**Supplementary material**

**Table S1.** Ectoparasites, haemoparasites and helminths obtained from African penguins at five colonies along the west coast of South Africa during autumn/winter 2016 and 2017. Sample sizes N=690 (ectoparasites), 640 (haemoparasites) and 363 (helminths).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parasite species | Colony | Total prevalence (%) | Mean abundance (±SE) |  | Mean intensity (±SE) | Sex:ratio (♂:♀) |
| Larvae | Nymphs  | Adults | Total |  | Larvae | Nymphs  | Adults | Total |
| Fleas |   |   |   |   |   |   |  |   |   |   |   |   |
| *P. humboldti* | Dassen Island | 40.83¹ | - | - | 1.77 (±0.30) | 1.77 (±0.30)¹ |  | - | - | 4.33 (±0.56) | 4.33 (±0.56)¹ | 0.87:1 |
|  | Dyer Island | 44.17 | 0 | - | 1.6 (±0.27) | 1.6 (±0.27) |  | 0 | - | 3.62 (±0.49) | 3.62 (±0.49) | 1.46:1 |
|  | Robben Island | 75.83 | 0 | - | 5.18 (±0.57) | 5.18 (±0.57) |  | 0 | - | 6.84 (±0.67) | 6.84 (±0.67) | 1.22:1 |
|  | Stony Point | 78.57 | 0 | - | 5.02 (±0.34) | 5.02 (±0.34) |  | 0 | - | 6.39 (±0.37) | 6.39 (±0.37) | 1.11:1 |
|  | Simon’s Town | 80 | 0 | - | 6.19 (±0.59) | 6.19 (±0.59) |  | 0 | - | 7.74 (±0.64) | 7.74 (±0.64) | 0.93:1 |
| *E. gallinacea* | Dassen Island | 35 | - | - | 1.73 (±0.30) | 1.73 (±0.30) |  | - | - | 4.95 (±0.60) | 4.95 (±0.60) | 0.16:1 |
| Lice |  |  |  |  |  |  |  |  |  |  |  |  |
| *A. demersus* | Dassen Island | 2.50 | - | - | 0.05 (±0.04) | 0.05 (±0.04) |  | - | - | 2 (±1) | 2 (±1) | 1:1 |
|  | Dyer Island | 1.67 | - | - | 0.02 (±0.01) | 0.02 (±0.01) |  | - | - | 1 | 1 | only female |
|  | Robben Island | 0.83 | - | - | 0.01 (±0.01) | 0.01 (±0.01) |  | - | - | 1 | 1 | only female |
|  | Stony Point | 0.95 | - | - | 0.01 (±0.01) | 0.01 (±0.01) |  | - | - | 1 | 1 | only female |
|  | Simon’s Town | 0 | - | - | 0 | 0 |  | - | - | 0 | 0 | 0 |
| Ticks |  |  |  |  |  |  |  |  |  |  |  |  |
| *O. capensis* | Dassen Island | 5.83 | 0.03 (±0.02) | 0.22 (±0.18) | 0 | 0.25 (±0.18) |  | 1.33 (±0.33) | 6.5 (±5.17) | 0 | 4.29 (±2.96) | 0 |
|  | Dyer Island | 4.17 | 0.1 (±0.05) | 0.02 (±0.01) | 0 | 0.12 (±0.06) |  | 2.40 (±0.68) | 1 | 0 | 2.80 (±0.80) | 0 |
|  |
|  | Robben Island | 10 | 0.13 (±0.04) | 0.01 (±0.01) | 0 | 0.13 (±0.04) |  | 1.36 (±0.20) | 1 | 0 | 1.33 (±0.19) | 0 |
|  | Stony Point | 15.71 | 0.31 (±0.08) | 0.03 (±0.01) | 0.005 (±0.005) | 0.35 (±0.08) |  | 2.28 (±0.39) | 1 | 1 | 2.21 (±0.35) | only female |
|  | Simon’s Town | 1.67 | 0.01 (±0.01) | 0.01 (±0.01) | 0 | 0.02 (±0.01) |  | 1 | 1 | 0 | 1 | 0 |
| Haemoparasites² |  |  |  |  |  |  |  |  |  |  |  |  |
| Piroplasmorida/ Haemospororida  | Dassen Island | 5.31 | - | - | - | - |  | - | - | - | - | - |
|  | Dyer Island | 23.58 | - | - | - | - |  | - | - | - | - | - |
|  | Robben Island | 7.83 | - | - | - | - |  | - | - | - | - | - |
|  | Stony Point | 55.61 | - | - | - | - |  | - | - | - | - | - |
|  | Simon’s Town | 35.64 | - | - | - | - |  | - | - | - | - | - |
| Spirochaetales | Dassen Island | 0.88 | - | - | - | - |  | - | - | - | - | - |
|  | Dyer Island | 1.89 | - | - | - | - |  | - | - | - | - | - |
|  | Robben Island | 0.87 | - | - | - | - |  | - | - | - | - | - |
|  | Stony Point | 1.95 | - | - | - | - |  | - | - | - | - | - |
|  | Simon’s Town | 0.99 | - | - | - | - |  | - | - | - | - | - |
| Helminths² |  |  |  |  |  |  |  |  |  |  |  |  |
| *Cardiocephaloides* spp. | Dassen Island | 41.51 | - | - | - | - |  | - | - | - | - | - |
|  | Dyer Island | 46.43 | - | - | - | - |  | - | - | - | - | - |
|  | Robben Island | 48.15 | - | - | - | - |  | - | - | - | - | - |
|  | Stony Point | 63.38 | - | - | - | - |  | - | - | - | - | - |
|  | Simon’s Town | 56.90 | - | - | - | - |  | - | - | - | - | - |
| *Renicola* spp. | Dassen Island | 0 | - | - | - | - |  | - | - | - | - | - |
|  | Dyer Island | 0 | - | - | - | - |  | - | - | - | - | - |
|  | Robben Island | 0 | - | - | - | - |  | - | - | - | - | - |
|  | Stony Point | 0 | - | - | - | - |  | - | - | - | - | - |
|  | Simon’s Town | 0 | - | - | - | - |  | - | - | - | - | - |
| *Contracaecum* spp. | Dassen Island | 5.66 | - | - | - | - |  | - | - | - | - | - |
|  | Dyer Island | 12.5 | - | - | - | - |  | - | - | - | - | - |
|  | Robben Island | 14.81 | - | - | - | - |  | - | - | - | - | - |
|  | Stony Point | 13.38 | - | - | - | - |  | - | - | - | - | - |
|  | Simon’s Town | 15.52 | - | - | - | - |  | - | - | - | - | - |
| *Cyathostoma* spp. | Dassen Island | 0 | - | - | - | - |  | - | - | - | - | - |
|  | Dyer Island | 3.57 | - | - | - | - |  | - | - | - | - | - |
|  | Robben Island | 0 | - | - | - | - |  | - | - | - | - | - |
|  | Stony Point | 6.34 | - | - | - | - |  | - | - | - | - | - |
|  | Simon’s Town | 0 | - | - | - | - |  | - | - | - | - | - |

¹Total prevalence, mean abundance and mean intensity of fleas in Dassen Island excluded larvae.

²Prevalence of haemo- and endoparasites is the presence of parasites at each group or genus from the total of hosts examined at each colony.

**Table S2.** Ectoparasites obtained from nests of African penguins (N = 547) in five colonies along the west coast of South Africa during autumn/winter 2016 and 2017.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Parasite species | Colony | Prevalence (%) |  | Mean abundance (±SE) |  | Mean intensity (±SE) | Sex:ratio (♂:♀) |
| Larvae | Nymphs | Adults | Total  |  | Larvae | Nymphs  | Adults | Total  |  | Larvae | Nymphs  | Adults | Total |  |
| Fleas |   |   |   |   |   |  |   |   |   |   |  |   |   |  |  |   |
| *P. humboldti* | Dassen Island¹ | - | - | 25 | 25 |  | - | - | 0.80 (±0.35) | 0.80 (±0.35) |  | - | - | 3.2 (±1.28) | 3.2 (±1.28) | 0.49:1 |
|  | Dyer Island | 26.25 | - | 22.50 | 36.25 |  | 8.25 (±2.68) | - | 0.63 (±0.20) | 8.88 (±2.69) |  | 31.43 (±8.48) | - | 2.78 (±0.67) | 24.48 (±6.54) | 0.53:1 |
|  | Robben Island | 61.25 | - | 32.50 | 70 |  | 10.49 (±2.18) | - | 0.76 (±0.26) | 11.25 (±2.20) |  | 17.12 (±3.23) | - | 2.35 (±0.73) | 16.07 (±2.92) | 0.43:1 |
|  | Stony Point | 56.39 | - | 29.96 | 62.11 |  | 15.51 (±2.17) | - | 0.73 (±0.12) | 16.24 (±2.22) |  | 27.51 (±3.50) | - | 2.43 (±0.32) | 26.14 (±3.30) | 0.83:1 |
|  | Simon’s Town | 70 | - | 61.25 | 77.50 |  | 39.30 (±8.62) | - | 3.14 (±0.48) | 42.44 (±8.97) |  | 56.14 (±11.63) | - | 5.12 (±0.63) | 54.76 (±11.10) | 0.76:1 |
| *E. gallinacea* | Dassen Island | - | - | 5 | 5 |  | - | - | 0.08 (±0.04) | 0.08 (±0.04) |  | - | - | 1.5 (±0.29) | 1.5 (±0.29) | 1:1 |
| Lice |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *A. demersus* | Dassen Island | - | - | 1.25 | 1.25 |  | - | - | 0.01 (±0.01) | 0.01 (±0.01) |  | - | - | 1 | 1 | only female  |
|  | Dyer Island | - | - | 0 | 0 |  | - | - | 0 | 0 |  | - | - | 0 | 0 | 0 |
|  | Robben Island | - | - | 0 | 0 |  | - | - | 0 | 0 |  | - | - | 0 | 0 | 0 |
|  | Stony Point | - | - | 0 | 0 |  | - | - | 0 | 0 |  | - | - | 0 | 0 | 0 |
|  | Simon’s Town | - | - | 0 | 0 |  | - | - | 0 | 0 |  | - | - | 0 | 0 | 0 |
| Ticks |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *O. capensis* | Dassen Island | 11.25 | 17.50 | 2.50 | 26.25 |  | 0.11 (±0.04) | 0.36 (±0.14) | 0.03 (±0.02) | 0.50 (±0.15) |  | 1 | 2.07 (±0.62) | 1 | 1.90 (±0.45) | only male  |
|  | Dyer Island | 12.50 | 33.75 | 27.50 | 46.25 |  | 0.38 (±0.17) | 2.10 (±0.78) | 1.06 (±0.34) | 3.54 (±1.20) |  | 3 (±1.09) | 6.22 (±2.13) | 3.86 (±1.03) | 7.65 (±2.43) | 0.51:1 |
|  | Robben Island | 2.5 | 16.25 | 6.25 | 18.75 |  | 0.13 (±0.10) | 0.35 (±0.12) | 0.13 (±0.07) | 0.60 (±0.25) |  | 5(±3) | 2.15 (±0.53) | 2 (±0.63) | 3.2 (±1.12) | 0.67:1 |
|  | Stony Point | 22.47 | 47.58 | 44.93 | 66.08 |  | 2.32 (±1.00) | 4.44 (±2.56) | 3.70 (±1.79) | 10.47 (±4.90) |  | 10.33 (±4.29) | 9.33 (±5.35) | 8.25 (±3.95) | 15.84 (±7.38) | 1.93:1 |
|   | Simon’s Town | 21.25 | 36.25 | 20 | 51.25 |  | 0.25 (±0.06) | 1.01 (±0.27) | 0.33 (±0.10) | 1.59 (±0.31) |  | 1.18 (±0.13) | 2.79 (±0.62) | 1.73 (±0.33) | 3.10 (±0.50) | 1.11:1 |

¹Prevalence, mean abundance and mean intensity of flea larvae are excluded in Dassen Island.

**Table S3.** Model selection based on Akaike Information Criterion (AIC). Numbers in brackets represent the different scenarios derived from the full model (assessed in the study) to reach the best model (in bold). Significant differences between the full and the best model (p-value) according to Chi-square test. Independent variables: location (mainland and island); colony (Stony Point, Simon’s Town, Dassen-, Dyer- and Robben Island), year (2016 and 2017), penguin age (adult and chick) and body mass.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Model | AIC | Chisq | df | p-value |
| ON-HOST ECTOPARASITES |   |   |   |   |
| Y=Total on-host ectoparasites |  |  |  |  |
| (1) Total on-host ectoparasites ~ location + year + age + body mass | 3286.88 |  |  |  |
| **(2) Total on-host ectoparasites ~ location + year + age** | 3283.78 | 3.1 | 1 | >0.05 |
| (1) Total on-host ectoparasites ~ colony + year + age + body mass | 3233.06 |  |  |  |
| **(2) Total on-host ectoparasites ~ colony + year + age** | 3231.14 | 1.92 | 1 | >0.05 |
| Y=On-host fleas |  |  |  |  |
| (1) on-host fleas ~ location + year + age + body mass | 3258.64 |  |  |  |
| **(2) on-host fleas ~ location + year + age** | 3255.7 | 2.94 | 1 | >0.05 |
| (1) on-host fleas ~ colony + year + age + body mass | 3203.32 |  |  |  |
| **(2) on-host fleas ~ colony + year + age** | 3201.17 | 2.15 | 1 | >0.05 |
| Y=Lice |  |  |  |  |
| (1) lice ~ location + year + age + body mass | 85.34 |  |  |  |
| **(2) lice ~ location + year + age** | 85.18 | 0.16 | 1 | >0.05 |
| (1) lice ~ colony + year + age + body mass | 88.62 |  |  |  |
| (2) lice ~ year + age + body mass | 85.81 |  |  |  |
| **(3) lice ~ year + age** | 85.48 | 3.14 | 2 | >0.05 |
| Y=On-host ticks |  |  |  |  |
| **(1) on-host ticks ~ location + year + age + body mass** | 371.76 | 0 | 0 | NA |
| **(1) on-host ticks ~ colony + year + age + body mass** | 353.89 | 0 | 0 | NA |
| HAEMOPARASITES |  |  |  |  |
| Y=Piroplasmids/Haemospororida |  |  |  |  |
| (1) Piroplasmids/Haemospororida ~ location + year + age + body mass | 604.42 |  |  |  |
| **(2) Piroplasmids/Haemospororida ~ location + age + body mass** | 603 | 1.42 | 1 | >0.05 |
| (1) Piroplasmids/Haemospororida ~ colony + year + age + body mass | 583.97 |  |  |  |
| **(2) Piroplasmids/Haemospororida ~ colony + age + body mass** | 582.71 | 1.26 | 1 | >0.05 |
| Y=Spirochaetales |  |  |  |  |
| (1) Spirochaetales ~ location + year + age + body mass | 93.21 |  |  |  |
| (2) Spirochaetales ~ location + age + body mass | 91.29 |  |  |  |
| **(3) Spirochaetales ~ age + body mass** | 89.58 | 3.63 | 2 | >0.05 |
| (1) Spirochaetales ~ colony + year + age + body mass | 98.34 |  |  |  |
| (2) Spirochaetales ~ year + age + body mass | 91.52 |  |  |  |
| **(3) Spirochaetales ~ age + body mass** | 89.58 | 8.76 | 2 | <0.05 |
| HELMINTH PARASITES |  |  |  |  |
| Y=Cardiocephaloides spp. |  |  |  |  |
| **(1) Cardiocephaloides ~ location + year + body mass** | 448.94 | 0 | 0 | NA |
| **(1) Cardiocephaloides ~ colony + year + body mass** | 454.02 | 0 | 0 | NA |
| Y=Contracaecum spp. |  |  |  |  |
| (1) Contracaecum ~ location + year + body mass | 282.04 |  |  |  |
| (2) Contracaecum ~ location + year | 280.28 |  |  |  |
| (3) Contracaecum ~ location | 278.7 |  |  |  |
| **(4) Contracaecum ~ 1** | 277.41 | 4.63 | 3 | >0.05 |
| (1) Contracaecum ~ colony + year + body mass | 285.25 |  |  |  |
| (2) Contracaecum ~ year + body mass | 280.68 |  |  |  |
| (3) Contracaecum ~ year | 279 |  |  |  |
| **(4) Contracaecum ~ 1** | 277.41 | 7.84 | 3 | <0.05 |
| Y=Cyathostoma spp. |  |  |  |  |
| **(1) Cyathostoma ~ location + year + body mass** | 85.38 | 0 | 0 |  |
| (1) Cyathostoma ~ colony + year + body mass | 81.22 |  |  |  |
| **(2) Cyathostoma ~ colony + year** | 81.08 | 0.14 | 1 | >0.05 |
| NEST ECTOPARASITES |  |  |  |  |
| Y=Total nest ectoparasites |  |  |  |  |
| **(1) Total nest ectoparasites ~ location + year** | 3402.93 | 0 | 0 | NA |
| **(1)Total nest ectoparasites~ colony + year** | 3397.12 | 0 | 0 | NA |
| Y=Total nest fleas |  |  |  |  |
| **(1) Total fleas ~ location + year** | 3044.07 | 0 | 0 | NA |
| **(1) Total fleas ~ colony + year** | 2998.44 | 0 | 0 | NA |
| Adult fleas |  |  |  |  |
| **(1) Adult fleas ~ location + year** | 1596.91 | 0 | 0 | NA |
| **(1)Adult fleas ~ colony + year** | 1556.82 | 0 | 0 | NA |
| Y=Flea larvae |  |  |  |  |
| **(1) Flea larvae ~ location + year** | 2860.44 | 0 | 0 | NA |
| **(1) Flea larvae ~ colony + year** | 2802.76 | 0 | 0 | NA |
| Y=Nest ticks |  |  |  |  |
| (1) Nest ticks ~ location + year | 2168.96 |  |  |  |
| **(2) Nest ticks ~ location** | 2168.92 | 0.04 | 1 | >0.05 |
| **(1) Nest ticks ~ colony + year** | 2146.11 | 0 | 0 | NA |