**Appendix 1. Supplementary tables.**

**Table S1.** Lists of flea and host species used in the analyses at the scale of compound flea communities across localities within a region.

|  |  |  |
| --- | --- | --- |
| Region | List of flea species | List of host species |
| Mongolia | *Amphipsylla longispina**Amphipsylla primaris**Ampphipsylla vinogradovi**Citellophilus altaicus**Citellophilus sungaris**Coptopsylla lamelifer**Ctenophthalmus arvalis**Echidnophaga oshanini**Echidnophaga tiscadaea**Frontopsylla elata**Frontopsylla hetera**Frotopsylla luculenta**Frontopsylla wagneri**Mesopsylla eucta**Mesopsylla hebes**Neopsylla acanthina**Neopsylla bidentata**Neopsylla pleskei**Nosopsyllus laeviceps**Ochotonobis hirticrus**Ophthalmopsylla kiritschenkovi**Ophthalmopsylla kukuschkini**Ophthalmopsylla praefecta**Ophthalmopsylla volgensis**Paramonopsyllus scalonae**Paradoxopsyllus scorodumovi**Pectinoctenus pavlovskii**Xenopsylla conformis**Xenopsylla skrjabini* | *Allactaga balikunica**Allactaga bullata**Allactaga elater**Allactaga sibirica**Allocricetulus curtatus**Alticola semicanus**Apodemus peninsulae**Cardiocranius paradoxus**Cricetulus longicaudatus**Cricetulus migratorius**Dipus sagitta**Euchoreutes naso**Hemiechinus auritus**Lagurus lagurus**Lasiopodomys brandtii**Marmota sibirica**Meriones meridianus**Merriones unguiculatus**Ochotona daurica**Ochotona pallasii**Phodopus campbelli**Phodopus roborovskii**Pygeretmus pumilio**Rhombomys opimus**Salpingotus crassicauda**Spermophilus alashanicus**Spermophilus erythrourus**Stylodipus andrewsi**Urocitellus undulatus* |
| Northwest Argentina | *Adoratopsylla intermedia**Agastopsylla nylota**Cleopsylla barquezi**Craneopsylla minerva**Ctenidiosomus austrinus**Delostichus talis**Ectinorus monicadiazae**Ectinorus sp.**Hectopsylla gracilis**Neotyphloceras chilensis**Neotyphloceras crassispina**Plocopsylla chicoanaensis**Plocopsylla inti**Plocopsylla sp.**Polygenis acodontis**Polygenis byturus**Polygenis pradoi**Polygenis puelche**Polygenis sp.**Polygenis tripus**Tetrapsyllus bleptus**Tetrapsyllus spegazzinii**Tiamastus cavicola* *Tiamastus palpalis* | *Abrothrix andina**Akodon albiventer**Akodon budini**Akodon caenosus**Akodon dolores**Akodon glaucinus**Akodon lutescens**Akodon puer**Akodon simulator**Akodon* sp.*Akodon spegazzinii**Akodon tartareus**Akodon tucumanensis**Calomys boliviae**Calomys callosus**Calomys musculinus**Calomys* sp.*Calomys venustus**Ctenomys* sp.*Eligmodontia bolsonensis**Eligmodontia puerulus**Eligmodontia* sp.*Graomys chacoensis**Graomys griseoflavus* *Lutreolina massoia**Microcavia maenas**Necromys lactens**Neotomys ebriosus**Oligoryzomys brendae**Oligoryzomys flavescens**Oxymycterus paramensis**Phyllotis caprinus**Phyllotis osilae**Phyllotis xanthopygus**Tapecomys primus**Thylamys sponsorius* |
| Patagonia | *Agastopsylla boxi**Craneopsylla minerva**Ectinorus galeanus**Ectinorus hapalus**Ectinorus ixanus**Ectinorus levipes**Ectinorus martini**Ectinorus onychius**Hectopsylla gracilis**Neotyphloceras crackensis**Neotyphloceras pardinasii**Plocopsylla lewisi**Plocopsylla silewi**Plocopsylla wilesi**Polygenis platensis**Polygenis rimatus**Sphinctopsylla ares**Tetrapsyllus bleptus**Tetrapsyllus rhombus**Tetrapsyllus tantillus**Tiamastus callens**Tiarapsylla argentina* | *Abrothrix hirta**Abrothrix olivacea**Akodon dolores**Akodon iniscatus**Calomys musculinus**Chelemys macronyx**Ctenomys* sp.*Eligmodontia morgani**Eligmodontia typus**Euneomys chinchilloides**Euneomys petersoni**Graomys griseoflavus**Loxodontomys micropus**Microcavia australis**Phyllotis xanthopygus**Reithrodon auritus**Thylamys pallidior* |
| Western Siberia | *Amalareus penicilliger**Amphipsulla kuznetzovi**Amphipsylla primaris**Amphipsylla rossica**Amphipsylla sibirica**Amphalius runatus**Catallagia dacenkoi**Catallagia ioffi**Ceratophylus indages**Citellophilus tesquorum**Corrodopsylla birulai**Ctenophthalmus arvalis**Ctenophthalmus asssimilis**Ctenophthalmus breviatus**Ctenophthalmus uncinatus**Ctenophthalmus wagneri**Doratopsylla dasycnema**Frotopsylla elata**Hystrichopsylla talpae**Leptopsylla segnis**Megabothris calcarifer**Megabothris rectangulatus**Megabothris turbidus**Megabothris walkeri**Neopsylla acanthina**Neopsylla mana**Neopsylla pleskei**Palaeopsylla soricis**Pectinoctenus pavlovskii**Peromyscopsylla bidentata**Peromyscopsylla silvatica**Rhadinopsylla altaica**Rhadinopsylla integella* | *Alticola strelzovi**Apodemus agrarius**Apodemus peninsulae**Apodemus speciosus**Apodemus uralensis**Arvicola amphibius**Craseomys rufocanus**Cricetus cricetus**Dicrostonyx torquatus**Eutamias sibiricus**Lagurus lagurus**Lemmmus sibiricus**Micromys minutus**Microtus agrestis**Microtus arvalis**Microtus gregalis**Microtus middendorffii**Microtus oeconomus**Mus musculus**Myodes glareolus**Myodes rutilus**Neomys fodiens**Ochotona alpina**Phodopus sungorus**Sicista betulina**Sorex araneus**Sorex caecutiens**Sorex daphaenodon**Sorex isodon**Sorex minutus**Sorex roboratus**Sorex tundrensis**Talpa altaica* |
| Slovakia | *Amalaraeus arvicolae**Amalaraeus penicilliger**Ceratophyllus sciurorum**Ctenophthalmus agyrtes**Ctenophthalmus assimilis**Ctenophthalmus bisoctodentatus**Ctenophthalmus obtusus**Ctenophthalmus solutus**Ctenophthalmus uncinatus**Doratopsylla dasycnema**Hystrichopsylla orientalis**Hystrichopsylla talpae**Leptopsylla segnis**Megabothris turbidus**Nosopsyllus fasciatus**Peromyscopsylla bidentata**Peromyscopsylla silvatica**Palaeopsylla similis**Palaeopsylla soricis**Rhadinopsylla integella**Rhadinopsylla penthacanta* | *Apodemus agrarius**Apodemus flavicollis**Apodemus sylvaticus**Apodemus uralensis**Arvicola amphibius**Crocidura leucodon**Glis glis**Micromys minutus**Microtus agrestis**Microtus arvalis**Microtus subterraneus**Muscardinus avellanarius**Mus musculus**Myodes glareolus**Neomys anomalus**Neomys fodiens**Rattus norvegicus**Sicista betulina**Sorex alpinus**Sorex araneus**Sorex minutus**Spermophilus citellus**Talpa europaea* |
| South Africa | *Chiastopsylla capensis**Chiastopsylla carus**Chiastopsylla coraxis**Chiastopsylla godfreyi**Chiastopsylla mulleri**Chiastopsylla nama**Chiastopsylla octavii**Chiastopsylla pitchfordi**Chiastopsylla quadrisetis**Chiastopsylla rossi**Ctenophthalmus calceatus**Ctenophthalmus natalensis**Demeillionia granti**Dinopsyllus ellobius**Dinopsyllus lypusus**Dinopsyllus tenax**Epirimia aganippes**Hypsophthalmus temporis**Listropsylla agrippinae**Listropsylla aricinae**Listropsylla dorippae**Praopsylla powelli**Xenopsylla brasiliensis**Xenopsylla eridos**Xenopsylla piriei**Xenopsylla trifaria* | *Crocidura* sp.*Desmodillus auricularis**Elephantulus edwwardii**Gerbillurus paeba**Mastomys natalensis**Micaelamys namaquensis**Mus minutoides**Mus musculus**Myotomys unisulcatus**Otomys irroratus**Parotomys brantsii**Rhabdomys pumilio**Myosorex* sp. |
| Tanzania | *Afristivalius torvus**Chiastopsylla rossi**Ctenophthalmus calceatus**Ctenophthalmus cophurus**Ctenophthalmus eximius**Ctenophthalmus hopkinsi**Ctenophthalmus kemmelberg**Ctenophthalmus leptodactylus**Ctenophthalmus teucqae**Dinopsyllus grypurus**Dinopsyllus longifrons**Dinopsyllus lypusus**Dinopsyllus pringlei**Dinopsyllus titan**Hypsophthalmus campestris**Leptopsylla aethiopica**Lybiastus duratus**Nosopsyllus incisus**Xenopsylla brasiliensis**Xenopsylla sarodes**Xiphiopsylla hyparetes* | *Aethomys chrysophilus**Arvicanthis* sp.*Cricetomys gambianus**Crocidura hildegardeae**Crocidura poensis**Crocidura* sp.*Dendromus nyikae**Grammomys ibeanus**Grammomys macmillani**Grammomys* sp.*Hylomyscus acrimontensis**Lemniscomys rosalia**Lophuromys aquilus**Mastomys natalensis**Otomys sp.**Paraxerus vexillarius**Praomys delectorum**Rattus rattus* |

**Table S2.** Host species used in the analyses at the scale of component flea communities.

|  |  |  |  |
| --- | --- | --- | --- |
| Region | Host species | Number of sampling sites | Flea species richness |
| Mongolia | *Allactaga bullata* | 36 | 12 |
|  | *Allactaga sibirica* | 52 | 15 |
|  | *Allocricetulus curtatus* | 16 | 10 |
|  | *Dipus sagitta* | 40 | 11 |
|  | *Meriones meridianus* | 38 | 10 |
|  | *Meriones unguiculatus* | 17 | 9 |
|  | *Phodopus roborovskii* | 22 | 10 |
| Patagonia | *Abrothrix hirta* | 5 | 8 |
|  | *Abrothrix olivacea* | 13 | 12 |
|  | *Akodon iniscatus* | 9 | 8 |
|  | *Reithrodon auritus* | 7 | 8 |
| Western Siberia | *Apodemus agrarius* | 15 | 11 |
|  | *Craseomys rufocanus* | 18 | 12 |
|  | *Microtus agrestis* | 18 | 13 |
|  | *Microtus gregalis* | 17 | 13 |
|  | *Microtus oeconomus* | 30 | 17 |
|  | *Myodes glareolus* | 22 | 16 |
|  | *Myodes rutilus* | 42 | 23 |
|  | *Sorex araneus* | 29 | 12 |
|  | *Sorex tundrensis* | 10 | 9 |
| Slovakia | *Apodemus flavicollis* | 13 | 12 |
|  | *Microtus arvalis* | 10 | 8 |
|  | *Microtus subterraneus* | 11 | 8 |
|  | *Myodes glareolus* | 13 | 13 |
| South Africa | *Micaelamys namaquensis* | 5 | 9 |
|  | *Rhabdomys pumilio* | 36 | 15 |
| Tanzania | *Grammomys ibeanus* | 10 | 12 |
|  | *Grammomys macmillani* | 7 | 8 |
|  | *Lophuromys kilonzoi* | 10 | 14 |
|  | *Mastomys natalensis* | 11 | 9 |
|  | *Praomys delectorum* | 10 | 12 |

**Table S3.** Host species used in the analyses at the scale of flea infracommunities.

|  |  |  |  |
| --- | --- | --- | --- |
| Region | Host species | Number of host individuals | Flea species richness |
| Mongolia | *Allactaga sibirica* | 10 | 7 |
|  | *Allocricetulus curtatus* | 5 | 8 |
|  | *Dipus sagitta* | 11 | 6 |
|  | *Meriones meridianus* | 12 | 8 |
|  | *Meriones unguiculatus* | 9 | 6 |
|  | *Phodopus roborovskii* | 16 | 10 |
| Patagonia | *Abrothrix olivacea* | 16 | 9 |
|  | *Akodon iniscatus* | 17 | 7 |
|  | *Reithrodon auritus* | 22 | 10 |
| Western Siberia | *Apodemus agrarius* | 12 | 8 |
|  | *Craseomys rufocanus* | 82 | 12 |
|  | *Microtus agrestis* | 33 | 9 |
|  | *Microtus gregalis* | 44 | 9 |
|  | *Microtus oeconomus* | 84 | 13 |
|  | *Myodes glareolus* | 23 | 10 |
|  | *Myodes rutilus* | 124 | 13 |
|  | *Sorex araneus* | 113 | 10 |
| Slovakia | *Apodemus flavicollis* | 199 | 9 |
|  | *Myodes glareolus* | 37 | 7 |
| South Africa | *Micaelamys namaquensis* | 18 | 6 |
|  | *Rhabdomys pumilio* | 33 | 6 |
| Tanzania | *Grammomys ibeanus* | 9 | 6 |
|  | *Lophuromys kilonzoi* | 25 | 11 |
|  | *Mastomys natalensis* | 24 | 6 |
|  | *Praomys delectorum* | 32 | 8 |

**Table S4.** Congruence between functional (F) and co-occurrence (Co) networks of component flea communities in 31 host species from six regions. M: modularity value, WS/BS: average within- and between-module similarity (for functional networks), Modules: number of detected modules, *DgM*: index of congruence (see text for explanation). *p*: proportion of *DgM* values from null models that are lower than the observed *DgM*; Process: the most likely process affecting community assembly inferred from comparison of the observed and null *DgM* values (HF: host-associated filtering, LS: limiting similarity, S: stochastic).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Host | Network | M | WS/BS | Modules | *DgM* | *p* | Process |
| *Allactaga bullata* | F |  | 0.75/0.63 | 5 |  |  |  |
|  | Co | 0.19 |  | 4 | 0.92 | 0.69 | S |
| *Allactaga sibirica* | F |  | 0.72/0.64 | 6 |  |  |  |
|  | Co | 0.19 |  | 4 | 0.88 | 0.52 | S |
| *Allocricetulus curtatus* | F |  | 0.75/0.63 | 5 |  |  |  |
|  | Co | 0.01 |  | 3 | 0.99 | 0.99 | LS |
| *Dipus sagitta* | F |  | 0.78/0.54 | 4 |  |  |  |
|  | Co | 0.25 |  | 3 | 0.85 | 0.75 | S |
| *Meriones meridianus* | F |  | 0.69/0.58 | 5 |  |  |  |
|  | Co | 0.01 |  | 2 | 0.85 | 0.30 | S |
| *Meriones unguiculatus* | F |  | 0.63/0.59 | 3 |  |  |  |
|  | Co | 0.13 |  | 3 | 0.16 | 0.04 | EF |
| *Phodopus roborovskii* | F |  | 0.75/0.63 | 4 |  |  |  |
|  | Co | 0.1 |  | 3 | 0.84 | 0.48 | S |
| *Abrothrix hirta* | F |  | 0.71/0.55 | 3 |  |  |  |
|  | Co | 0.12 |  | 2 | 0.73 | 0.32 | S |
| *Abrothrix olivacea* | F |  | 0.74/0.63 | 3 |  |  |  |
|  | Co | 0.07 |  | 3 | 0.63 | 0.22 | S |
| *Akodon iniscatus* | F |  | 0.85/0.58 | 4 |  |  |  |
|  | Co | 0.14 |  | 2 | 0.99 | 0.99 | LS |
| *Reithrodon auritus* | F |  | 0.77/0.56 | 5 |  |  |  |
|  | Co | 0.07 |  | 2 | 0.92 | 0.98 | LS |
| *Apodemus agrarius* | F |  | 0.72/0.60 | 4 |  |  |  |
|  | Co | 0.13 |  | 3 | 0.78 | 0.18 | S |
| *Craseomys rufocanus* | F |  | 0.73/0.61 | 5 |  |  |  |
|  | Co | 0.11 |  | 3 | 0.97 | 0.99 | LS |
| *Microtus agrestis* | F |  | 0.74/0.67 | 4 |  |  |  |
|  | Co | 0.09 |  | 3 | 0.97 | 0.98 | LS |
| *Microtus gregalis* | F |  | 0.73/0.65 | 4 |  |  |  |
|  | Co | 0.16 |  | 3 | 0.55 | 0.02 | EF |
| *Microtus oeconomus* | F |  | 0.76/0.69 | 8 |  |  |  |
|  | Co | 0.12 |  | 4 | 0.86 | 0.12 | S |
| *Myodes glareolus* (Siberia) | F |  | 0.75/0.69 | 4 |  |  |  |
|  | Co | 0.09 |  | 4 | 0.96 | 0.25 | S |
| *Myodes rutilus* | F |  | 0.76/0.69 | 6 |  |  |  |
|  | Co | 0.12 |  | 4 | 0.97 | 0.90 | S |
| *Sorex araneus* | F |  | 0.69/0.65 | 5 |  |  |  |
|  | Co | 0.09 |  | 2 | 0.83 | 0.07 | S |
| *Sorex tundrensis* | F |  | 0.72/0.69 | 4 |  |  |  |
|  | Co | 0.17 |  | 2 | 0.82 | 0.99 | LS |
| *Apodemus flavicollis* | F |  | 0.77/0.67 | 6 |  |  |  |
|  | Co | 0.02 |  | 3 | 0.57 | 0.03 | EF |
| *Microtus arvalis* | F |  | 0.88/0.68 | 3 |  |  |  |
|  | Co | 0.07 |  | 2 | 0.90 | 0.99 | LS |
| *Microtus subterraneus* | F |  | 0.95/0.63 | 4 |  |  |  |
|  | Co | 0.1 |  | 2 | 0.46 | 0.02 | EF |
| *Myodes glareolus* (Slovakia) | F |  | 0.85/0.71 | 5 |  |  |  |
|  | Co | 0.08 |  | 3 | 0.69 | 0.25 | S |
| *Micaelamys namaquensis* | F |  | 0.67/0.55 | 2 |  |  |  |
|  | Co | 0.22 |  | 2 | 0.55 | 0.98 | LS |
| *Rhabdomys pumilio* | F |  | 0.62/0.50 | 4 |  |  |  |
|  | Co | 0.20 |  | 4 | 0.33 | 0.35 | S |
| *Grammomys ibeanus* | F |  | 0.82/0.61 | 5 |  |  |  |
|  | Co | 0.28 |  | 3 | 0.85 | 0.55 | S |
| *Grammomys macmillani* | F |  | 0.69/0.58 | 4 |  |  |  |
|  | Co | 0.18 |  | 3 | 0.99 | 0.99 | LS |
| *Lophuromys kilonzoi* | F |  | 0.75/0.62 | 5 |  |  |  |
|  | Co | 0.15 |  | 2 | 0.75 | 0.12 | S |
| *Mastomys natalensis* | F |  | 0.80/0.59 | 5 |  |  |  |
|  | Co | 0.19 |  | 3 | 0.94 | 0.52 | S |
| *Praomys delectorum* | F |  | 0.82/0.64 | 4 |  |  |  |
|  | Co | 0.03 |  | 3 | 0.65 | 0.12 | S |

**Table S5.** Congruence between functional (F) and co-occurrence (Co) networks of flea infracommunities in 25 host species from six regions. M: modularity value, WS/BS: average within- and between-module similarity (for functional networks), Modules: number of detected modules, *DgM*: index of congruence (see text for explanation). *p*: proportion of *DgM* values from null models that are lower than the observed *DgM*; Process: the most likely process affecting community assembly inferred from comparison of the observed and null *DgM* values (EF: environmental filtering, LS: limiting similarity, S: stochastic).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Host | Network | M | WS/BS | Modules | *DgM* | *p* | Process |
| *Allocricetulus curtatus* | F |  | 0.87/0.70 | 5 |  |  |  |
|  | Co | 0.23 |  | 2 | 0.95 | 0.99 | LS |
| *Allactaga sibirica* | F |  | 0.98/0.77 | 4 |  |  |  |
|  | Co | 0.33 |  | 3 | 0.99 | 0.99 | LS |
| *Dipus sagitta* | F |  | 0.77/0.40 | 2 |  |  |  |
|  | Co | 0.04 |  | 3 | 0.66 | 0.99 | LS |
| *Meriones meridianus* | F |  | 0.65/0.56 | 4 |  |  |  |
|  | Co | 0.11 |  | 3 | 0.77 | 0.18 | S |
| *Meriones unguiculatus* | F |  | 0.75/0.46 | 2 |  |  |  |
|  | Co | 0.22 |  | 2 | 0.83 | 0.99 | LS |
| *Phodopus roborovskii* | F |  | 0.75/0.62 | 4 |  |  |  |
|  | Co | 0.35 |  | 3 | 0.93 | 0.70 | S |
| *Abrothrix olivacea* | F |  | 0.76/0.63 | 3 |  |  |  |
|  | Co | 0.08 |  | 3 | 0.80 | 0.47 | S |
| *Akodon iniscatus* | F |  | 0.85/0.61 | 4 |  |  |  |
|  | Co | 0.18 |  | 3 | 0.66 | 0.08 | S |
| *Reithrodon auritus* | F |  | 0.77/0.56 | 5 |  |  |  |
|  | Co | 0.15 |  | 3 | 0.94 | 0.98 | LS |
| *Apodemus agrarius* | F |  | 0.84/0.56 | 2 |  |  |  |
|  | Co | 0.28 |  | 3 | 0.77 | 0.98 | LS |
| *Craseomys rufocanus* | F |  | 0.73/0.61 | 5 |  |  |  |
|  | Co | 0.09 |  | 5 | 0.80 | 0.25 | S |
| *Microtus agrestis* | F |  | 0.70/0.65 | 4 |  |  |  |
|  | Co | 0.07 |  | 2 | 0.80 | 0.08 | S |
| *Microtus gregalis* | F |  | 0.75/0.67 | 4 |  |  |  |
|  | Co | 0.27 |  | 3 | 0.99 | 0.99 | LS |
| *Microtus oeconomus* | F |  | 0.71/0.61 | 6 |  |  |  |
|  | Co | 0.10 |  | 3 | 0.75 | 0.01 | HF |
| *Myodes glareolus* (Siberia) | F |  | 0.68/0.62 | 4 |  |  |  |
|  | Co | 0.35 |  | 4 | 0.37 | 0.15 | S |
| *Myodes rutilus* | F |  | 0.72/0.62 | 2 |  |  |  |
|  | Co | 0.06 |  | 3 | 0.64 | 0.99 | LS |
| *Sorex araneus* | F |  | 0.67/0.59 | 4 |  |  |  |
|  | Co | 0.11 |  | 3 | 0.77 | 0.02 | HF |
| *Apodemus flavicollis* | F |  | 0.67/0.59 | 5 |  |  |  |
|  | Co | 0.30 |  | 3 | 0.72 | 0.15 | S |
| *Myodes glareolus* (Slovakia) | F |  | 0.85/0.72 | 4 |  |  |  |
|  | Co | 0.29 |  | 3 | 0.99 | 0.99 | LS |
| *Micaelamys namaquensis* | F |  | 0.68/0.50 | 2 |  |  |  |
|  | Co | 0.24 |  | 2 | 0.75 | 0.98 | LS |
| *Rhabdomys pumilio* | F |  | 0.64/0.58 | 2 |  |  |  |
|  | Co | 0.04 |  | 2 | 0.99 | 0.99 | LS |
| *Grammomys ibeanus* | F |  | 0.79/0.67 | 4 |  |  |  |
|  | Co | 0.42 |  | 3 | 0.99 | 0.99 | LS |
| *Lophuromys kilonzoi* | F |  | 0.76/0.65 | 4 |  |  |  |
|  | Co | 0.46 |  | 4 | 0.42 | 0.02 | HF |
| *Mastomys natalensis* | F |  | 0.62/0.51 | 2 |  |  |  |
|  | Co | 0.01 |  | 2 | 0.66 | 0.99 | LS |
| *Praomys delectorum* | F |  | 0.62/0.51 | 4 |  |  |  |
|  | Co | 0.24 |  | 3 | 0.94 | 0.42 | S |

**Appendix 2. Scheme of constructing presence/absence matrices of flea-host interactions for different hierarchical scales**

1. Compound communities at the scale of a biogeographic realm

1a. Flea distribution among regions (within a biogeographic realm)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Region 1 | Region 2 | Region 3 |
| Flea species 1 |  |  |  |
| Flea species 2 |  |  |  |
| Flea species 3 |  |  |  |

1b. Fleas distribution among host species (within a biogeographic realm)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Host species 1 | Host species 2 | Host species 3 |
| Flea species 1 |  |  |  |
| Flea species 2 |  |  |  |
| Flea species 3 |  |  |  |

2. Compound communities at a regional scale

2a. Flea distribution among sampling sites (within a region)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Site 1 | Site 2 | Site 3 |
| Flea species 1 |  |  |  |
| Flea species 2 |  |  |  |
| Flea species 3 |  |  |  |

2b. Fleas distribution among host species (within a region)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Host species 1 | Host species 2 | Host species 3 |
| Flea species 1 |  |  |  |
| Flea species 2 |  |  |  |
| Flea species 3 |  |  |  |

3. Component communities

Distribution of flea species harboured by the same host species among sampling sites (within a region)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Site 1 | Site 2 | Site 3 |
| Flea species 1 |  |  |  |
| Flea species 2 |  |  |  |
| Flea species 3 |  |  |  |

4. Infracommunities

Distribution of flea species harboured by the same host species at the same sampling site

|  |  |  |  |
| --- | --- | --- | --- |
|  | Host individual 1 | Host individual 2 | Host individual 3 |
| Flea species 1 |  |  |  |
| Flea species 2 |  |  |  |
| Flea species 3 |  |  |  |

**Appendix 3. Supplementary figures.**

**Fig. S1.** Modules based on trait similarity and spatial (across localities) co-occurrence similarity for component communities of fleas harboured by *Abrothrix olivacea* in Patagonia. The number inside or near the circle is the number of species in the module. In trait-associated modules, the number in parentheses is average within-module similarity (above line) and between-module similarity (below line) between pairs of species. Edge width is proportional to average similarity between species belonging to the modules.



**Fig. S2.** Modules based on trait similarity and similarity of co-occurrence across host individuals for infracommunities of fleas harboured by *Lophuromys kilonzoi* in Grewal (Gologolo, Tanzania). The number inside or near the circle is the number of species in the module. In trait-associated modules, the number in parentheses is average within-module similarity (above line) and between-module similarity (below line) between pairs of species. Edge width is proportional to average similarity between species belonging to the modules.

