***Supplementary Material***

**TABLE S1** Topological properties of the empirical molecular ecological networks (MENs) of additional microbial communities and their associated random MENs

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Empirical networks** | | | | | | |  | **Random networks** | | |
| **Threshold** | **Total nodes &  (links)** | **Links  interaction negative/ positive** | **Average Connectivity (avgK)** | **Average  clustering  coefficient  (*avgCC*)** | **Average  path  distance  (GD)** | **Modularity & (the number of modules)** |  | **Average  clustering  coefficient  (*avgCC*)** | **Average path  distance  (GD)** | **Modularity (M)** |
| C | 0.97 | 109 (1067) | 37/1030 | 19.58 | 0.597a | 2.235a | 0.286 (4)a |  | 0.418 ± 0.012 | 1.992 ± 0.011 | 0.127 ± 0.006 |
| P | 0.97 | 157 (1054) | 105/949 | 13.43 | 0.576a | 2.747a\* | 0.482 (6)a\* | | 0.194 ± 0.011 | 2.303 ± 0.012 | 0.195 ± 0.005 |
| OP | 0.97 | 204 (937) | 247/690 | 12.19 | 0.620a\* | 5.381a\* | 0.704 (8)a\* | | 0.070 ± 0.006 | 2.672 ± 0.016 | 0.275 ± 0.007 |
| TP | 0.97 | 89 (1014) | 27/987 | 22.79 | 0.707a\* | 2.418a\* | 0.158 (4)a\* | | 0.616 ± 0.020 | 1.930 ± 0.022 | 0.086 ± 0.005 |

Notes: \* stands for the values are significantly different from that in the control at *P* < 0.001 within the same column.

a stands for the values in empirical networks are significantly different from that in random networks at *P* < 0.001.

C (control): basal diet; P: basal diet supplementation with 0.5% PHB; OP: basal diet supplementation with 1% PHB; TP: basal diet supplementation with 3% PHB.

**TABLE S2** The composition of the ecological network of sea cucumber intestinal microbiota in the C, P, OP and TP treatments

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Index** | **C** | **P** | **OP** | **TP** | **Index** | **C** | **P** | **OP** | **TP** |
| 67-14 | 1 | 1 | 1 | 0 | Corynebacteriaceae | 0 | 1 | 1 | 0 |
| Aerococcaceae | 1 | 1 | 1 | 1 | Defluviitaleaceae | 0 | 1 | 0 | 0 |
| Arcobacteraceae | 1 | 1 | 0 | 1 | Granulosicoccaceae | 0 | 1 | 2 | 0 |
| Bacillaceae | 4 | 9 | 7 | 1 | Kineosporiaceae | 0 | 1 | 0 | 0 |
| Bdellovibrionaceae | 1 | 0 | 1 | 0 | Legionellaceae | 0 | 2 | 5 | 0 |
| Bogoriellaceae | 1 | 0 | 1 | 0 | Methyloligellaceae | 0 | 1 | 2 | 1 |
| Brevibacillaceae | 1 | 1 | 1 | 1 | Parachlamydiaceae | 0 | 1 | 0 | 0 |
| Brevibacteriaceae | 1 | 2 | 2 | 1 | Peptostreptococcaceae | 0 | 1 | 1 | 0 |
| Burkholderiaceae | 4 | 2 | 5 | 1 | Pseudoalteromonadaceae | 0 | 1 | 1 | 1 |
| Criblamydiaceae | 1 | 1 | 1 | 1 | Rhizobiales\_Incertae\_Sedis | 0 | 1 | 1 | 1 |
| Cryomorphaceae | 1 | 0 | 0 | 0 | Sanguibacteraceae | 0 | 1 | 1 | 1 |
| Dermabacteraceae | 1 | 1 | 1 | 1 | Streptococcaceae | 0 | 1 | 2 | 1 |
| Devosiaceae | 1 | 0 | 1 | 0 | Thermoactinomycetaceae | 0 | 1 | 1 | 0 |
| Dietziaceae | 2 | 2 | 2 | 2 | Vagococcaceae | 0 | 1 | 1 | 0 |
| Exiguobacteraceae | 2 | 2 | 2 | 2 | Beggiatoaceae | 0 | 0 | 1 | 0 |
| Flavobacteriaceae | 4 | 6 | 5 | 3 | Caulobacteraceae | 0 | 0 | 1 | 0 |
| Geodermatophilaceae | 2 | 2 | 3 | 2 | Colwelliaceae | 0 | 0 | 1 | 0 |
| Halomonadaceae | 2 | 1 | 1 | 1 | Comamonadaceae | 0 | 0 | 1 | 0 |
| Hyphomicrobiaceae | 1 | 3 | 5 | 2 | Coxiellaceae | 0 | 0 | 1 | 0 |
| Iamiaceae | 1 | 1 | 2 | 0 | Lachnospiraceae | 0 | 0 | 1 | 0 |
| Intrasporangiaceae | 4 | 4 | 3 | 3 | Leuconostocaceae | 0 | 0 | 1 | 0 |
| JG30-KF-CM45 | 2 | 4 | 3 | 0 | Limnochordaceae | 0 | 0 | 1 | 0 |
| Jonesiaceae | 1 | 1 | 1 | 0 | Propionibacteriaceae | 0 | 0 | 1 | 0 |
| Marinococcaceae | 1 | 2 | 2 | 1 | Rhodobiaceae | 0 | 0 | 1 | 1 |
| Microbacteriaceae | 3 | 3 | 3 | 2 | Stappiaceae | 0 | 0 | 1 | 0 |
| Microbulbiferaceae | 2 | 2 | 3 | 1 | Vermiphilaceae | 0 | 0 | 1 | 0 |
| Micrococcaceae | 3 | 3 | 1 | 2 | Weeksellaceae | 0 | 0 | 1 | 0 |
| Micromonosporaceae | 3 | 2 | 3 | 1 | Woeseiaceae | 0 | 0 | 1 | 0 |
| Microtrichaceae | 2 | 2 | 1 | 1 | Enterococcaceae | 0 | 0 | 0 | 1 |
| Moraxellaceae | 1 | 5 | 4 | 4 | norank\_o\_\_Babeliales | 1 | 1 | 1 | 1 |
| Mycobacteriaceae | 2 | 2 | 3 | 2 | norank\_o\_\_Chloroplast | 1 | 2 | 1 | 2 |
| Nocardiaceae | 3 | 2 | 3 | 1 | norank\_o\_\_Frankiales | 1 | 0 | 0 | 0 |
| Nocardioidaceae | 5 | 4 | 6 | 0 | norank\_o\_\_Gaiellales | 1 | 1 | 2 | 1 |
| Nocardiopsaceae | 1 | 1 | 1 | 1 | norank\_o\_\_norank\_c\_\_Gammaproteobacteria | 2 | 1 | 3 | 2 |
| Paenibacillaceae | 3 | 3 | 6 | 1 | norank\_o\_\_Microtrichales | 0 | 1 | 1 | 0 |
| Planococcaceae | 3 | 4 | 4 | 2 | norank\_o\_\_norank\_c\_\_KD4-96 | 0 | 1 | 2 | 0 |
| Promicromonosporaceae | 1 | 1 | 1 | 1 | norank\_o\_\_Peptostreptococcales-Tissierellales | 0 | 1 | 1 | 0 |
| Pseudonocardiaceae | 1 | 3 | 3 | 1 | norank\_o\_\_Saccharimonadales | 0 | 1 | 1 | 0 |
| Psychromonadaceae | 1 | 2 | 1 | 1 | norank\_o\_\_norank\_c\_\_Limnochordia | 0 | 0 | 1 | 0 |
| Rhizobiaceae | 4 | 4 | 6 | 2 | norank\_o\_\_PeM15 | 0 | 0 | 1 | 0 |
| Rhodobacteraceae | 12 | 16 | 16 | 15 | norank\_o\_\_Syntrophobacterales | 0 | 0 | 1 | 0 |
| Rubritaleaceae | 3 | 2 | 6 | 3 | unclassified\_o\_\_Chlamydiales | 3 | 2 | 4 | 2 |
| Sphingomonadaceae | 1 | 2 | 1 | 1 | unclassified\_o\_\_Micrococcales | 1 | 1 | 1 | 0 |
| Staphylococcaceae | 1 | 4 | 4 | 2 | unclassified\_c\_\_Alphaproteobacteria | 0 | 1 | 1 | 1 |
| Streptomycetaceae | 2 | 4 | 4 | 1 | unclassified\_c\_\_Gammaproteobacteria | 0 | 1 | 5 | 2 |
| Vibrionaceae | 1 | 2 | 2 | 1 | unclassified\_o\_\_Rhizobiales | 0 | 1 | 1 | 0 |
| Alicyclobacillaceae | 0 | 1 | 2 | 0 | unclassified\_o\_\_Alphaproteobacteria\_Incertae\_Sedis | 0 | 0 | 1 | 0 |
| Beijerinckiaceae | 0 | 2 | 1 | 1 | unclassified\_o\_\_Babeliales | 0 | 0 | 1 | 0 |
| Carnobacteriaceae | 0 | 1 | 3 | 0 | unclassified\_o\_\_Gammaproteobacteria\_Incertae\_Sedis | 0 | 0 | 1 | 0 |
| Clostridiaceae | 0 | 1 | 2 | 1 |  |  |  |  |  |

Notes: C (control): basal diet; P: basal diet supplementation with 0.5% PHB; OP: basal diet supplementation with 1% PHB; TP: basal diet supplementation with 3% PHB.

**TABLE S3** Topological roles of intestinal microbiota

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatment** | **Topological roles** | **OTUs** | **Module number** | **Phylogenetic associations** |
| C | Connectors | OTU2110 | C1 | Rhodobacteraceae |
| Connectors | OTU2338 | C4 | Halomonadaceae |
| Connectors | OTU2412 | C2 | Dermabacteraceae |
| Connectors | OTU2758 | C1 | Arcobacteraceae |
| P | Connectors | OTU1690 | P1 | JG30-KF-CM45 |
| Connectors | OTU1728 | P2 | Intrasporangiaceae |
| Connectors | OTU1935 | P2 | Rhizobiales\_Incertae\_Sedis |
| Connectors | OTU1939 | P1 | Micrococcaceae |
| Connectors | OTU2011 | P1 | Rhodobacteraceae |
| Connectors | OTU2104 | P1 | JG30-KF-CM45 |
| Connectors | OTU2369 | P1 | Halomonadaceae |
| Connectors | OTU2447 | P2 | unclassified\_o\_Rhizobiales |
| Connectors | OTU2672 | P1 | Sphingomonadaceae |
| Connectors | OTU516 | P3 | Nocardioidaceae |
| Module hubs | OTU2252 | P1 | Iamiaceae |
| Network hubs | OTU1924 | P2 | Iamiaceae |
| OP | Connectors | OTU2005 | OP3 | Moraxellaceae |
| Connectors | OTU2325 | OP6 | Colwelliaceae |
| Module hubs | OTU2558 | OP5 | Psychromonadaceae |
| TP | Connectors | OTU1603 | TP1 | Bacillaceae |
| Connectors | OTU1900 | TP1 | Micrococcaceae |
| Connectors | OTU2339 | TP1 | Moraxellaceae |
| Connectors | OTU2365 | TP3 | Pseudoalteromonadaceae |
| Connectors | OTU2758 | TP1 | Arcobacteraceae |
| Module hubs | OTU2362 | TP1 | Rhodobacteraceae |

Notes: C (control): basal diet; P: basal diet supplementation with 0.5% PHB; OP: basal diet supplementation with 1% PHB; TP: basal diet supplementation with 3% PHB.