

PCA Result

- Transitional Environment

PCA performed at the genus level in the transition environment consists of benthic abundance data from 2 samples with 11 variables. The analysis showed that the first component (PC1) explained the largest proportion of variation in the data. Figure S1 shows the PCA loadings for component 1 in the transition environment at the genus level. These loadings indicate the relative contribution of each foraminiferal genus to PC1. PC1 represents the most influential principal component.

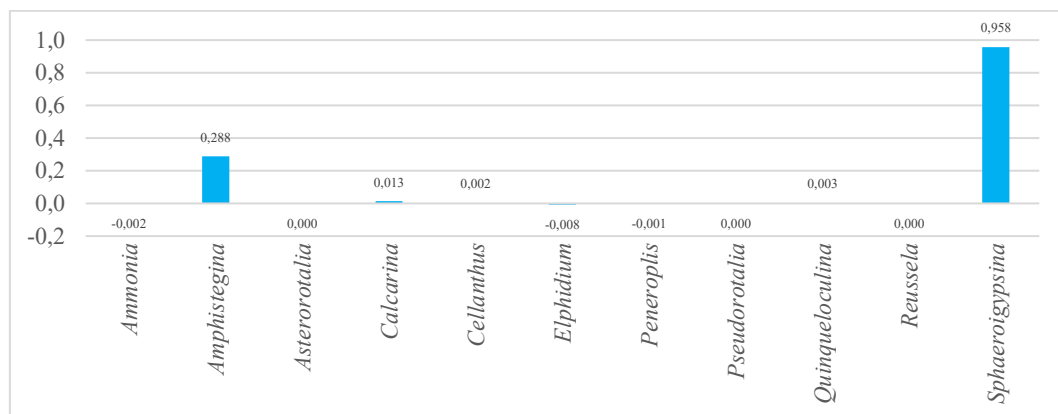


Figure S1. PCA loadings (component 1) transitional environment (genus)

PC1 at the genus level has a variance of 100%, indicating that this single component explains all the variation in the dataset. PC1 loadings at the genus level (Figure S1) demonstrate that *Sphaerogypsina* and *Amphistegina* exhibit the highest loading values.

Meanwhile, PCA performed at the species level in the transition environment consists of benthic foraminiferal abundance data from 2 samples with 20 variables. Based on the data, PCA analysis results show the 100% variance. PCA loadings for component 1 at the species level are displayed in Figure S2.

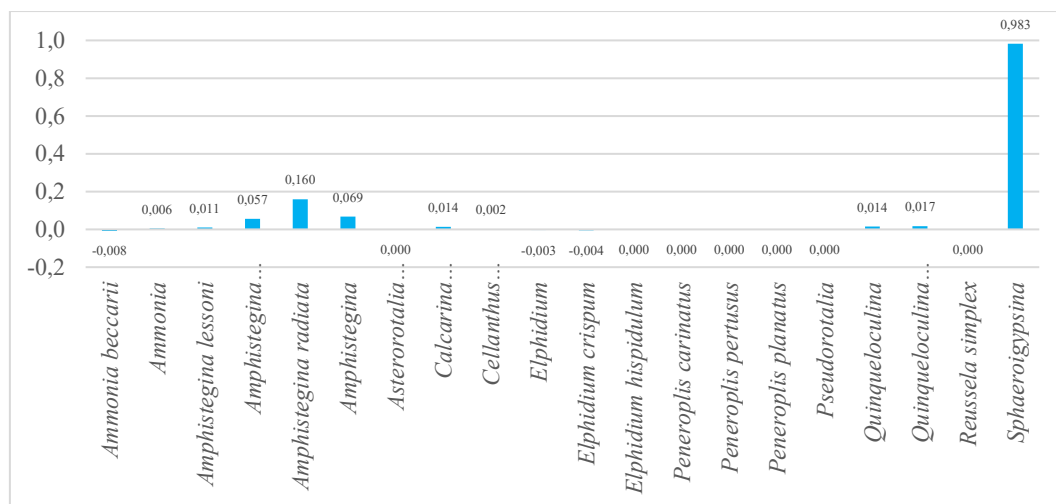


Figure S2. PCA loadings (component 1) transitional environment (species)

PC1 represents the most influential principal component. PC1 loadings at the species level show that the components providing the highest influence are *Sphaerogypsina* and *Amphistegina*.

- Inner neritic environment

On inner neritic environment, PCA data at the genus level consisted of benthic abundance from 7 samples with 37 variables. Based on these data, PCA analysis showed PC1 accounting for 96% of the variance. PC1 at the genus level represents the most influential principal component. PC1 loadings in Figure S3 show that the genera providing the greatest influence are *Ammonia*, *Asterorotalia*, and *Elphidium*.

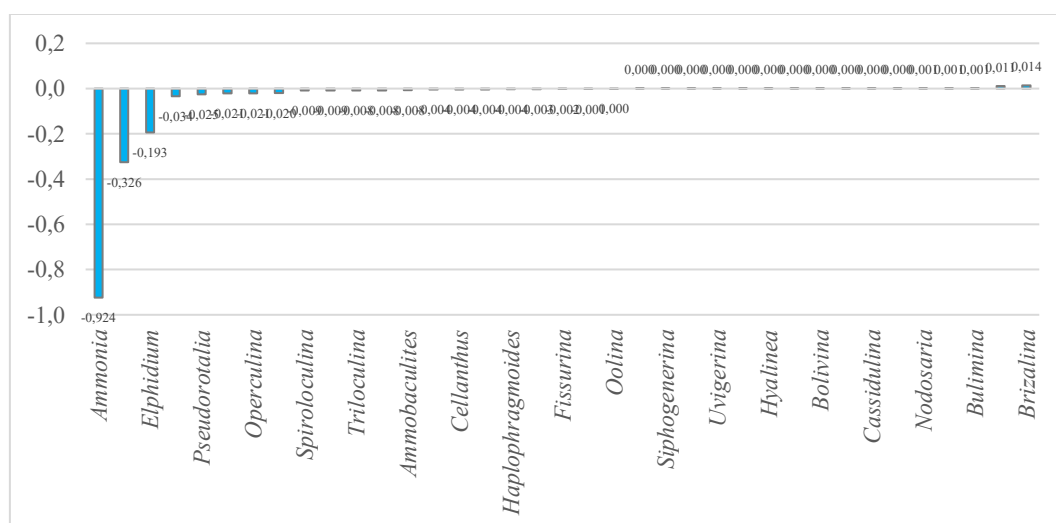


Figure S3. PCA loadings (component 1) inner neritic environment (genus)

Meanwhile, PCA data at the species level consists of benthic foraminiferal abundance from 7 samples with 76 variables. Based on these data, PCA analysis results show 82% of the variance. PC1 loadings in Figure S4 show that the species providing the highest influence are *Ammonia*, sp., *Asterorotalia trispinosa*, and *Elphidium hispidulum*.

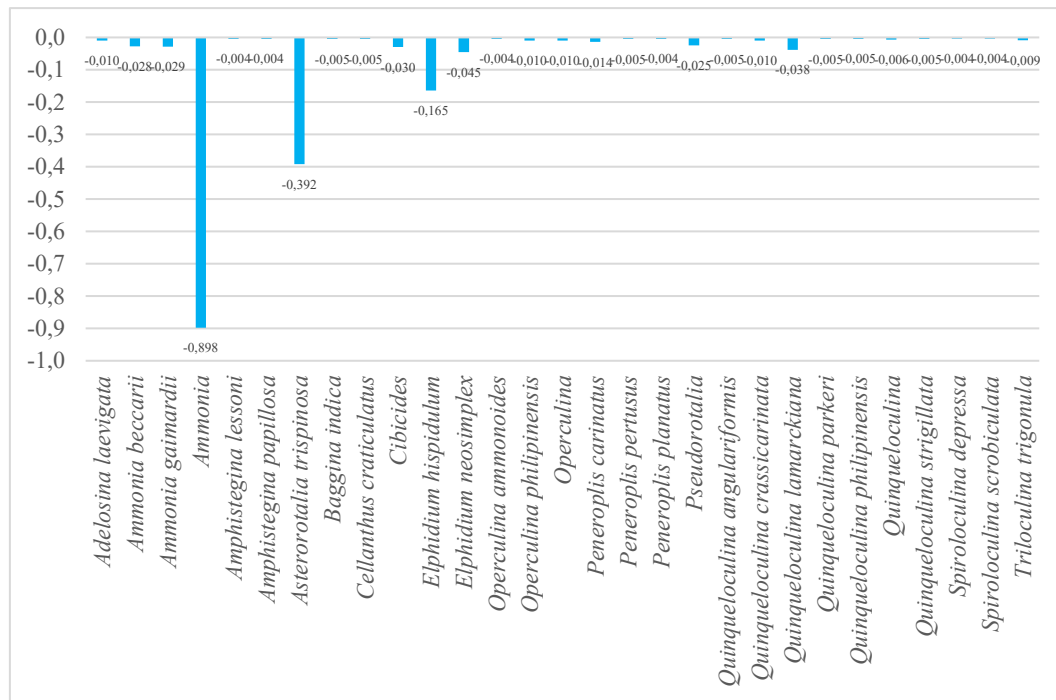


Figure S4. PCA loadings (component 1) inner neritic environment (species)

PC2 loadings at the species level are the second factor influencing foraminiferal distribution. PC2 has 16.25% of the variance. PC2 loadings in Figure S5 show that the species providing the highest influence are *Ammonia tepida*, *Quinqueloculina seminulum*, *Elphidium hispidulum*, and *Ammobaculites agglutinans*.

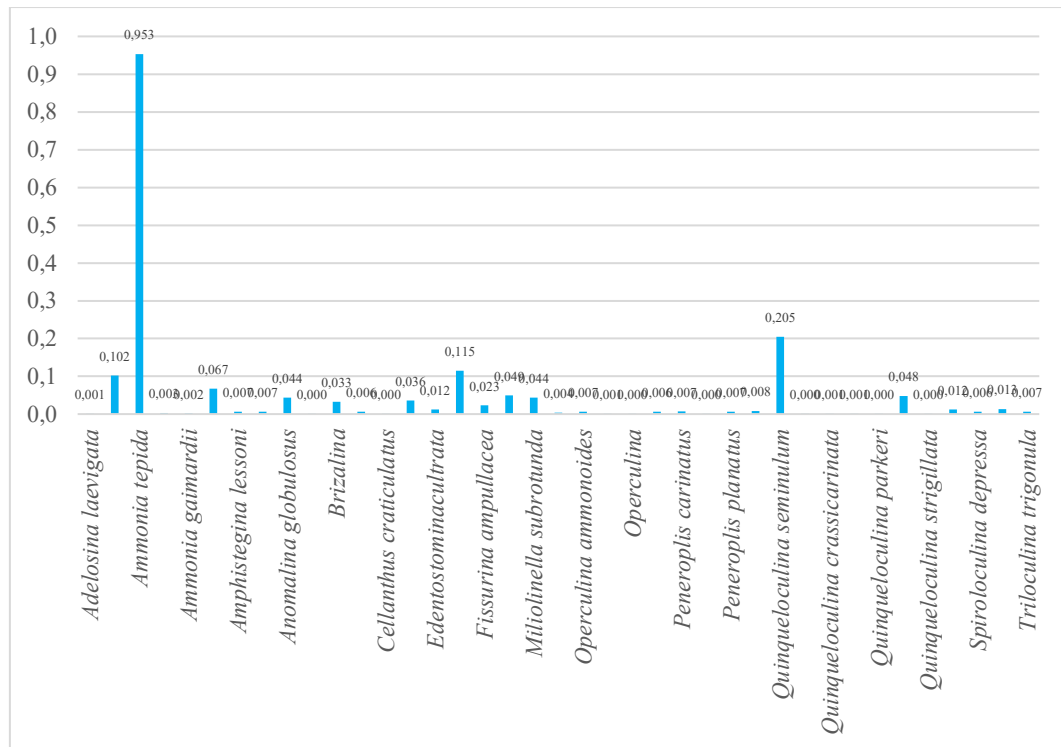


Figure S5. PCA loadings (component 2) inner neritic environment (species)

- Middle neritic environment

PCA analysis of the middle neritic environment at the genus level was performed using benthic abundance data from 6 samples with 53 variables. Based on the data, PC1 for the middle neritic environment at the genus level has 98% of the variance. PC1 loadings in Figure S6 show that the foraminiferal assemblage providing the highest influence consists of *Pseudorotalia*, *Quinqueloculina*, *Operculina*, *Cibicides*, *Ammonia*, *Brizalina*, and *Elphidium*.

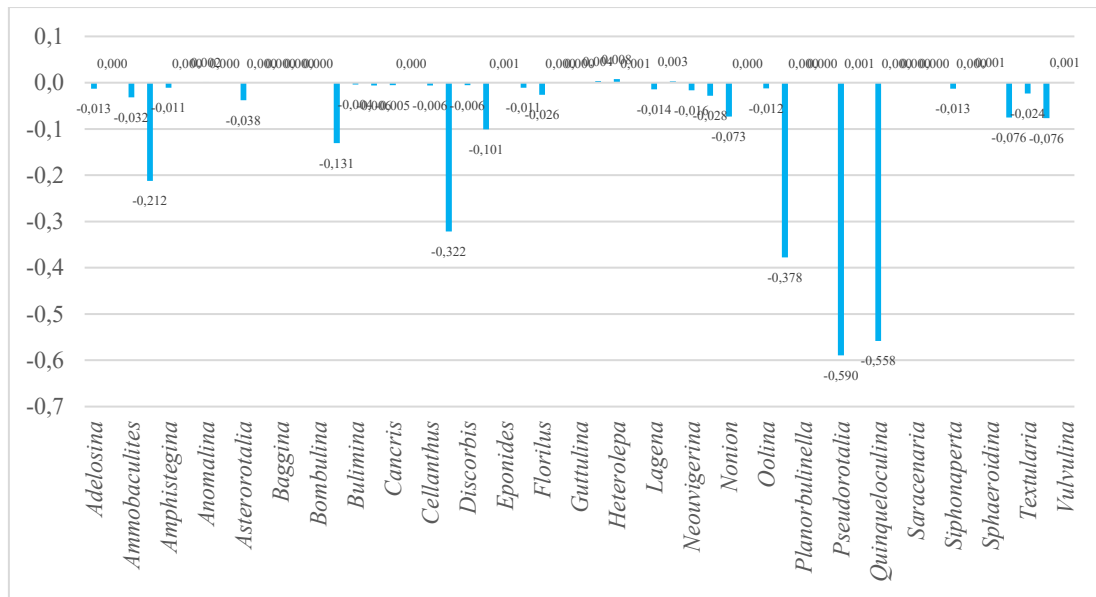


Figure S6. PCA loadings (component 1) middle neritic environment (genus)

Middle neritic environment PCA at the species level analyzed benthic foraminiferal abundance from 6 samples with 100 variables and show 97% of the variance. PC1 loadings in Figure S7 show that the foraminiferal assemblage providing the highest influence consists of *Quinqueloculina seminulum*, *Cibicides*, sp., *Operculina philippinensis*, *Ammonia beccarii*, *Pseudorotalia*, sp., *Operculina*, sp., *Quinqueloculina granulocostata*, *Triloculina tricarinata*, and *Nonion scaphum*.

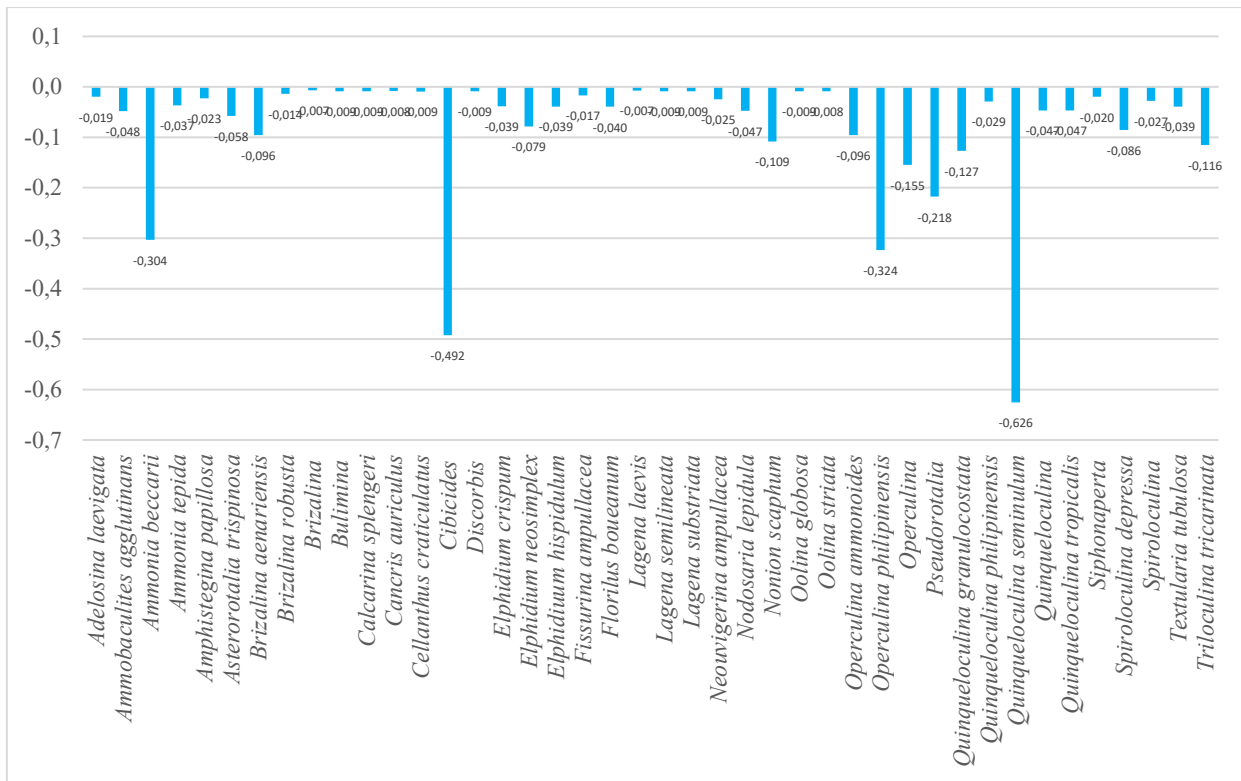


Figure S7. PCA loadings (component 1) middle neritic environment (species)

- Outer neritic environment

PCA analysis of the outer neritic environment at the genus level was performed using benthic abundance data from 5 samples with 38 variables. According to the data, PC1 at the genus level in the outer neritic environment has 99.9% of the variance. The PC1 loadings (Figure S8) indicate that *Brizalina*, *Amphistegina*, *Cibicides*, and *Gyroidina* are the most influential genera.

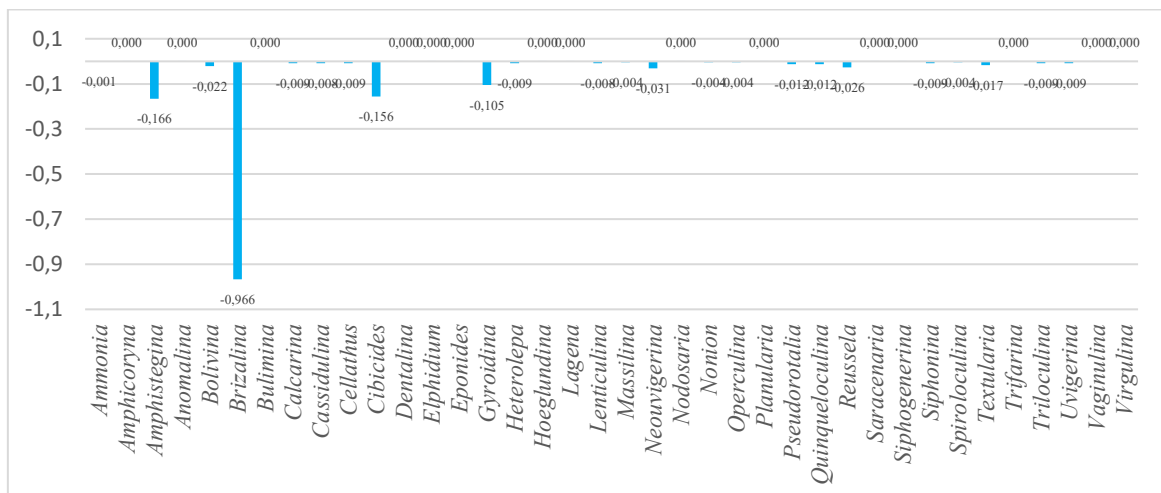


Figure S8. PCA loadings (component 1) outer neritic environment (genus)

Species level PCA analysis of the outer neritic environment analyzed benthic foraminiferal abundance from 5 samples with 73 variables and show 99.8% of the variance. Figure S9 shows that the PC1 loadings are dominated by *Brizalina aenariensis*, *Cibicides* sp., *Amphistegina papillosa*, *Gyroidina broeckhiana*, and *Brizalina robusta*.

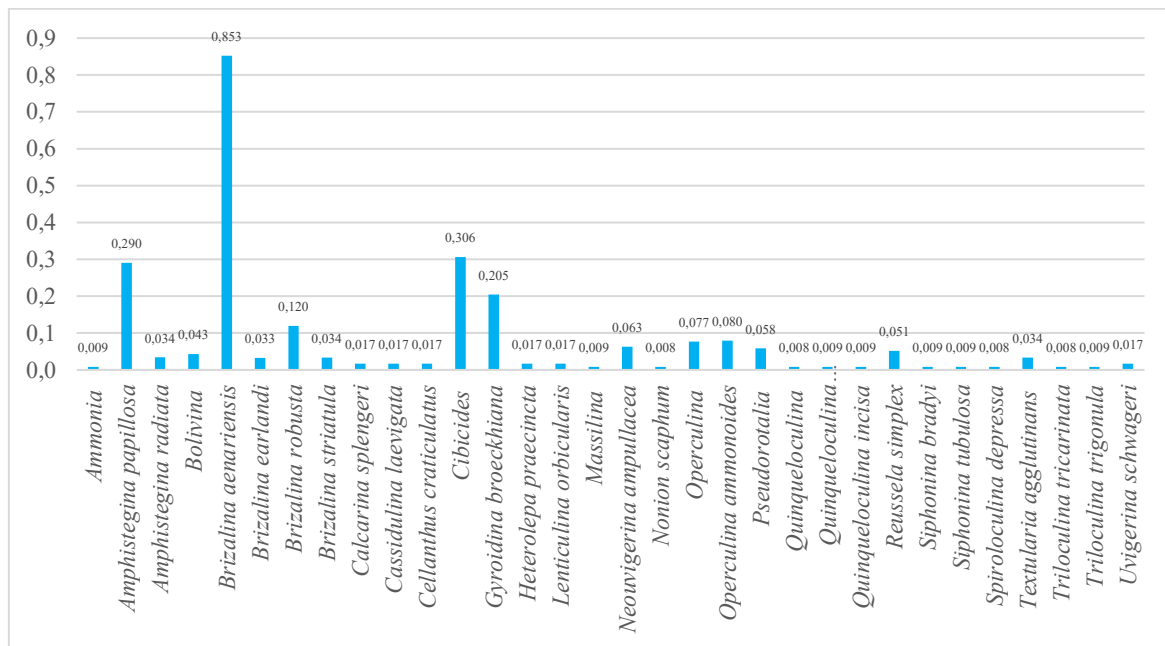


Figure S9. PCA loadings (component 1) outer neritic environment (species)

The PCA results demonstrate remarkably consistent patterns across both taxonomic levels, with variance values exceeding 99%, indicating that PC1 accounts for virtually all data variability in the outer neritic environment. This strong concordance between dominant foraminiferal assemblages at both taxonomic levels provides robust support for the ecological interpretation of this environment.

- Upper bathyal environment

PCA analysis of the upper bathyal environment at the genus level was performed using benthic foraminiferal abundance data from 6 samples with 55 variables. Based on data, PC1 for the upper bathyal environment at the genus level exhibits 81% of the variance. Figure S10 shows that the PC1 loadings are dominated by *Brizalina*, *Uvigerina*, *Lenticulina*, and *Bulimina*.

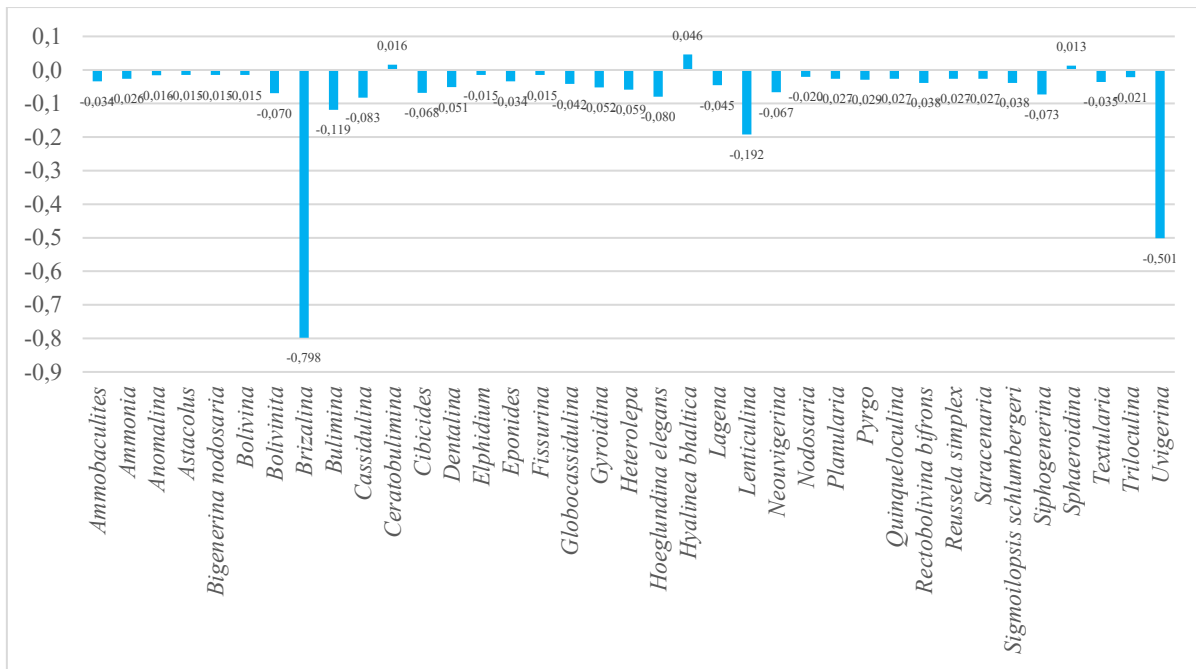


Figure S10. PCA loadings (component 1) upper bathyal environment (genus)

Species level PCA analysis of the upper bathyal environment analyzed benthic foraminiferal abundance from 6 samples with 81 variables. Based on these data, PCA analysis results explain 54% of the variance. Figure S11 shows the PCA loadings for component 1 at the species level, where the species providing the highest influence are *Uvigerina asperula*, *Brizalina aenariensis*, *Brizalina* sp., *Neovigerina ampullacea*, *Lenticulina calcar*, *Hoeglundina elegans*, *Uvigerina peregrina*, *Cassidulina* sp., *Heterolepa praecincta*, *Bolivinita subangularis*, and *Hyalinea balthica*.

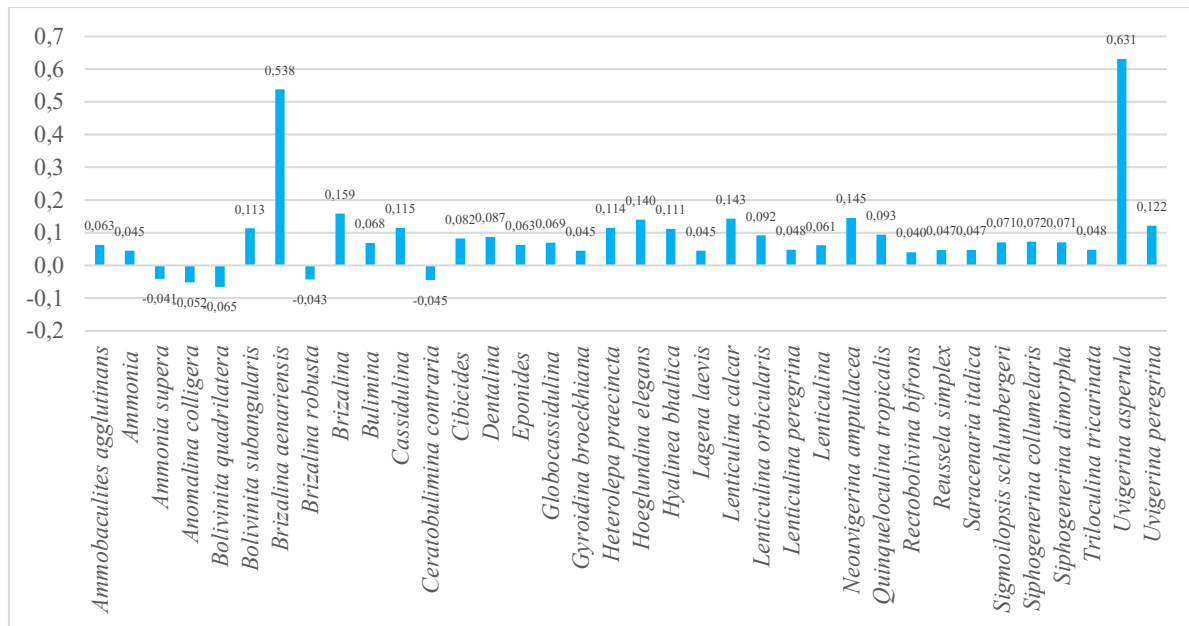


Figure S11. PCA loadings (component 1) upper bathyal environment (species)

PCA analysis of the upper bathyal environment shows consistent foraminiferal distribution patterns between genus and species levels. The dominance of *Brizalina* and *Uvigerina* genera in PC1 at the genus level correlates with the dominance of *Brizalina aenariensis* and *Uvigerina asperula* in PC1 at the species level, indicating consistency of ecological factors influencing both taxonomic levels.

PC2 at the genus level in the upper bathyal environment explain 11% of the variance. PC2 loadings (Figure S12) shows that the genera providing the highest influence are *Lenticulina*, *Hoeglundina*, *Neouvigerina*, *Siphogenerina*, *Uvigerina*, *Heterolepa*, *Eponides*, *Ammobaculites*, *Dentalina*, *Pyrgo*, *Nodosaria*, *Lagena*, *Ammonia*, *Rectobolivina*, *Brizalina*, *Bolivinita*, and *Bulimina*.

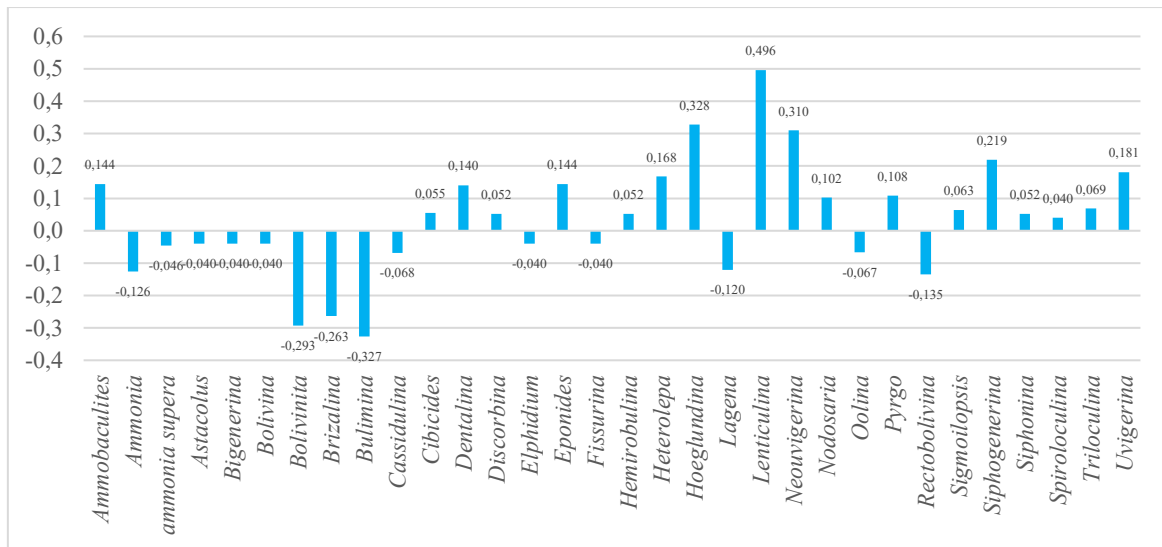


Figure S12. PCA loadings (component 2) upper bathyal environment (genus)

PC2 for the species level in the bathyal environment has 27% of the variance and PC2 loadings (Figure S13) is dominated by *Bulimina marginata*, *Uvigerina asperula*, *Brizalina* sp., *Brizalina robusta*, *Neouvierina ampullacea*, *Uvigerina peregrina*, *Quinqueloculina seminulum*, *Hoeglundina elegans*, *Lenticulina calcar*, *Dentalina* sp., *Heterolepa praecincta*, *Siphogenerina columellaris*, *Eponides* sp., *Ammobaculites agglutinans*, *Bolivinita subangularis*, *Rectobolivina bifrons*, *Cassidulina* sp., and *Bolivinita quadrilatera*.

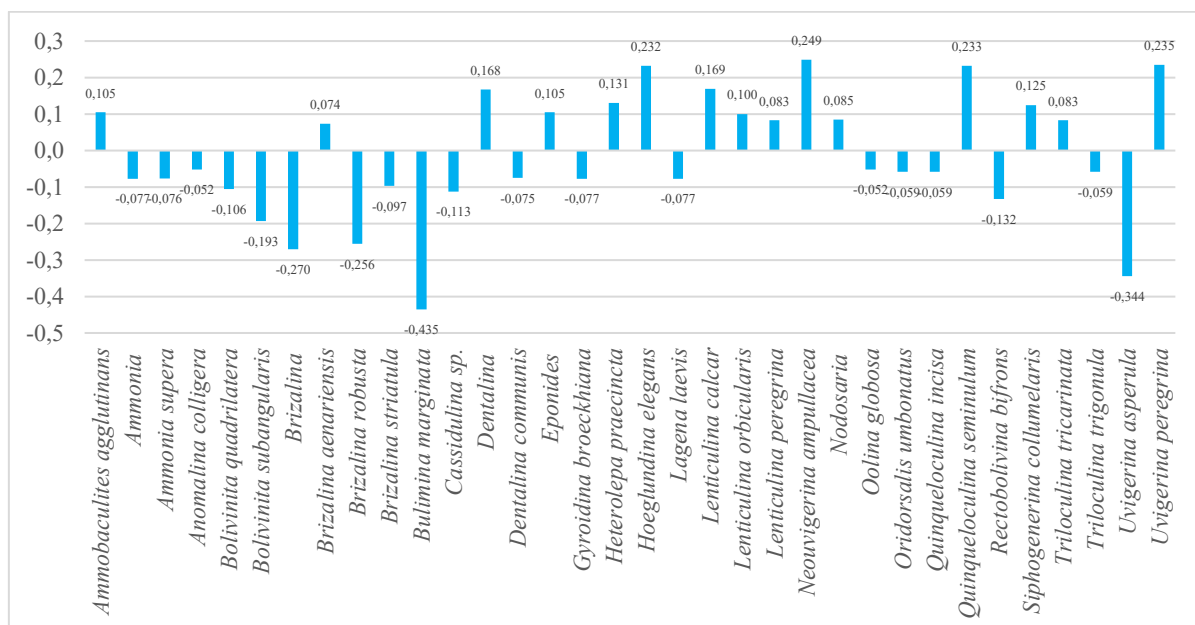


Figure S13. PCA loadings (component 2) upper bathyal environment (species)

- Lower bathyal environment

Lower bathyal environment PCA at the genus level analyzed benthic foraminiferal abundance from 9 samples with 42 variables, yielding 87% of the variance.

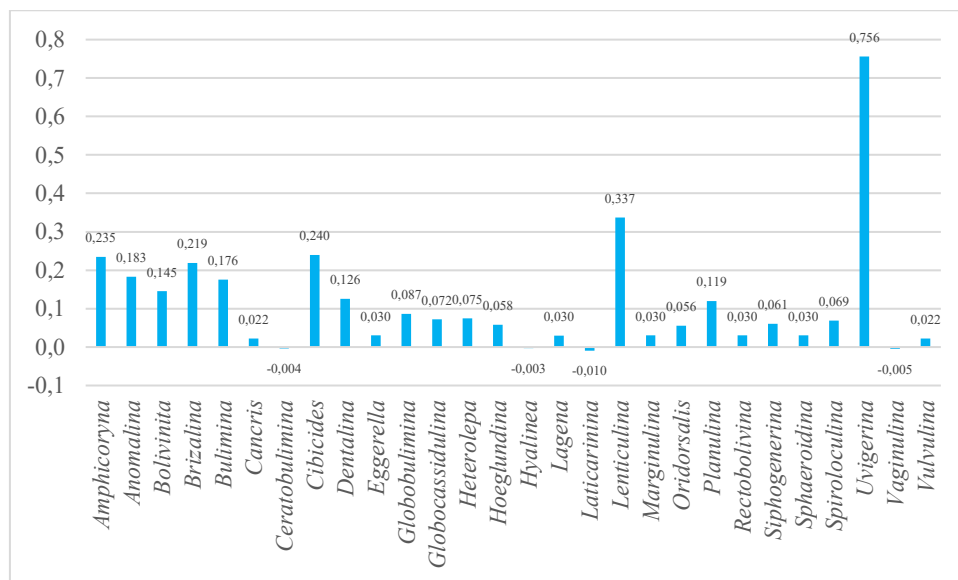


Figure S14. PCA loadings (component 1) lower bathyal environment (genus)

According to Figure S14, PC1 loadings at the genus level in the lower bathyal environment indicate that genera are most influential: *Uvigerina*, *Lenticulina*, *Cibicides*, *Amphotryna*, *Brizalina*, *Anomalina*, *Bulimina*, *Bolivinita*, *Dentalina* and *Planulina*.

Meanwhile, species level PCA analysis of the lower bathyal environment analyzed benthic foraminiferal abundance from 9 samples with 70 variables, Based on data, PCA analysis results show 71% of the variance. PC1 loadings in Figure S15 show that the species providing the highest influence are *Uvigerina peregrina*, *Lenticulina orbicularis*, *Anomalina colligera*, *Amphotryna scalaris*, *Bolivinita quadrilatera*, *Planulina ariminensis*, *Brizalina robusta*, *Uvigerina* sp., *Bulimina* sp., *Globobulimina pacifica*, and *Brizalina* sp. This assemblage of species is characteristic of deep marine environments.

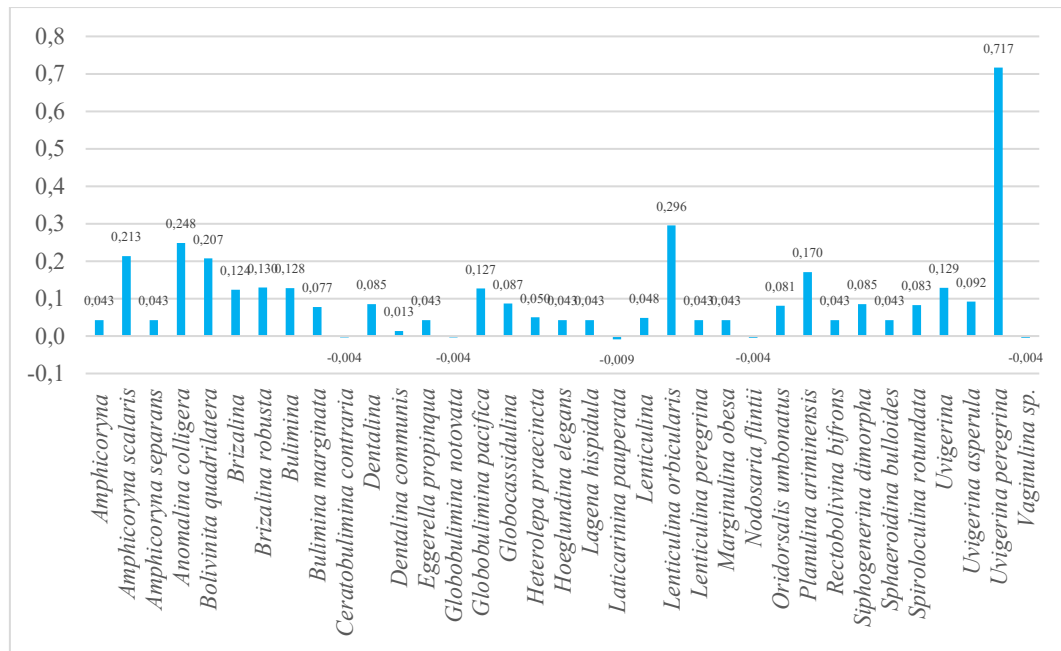


Figure S15. PCA loadings (component 1) lower bathyal environment (species)

The PCA analysis of the lower bathyal environment exhibits remarkable consistency in foraminiferal distribution patterns between genus and species taxonomic levels. This strong taxonomic alignment is particularly evident in the dominance of *Uvigerina* as a genus level component and *Uvigerina peregrina* as the corresponding species level component, both representing the primary loading factors in their respective PC1 analyses. This concordance reinforces the ecological significance of this taxon in characterizing lower bathyal environments.

PCA loadings for component 2 at the genus level are displayed in Figure S16. Based on this figure, PC2 at the genus level in the lower bathyal environment with 9% of the variance shows that the genera providing the highest influence are *Dentalina*, *Heterolepa*, *Cibicides*, *Hoeglundina elegans*, *Cancris*, *Vulvulina*, *Nodosaria*, *Lenticulina*, *Brizalina*, *Astacolus*, *Planularia*, and *Martinotiella*.

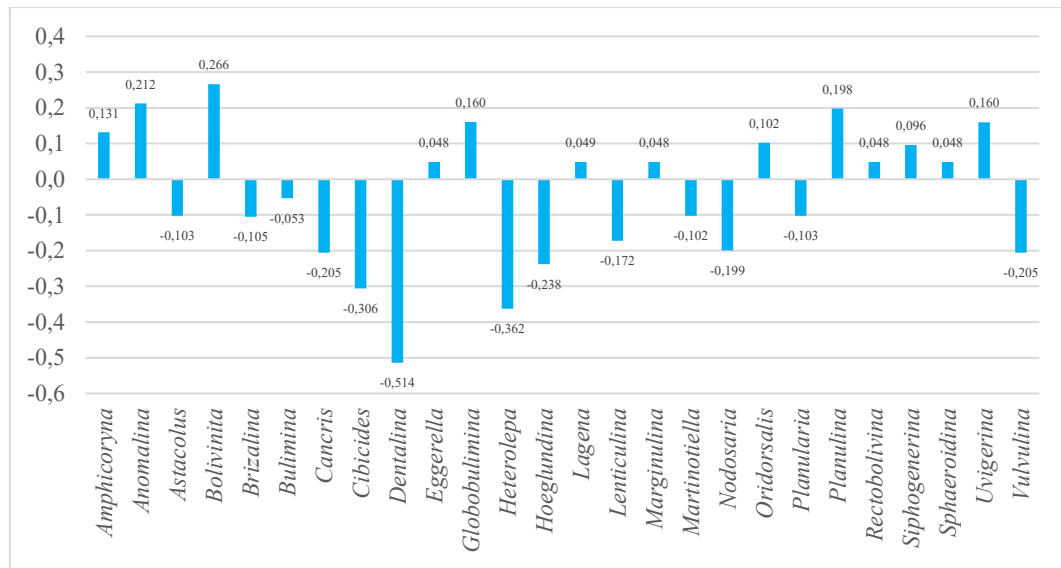


Figure S16. PCA loadings (component 2) lower bathyal environment (genus)

Figure S17 presents the PCA loadings for the second principal component (PC2) at the species level. Based on this analysis, PC2 in the lower bathyal environment explains 25% of the variance, showing that the most influential species are *Dentalina communis*, *Cibicides*, sp., *Heterolepa praecincta*, *Uvigerina asperula*, *Lenticulina iota*, *Lenticulina* sp., *Hoeglundina elegans*, *Bulimina marginata*, *Cancris auriculus*, *Vulvulina pennatula*, *Nodosaria radicularis*, *Uvigerina schwageri*, *Amphicoryna hirsuta*, *Brizalina robusta*, *Uvigerina* sp., and *Uvigerina peregrina*.

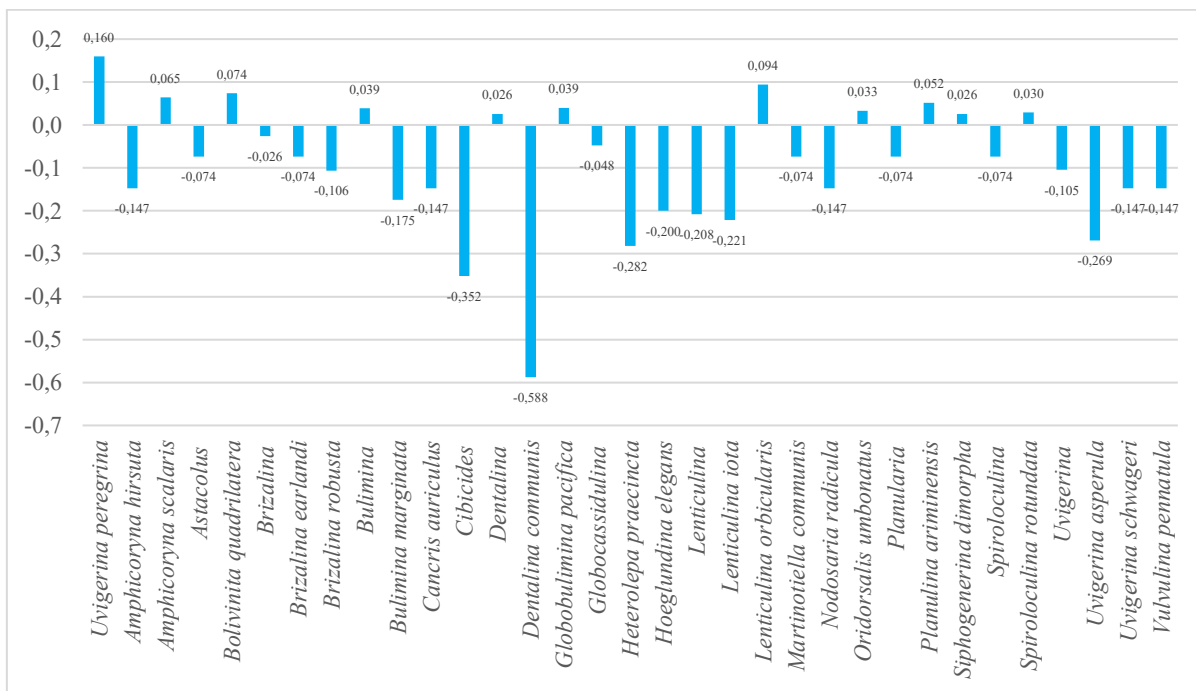


Figure S17. PCA loadings (component 2) lower bathyal environment (species)

The PC2 analysis in the lower bathyal environment demonstrates correspondence between foraminiferal factor loadings at both taxonomic levels. Specifically, the dominant genera *Dentalina*, *Heterolepa*, *Cibicides*, *Hoeglundina*, and *Lenticulina* correspond directly to their representative species: *Dentalina communis*, *Heterolepa praecincta*, *Cibicides* sp., *Hoeglundina elegans*, and *Lenticulina iota*, respectively.