact periods. Values are shown as minimum, mean, median, and maximum (mg/kg dry weight) and n means number of samples analyzed. Significant differences (p< 0.05) are bold.

|  |
| --- |
| **Essential Elements - Blood** |
| **Element** | **Cr** | **Cr** | **Cu** | **Cu** | **Fe** | **Fe** | **Mn** | **Mn** | **Zn** | **Zn** |
| **Period** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** |
| **N sampled** | **(n = 7)** | **(n = 10)** | **(n = 6)** | **(n = 10)** | **(n = 7)** | **(n = 10)** | **(n = 7)** | **(n = 10)** | **(n = 7)** | **(n = 10)** |
| p value | **0.002** | **0.001** | 0.887 | **0.003** | **0.003** |
| Minimum | 0.110 | 0.062 | 1.140 | 0.024 | 114.520 | 102,538 | 2.120 | 1.435 | 3.090 | 0.838 |
| Mean | 2.480 | 0.172 | 12.052 | 0.125 | 211.601 | 206.338 | 7.206 | 4.125 | 41.307 | 6.219 |
| Median | 1.440 | 0.913 | 6.270 | 0.056 | 200.450 | 209.401 | 7.430 | 2.443 | 34.410 | 5.670 |
| Maximum | 5.970 | 0.897 | 32.380 | 0.807 | 364.380 | 286.231 | 10.130 | 19.354 | 98.130 | 16.081 |
| **Non-essential Elements - Blood** |
| **Element** | **As** | **As** | **Cd** | **Cd** | **Hg** | **Hg** | **Pb** | **Pb** | **-** | **-** |
| **Period** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **-** | **-** |
| **N sampled** | **(n = 7)** | **(n = 10)** | **(n = 5)** | **(n = 10)** | **(n = 7)** | **(n = 10)** | **(n = 7)** | **(n = 10)** | **-** | **-** |
| p value | 0.315 | 0.107 | 0.315 | **0.004** | - |
| Minimum | 0.005 | 0.277 | 0.020 | 0.040 | 0.010 | 0.031 | 0.002 | 0.006 | - | - |
| Mean | 0.394 | 0.490 | 0.102 | 0.095 | 0.230 | 0.088 | 0.310 | 0.023 | - | - |
| Median | 0.310 | 0.451 | 0.030 | 0.058 | 0.100 | 0.066 | 0.410 | 0.014 | - | - |
| Maximum | 0.800 | 0.852 | 0.320 | 0.400 | 0.630 | 0.251 | 0.550 | 0.088 | - | - |
| **Essential Elements - Feathers** |
| **Element** | **Cr** | **Cr** | **Cu** | **Cu** | **Fe** | **Fe** | **Mn** | **Mn** | **Zn** | **Zn** |
| **Period** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** |
| **N sampled** | **(n = 6)** | **(n = 10)** | **(n = 7)** | **(n = 10)** | **(n = 7)** | **(n = 10)** | **(n = 7)** | **(n = 10)** | **(n = 7)** | **(n = 10)** |
| p value | **0.002** | **0.0002** | **0.0001** | **0.0001** | **0.025** |
| Minimum | 1.850 | 0.052 | 1.330 | 0.006 | 101.890 | 19.212 | 56.000 | 13.846 | 9.000 | 4.115 |
| Mean | 8.280 | 0.972 | 43.929 | 0.661 | 392.891 | 40.228 | 134.341 | 18.939 | 99.899 | 25.445 |
| Median | 4.440 | 0.535 | 38.630 | 0.365 | 320.500 | 41.386 | 106.000 | 16.792 | 127.560 | 21.118 |
| Maximum | 18.750 | 2.884 | 91.590 | 3.652 | 670.870 | 65.066 | 254.000 | 29.618 | 161.750 | 66.044 |
| **Non-essential Elements - Feathers** |
| **Element** | **As** | **As** | **Cd** | **Cd** | **Hg** | **Hg** | **Pb** | **Pb** | **-** | **-** |
| **Period** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **-** | **-** |
| **N sampled** | **(n = 7)** | **(n = 10)** | **(n = 5)** | **(n = 10)** | **(n = 7)** | **(n = 10)** | **(n = 7)** | **(n = 10)** | **-** | **-** |
| p value | **0.014** | 0.514 | **0.0001** | **0.0001** | - |
| Minimum | 1.630 | 0.969 | 0.040 | 0.296 | 0.470 | 0.019 | 0.410 | 0.013 | - | - |
| Mean | 19.709 | 2.451 | 0.352 | 0.436 | 2.337 | 0.031 | 0.866 | 0.099 | - | - |
| Median | 5.430 | 2.471 | 0.340 | 0.396 | 1.570 | 0.029 | 0.840 | 0.091 | - | - |
| Maximum | 63.330 | 3.762 | 0.700 | 0.714 | 6.870 | 0.046 | 1.310 | 0.292 | - | - |

Table S3. Correlation (*rho*) between concentrations of elements in blood *versus* feather samples of brown boobies *Sula leucogaster*, red-billed tropicbirds *Phaethon aethereus*, and Trindade petrels *Pterodroma arminjoniana* sampled before and after Fundão dam collapse. Essential elements: chromium (Cr), copper (Cu), iron (Fe), manganese (Mn); and non-essential elements: arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb). Significant correlations (p < 0.05) are bold. Sample sizes are given in parenthesis.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Before |  | After |
| Element | Brown booby(n = 7) | Red-billed tropicbird(n = 10) | Trindade petrel(n = 9) |  | Brown booby(n = 10) | Red-billed tropicbird(n = 7) | Trindade petrel(n = 10) |
| Cr | 0.314 | 0.036 | 0.600 |  | 0.273 | 0.607 | -0.297 |
| Cu | **0.893** | 0.048 | 0.250 |  | -0.503 | -0.393 | -0.139 |
| Fe | 0.750 | 0.588 | 0.517 |  | 0.612 | -0.250 | -0.188 |
| Mn | 0 | 0.030 | 0.517 |  | -0.152 | -0.286 | 0.115 |
| Zn | -0.357 | 0.183 | -0.310 |  | -0.527 | 0.250 | 0.358 |
| As | **0.893** | 0.273 | 0.092 |  | 0.030 | 0.071 | -0.103 |
| Cd | -0.154 | - | - |  | -0.261 | 0 | -0.176 |
| Hg | **0.786** | -0.427 | -0.100 |  | 0.079 | 0.500 | 0.370 |
| Pb | 0.357 | 0.360 | 0.075 |  | **-0.657** | -0.214 | -0.103 |

Table S4. Concentrations of trace elements arsenic (As), cadmium (Ca), chromium (Cr), iron (Fe), mercury (Hg), and lead (Pb) in blood and feather samples of red-billed tropicbird *Phaethon aethereus* of before and after impact periods. Values are shown as minimum, mean, median, and maximum (mg/kg dry weight) and n means number of samples analyzed. Significant differences (p < 0.05) are bold.

|  |
| --- |
| **Essential Elements – Blood** |
| **Element** | **Cr** | **Cr** | **Cu** | **Cu** | **Fe** | **Fe** | **Mn** | **Mn** | **Zn** | **Zn** |
| **Period** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** |
| **N sampled** | **(n = 9)** | **(n = 10)** | **(n = 8)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 9)** | **(n = 10)** |
| p value | 0.182 | **0.012** | 1 | 0.218 | 0.156 |
| Minimum | 0.060 | 0.023 | 0.260 | 0.032 | 64.800 | 78.544 | 2.610 | 2.543 | 1.440 | 0.378 |
| Mean | 2.069 | 0.504 | 1.723 | 0.684 | 276.796 | 334.284 | 13.446 | 18.862 | 6.114 | 5.262 |
| Median | 1.070 | 0.192 | 2.210 | 0.206 | 282.490 | 261.511 | 10.690 | 5.913 | 6.670 | 2.6513 |
| Maximum | 9.060 | 2.987 | 2.500 | 4.505 | 499.640 | 873.500 | 26.710 | 116.880 | 9.740 | 22.064 |
| **Non-essential Elements – Blood** |
| **Element** | **As** | **As** | **Cd** | **Cd** | **Hg** | **Hg** | **Pb** | **Pb** | **-** | **-** |
| **Period** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **-** | **-** |
| **N sampled** | **(n = 10)** | **(n = 10)** | **(n = 6)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **-** | **-** |
| p value | **0.0003** | **0.022** | **0.014** | 0.089 | - |
| Minimum | 0.060 | 0.232 | 0.000 | 0.063 | 0.080 | 0.045 | 0.030 | 0.004 | - | - |
| Mean | 0.376 | 3.711 | 0.080 | 0.449 | 0.249 | 0.091 | 0.276 | 0.763 | - | - |
| Median | 0.385 | 1.288 | 0.040 | 0.143 | 0.200 | 0.084 | 0.160 | 0.192 | - | - |
| Maximum | 0.660 | 21.580 | 0.310 | 2.657 | 0.590 | 0.182 | 1.100 | 6.495 | - | - |
| **Essential Elements – Feathers** |
| **Element** | **Cr** | **Cr** | **Cu** | **Cu** | **Fe** | **Fe** | **Mn** | **Mn** | **Zn** | **Zn** |
| **N sampled** | **(n = 8)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** |
| p value | **0.0008** | **<0.001** | **<0.001** | **0.002** | **<0.001** |
| Minimum | 0.370 | 0.012 | 1.260 | 0.035 | 68.350 | 19.013 | 7.350 | 9.597 | 93.650 | 1.679 |
| Mean | 1.695 | 0.315 | 4.763 | 0.192 | 182.017 | 47.527 | 37.425 | 13.180 | 217.899 | 30.795 |
| Median | 1.815 | 0.344 | 3.695 | 0.098 | 168.010 | 40.637 | 34.965 | 11.965 | 156.185 | 21.925 |
| Maximum | 3.680 | 0.563 | 10.070 | 0.627 | 390.500 | 86.519 | 69.970 | 23.899 | 457.500 | 84.241 |
| **Non-essential Elements – Feathers** |
| **Element** | **As** | **As** | **Cd** | **Cd** | **Hg** | **Hg** | **Pb** | **Pb** | **-** | **-** |
| **N sampled** | **(n = 10)** | **(n = 10)** | **(n = 5)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **(n = 10)** | **-** | **-** |
| p value | **<0.001** | **0.003** | **<0.001** | **0.001** | - |
| Minimum | 0.010 | 1.271 | 0.010 | 0.229 | 0.187 | 0.014 | 0.080 | 0.057 | - | - |
| Mean | 0.504 | 5.036 | 0.042 | 0.029 | 0.380 | 0.020 | 0.400 | 0.115 | - | - |
| Median | 0.515 | 4.176 | 0.040 | 0.288 | 0.360 | 0.019 | 0.355 | 0.110 | - | - |
| Maximum | 1.020 | 10.511 | 0.080 | 0.338 | 0.650 | 0.033 | 0.760 | 0.207 | - | - |

Table S5. Concentrations of trace elements arsenic (As), cadmium (Ca), chromium (Cr), iron (Fe), mercury (Hg), and lead (Pb) in blood and feather samples of Trindade petrel *Pterodroma arminjoniana* of before and after impact periods. Values are shown as minimum, mean, median, and maximum (mg/kg dry weight) and n means number of samples analyzed. Significant differences (p < 0.05) are bold.

|  |
| --- |
| **Essential Elements – Blood** |
| **Element** | **Cr** | **Cr** | **Cu** | **Cu** | **Fe** | **Fe** | **Mn** | **Mn** | **Zn** | **Zn** |
| **Period** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** |
| **N sampled** | **(n = 6)** | **(n = 10)** | **(n = 9)** | **(n = 10)** | **(n = 9)** | **(n = 10)** | **(n = 9)** | **(n = 10)** | **(n = 8)** | **(n = 10)** |
| p value | 0.958 | **0.010** | 0.661 | 0.156 | **0.006** |
| Minimum | 0.220 | 0.157 | 0.390 | 0.004 | 38.260 | 202.063 | 9.700 | 6.829 | 8.480 | 0.218 |
| Mean | 3.043 | 2.857 | 2.459 | 1.289 | 378.929 | 405.553 | 43.427 | 39.693 | 31.673 | 7.723 |
| Median | 1.945 | 1.507 | 1.890 | 0.171 | 418.330 | 277.439 | 27.510 | 16.080 | 22.010 | 3.417 |
| Maximum | 10.320 | 8.188 | 6.190 | 10.620 | 648.930 | 815.714 | 104.400 | 200.000 | 73.450 | 27.300 |
| **Non-essential Elements – Blood** |
| **Element** | **As** | **As** | **Cd** | **Cd** | **Hg** | **Hg** | **Pb** | **Pb** | **-** | **-** |
| **Period** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **-** | **-** |
| **N sampled** | **(n = 9)** | **(n = 10)** | **(n = 5)** | **(n = 10)** | **(n = 9)** | **(n = 10)** | **(n = 9)** | **(n = 10)** | **-** | **-** |
| p value | **0.0003** | **0.0004** | **0.0003** | 0.780 | - |
| Minimum | 0.220 | 0.988 | 0.010 | 0.170 | 0.110 | 0.006 | 0.090 | 0.006 | - | - |
| Mean | 0.584 | 7.477 | 0.082 | 0.901 | 0.394 | 0.042 | 0.478 | 0.893 | - | - |
| Median | 0.520 | 6.081 | 0.030 | 0.365 | 0.300 | 0.024 | 0.420 | 0.286 | - | - |
| Maximum | 0.920 | 19.600 | 0.190 | 4.292 | 0.910 | 0.222 | 1.040 | 4.004 | - | - |
| **Essential Elements – Feathers** |
| **Element** | **Cr** | **Cr** | **Cu** | **Cu** | **Fe** | **Fe** | **Mn** | **Mn** | **Zn** | **Zn** |
| **Period** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** |
| **N sampled** | **(n = 7)** | **(n = 10)** | **(n = 9)** | **(n = 10)** | **(n = 9)** | **(n = 10)** | **(n = 9)** | **(n = 10)** | **(n = 9)** | **(n = 10)** |
| p value | **0.043** | **0.0007** | **<0.001** | **<0.001** | **<0.001** |
| Minimum | 0.030 | 0.011 | 1.500 | 0.111 | 107.900 | 20.595 | 24.960 | 8.737 | 103.400 | 0.514 |
| Mean | 3.160 | 0.411 | 4.294 | 1.436 | 347.294 | 36.422 | 107.202 | 12.979 | 248.050 | 12.877 |
| Median | 3.190 | 0.326 | 4.540 | 1.576 | 281.190 | 27.359 | 90.110 | 11.446 | 226.620 | 13.643 |
| Maximum | 6.110 | 0.893 | 6.810 | 3.130 | 833.000 | 82.422 | 235.800 | 24.164 | 523.570 | 31.078 |
| **Non-essential Elements – Feathers** |
| **Element** | **As** | **As** | **Cd** | **Cd** | **Hg** | **Hg** | **Pb** | **Pb** | **-** | **-** |
| **Period** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **-** | **-** |
| **N sampled** | **(n = 9)** | **(n = 10)** | **(n = 5)** | **(n = 10)** | **(n = 9)** | **(n = 10)** | **(n = 9)** | **(n = 10)** | **-** | **-** |
| p value | **0.017** | 0.250 | 0.156 | 0.270 | - |
| Minimum | 0.100 | 0.604 | 0.040 | 0.113 | 0.030 | 0.022 | 0.060 | 0.027 | - | - |
| Mean | 1.111 | 2.332 | 0.116 | 0.250 | 0.419 | 0.238 | 0.408 | 0.246 | - | - |
| Median | 0.960 | 2.449 | 0.130 | 0.255 | 0.510 | 0.161 | 0.460 | 0.172 | - | - |
| Maximum | 2.560 | 3.707 | 0.180 | 0.369 | 0.780 | 0.823 | 0.930 | 0.953 | - | - |



Fig S1. Concentrations of the essential trace elements **a** chromium (Cr), **b** copper (Cu), **c** iron (Fe), **d** manganese (Mn), and **e** zinc (Zn), and the non-essential **f** arsenic (As), **g** cadmium (Cd), **h** mercury (Hg), and **i** lead (Pb) in blood and feathers samples of brown booby *Sula leucogaster* frombefore and after impact.



Fig S2. Concentrations of the essential trace elements **a** chromium (Cr), **b** copper (Cu), **c** iron (Fe), **d** manganese (Mn), and **e** zinc (Zn), and the non-essential **f** arsenic (As), **g** cadmium (Cd), **h** mercury (Hg), and **i** lead (Pb) in blood and feathers samples of red-billed tropicbird *Phaethon aethereus* frombefore and after impact.



Fig S3. Concentrations of the essential trace elements **a** chromium (Cr), **b** copper (Cu), **c** iron (Fe), **d** manganese (Mn), and **e** zinc (Zn), and the non-essential **f** arsenic (As), **g** cadmium (Cd), **h** mercury (Hg), and **i** lead (Pb) in blood and feathers samples of Trindade petrel *Pterodroma arminjoniana* from before and after impact.