**Metabarcoding of the bacterial assemblages associated with *Toxopneustes roseus* in the Mexican Central Pacific**

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**Supplementary material**

**Table S1.** Environmental variables were used as predictors to evaluate the relationship with the bacterial assemblage of *T. roseus* at the spatial and spatio-temporal models. We included all variables recorded in the study, such as variables with multicollinearity, variables considered for the canonical redundancy analysis (RDA,) and variables selected in the final RDA models. Codes: SST: Sea surface temperature; Salt: Salinity; DO: Dissolved oxygen; CEL: Light extinction coefficient; Clα: Chlorophyll-α; ColiTotal: Total coliforms; ColiFec; Fecal coliforms; Lat: Latitude; Lon: Longitude; Prof: Depth; TIC: Topographic complexity index; CCV: Live coral cover; CH: hydrocoral cover; CHZ: Hydrozoan cover; COct: Octocoral cover; CEsp: Sponge cover; CMacro: Macroalgae Cover; CTurf: Coverage of filamentous algae (grass); CACC: Cover of crusty coralline algae; POOP; Articulated calcareous algae cover; VOC: Vagile organism coverage; COS: Coverage of sessile organisms; CSA: Sandy substrate cover; CEsc: Debris Cover; RSE: Coverage of rocky substrate; Others: Coverage of others; CCMR: Coral cover with recent death; CBC: Coral bleaching coverage.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| Recorded Variables | Collinear Variables | Tested Variables RDA Analysis | Variables Final RDA Model |
|  |  |  |  |
|  |  | | |
| TSM | Spatial model | | |
| Salt | CEL | CEL | Prof |
| OD | PO4 | ColiFec | CCV |
| CEL | Lat | PO4 | CEsp |
| Clα | Prof | Lat | CSA |
| ColiTotal | CCV | Prof |  |
| ColiFec | CEsp | CCV |  |
| NO3+NO2 | CACC | CEsp |  |
| NH4 | CACA | CACC |  |
| PO4 | CSA | CACA |  |
| SiO2 | CEsc | CSA |  |
| Lat |  | CEsc |  |
| Lon |  |  |  |
| Prof | Spatial-temporal model | | |
| ICT | CEL | TSM | TSM |
| CCV | ColiTotal | Sal | Sal |
| CH | ColiFec | OD | OD |
| CHZ | NH4 | CEL | CEL |
| COct | PO4 | Clα | ColiFec |
| CEsp | SiO2 | ColiFec | CEsp |
| CMacro | Prof | NH4 | CMacro |
| CTurf | CCV | PO4 | CSA |
| CACC | COct | Prof |  |
| CACA | CTurf | CCV |  |
| COV | CSR | COct |  |
| COS |  | CEsp |  |
| CSA |  | CMacro |  |
| CEsc |  | CTurf |  |
| CSR |  | CACC |  |
| Otros |  | CSA |  |
| CCMR |  | CEsc |  |
| CBC |  | CSR |  |
|  |  |  |  |

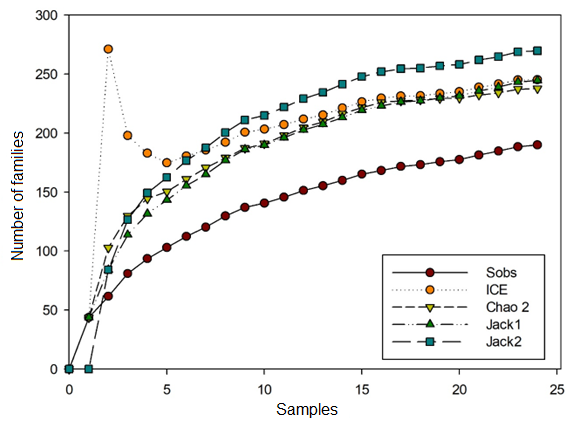
Note: For subsequent analyzes at the spatial level (multicollinearity and RDA models), only environmental variables that presented significant differences between the study sites and that were potentially related to the bacterial assembly of *T. roseus* were used.

**Table S2.** Results of the three-way PERMANOVA with crossed factors for the alpha (N, 0D, 1D, 2D, 21D) and beta (family composition and abundance) diversity of the bacterial assemblage associated with the sea urchin *T. roseus*. Codes: C.V.% = Coefficient of explained variation in percentage. Values in bold correspond to significant differences (P ≤ 0.05).

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| Factors | Pseudo-*F* | *P*-value | C.V.% |
|  |  |  |  |
|  |  |  |  |
| Alpha diversity |  |  |  |
| Site | 2.2408 | 0.1311 | 32.2 |
| Season | 0.3089 | 0.7644 | 0.0 |
| Year | 1.3691 | 0.2767 | 10.1 |
| Site\*Season | 0.4200 | 0.9144 | 0.0 |
| Site\*Season | 0.2318 | 0.9902 | 0.0 |
| Season\*Year | 0.5434 | 0.6259 | 0.0 |
| Residuals |  |  | 57.7 |
|  |  |  |  |
| Beta diversity |  |  |  |
| Site | 1.9401 | 0.0691 | 15.7 |
| Season | 1.5836 | 0.1999 | 7.1 |
| Year | 2.7850 | 0.0605 | 12.5 |
| Site\*Season | 1.1568 | 0.3345 | 9.0 |
| Site\*Season | 1.4787 | 0.1437 | 15.8 |
| Season\*Year | 1.3302 | 0.2825 | 7.6 |
| Residuals |  |  | 32.3 |
|  |  |  |  |

**Table S3.** Total observed and expected richness of bacterial families from the non-parametric estimators ICE, Chao 2, Jackknife 1 and Jackknife 2, with their respective percentage of representativeness according to all the sites and times studied. The average of the expected wealth and percentage of representativeness of the non-parametric estimators is included in the table.

|  |  |  |
| --- | --- | --- |
|  |  |  |
| Estimator / Average | Observed richness / Expected | Representativeness % |
|  |  |  |
|  |  |  |
| Observed richness | 190 | – |
| ICE | 245.3 | 77.5 |
| Chao 2 | 244.6 | 77.7 |
| Jackknife 1 | 269.7 | 70.5 |
| Jackknife 2 | 245.3 | 77.5 |
| Average | 296.9 | 76.4 |
|  |  |  |



**Figure S1.** Rarefaction curves based on samples from the entire sampling effort (all sites and times studied). The figure compares the observed (Sobs) and expected richness of the non-parametric estimators (ICE, Chao 2, Jacknife 1, Jacknife 2) of the bacterial families associated with the sea urchin *T. roseus*.

**Table S4.** A posteriori tests of the Site factor of the PERMANOVA models of the alpha and beta diversity of the bacterial assemblage associated with the sea urchin *T. roseus*, as well as the environmental variables. Values in bold correspond to significant differences (P ≤ 0.05). Codes: MC: Monte Carlo tests; PNII: Isla Isabel National Park; PNIM: Islas Marietas National Park; BCH: Islas e islotes de Bahía Chamela Sanctuary; CUM: Bahía Cuastecomates-Punta Melaque; CRZ: Carrizales; PB: Punto B.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| Groups | Alpha diversity | Beta diversity | Environmental variables |
| *P*-value | *P*-value | *P*-value (MC) |
|  |  |  |  |
|  |  |  |  |
| PNII, PNIM | 0.0881 | **0.0268** | 0.2927 |
| PNII, BCH | **0.0302** | **0.0275** | 0.2851 |
| PNII, CUM | **0.0348** | **0.0292** | 0.3375 |
| PNII, CRZ | **0.0319** | **0.0284** | 0.1957 |
| PNII, PB | **0.0349** | 0.0590 | 0.3643 |
| PNIM, BCH | 0.4299 | 0.3488 | 0.4321 |
| PNIM, CUM | 0.3959 | 0.9063 | 0.3836 |
| PNIM, CRZ | 0.3930 | 0.5903 | 0.2864 |
| PNIM, PB | 0.3093 | 0.4011 | 0.4635 |
| BCH, CUM | 0.8498 | 0.6364 | 0.4870 |
| BCH, CRZ | 0.5414 | 0.8164 | 0.2834 |
| BCH, PB | 0.7695 | 0.5719 | 0.4582 |
| CUM, CRZ | 0.6870 | 0.9003 | 0.2853 |
| CUM, PB | 0.6764 | 0.5295 | 0.3298 |
| CRZ, PB | 0.6391 | 0.5272 | 0.2794 |
|  |  |  |  |

**Table S5.** Results obtained from the similarity percentage analysis (SIMPER) at a cut-off at 65% of the cumulative contribution to the average dissimilarity. Comparisons of variables (bacterial families) are shown between paired groups of years (2017-2018 and 2018-2019) and sites (PNII: Isla Isabel National Park; PNIM: Islas Marietas National Park; BCH: Islas e islotes de Bahía Chamela Sanctuary; CUM: Bahía Cuastecomates-Punta Melaque; CRZ: Carrizales; PB: Punto B).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | | | | | | |
| Variable | Average value | Average value | Dist.Cua.Prom. | Dist.Cua./DE | Contrib% | Cum.% |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Groups 2017-2018 and 2018-2019 | |  |  |  |  |  |
| Average square distance = 96.88 | | | | | | |
|  | Group 2017-2018 | Group 2018-2019 |  |  |  |  |
| Helicobacteraceae | 6.57 | 4.97 | 19 | 0.89 | 19.56 | 19.56 |
| Desulfovibrionaceae | 0.604 | 2.57 | 11.2 | 0.64 | 11.55 | 31.11 |
| Burkholderiaceae | 1.11 | 1.05 | 8.54 | 0.61 | 8.82 | 39.92 |
| Flavobacteriaceae | 1.37 | 1.83 | 4.4 | 0.57 | 4.54 | 44.46 |
| Spiroplasmataceae | 0.557 | 1.67 | 4.16 | 0.9 | 4.3 | 48.76 |
| Desulfonatronaceae | 8.88E-02 | 1.15 | 3.98 | 0.55 | 4.11 | 52.86 |
| Campylobacteraceae | 2.15 | 1.32 | 3.28 | 0.94 | 3.39 | 56.25 |
| Acholeplasmataceae | 1.45 | 0.603 | 3.15 | 0.65 | 3.25 | 59.5 |
| Vibrionaceae | 1.54 | 1.79 | 2.84 | 0.8 | 2.93 | 62.44 |
| Moraxellaceae | 8.26E-02 | 0.774 | 2.55 | 0.34 | 2.63 | 65.07 |
|  |  |  |  |  |  |  |
| Groups PNII and PNIM | |  |  |  |  |  |
| Average square distance = 123.62 | |  |  |  |  |  |
|  | Group PNII | Group PNIM |  |  |  |  |
| Helicobacteraceae | 1.15 | 7.18 | 37.3 | 3.14 | 30.18 | 30.18 |
| Burkholderiaceae | 1.26 | 1.8 | 13 | 0.7 | 10.48 | 40.66 |
| Flammeovirgaceae | 1.57 | 0.285 | 6.74 | 0.56 | 5.45 | 46.11 |
| Moraxellaceae | 1.65 | 0.181 | 6.7 | 0.57 | 5.42 | 51.53 |
| Saprospiraceae | 1.23 | 2.93E-02 | 5.96 | 0.56 | 4.82 | 56.35 |
| Acholeplasmataceae | 2.11 | 1.16 | 4.56 | 1.17 | 3.69 | 60.04 |
| Campylobacteraceae | 0.81 | 2.27 | 4.19 | 1.01 | 3.39 | 63.43 |
| Spirochaetaceae | 1.58 | 0.118 | 3.69 | 0.9 | 2.98 | 66.41 |
|  |  |  |  |  |  |  |
| Groups PNII and BCH | |  |  |  |  |  |
| Average square distance = 136.46 | |  |  |  |  |  |
|  | Group PNII | Group BCH |  |  |  |  |
| Helicobacteraceae | 1.15 | 6.95 | 36.8 | 1.83 | 26.95 | 26.95 |
| Flammeovirgaceae | 1.57 | 6.78E-02 | 7.32 | 0.57 | 5.36 | 32.31 |
| Acholeplasmataceae | 2.11 | 1.04 | 6.4 | 0.94 | 4.69 | 37 |
| Desulfovibrionaceae | 0.938 | 2.42 | 6.28 | 0.7 | 4.6 | 41.6 |
| Moraxellaceae | 1.65 | 0.553 | 6.04 | 0.57 | 4.43 | 46.03 |
| Saprospiraceae | 1.23 | 8.46E-02 | 5.85 | 0.56 | 4.29 | 50.32 |
| Burkholderiaceae | 1.26 | 0 | 5.58 | 0.56 | 4.09 | 54.41 |
| Campylobacteraceae | 0.81 | 2.27 | 4.19 | 1.15 | 3.07 | 57.47 |
| Spirochaetaceae | 1.58 | 5.95E-02 | 3.86 | 0.91 | 2.83 | 60.3 |
| Oscillospiraceae | 1.23 | 1.22 | 3.86 | 0.79 | 2.83 | 63.13 |
| Vibrionaceae | 2.8 | 1.24 | 3.55 | 0.87 | 2.6 | 65.73 |
|  |  |  |  |  |  |  |
| Groups PNIM and BCH | |  |  |  |  |  |
| Average square distance = 62.09 | |  |  |  |  |  |
|  | Group PNIM | Group BCH |  |  |  |  |
| Burkholderiaceae | 1.8 | 0 | 11.9 | 0.56 | 19.19 | 19.19 |
| Desulfovibrionaceae | 0.353 | 2.42 | 8.49 | 0.75 | 13.67 | 32.87 |
| Oscillospiraceae | 0.329 | 1.22 | 3.96 | 0.57 | 6.38 | 39.25 |
| Helicobacteraceae | 7.18 | 6.95 | 3.29 | 0.79 | 5.3 | 44.55 |
| Spiroplasmataceae | 1.77 | 0.989 | 3.02 | 0.93 | 4.86 | 49.42 |
| Flavobacteriaceae | 1.82 | 1.44 | 2.49 | 0.9 | 4.01 | 53.43 |
| Campylobacteraceae | 2.27 | 2.27 | 2.29 | 0.8 | 3.69 | 57.12 |
| Desulfonatronaceae | 2.36E-02 | 1.17 | 2.17 | 0.81 | 3.49 | 60.62 |
| Sphingobacteriaceae | 1.13 | 0 | 1.71 | 1.18 | 2.75 | 63.37 |
| Planococcaceae | 0.674 | 0.926 | 1.7 | 0.7 | 2.73 | 66.1 |
|  |  |  |  |  |  |  |
| Groups PNII and CUM | |  |  |  |  |  |
| Average square distance = 138.16 | |  |  |  |  |  |
|  | Group PNII | Group CUM |  |  |  |  |
| Helicobacteraceae | 1.15 | 7.42 | 41.7 | 2.17 | 30.21 | 30.21 |
| Burkholderiaceae | 1.26 | 1.54 | 10.8 | 0.73 | 7.84 | 38.05 |
| Flammeovirgaceae | 1.57 | 9.92E-02 | 7.24 | 0.57 | 5.24 | 43.29 |
| Moraxellaceae | 1.65 | 1.69E-02 | 7.18 | 0.58 | 5.2 | 48.49 |
| Saprospiraceae | 1.23 | 0 | 6.03 | 0.56 | 4.37 | 52.86 |
| Acholeplasmataceae | 2.11 | 0.907 | 5.43 | 0.97 | 3.93 | 56.78 |
| Spiroplasmataceae | 0.678 | 1.79 | 5.03 | 0.95 | 3.64 | 60.43 |
| Vibrionaceae | 2.8 | 1.07 | 4.63 | 0.91 | 3.35 | 63.78 |
| Spirochaetaceae | 1.58 | 0.405 | 3.23 | 0.84 | 2.34 | 66.12 |
|  |  |  |  |  |  |  |
| Groups PNIM and CUM | |  |  |  |  |  |
| Average square distance = 51.33 | |  |  |  |  |  |
|  | Group PNIM | Group CUM |  |  |  |  |
| Burkholderiaceae | 1.8 | 1.54 | 15.5 | 0.74 | 30.16 | 30.16 |
| Spiroplasmataceae | 1.77 | 1.79 | 4.47 | 1.06 | 8.71 | 38.88 |
| Desulfovibrionaceae | 0.353 | 1.17 | 3.38 | 0.59 | 6.59 | 45.47 |
| Helicobacteraceae | 7.18 | 7.42 | 2.57 | 0.95 | 5.01 | 50.48 |
| Campylobacteraceae | 2.27 | 1.61 | 2.53 | 0.74 | 4.93 | 55.41 |
| Flavobacteriaceae | 1.82 | 1.38 | 2.15 | 0.89 | 4.2 | 59.61 |
| Vibrionaceae | 1.86 | 1.07 | 1.89 | 0.87 | 3.69 | 63.3 |
| Nostocaceae | 0.974 | 0 | 1.57 | 0.95 | 3.06 | 66.35 |
|  |  |  |  |  |  |  |
| Groups BCH and CUM | |  |  |  |  |  |
| Average square distance = 60.95 | |  |  |  |  |  |
|  | Group BCH | Group CUM |  |  |  |  |
| Burkholderiaceae | 0 | 1.54 | 9.14 | 0.56 | 14.99 | 14.99 |
| Desulfovibrionaceae | 2.42 | 1.17 | 7.92 | 0.78 | 13 | 27.99 |
| Spiroplasmataceae | 0.989 | 1.79 | 5.07 | 0.97 | 8.32 | 36.31 |
| Helicobacteraceae | 6.95 | 7.42 | 4.98 | 0.77 | 8.17 | 44.47 |
| Oscillospiraceae | 1.22 | 0.519 | 3.71 | 0.59 | 6.09 | 50.56 |
| Campylobacteraceae | 2.27 | 1.61 | 2.53 | 0.79 | 4.15 | 54.71 |
| Flavobacteriaceae | 1.44 | 1.38 | 2.45 | 0.9 | 4.02 | 58.74 |
| Planococcaceae | 0.926 | 0.918 | 2.32 | 0.82 | 3.8 | 62.54 |
| Acholeplasmataceae | 1.04 | 0.907 | 2 | 0.78 | 3.27 | 65.81 |
|  |  |  |  |  |  |  |
| Groups PNII and CRZ | |  |  |  |  |  |
| Average square distance = 145.12 | |  |  |  |  |  |
|  | Group PNII | Group CRZ |  |  |  |  |
| Helicobacteraceae | 1.15 | 6.78 | 41.2 | 1.47 | 28.41 | 28.41 |
| Desulfovibrionaceae | 0.938 | 2.01 | 8.96 | 0.6 | 6.18 | 34.58 |
| Moraxellaceae | 1.65 | 1.75E-02 | 7.18 | 0.58 | 4.95 | 39.53 |
| Burkholderiaceae | 1.26 | 1.72 | 7.15 | 0.91 | 4.92 | 44.45 |
| Flammeovirgaceae | 1.57 | 0.365 | 6.79 | 0.57 | 4.68 | 49.13 |
| Acholeplasmataceae | 2.11 | 0.735 | 6.16 | 0.93 | 4.25 | 53.38 |
| Saprospiraceae | 1.23 | 1.79E-02 | 5.99 | 0.56 | 4.13 | 57.51 |
| Desulfonatronaceae | 2.56E-02 | 1.15 | 5.22 | 0.56 | 3.6 | 61.1 |
| Vibrionaceae | 2.8 | 1.61 | 4.73 | 0.97 | 3.26 | 64.36 |
| Spirochaetaceae | 1.58 | 0.159 | 3.58 | 0.89 | 2.47 | 66.83 |
|  |  |  |  |  |  |  |
| Groups PNIM and CRZ | |  |  |  |  |  |
| Average square distance = 66.16 | |  |  |  |  |  |
|  | Group PNIM | Group CRZ |  |  |  |  |
| Burkholderiaceae | 1.8 | 1.72 | 11.6 | 0.77 | 17.56 | 17.56 |
| Desulfovibrionaceae | 0.353 | 2.01 | 10.7 | 0.59 | 16.15 | 33.7 |
| Helicobacteraceae | 7.18 | 6.78 | 9.83 | 0.73 | 14.85 | 48.56 |
| Desulfonatronaceae | 2.36E-02 | 1.15 | 5.22 | 0.56 | 7.89 | 56.45 |
| Spiroplasmataceae | 1.77 | 1.27 | 3.81 | 0.95 | 5.76 | 62.21 |
| Vibrionaceae | 1.86 | 1.61 | 3.02 | 1.06 | 4.56 | 66.78 |
|  |  |  |  |  |  |  |
| Groups BCH and CRZ | |  |  |  |  |  |
| Average square distance = 68.92 | |  |  |  |  |  |
|  | Group BCH | Group CRZ |  |  |  |  |
| Helicobacteraceae | 6.95 | 6.78 | 11.9 | 0.77 | 17.31 | 17.31 |
| Desulfovibrionaceae | 2.42 | 2.01 | 11.7 | 0.84 | 17.04 | 34.35 |
| Burkholderiaceae | 0 | 1.72 | 5.89 | 0.97 | 8.54 | 42.89 |
| Desulfonatronaceae | 1.17 | 1.15 | 4.81 | 0.79 | 6.98 | 49.87 |
| Oscillospiraceae | 1.22 | 0.186 | 4.21 | 0.57 | 6.1 | 55.98 |
| Spiroplasmataceae | 0.989 | 1.27 | 3.59 | 0.77 | 5.21 | 61.19 |
| Vibrionaceae | 1.24 | 1.61 | 3.1 | 0.78 | 4.49 | 65.69 |
|  |  |  |  |  |  |  |
| Groups CUM and CRZ | |  |  |  |  |  |
| Average square distance = 66.57 | |  |  |  |  |  |
|  | Group CUM | Group CRZ |  |  |  |  |
| Helicobacteraceae | 7.42 | 6.78 | 11.6 | 0.69 | 17.41 | 17.41 |
| Desulfovibrionaceae | 1.17 | 2.01 | 10.8 | 0.67 | 16.22 | 33.63 |
| Burkholderiaceae | 1.54 | 1.72 | 9.73 | 0.83 | 14.61 | 48.24 |
| Spiroplasmataceae | 1.79 | 1.27 | 5.85 | 0.94 | 8.79 | 57.03 |
| Desulfonatronaceae | 0.239 | 1.15 | 4.92 | 0.57 | 7.4 | 64.43 |
| Vibrionaceae | 1.07 | 1.61 | 3.76 | 0.75 | 5.65 | 70.08 |
|  |  |  |  |  |  |  |
| Groups PNII and PB | |  |  |  |  |  |
| Average square distance = 139.39 | |  |  |  |  |  |
|  | Group PNII | Group PB |  |  |  |  |
| Helicobacteraceae | 1.15 | 5.14 | 25.7 | 0.94 | 18.44 | 18.44 |
| Desulfovibrionaceae | 0.938 | 2.62 | 12.3 | 0.57 | 8.8 | 27.24 |
| Flavobacteriaceae | 1.84 | 2.5 | 7.56 | 1.03 | 5.42 | 32.66 |
| Acholeplasmataceae | 2.11 | 0.219 | 7.35 | 0.95 | 5.27 | 37.94 |
| Flammeovirgaceae | 1.57 | 0.134 | 7.16 | 0.57 | 5.14 | 43.08 |
| Moraxellaceae | 1.65 | 0.147 | 6.83 | 0.57 | 4.9 | 47.98 |
| Saprospiraceae | 1.23 | 0.124 | 5.79 | 0.56 | 4.15 | 52.13 |
| Burkholderiaceae | 1.26 | 0.155 | 5.28 | 0.56 | 3.79 | 55.92 |
| Desulfonatronaceae | 2.56E-02 | 1.1 | 4.8 | 0.56 | 3.44 | 59.36 |
| Vibrionaceae | 2.8 | 1.41 | 4.22 | 0.82 | 3.03 | 62.39 |
| Campylobacteraceae | 0.81 | 1.66 | 3.9 | 0.75 | 2.8 | 65.19 |
|  |  |  |  |  |  |  |
| Groups PNIM and PB | |  |  |  |  |  |
| Average square distance = 87.94 | |  |  |  |  |  |
|  | Group PNIM | Group PB |  |  |  |  |
| Desulfovibrionaceae | 0.353 | 2.62 | 14.7 | 0.58 | 16.71 | 16.71 |
| Helicobacteraceae | 7.18 | 5.14 | 14 | 1 | 15.95 | 32.66 |
| Burkholderiaceae | 1.8 | 0.155 | 11.5 | 0.56 | 13.02 | 45.68 |
| Flavobacteriaceae | 1.82 | 2.5 | 8.42 | 0.92 | 9.57 | 55.26 |
| Desulfonatronaceae | 2.36E-02 | 1.1 | 4.8 | 0.56 | 5.46 | 60.71 |
| Prolixibacteraceae | 0.603 | 1.54 | 4.23 | 0.7 | 4.81 | 65.52 |
|  |  |  |  |  |  |  |
| Groups BCH and PB | |  |  |  |  |  |
| Average square distance = 84.14 | |  |  |  |  |  |
|  | Group BCH | Group PB |  |  |  |  |
| Helicobacteraceae | 6.95 | 5.14 | 15.4 | 0.93 | 18.25 | 18.25 |
| Desulfovibrionaceae | 2.42 | 2.62 | 13.2 | 0.75 | 15.73 | 33.98 |
| Flavobacteriaceae | 1.44 | 2.5 | 9.57 | 0.84 | 11.37 | 45.35 |
| Sphingobacteriaceae | 0 | 1.48 | 4.9 | 0.65 | 5.82 | 51.17 |
| Desulfonatronaceae | 1.17 | 1.1 | 4.5 | 0.81 | 5.35 | 56.52 |
| Prolixibacteraceae | 0.803 | 1.54 | 4.33 | 0.72 | 5.15 | 61.66 |
| Oscillospiraceae | 1.22 | 0.598 | 3.81 | 0.61 | 4.53 | 66.2 |
|  |  |  |  |  |  |  |
| Groups CUM and PB | |  |  |  |  |  |
| Average square distance = 91.21 | |  |  |  |  |  |
|  | Group CUM | Group PB |  |  |  |  |
| Helicobacteraceae | 7.42 | 5.14 | 16.6 | 0.92 | 18.16 | 18.16 |
| Desulfovibrionaceae | 1.17 | 2.62 | 13.8 | 0.62 | 15.15 | 33.31 |
| Flavobacteriaceae | 1.38 | 2.5 | 9.3 | 0.84 | 10.2 | 43.5 |
| Burkholderiaceae | 1.54 | 0.155 | 8.75 | 0.56 | 9.6 | 53.1 |
| Spiroplasmataceae | 1.79 | 0.186 | 5.93 | 0.94 | 6.5 | 59.6 |
| Desulfonatronaceae | 0.239 | 1.1 | 4.52 | 0.57 | 4.96 | 64.56 |
| Prolixibacteraceae | 0.55 | 1.54 | 4.45 | 0.7 | 4.88 | 69.44 |
|  |  |  |  |  |  |  |
| Groups CRZ and PB | |  |  |  |  |  |
| Average square distance = 97.44 | |  |  |  |  |  |
|  | Group CRZ | Group PB |  |  |  |  |
| Helicobacteraceae | 6.78 | 5.14 | 21.2 | 0.94 | 21.74 | 21.74 |
| Desulfovibrionaceae | 2.01 | 2.62 | 17.3 | 0.74 | 17.77 | 39.51 |
| Flavobacteriaceae | 0.595 | 2.5 | 11 | 0.79 | 11.3 | 50.81 |
| Desulfonatronaceae | 1.15 | 1.1 | 7.6 | 0.75 | 7.79 | 58.6 |
| Burkholderiaceae | 1.72 | 0.155 | 5.45 | 0.96 | 5.6 | 64.2 |
| Prolixibacteraceae | 2.58E-02 | 1.54 | 5.39 | 0.7 | 5.53 | 69.73 |
|  |  |  |  |  |  |  |

**Table S6.** Results obtained from the similarity percentage analysis (SIMPER) at a cut-off at 65% of the cumulative contribution to the average dissimilarity. Comparisons of environmental variables are shown between paired groups of years (2017-2018 and 2018-2019) and sites (PNII: Isla Isabel National Park; PNIM: Islas Marietas National Park; BCH: Islas e islotes de Bahía Chamela Sanctuary; CUM: Bahía Cuastecomates-Punta Melaque; CRZ: Carrizales; PB: Punto B).

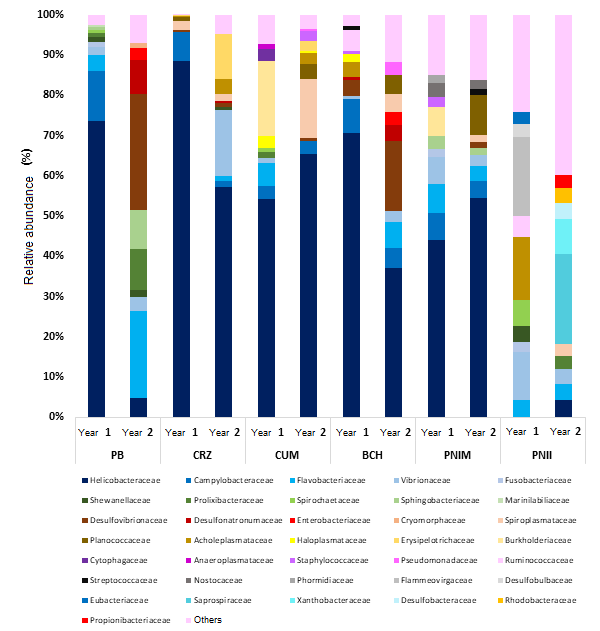
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | | | | | | |
| Variable | Average value | Average value | Dist.Cua.Prom. | Dist.Cua./DE | Contrib% | Cum.% |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Groups 2017-2018 and 2018-2019 | |  |  |  |  |  |
| Average square distance = 27.96 | | | | | | |
|  | Group 2017-2018 | Group 2018-2019 |  |  |  |  |
| Chlorophyll α | -0.849 | 0.849 | 3.25 | 1.47 | 11.61 | 11.61 |
| Ammonium | 0.002 | -0.002 | 2.25 | 0.65 | 8.05 | 19.66 |
| Dissolved oxygen | -0.689 | 0.689 | 2.19 | 1.29 | 7.85 | 27.51 |
| Nitrate and nitrite | -0.261 | 0.261 | 2.14 | 1.18 | 7.67 | 35.18 |
| Temperature | 0.156 | -0.156 | 2.07 | 0.9 | 7.41 | 42.59 |
| Crustose calcareous algae | 0.361 | -0.361 | 2.01 | 1.31 | 7.2 | 49.79 |
| Macroalgae | 0.27 | -0.27 | 1.87 | 0.6 | 6.68 | 56.47 |
| Salinity | -0.317 | 0.317 | 1.79 | 0.41 | 6.42 | 62.89 |
| Silicate | 0.073 | -0.073 | 1.58 | 0.7 | 5.65 | 68.54 |
|  |  |  |  |  |  |  |
| Groups PNII and PNIM | |  |  |  |  |  |
| Average square distance = 34.45 | |  |  |  |  |  |
|  | Group PNII | Group PNIM |  |  |  |  |
| Salinity | -1.5 | 0.483 | 6.66 | 0.72 | 19.32 | 19.32 |
| Sponge | 1.96 | -0.308 | 5.22 | 2.86 | 15.17 | 34.49 |
| Articulated calcareous algae | -0.738 | 1.13 | 4.97 | 0.77 | 14.43 | 48.92 |
| Sand | -0.962 | 0.977 | 4.1 | 1.28 | 11.91 | 60.83 |
| Temperature | 0.663 | -1.11 | 3.14 | 21.84 | 9.12 | 69.94 |
|  |  |  |  |  |  |  |
| Groups PNII and BCH | |  |  |  |  |  |
| Average square distance = 54.07 | |  |  |  |  |  |
|  | Group PNII | Group BCH |  |  |  |  |
| Phosphate | 1.42 | -0.915 | 8.53 | 0.74 | 15.78 | 15.78 |
| Sponge | 1.96 | -0.591 | 6.9 | 1.52 | 12.76 | 28.54 |
| Salinity | -1.5 | 0.359 | 5.87 | 0.72 | 10.87 | 39.4 |
| Depth | 1.29 | -0.942 | 4.97 | 1.3 | 9.2 | 48.6 |
| Rock | -0.531 | 1.35 | 4.6 | 0.84 | 8.51 | 57.12 |
| Nitrate and nitrite | 0.729 | -1.01 | 4.37 | 0.76 | 8.08 | 65.2 |
|  |  |  |  |  |  |  |
| Groups PNIM and BCH | |  |  |  |  |  |
| Average square distance = 39.55 | |  |  |  |  |  |
|  | Group PNIM | Group BCH |  |  |  |  |
| Crustose calcareous algae | -0.146 | 0.761 | 4.61 | 0.92 | 11.65 | 11.65 |
| Rock | -0.724 | 1.35 | 4.57 | 1.54 | 11.55 | 23.19 |
| Depth | 1.17 | -0.942 | 4.48 | 1.28 | 11.32 | 34.52 |
| Ammonium | -0.223 | 0.936 | 3.91 | 0.74 | 9.89 | 44.41 |
| Articulated calcareous algae | 1.13 | -0.324 | 3.64 | 0.72 | 9.2 | 53.61 |
| Sand | 0.977 | 0.562 | 3.61 | 1.66 | 9.13 | 62.74 |
| Temperature | -1.11 | 3.32E-02 | 2.78 | 0.71 | 7.02 | 69.76 |
|  |  |  |  |  |  |  |
| Groups PNII and CUM | |  |  |  |  |  |
| Average square distance = 41.79 | |  |  |  |  |  |
|  | Group PNII | Group CUM |  |  |  |  |
| Sponge | 1.96 | -0.609 | 6.95 | 1.6 | 16.64 | 16.64 |
| Depth | 1.29 | -1.18 | 6.11 | Undefined! | 14.63 | 31.27 |
| Salinity | -1.5 | 0.314 | 5.78 | 0.71 | 13.83 | 45.1 |
| Light extinction coefficient | -0.974 | 1.01 | 5.35 | 0.8 | 12.79 | 57.9 |
| Phosphate | 1.42 | -0.279 | 4.32 | 0.75 | 10.33 | 68.22 |
|  |  |  |  |  |  |  |
| Groups PNIM and CUM | |  |  |  |  |  |
| Average square distance = 29.46 | |  |  |  |  |  |
|  | Group PNIM | Group CUM |  |  |  |  |
| Light extinction coefficient | -0.927 | 1.01 | 5.82 | 0.74 | 19.77 | 19.77 |
| Depth | 1.17 | -1.18 | 5.56 | 1.32 | 18.89 | 38.66 |
| Nitrate and nitrite | -0.419 | 0.186 | 2.75 | 1.04 | 9.33 | 47.99 |
| Articulated calcareous algae | 1.13 | -0.192 | 2.61 | 0.75 | 8.87 | 56.86 |
| Sand | 0.977 | -0.481 | 2.31 | 1.32 | 7.83 | 64.69 |
| Temperature | -1.11 | -0.297 | 2.09 | 0.76 | 7.08 | 71.77 |
|  |  |  |  |  |  |  |
| Groups BCH and CUM | |  |  |  |  |  |
| Average square distance = 20.75 | |  |  |  |  |  |
|  | Group BCH | Group CUM |  |  |  |  |
| Macroalgae | -0.676 | 1.01 | 4.83 | 0.72 | 23.27 | 23.27 |
| Ammonium | 0.936 | -0.359 | 3.73 | 0.71 | 17.97 | 41.23 |
| Rock | 1.35 | 4.68E-02 | 3.54 | 0.71 | 17.04 | 58.27 |
| Sand | 0.562 | -0.481 | 3.13 | 0.74 | 15.1 | 73.37 |
|  |  |  |  |  |  |  |
| Groups PNII and CRZ | |  |  |  |  |  |
| Average square distance = 45.15 | |  |  |  |  |  |
|  | Group PNII | Group CRZ |  |  |  |  |
| Live coral | -0.851 | 2.02 | 8.25 | 8.83 | 18.26 | 18.26 |
| Sponge | 1.96 | -0.702 | 7.34 | 1.93 | 16.25 | 34.51 |
| Filamentous algae | 1 | -1.63 | 6.94 | 5.65 | 15.38 | 49.89 |
| Salinity | -1.5 | 0.317 | 5.63 | 0.72 | 12.46 | 62.35 |
| Phosphate | 1.42 | -0.398 | 4.96 | 0.75 | 10.99 | 73.34 |
|  |  |  |  |  |  |  |
| Groups PNIM and CRZ | |  |  |  |  |  |
| Average square distance = 30.75 | |  |  |  |  |  |
|  | Group PNIM | Group CRZ |  |  |  |  |
| Articulated calcareous algae | 1.13 | -0.853 | 5.33 | 0.8 | 17.33 | 17.33 |
| Live coral | -0.281 | 2.02 | 5.29 | 16.56 | 17.2 | 34.52 |
| Filamentous algae | 0.363 | -1.63 | 3.96 | 11.4 | 12.87 | 47.4 |
| Sand | 0.977 | -0.737 | 3.16 | 1.4 | 10.27 | 57.66 |
| Crustose calcareous algae | -0.146 | -1.29 | 3.02 | 0.71 | 9.83 | 67.49 |
|  |  |  |  |  |  |  |
| Groups BCH and CRZ | |  |  |  |  |  |
| Average square distance = 29.57 | |  |  |  |  |  |
|  | Group BCH | Group CRZ |  |  |  |  |
| Crustose calcareous algae | 0.761 | -1.29 | 4.59 | 1.25 | 15.51 | 15.51 |
| Rock | 1.35 | -0.565 | 4.51 | 0.91 | 15.25 | 30.76 |
| Ammonium | 0.936 | -0.571 | 4.4 | 0.71 | 14.89 | 45.65 |
| Live coral | -4.88E-02 | 2.02 | 4.3 | 4.59 | 14.54 | 60.18 |
| Sand | 0.562 | -0.737 | 3.61 | 0.71 | 12.22 | 72.41 |
|  | |  |  |  |  |  |
| Groups CUM and CRZ | |  |  |  |  |  |
| Average square distance = 22.35 | |  |  |  |  |  |
|  | Group CUM | Group CRZ |  |  |  |  |
| Macroalgae | 1.01 | -0.691 | 5.11 | 0.71 | 22.84 | 22.84 |
| Live coral | -6.85E-02 | 2.02 | 4.38 | 4.8 | 19.58 | 42.43 |
| Crustose calcareous algae | 0.258 | -1.29 | 2.38 | 16.59 | 10.66 | 53.08 |
| Nitrate and nitrite | 0.186 | -0.189 | 2.25 | 1.46 | 10.05 | 63.14 |
| Light extinction coefficient | 1.01 | -0.317 | 1.81 | 2.47 | 8.09 | 71.23 |
|  |  |  |  |  |  |  |
| Groups PNII and PB | |  |  |  |  |  |
| Average square distance = 46.38 | |  |  |  |  |  |
|  | Group PNII | Group PB |  |  |  |  |
| Fecal coliforms | -0.344 | 1.71 | 6.21 | 0.76 | 13.38 | 13.38 |
| Salinity | -1.5 | 2.56E-02 | 4.83 | 0.71 | 10.42 | 23.8 |
| Phosphate | 1.42 | -8.01E-02 | 4.04 | 0.71 | 8.7 | 32.5 |
| Temperature | 0.663 | 0.792 | 3.82 | 5.36 | 8.23 | 40.74 |
| Articulated calcareous algae | -0.738 | 0.976 | 3.27 | 1.17 | 7.05 | 47.79 |
| Silicate | -1.78E-02 | 1.35 | 3.22 | 0.72 | 6.95 | 54.74 |
| Sponge | 1.96 | 0.25 | 3.07 | 1.67 | 6.61 | 61.35 |
| Ammonium | -0.491 | 0.708 | 3 | 0.71 | 6.46 | 67.81 |
|  | |  |  |  |  |  |
| Groups PNIM and PB | |  |  |  |  |  |
| Average square distance = 44.48 | |  |  |  |  |  |
|  | Group PNIM | Group PB |  |  |  |  |
| Temperature | -1.11 | 0.792 | 7.3 | 0.71 | 16.42 | 16.42 |
| Fecal coliforms | -0.344 | 1.71 | 6.21 | 0.76 | 13.96 | 30.38 |
| Dissolved oxygen | 0.937 | -1.1 | 4.27 | 2.08 | 9.59 | 39.97 |
| Silicate | 0.27 | 1.35 | 3.6 | 0.75 | 8.1 | 48.07 |
| Nitrate and nitrite | -0.419 | 0.701 | 3.3 | 0.73 | 7.42 | 55.49 |
| Articulated calcareous algae | 1.13 | 0.976 | 3.23 | 4.12 | 7.27 | 62.76 |
| Rock | -0.724 | 0.42 | 2.89 | 0.71 | 6.49 | 69.25 |
|  |  |  |  |  |  |  |
| Groups BCH and PB | |  |  |  |  |  |
| Average square distance = 39.03 | |  |  |  |  |  |
|  | Group BCH | Group PB |  |  |  |  |
| Silicate | -0.88 | 1.35 | 6.67 | 0.81 | 17.1 | 17.1 |
| Ammonium | 0.936 | 0.708 | 6.65 | 4.01 | 17.03 | 34.13 |
| Fecal coliforms | -0.344 | 1.71 | 6.21 | 0.76 | 15.91 | 50.03 |
| Rock | 1.35 | 0.42 | 3.97 | 0.85 | 10.17 | 60.2 |
| Nitrate and nitrite | -1.01 | 0.701 | 2.99 | 2.33 | 7.66 | 67.86 |
|  |  |  |  |  |  |  |
| Groups CUM and PB | |  |  |  |  |  |
| Average square distance = 32.70 | |  |  |  |  |  |
|  | Group CUM | Group PB |  |  |  |  |
| Fecal coliforms | -0.344 | 1.71 | 6.21 | 0.76 | 18.98 | 18.98 |
| Silicate | -0.669 | 1.35 | 5.82 | 0.77 | 17.79 | 36.78 |
| Macroalgae | 1.01 | -0.467 | 4.6 | 0.71 | 14.06 | 50.84 |
| Ammonium | -0.359 | 0.708 | 2.43 | 0.71 | 7.43 | 58.28 |
| Filamentous algae | -0.474 | 1.01 | 2.25 | 2.63 | 6.88 | 65.16 |
|  |  |  |  |  |  |  |
| Groups CRZ and PB | |  |  |  |  |  |
| Average square distance = 48.78 | |  |  |  |  |  |
|  | Group CRZ | Group PB |  |  |  |  |
| Live coral | 2.02 | -0.769 | 7.77 | 42.67 | 15.92 | 15.92 |
| Filamentous algae | -1.63 | 1.01 | 7.05 | 3.26 | 14.44 | 30.37 |
| Silicate | -5.81E-02 | 1.35 | 6.26 | 0.76 | 12.84 | 43.21 |
| Fecal coliforms | -0.338 | 1.71 | 6.17 | 0.76 | 12.66 | 55.86 |
| Articulated calcareous algae | -0.853 | 0.976 | 3.72 | 1.18 | 7.62 | 63.48 |
| Ammonium | -0.571 | 0.708 | 2.86 | 0.71 | 5.87 | 69.35 |
|  |  |  |  |  |  |  |

**Table S7.** Results obtained from the similarity percentage analysis (SIMPER) at a cut-off at 65% of the cumulative contribution of the bacterial families to the average dissimilarity. Comparisons of bacterial families were made between paired groups of years (2017-2018 and 2018-2019) and sites (PNII: Isla Isabel National Park; PNIM: Islas Marietas National Park; BCH: Islas e islotes de Bahía Chamela Sanctuary; CUM: Bahía Cuastecomates-Punta Melaque; CRZ: Carrizales; PB: Punto B).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | | | | | | |
| Variable | Valor Promedio | Valor Promedio | Dist.Cua.Prom. | Dist.Cua./DE | Contrib% | Cum.% |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Groups 2017-2018 and 2018-2019 | |  |  |  |  |  |
| Average square distance = 64.46 | | | | | | |
|  | Group 2017-2018 | Group 2018-2019 |  |  |  |  |
| Helicobacteraceae | 6.85 | 5.57 | 8.72 | 0.55 | 13.53 | 13.53 |
| Burkholderiaceae | 1.19 | 0.887 | 6.14 | 0.86 | 9.53 | 23.06 |
| Desulfovibrionaceae | 0.73 | 2.31 | 5.02 | 0.54 | 7.79 | 30.85 |
| Spiroplasmataceae | 0.535 | 2.09 | 4.1 | 0.74 | 6.37 | 37.22 |
| Saprospiraceae | 0.009 | 0.912 | 3.76 | 0.41 | 5.84 | 43.06 |
| Vibrionaceae | 1.61 | 1.95 | 3.26 | 0.56 | 5.05 | 48.11 |
| Acholeplasmataceae | 1.47 | 0.857 | 3.2 | 0.68 | 4.96 | 53.07 |
| Flavobacteriaceae | 1.58 | 2.08 | 3.16 | 1.09 | 4.91 | 57.97 |
| Flammeovirgaceae | 0.858 | 0.258 | 2.67 | 0.42 | 4.14 | 62.12 |
| Campylobacteraceae | 2.49 | 1.33 | 2.29 | 0.64 | 3.55 | 65.67 |
|  |  |  |  |  |  |  |
| Groups PNII and PNIM | |  |  |  |  |  |
| Average square distance = 94.85 | |  |  |  |  |  |
|  | Group PNII | Group PNIM |  |  |  |  |
| Helicobacteraceae | 1.41 | 7.01 | 31.4 | 6.45 | 33.13 | 33.13 |
| Saprospiraceae | 2.37 | 5.57E-02 | 10.9 | 0.71 | 11.53 | 44.65 |
| Flammeovirgaceae | 2.45 | 0.328 | 8.02 | 0.71 | 8.45 | 53.11 |
| Burkholderiaceae | 0.708 | 1.42 | 3.92 | 1.05 | 4.13 | 57.24 |
| Acholeplasmataceae | 2.19 | 1.25 | 3.7 | 0.83 | 3.91 | 61.15 |
| Xanthobacteraceae | 1.56 | 0.122 | 3.65 | 0.71 | 3.85 | 65 |
| Spirochaetaceae | 1.73 | 0.227 | 3.09 | 0.79 | 3.26 | 68.26 |
|  |  |  |  |  |  |  |
| Groups PNII and BCH | |  |  |  |  |  |
| Average square distance = 115.89 | |  |  |  |  |  |
|  | Group PNII | Group BCH |  |  |  |  |
| Helicobacteraceae | 1.41 | 7.25 | 37.5 | 1.23 | 32.36 | 32.36 |
| Saprospiraceae | 2.37 | 0.122 | 10.1 | 0.71 | 8.69 | 41.04 |
| Flammeovirgaceae | 2.45 | 9.39E-02 | 9.86 | 0.71 | 8.51 | 49.55 |
| Desulfovibrionaceae | 1.04 | 3.09 | 5.09 | 0.93 | 4.39 | 53.94 |
| Xanthobacteraceae | 1.56 | 0 | 4.34 | 0.71 | 3.74 | 57.68 |
| Spirochaetaceae | 1.73 | 8.23E-02 | 3.58 | 0.82 | 3.09 | 60.77 |
| Vibrionaceae | 2.68 | 1.24 | 3.41 | 0.72 | 2.94 | 63.71 |
| Campylobacteraceae | 0.892 | 2.54 | 2.79 | 2.45 | 2.41 | 66.12 |
|  |  |  |  |  |  |  |
| Groups PNIM and BCH | |  |  |  |  |  |
| Average square distance = 44.37 | |  |  |  |  |  |
|  | Group PNIM | Group BCH |  |  |  |  |
| Desulfovibrionaceae | 0.693 | 3.09 | 6 | 1.77 | 13.53 | 13.53 |
| Burkholderiaceae | 1.42 | 0 | 3.65 | 0.71 | 8.22 | 21.75 |
| Flavobacteriaceae | 2.3 | 1.46 | 3 | 0.83 | 6.76 | 28.51 |
| Sphingobacteriaceae | 1.58 | 0 | 2.55 | 2.44 | 5.74 | 34.25 |
| Helicobacteraceae | 7.01 | 7.25 | 2.4 | 2.27 | 5.41 | 39.66 |
| Nostocaceae | 1.64 | 0.163 | 2.31 | 1.51 | 5.2 | 44.86 |
| Desulfonatronumaceae | 0.05 | 1.45 | 2.22 | 1.11 | 5 | 49.86 |
| Phormidiaceae | 1.26 | 0 | 1.61 | 2.48 | 3.64 | 53.5 |
| Ruminococcaceae | 0.63 | 1.31 | 1.57 | 0.77 | 3.54 | 57.04 |
| Vibrionaceae | 2.12 | 1.24 | 1.54 | 0.71 | 3.48 | 60.52 |
| Idiomarinaceae | 1.17 | 0 | 1.39 | 3.22 | 3.12 | 63.64 |
| Pseudomonadaceae | 0.13 | 0.987 | 1.32 | 0.71 | 2.97 | 66.62 |
|  |  |  |  |  |  |  |
| Groups PNII and CUM | |  |  |  |  |  |
| Average square distance = 122.66 | |  |  |  |  |  |
|  | Group PNII | Group CUM |  |  |  |  |
| Helicobacteraceae | 1.41 | 7.73 | 40.1 | 7.15 | 32.66 | 32.66 |
| Saprospiraceae | 2.37 | 0 | 11.2 | 0.71 | 9.12 | 41.79 |
| Burkholderiaceae | 0.708 | 2.22 | 9.4 | 0.82 | 7.67 | 49.46 |
| Flammeovirgaceae | 2.45 | 0.142 | 8.71 | 0.73 | 7.1 | 56.56 |
| Acholeplasmataceae | 2.19 | 1.21 | 5.74 | 0.95 | 4.68 | 61.24 |
| Xanthobacteraceae | 1.56 | 0.08 | 3.91 | 0.71 | 3.19 | 64.43 |
| Vibrionaceae | 2.68 | 0.867 | 3.47 | 1.52 | 2.83 | 67.26 |
|  |  |  |  |  |  |  |
| Groups PNIM and CUM | |  |  |  |  |  |
| Average square distance = 25.05 | |  |  |  |  |  |
|  | Group PNIM | Group CUM |  |  |  |  |
| Nostocaceae | 1.64 | 0 | 2.72 | 2.9 | 10.87 | 10.87 |
| Staphylococcaceae | 0.917 | 0.764 | 1.99 | 3.3 | 7.95 | 18.82 |
| Phormidiaceae | 1.26 | 0 | 1.61 | 2.48 | 6.45 | 25.27 |
| Vibrionaceae | 2.12 | 0.867 | 1.59 | 2.69 | 6.36 | 31.62 |
| Flavobacteriaceae | 2.3 | 1.29 | 1.51 | 0.75 | 6.04 | 37.66 |
| Idiomarinaceae | 1.17 | 0 | 1.39 | 3.22 | 5.53 | 43.19 |
| Burkholderiaceae | 1.42 | 2.22 | 1.31 | 0.71 | 5.25 | 48.44 |
| Erysipelotrichaceae | 1.01 | 0.798 | 1.17 | 1.88 | 4.65 | 53.09 |
| Sphingobacteriaceae | 1.58 | 0.519 | 1.14 | 2.81 | 4.56 | 57.65 |
| Cytophagaceae | 0.468 | 0.862 | 0.975 | 0.97 | 3.89 | 61.54 |
| Prolixibacteraceae | 1.06 | 0.588 | 0.591 | 0.73 | 2.36 | 63.9 |
| Spiroplasmataceae | 1.97 | 1.91 | 0.57 | 4.69 | 2.28 | 66.17 |
|  |  |  |  |  |  |  |
| Groups BCH and CUM | |  |  |  |  |  |
| Average square distance = 47.57 | |  |  |  |  |  |
|  | Group BCH | Group CUM |  |  |  |  |
| Burkholderiaceae | 0 | 2.22 | 9.33 | 0.71 | 19.62 | 19.62 |
| Desulfovibrionaceae | 3.09 | 0.585 | 6.83 | 1.29 | 14.37 | 33.99 |
| Flavobacteriaceae | 1.46 | 1.29 | 4.94 | 4.69 | 10.38 | 44.37 |
| Helicobacteraceae | 7.25 | 7.73 | 2.56 | 1.23 | 5.37 | 49.74 |
| Desulfonatronumaceae | 1.45 | 0.096 | 2.03 | 1.17 | 4.27 | 54.01 |
| Prolixibacteraceae | 0.812 | 0.588 | 2.01 | 2.26 | 4.22 | 58.24 |
| Acholeplasmataceae | 0.949 | 1.21 | 1.96 | 1.96 | 4.12 | 62.36 |
| Spiroplasmataceae | 1.21 | 1.91 | 1.6 | 0.76 | 3.36 | 65.71 |
|  |  |  |  |  |  |  |
| Groups PNII and CRZ | |  |  |  |  |  |
| Average square distance = 139.59 | |  |  |  |  |  |
|  | Group PNII | Group CRZ |  |  |  |  |
| Helicobacteraceae | 1.41 | 8.49 | 52.7 | 1.65 | 37.73 | 37.73 |
| Saprospiraceae | 2.37 | 0.035 | 10.9 | 0.71 | 7.78 | 45.51 |
| Flammeovirgaceae | 2.45 | 0.131 | 9.84 | 0.71 | 7.05 | 52.55 |
| Vibrionaceae | 2.68 | 2.12 | 7.6 | 1.78 | 5.44 | 58 |
| Acholeplasmataceae | 2.19 | 1.16 | 7.36 | 1.01 | 5.27 | 63.27 |
| Xanthobacteraceae | 1.56 | 0 | 4.34 | 0.71 | 3.11 | 66.38 |
|  |  |  |  |  |  |  |
| Groups PNIM and CRZ | |  |  |  |  |  |
| Average square distance = 43.55 | |  |  |  |  |  |
|  | Group PNIM | Group CRZ |  |  |  |  |
| Burkholderiaceae | 1.42 | 1.68 | 8.8 | 4.07 | 20.21 | 20.21 |
| Vibrionaceae | 2.12 | 2.12 | 5.86 | 3331.34 | 13.44 | 33.66 |
| Flavobacteriaceae | 2.3 | 0.583 | 3.91 | 0.82 | 8.98 | 42.64 |
| Helicobacteraceae | 7.01 | 8.49 | 3.86 | 0.71 | 8.86 | 51.5 |
| Nostocaceae | 1.64 | 0.035 | 2.62 | 2.43 | 6.02 | 57.53 |
| Sphingobacteriaceae | 1.58 | 0.182 | 2.12 | 1.29 | 4.88 | 62.41 |
| Spiroplasmataceae | 1.97 | 1.42 | 1.88 | 0.96 | 4.32 | 66.73 |
|  |  |  |  |  |  |  |
| Groups BCH and CRZ | |  |  |  |  |  |
| Average square distance = 37.58 | |  |  |  |  |  |
|  | Group BCH | Group CRZ |  |  |  |  |
| Desulfovibrionaceae | 3.09 | 0.797 | 5.9 | 1.14 | 15.7 | 15.7 |
| Burkholderiaceae | 0 | 1.68 | 5.64 | 0.71 | 15 | 30.7 |
| Vibrionaceae | 1.24 | 2.12 | 3.17 | 0.82 | 8.43 | 39.13 |
| Acholeplasmataceae | 0.949 | 1.16 | 2.93 | 2.91 | 7.8 | 46.93 |
| Ruminococcaceae | 1.31 | 0.172 | 2.08 | 0.73 | 5.54 | 52.47 |
| Planococcaceae | 1.1 | 0.722 | 1.91 | 1.35 | 5.08 | 57.55 |
| Pseudomonadaceae | 0.987 | 0 | 1.64 | 0.72 | 4.35 | 61.9 |
| Helicobacteraceae | 7.25 | 8.49 | 1.59 | 1.89 | 4.23 | 66.13 |
|  |  |  |  |  |  |  |
| Groups CUM and CRZ | |  |  |  |  |  |
| Average square distance = 44.50 | |  |  |  |  |  |
|  | Group CUM | Group CRZ |  |  |  |  |
| Burkholderiaceae | 2.22 | 1.68 | 14.5 | 2.51 | 32.69 | 32.69 |
| Vibrionaceae | 0.867 | 2.12 | 6.64 | 0.83 | 14.92 | 47.61 |
| Spiroplasmataceae | 1.91 | 1.42 | 4.28 | 1.52 | 9.62 | 57.23 |
| Flavobacteriaceae | 1.29 | 0.583 | 3.32 | 0.99 | 7.47 | 64.7 |
| Helicobacteraceae | 7.73 | 8.49 | 2.22 | 0.81 | 4.99 | 69.69 |
|  |  |  |  |  |  |  |
| Groups PNII and PB | |  |  |  |  |  |
| Average square distance = 116.91 | |  |  |  |  |  |
|  | Group PNII | Group PB |  |  |  |  |
| Helicobacteraceae | 1.41 | 5.39 | 30.8 | 0.71 | 26.32 | 26.32 |
| Flammeovirgaceae | 2.45 | 0.2 | 9.82 | 0.71 | 8.4 | 34.72 |
| Saprospiraceae | 2.37 | 0.185 | 9.51 | 0.71 | 8.13 | 42.85 |
| Desulfovibrionaceae | 1.04 | 2.93 | 8.89 | 0.72 | 7.61 | 50.46 |
| Acholeplasmataceae | 2.19 | 0.228 | 6.19 | 0.73 | 5.29 | 55.75 |
| Xanthobacteraceae | 1.56 | 0 | 4.34 | 0.71 | 3.71 | 59.46 |
| Desulfonatronumaceae | 0.05 | 1.47 | 4.04 | 0.71 | 3.45 | 62.91 |
| Flavobacteriaceae | 2.03 | 3.3 | 3.57 | 0.71 | 3.05 | 65.97 |
|  |  |  |  |  |  |  |
| Groups PNIM and PB | |  |  |  |  |  |
| Average square distance = 63.89 | |  |  |  |  |  |
|  | Group PNIM | Group PB |  |  |  |  |
| Helicobacteraceae | 7.01 | 5.39 | 15.3 | 0.94 | 23.9 | 23.9 |
| Desulfovibrionaceae | 0.693 | 2.93 | 8.5 | 0.72 | 13.3 | 37.2 |
| Desulfonatronumaceae | 0.05 | 1.47 | 4.05 | 0.71 | 6.34 | 43.54 |
| Flavobacteriaceae | 2.3 | 3.3 | 4 | 0.82 | 6.27 | 49.81 |
| Spiroplasmataceae | 1.97 | 0.248 | 3.79 | 0.86 | 5.93 | 55.75 |
| Burkholderiaceae | 1.42 | 0.207 | 3.67 | 0.72 | 5.75 | 61.5 |
| Nostocaceae | 1.64 | 0 | 2.72 | 2.9 | 4.26 | 65.76 |
|  |  |  |  |  |  |  |
| Groups BCH and PB | |  |  |  |  |  |
| Average square distance = 37.14 | |  |  |  |  |  |
|  | Group BCH | Group PB |  |  |  |  |
| Helicobacteraceae | 7.25 | 5.39 | 7.57 | 0.71 | 20.4 | 20.4 |
| Sphingobacteriaceae | 0 | 1.95 | 5.15 | 0.8 | 13.86 | 34.26 |
| Flavobacteriaceae | 1.46 | 3.3 | 3.45 | 3.02 | 9.28 | 43.54 |
| Desulfovibrionaceae | 3.09 | 2.93 | 1.9 | 3.02 | 5.12 | 48.67 |
| Campylobacteraceae | 2.54 | 2.01 | 1.71 | 0.95 | 4.59 | 53.26 |
| Prolixibacteraceae | 0.812 | 2.09 | 1.7 | 1.68 | 4.59 | 57.85 |
| Planococcaceae | 1.1 | 0.227 | 1.51 | 0.71 | 4.08 | 61.93 |
| Ruminococcaceae | 1.31 | 0.745 | 1.43 | 0.84 | 3.84 | 65.77 |
|  |  |  |  |  |  |  |
| Groups CUM and PB | |  |  |  |  |  |
| Average square distance = 84.98 | |  |  |  |  |  |
|  | Group CUM | Group PB |  |  |  |  |
| Helicobacteraceae | 7.73 | 5.39 | 18.1 | 0.77 | 21.3 | 21.3 |
| Flavobacteriaceae | 1.29 | 3.3 | 9.97 | 0.72 | 11.74 | 33.04 |
| Desulfovibrionaceae | 0.585 | 2.93 | 9.97 | 0.71 | 11.73 | 44.77 |
| Burkholderiaceae | 2.22 | 0.207 | 9.37 | 0.71 | 11.02 | 55.79 |
| Spiroplasmataceae | 1.91 | 0.248 | 5.54 | 0.71 | 6.52 | 62.3 |
| Prolixibacteraceae | 0.588 | 2.09 | 5.08 | 0.71 | 5.97 | 68.28 |
|  |  |  |  |  |  |  |
| Groups CRZ and PB | |  |  |  |  |  |
| Average square distance = 62.74 | |  |  |  |  |  |
|  | Group CRZ | Group PB |  |  |  |  |
| Helicobacteraceae | 8.49 | 5.39 | 14.7 | 0.74 | 23.5 | 23.5 |
| Desulfovibrionaceae | 0.797 | 2.93 | 9.25 | 0.71 | 14.74 | 38.25 |
| Flavobacteriaceae | 0.583 | 3.3 | 7.98 | 1.37 | 12.71 | 50.96 |
| Prolixibacteraceae | 0.051 | 2.09 | 5.23 | 0.87 | 8.34 | 59.3 |
| Burkholderiaceae | 1.68 | 0.207 | 4.33 | 0.71 | 6.9 | 66.2 |
|  |  |  |  |  |  |  |

**Table S8.** Conditional effects of the environmental variables selected for the canonical redundancy analyzes (RDA) models at the spatial and spatio-temporal levels. Values in bold correspond to significant variables.(*P* ≤ 0.05).

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| Variable | Lambda | *F*-value | *P*-value |
|  |  |  |  |
|  |  |  |  |
| Spatial model |  |  |  |
| Sponge cover | 0.50 | 3.96 | **0.004** |
| Depth | 0.15 | 1.23 | 0.326 |
| Sand cover | 0.14 | 1.23 | 0.360 |
| Live coral cover | 0.13 | 1.74 | 0.354 |
|  |  |  |  |
| Spatial-temporal model |  |  |  |
| Sponge cover | 0.13 | 4.19 | **0.003** |
| Salinity | 0.13 | 2.37 | **0.021** |
| Dissolved oxygen | 0.10 | 2.22 | **0.034** |
| Fecal coliforms | 0.14 | 2.41 | 0.078 |
| Phosphates | 0.07 | 2.11 | 0.120 |
| Macroalgae | 0.09 | 2.00 | 0.140 |
| Light extinction coefficient | 0.05 | 1.75 | 0.200 |
| Spatial model α | 0.04 | 1.61 | 0.225 |
|  |  |  |  |



**Figure S2.** Average relative abundance of the ten most abundant bacterial families of the sea urchin *T. roseus* at a spatio-temporal level (site per year) Codes: PNII: Isla Isabel National Park; PNIM: Islas Marietas National Park; BCH: Islas e islotes de Bahía Chamela Sanctuary; CUM: Bahía Cuastecomates-Punta Melaque; CRZ: Carrizales; PB: Punto B.