



Supplement of

Reassessment of the global distribution and diversity of modern planktonic foraminifera from the FORCIS database

Sonia Chaabane et al.

Correspondence to: Sonia Chaabane (sonia.chaabane@gmail.com, chaabane@cerege.fr, and sonia.chaabane@mpic.de)

The copyright of individual parts of the supplement might differ from the article licence.

1 **Supplementary material**

2

3 **Figures**

4

5 **Figure S1. Sensitivity analysis of alpha values for threshold determination in species**
6 **presence.** Sensitivity test conducted across all species to evaluate the impact of varying alpha
7 values (0.10, 0.15, 0.20, 0.25, 0.30) on the number of significant latitudinal bands representing
8 species presence.

9

10 **Figure S2. Sensitivity analysis of alpha values and their effect on the number of significant**
11 **latitudinal bands.** Violin plots show the distribution of significant latitudinal bands in species
12 presence across different alpha values (0.10, 0.15, 0.20, 0.25, 0.30). The width of each violin
13 represents the density of observations, with individual data points overlaid to illustrate
14 variability. Red dots indicate the mean number of significant bands for each alpha value. A
15 decreasing trend suggests that higher alpha values lead to a more stringent threshold for species
16 presence, reducing the number of latitudinal bands deemed significant.

17

18 **Fig. S3. Latitudinal distribution patterns of planktonic Foraminifera species where the**
19 **entire assemblage has been counted to species level.** The left-hand side of each panel displays
20 Robinson projection maps illustrating species presence (blue dots) and absence (gray dots)
21 across global sampling sites (1970–2018), overlain on historical biogeographic provinces
22 (colored bands) as defined by Bé and Tolderlund (1971), spanning global, polar, subpolar,
23 temperate, subtropical, and tropical zones (from top to bottom panels). Adjacent histograms
24 (right-hand side of each panel) show the presence rate of each species within 10° latitude bins.
25 Dark gray bars represent latitudinal bins where species are outside of their expected
26 biogeographic province, while light gray bars correspond to bins where species are within their
27 expected habitats. The dashed red line denotes the species-specific threshold used to identify
28 significant distribution patterns.

29

30 **Fig. S4. Latitudinal distribution patterns of planktonic Foraminifera species, based on**
31 **samples where the entire assemblage was counted to species level, comparing species**
32 **proportions between fine ($\leq 200 \mu\text{m}$) and coarse ($> 200 \mu\text{m}$) mesh sizes.** The left-hand side
33 of each panel displays Robinson projection maps illustrating species presence (green dots:
34 species collected with fine mesh size ($\leq 200 \mu\text{m}$); purple dots: species collected with coarse
35 mesh size ($> 200 \mu\text{m}$)) and absence (gray dots) across global sampling sites (1970–2018),
36 overlain on historical biogeographic provinces (colored bands) as defined by Bé and Tolderlund
37 (1971), spanning global, polar, subpolar, temperate, subtropical, and tropical zones (from top
38 to bottom panels). Adjacent histograms (right-hand side of each panel) show the presence rate
39 of each species within 10° latitude bins of the PF in the fine ($\leq 200 \mu\text{m}$) mesh sizes. Dark gray
40 bars represent latitudinal bins where species are outside of their expected biogeographic
41 province, while light gray bars correspond to bins where species are within their expected
42 habitats. The dashed red line denotes the species-specific threshold used to identify significant
43 distribution patterns.

44

45 **Fig. S5. Distribution of mean relative abundance of planktonic Foraminifera species in**
46 **the different oceanic basins.** Species are ordered by increasing mean relative abundance in the
47 blue histograms. The red dashed line indicates the 25th percentile threshold used to identify
48 rare species based on abundance. In the broader biodiversity analysis, species rarity was defined
49 using a dual-criteria approach combining both relative abundance and frequency of occurrence
50 across samples, where species below the 25th percentile in both metrics were considered rare.

51

52 **Figure S6. Latitudinal Shannon diversity index of planktonic Foraminifera at different**
53 **ocean basins.** Latitudinal patterns in Shannon diversity index for PF, spanning from -80° (more
54 than 70° South) to 80° (more than 80° North) in 10° intervals. Derived from samples collected
55 using plankton net, pump, and CPR, the analyses encompass data from the surface 200 m of the
56 water column since 1970. This comprehensive examination offers insights into the latitudinal
57 distribution of PF diversity across ocean basins.

58

59 **Figure S7. Latitudinal Diversity Gradient of the 26 major Planktonic Foraminifera**
60 **species across ocean basins.** Relationship between latitude and PF species richness, across
61 different ocean basins. Each dot represents the observed species richness at a sampling location,
62 color-coded by the corresponding ocean basin. The overall latitudinal diversity gradient is
63 derived from species richness data aggregated between 1970 and 2018. The analysis is restricted
64 to samples from depths shallower than 200 meters to capture near-surface habitat diversity.

65

66 **Figure S8. Species-wise tests of among-basin differences in depth of maximum abundance.**
67 For each planktonic foraminifera species, the left matrix reports pairwise differences in the
68 depth of maximum abundance between ocean basins (Games–Howell tests following a
69 significant one-way Welch ANOVA; Benjamini–Hochberg adjusted p-values shown; grey =
70 insufficient data, <5 profiles per basin). The right heatmap shows Pearson correlations of basin-
71 wise depth of maximum abundance distributions (10-m bins from 0–200 m), highlighting where
72 vertical-habitat shapes are similar ($0 < r \leq 1$) or distinct ($-1 \leq r < 0$).

73

74 **Figure S9. Temperature tolerance of planktonic Foraminifera in different ocean basins.**
75 Temperature-related preferences of PF across various ocean basins and ecological provinces
76 (global, polar, subpolar, temperate, subtropical, and tropical). The dataset covers water depth
77 ranges from the sea surface to 100 m, starting from 1970. Mean in-situ temperatures are
78 computed from minimum and maximum temperature values extracted from the Reanalysis Data
79 Hadley EN 4.2.1 analysis g10 dataset, providing temperature information at a $1 \times 1^\circ$ resolution
80 in the (A) North Atlantic Ocean, (B) South Atlantic Ocean, (C) North Pacific Ocean, (D) Indian
81 Ocean, (E) Southern Ocean, and (F) Arctic Ocean.

82

83 **Figure S10. Temperature-related abundance patterns in planktonic Foraminifera**
84 **sampled with different mesh sizes.** Heatmap presents the abundance of the most abundant
85 planktonic Foraminifera species collected with different mesh sizes and sourced the FORCIS
86 database (Chaabane et al., 2023). Data are from samples collected by plankton nets and pumps
87 across the global ocean. Temperature bins are spaced at 1°C intervals (x-axis), and encompass

88 the depth range of 0 to 100 m after 1970. Mean in-situ temperatures are computed from
 89 minimum and maximum temperature values extracted from the Reanalysis Data Hadley EN
 90 4.2.1 analysis g10 dataset, providing temperature information at a 1x001° resolution.

91

92 **Figure S11. Temperature-related abundance variations of planktonic Foraminifera**
 93 **collected with net mesh size between 100 and 200 µm.** Heatmap presents the abundance of
 94 the most abundant planktonic Foraminifera species collected with net mesh size between 100
 95 and 150 µm and sourced from the FORCIS database (Chaabane et al., 2023). Data are from
 96 samples collected by plankton nets and pumps across the global ocean. Temperature bins are
 97 spaced at 1 °C intervals (x-axis), and encompass the depth range of 0 to 100 m after 1970. Mean
 98 in-situ temperatures are computed from minimum and maximum temperature values extracted
 99 from the Reanalysis Data Hadley EN 4.2.1 analysis g10 dataset, providing temperature
 100 information at a 1x1° resolution.

101

102 **Table**

103

104 **Table S1.** Planktonic Foraminifera species names in FORCIS and their corresponding
 105 biogeographic provinces and adult test size.

106

Species name	Habitat*	Number of significant bands	Adult size category**	New habitat
<i>G. bulloides</i>	Global	14	Medium	Global
<i>G. glutinata</i>	Global	14	Medium	Global
<i>G. inflata</i>	Global	12	Medium	Global
<i>T. quinqueloba</i>	Global	12	Small	Global
<i>N. pachyderma</i>	Polar	9	Medium	Polar
<i>G. uvula</i>	Subpolar	7	Small	Temperate to subpolar

<i>G. crassaformis</i>	Temperate	5	Medium	Temperate
<i>G. hirsuta</i>	Temperate	8	Medium	Temperate
<i>G. scitula</i>	Temperate	10	Medium	Temperate to subpolar
<i>N. incompta</i>	Temperate	11	Medium	Temperate to subpolar
<i>T. humilis</i>	Temperate	5	Small	Temperate
<i>G. calida</i>	Subtropical	5	Large	Subtropical to temperate
<i>G. cultrata</i>	Subtropical	7	Large	Tropical to subtropical
<i>G. ruber</i>	Subtropical	10	Medium	Tropical to temperate
<i>G. rubescens</i>	Subtropical	6	Small	Subtropical
<i>G. siphonifera</i>	Subtropical	10	Large	Tropical to temperate
<i>G. truncatulinooides</i>	Subtropical	7	Large	Subtropical
<i>H. pelagica</i>	Subtropical	9	Large	Tropical to temperate
<i>N. dutertrei</i>	Subtropical	10	Medium	Tropical to temperate
<i>O. universa</i>	Subtropical	11	Large	Tropical to temperate
<i>T. sacculifer</i>	Subtropical	10	Medium	Tropical to temperate
<i>G. conglobatus</i>	Tropical	9	Medium	Tropical to subtropical
<i>G. conglomerata</i>	Tropical	4	Medium	Tropical
<i>G. hexagonus</i>	Tropical	5	Medium	Tropical
<i>G. ruber ruber</i>	Tropical	7	Medium	Tropical
<i>P. obliquiloculata</i>	Tropical	6	Medium	Tropical

107 * According to [Bé and Tolderlund, 1971](#) and adapted to a more recent concept of the species'
 108 ecology as provided by [Schiebel and Hemleben \(2017\)](#).
 109 ** From [Chaabane et al. 2024](#) based on [Brummer & Kucera, 2022](#), [Schiebel and Hemleben,](#)
 110 [2017](#), [Meilland et al. 2021](#), [Meilland et al. 2022](#).
 111 *** [Kucera et al. 2007](#)

112
 113
 114
 115
 116

Table S2. Latitudinal ranges of primary and transitional ecological provinces, as well as the distribution of ubiquitous species of planktonic Foraminifera.

Biogeographic province	Latitude Range
Primary provinces	
Tropical	0° – 20° N/S
Subtropical	20° – 40° N/S
Temperate	40° – 60° N/S
Subpolar	60° – 70° N/S
Polar Zone	70° – 90° N/S
Transitional provinces	
Tropical-to-Subtropical	0° – 40° N/S
Subtropical-to-Temperate	20° – 60° N/S
Temperate-to-Subpolar	40° – 70° N/S
Subpolar-to-Polar	>70° N/S
Ubiquitous	Present across all latitudes

117
 118
 119
 120
 121
 122

Table S3. Comparison of biogeographic provinces for planktonic foraminifera species based on different sensitivity tests: number of significant bands from (1) samples with species proportions from the fine fraction ($\leq 200 \mu\text{m}$); (2) samples where the entire assemblage was identified to species level; and (3) samples from the FORCIS database.

Species name	Significant bands ($\leq 200 \mu\text{m}$)	Habitat ($\leq 200 \mu\text{m}$)	Significant bands (All shells counted)	Habitat (all shells counted)	Significant bands (All samples)	Habitat (All samples)
<i>G. bulloides</i>	14	Global	14	Global	14	Global
<i>G. glutinata</i>	14	Global	14	Global	14	Global
<i>G. inflata</i>	10	Subtropical to subpolar	11	Subtropical to subpolar	12	Global
<i>T. quinqueloba</i>	12	Global	12	Global	12	Global
<i>N. pachyderma</i>	7	Polar	7	Polar	7	Polar
<i>G. uvula</i>	6	Temperate to subpolar	7	Temperate to subpolar	7	Temperate to subpolar
<i>G. crassaformis</i>	4	Temperate	4	Temperate	5	Temperate
<i>G. hirsuta</i>	6	Temperate	7	Temperate	8	Temperate
<i>G. scitula</i>	9	Temperate to subpolar	10	Temperate to subpolar	10	Temperate to subpolar
<i>N. incompta</i>	12	Global	11	Temperate to subpolar	11	Temperate to subpolar
<i>T. humilis</i>	5	Temperate	5	Temperate	5	Temperate
<i>G. calida</i>	6	Tropical to temperate	5	Subtropical to temperate	5	Subtropical to temperate
<i>G. cultrata</i>	8	Tropical to subtropical	7	Tropical to subtropical	7	Tropical to subtropical
<i>G. ruber</i>	10	Tropical to temperate	11	Tropical to temperate	10	Tropical to temperate
<i>G. rubescens</i>	6	Subtropical	6	Subtropical	6	Subtropical
<i>G. siphonifera</i>	10	Tropical to temperate	10	Tropical to temperate	10	Tropical to temperate

<i>G. truncatulinoides</i>	6	Subtropical	7	Subtropical	7	Subtropical
<i>H. pelagica</i>	9	Tropical to temperate	9	Tropical to temperate	9	Tropical to temperate
<i>N. dutertrei</i>	9	Tropical to temperate	10	Tropical to temperate	10	Tropical to temperate
<i>O. universa</i>	10	Tropical to temperate	10	Tropical to temperate	11	Tropical to temperate
<i>T. sacculifer</i>	10	Tropical to temperate	10	Tropical to temperate	10	Tropical to temperate
<i>G. conglobatus</i>	8	Tropical to subtropical	7	Tropical to subtropical	9	Tropical to subtropical
<i>G. conglomerata</i>	4	Tropical	4	Tropical	4	Tropical
<i>G. hexagonus</i>	4	Tropical	5	Tropical	5	Tropical
<i>G. ruber ruber</i>	4	Tropical	6	Tropical	7	Tropical
<i>P. obliquiloculata</i>	4	Tropical	3	Tropical	6	Tropical

123

124

125

126 **Table S4.** Classification of planktonic foraminifera species based on the number of significant

127 latitudinal bands.

128

Number of Significant Bands	Ecological Category	Description
≥ 12	Global	Species broadly distributed across many latitudinal bands worldwide.
9 to 11	Wide Range (Subtropical to Polar)	Species with broad but not fully global distributions, often spanning subtropical to polar or temperate to subpolar zones.

6 to 8	Intermediate Range (Tropical, Temperate to Subpolar)	Species with moderate latitudinal ranges, typically spanning tropical to subpolar or subtropical to temperate zones.
≤ 6	Restricted Range (Tropical/Subtropical/Temperate)	Species with limited latitudinal presence, usually confined to tropical, subtropical, or temperate zones.

129

130

131

132 **Table S5.** Number of unique sampling profiles underlying the boxplots in Figure 3, showing
 133 the occurrences of each PF species across the major ocean basins.

134

Species	North Atlantic	South Atlantic	North Pacific	Arctic Ocean	Indian Ocean
<i>Globigerinoides ruber ruber</i>	53	0	0	0	0
<i>Globigerinoides conglobatus</i>	12	0	7	0	12
<i>Globigerinoides ruber</i>	84	3	11	0	36
<i>Trilobatus sacculifer</i>	90	3	9	0	38
<i>Neogloboquadrina dutertrei</i>	55	0	15	0	39
<i>Globigerinita uvula</i>	69	0	0	8	28
<i>Globorotalia cultrata</i>	38	3	6	0	31

<i>Orbulina universa</i>	76	5	6	0	20
<i>Globoturborotalita rubescens</i>	51	0	5	0	27
<i>Pulleniatina obliquiloculata</i>	8	0	4	0	12
<i>Globigerina bulloides</i>	127	13	13	9	48
<i>Globigerinita glutinata</i>	133	3	12	9	48
<i>Neogloboquadrina incompta</i>	110	5	8	8	26
<i>Globigerinella siphonifera</i>	82	3	7	0	34
<i>Turborotalita quinqueloba</i>	136	4	8	9	39
<i>Neogloboquadrina pachyderma</i>	76	5	2	21	23
<i>Globigerinella calida</i>	40	5	7	0	31
<i>Globorotalia inflata</i>	64	5	2	0	16
<i>Globoquadrina conglomeraata</i>	0	0	5	0	7
<i>Globorotalia scitula</i>	90	3	3	5	34
<i>Hastigerina pelagica</i>	33	4	3	0	17

<i>Turborotalita humilis</i>	26	0	0	0	0
<i>Globorotalia hirsuta</i>	25	0	0	0	4
<i>Globorotalia truncatulinoides</i>	36	4	0	0	0
<i>Globorotalia crassaformis</i>	10	0	0	0	0
<i>Globorotaloides hexagonus</i>	0	0	4	0	20

135

136

137 **Table S6.** Number of unique samples underlying the boxplots in Figure S8, indicating the

138 occurrences of each planktonic foraminifera species across the major ocean basins.

139

Species	North Atlantic	South Atlantic	North Pacific	Arctic Ocean	Indian Ocean	Southern Ocean
<i>Globigerinoides ruber ruber</i>	289	70	0	0	0	0
<i>Globigerinoides conglobatus</i>	39	5	56	0	38	0
<i>Globigerinoides ruber</i>	556	132	92	0	337	0
<i>Trilobatus sacculifer</i>	470	133	82	0	359	0
<i>Neogloboquadrina dutertrei</i>	268	70	87	3	292	0
<i>Globigerinita uvula</i>	230	0	0	21	190	0

<i>Globorotalia cultrata</i>	170	77	46	0	249	0
<i>Orbulina universa</i>	388	98	33	0	100	0
<i>Globoturborotalita rubescens</i>	212	52	37	0	121	0
<i>Pulleniatina obliquiloculata</i>	39	0	50	0	110	0
<i>Globigerina bulloides</i>	626	107	80	32	949	92
<i>Globigerinita glutinata</i>	700	123	84	27	396	0
<i>Neogloboquadrina incompta</i>	659	48	57	55	430	4
<i>Globigerinella siphonifera</i>	497	81	66	0	281	0
<i>Turborotalita quinqueloba</i>	724	17	56	62	303	0
<i>Neogloboquadrina pachyderma</i>	316	49	14	115	679	24
<i>Globigerinella calida</i>	167	53	53	0	178	0
<i>Globorotalia inflata</i>	378	67	5	0	34	0
<i>Globoquadrina conglomerata</i>	0	0	37	0	26	0
<i>Globorotalia scitula</i>	342	34	4	8	105	0
<i>Hastigerina pelagica</i>	73	32	20	0	56	0

<i>Turborotalita humilis</i>	69	0	5	0	3	0
<i>Globorotalia hirsuta</i>	95	0	0	0	3	0
<i>Globorotalia truncatulinoides</i>	126	38	0	0	10	0
<i>Globorotalia crassaformis</i>	7	3	0	0	0	0
<i>Globorotaloides hexagonus</i>	0	0	9	0	41	0

140

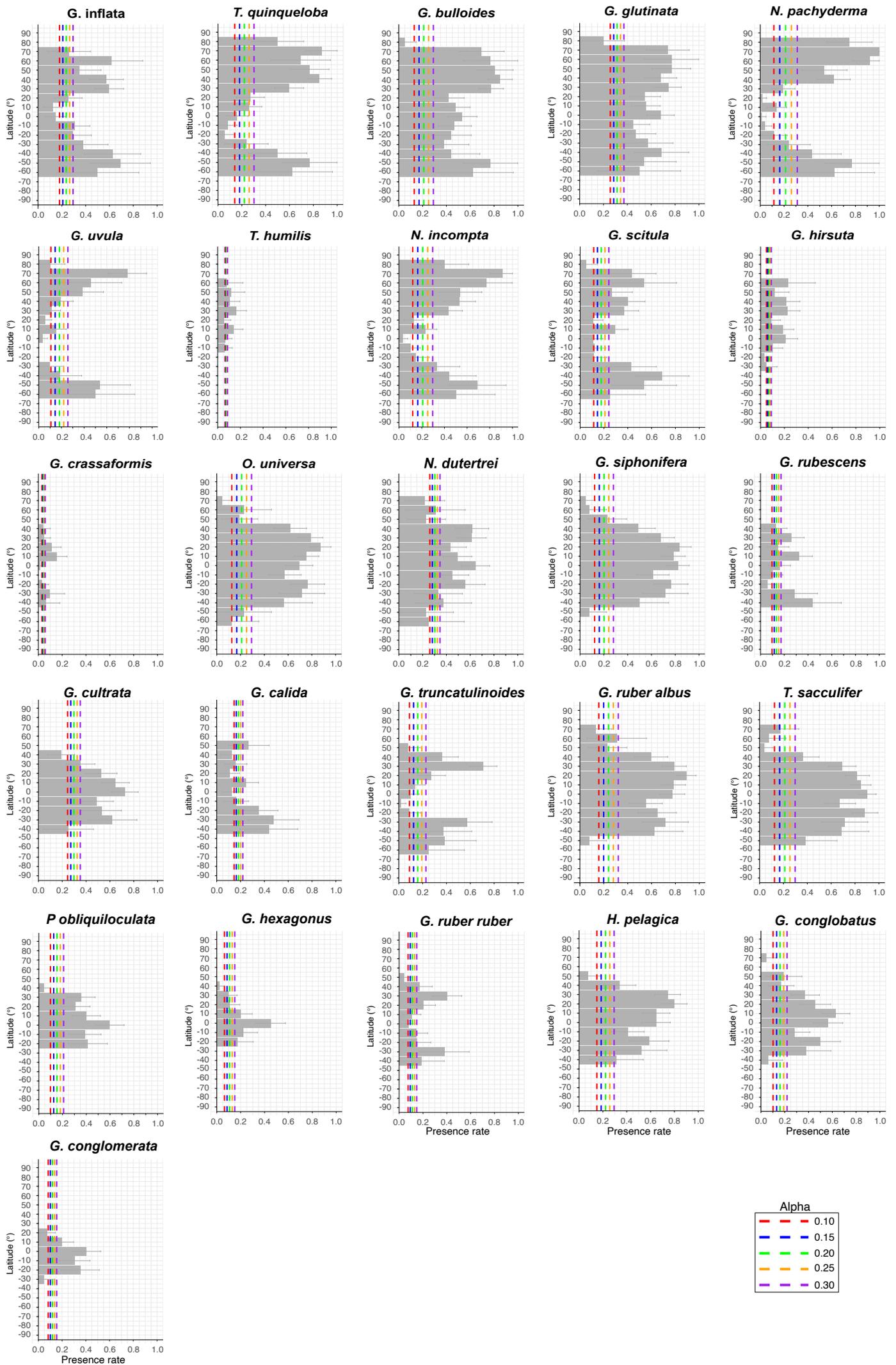


Fig. S1

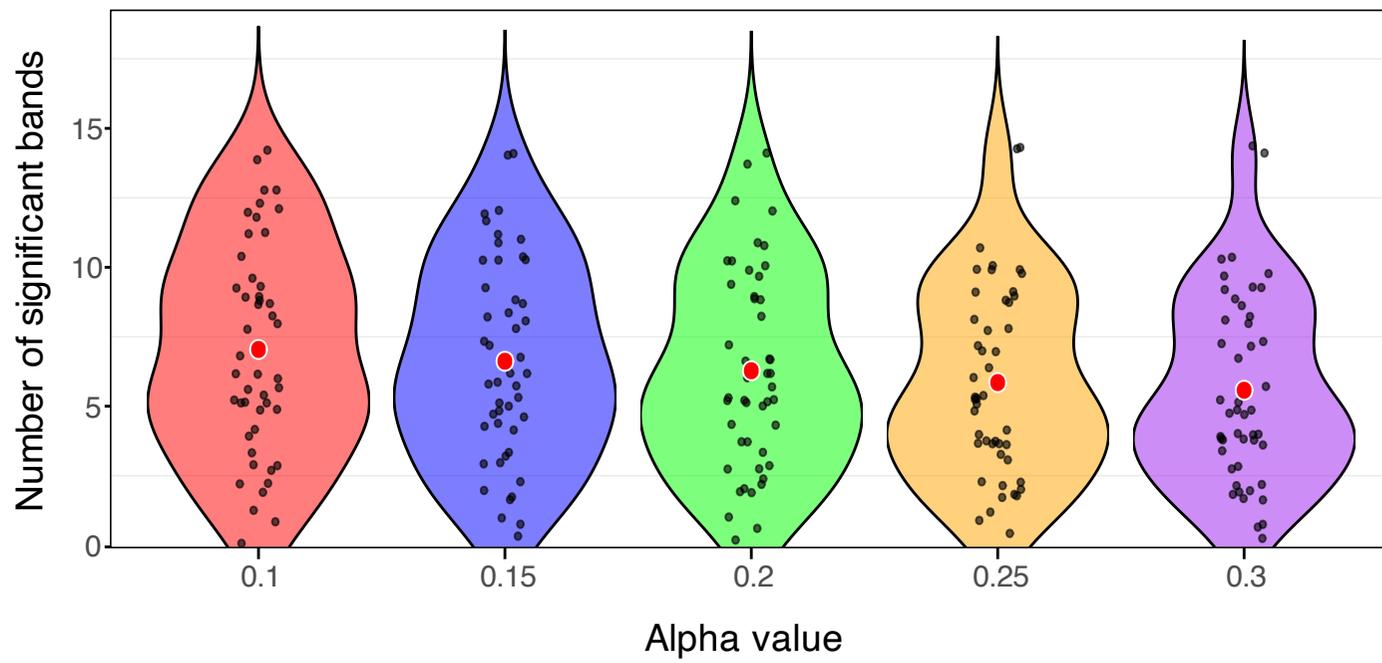
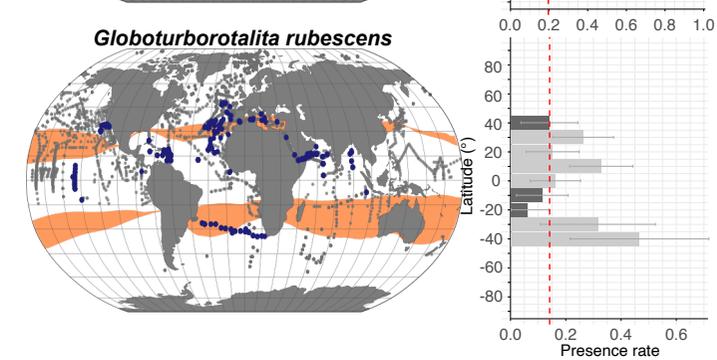
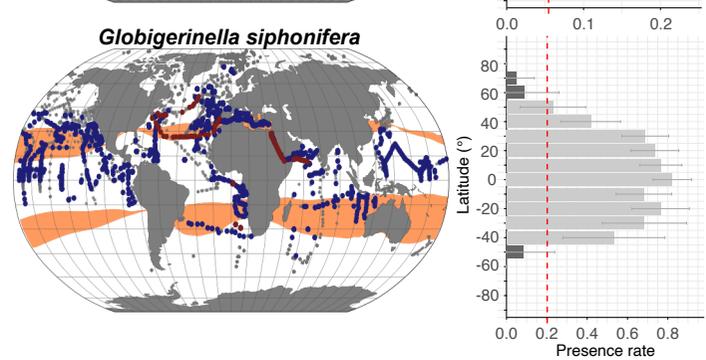
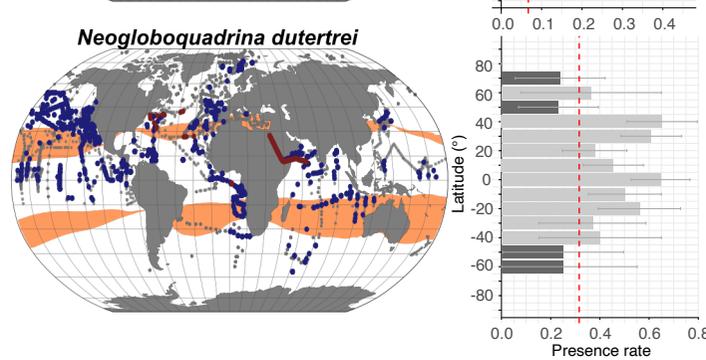
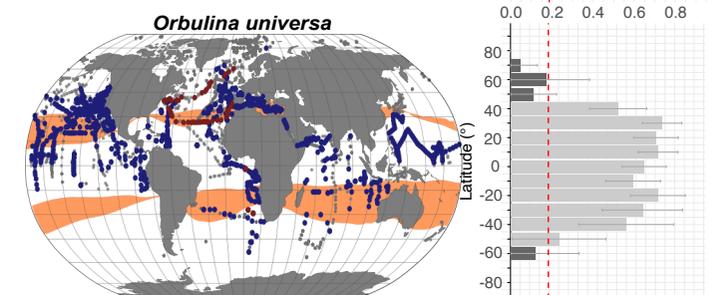
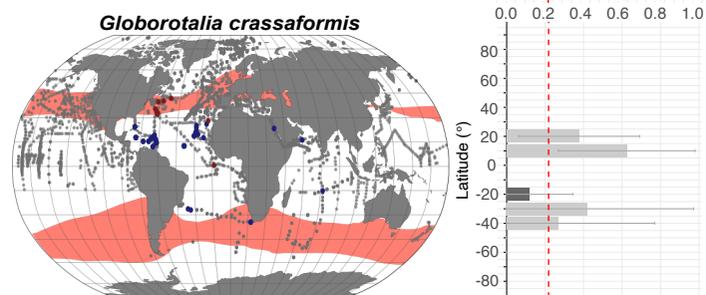
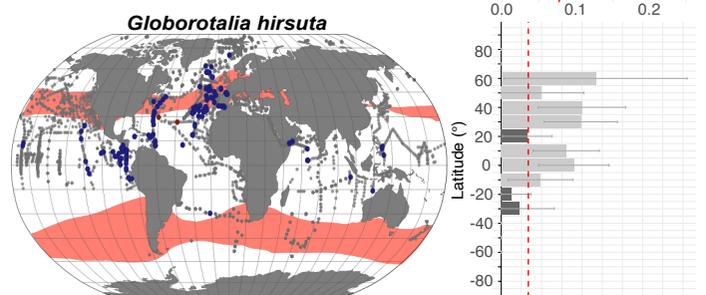
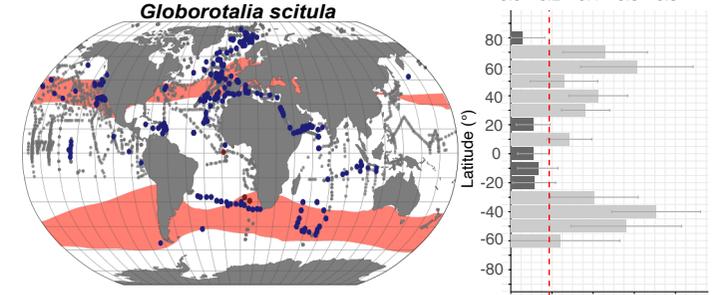
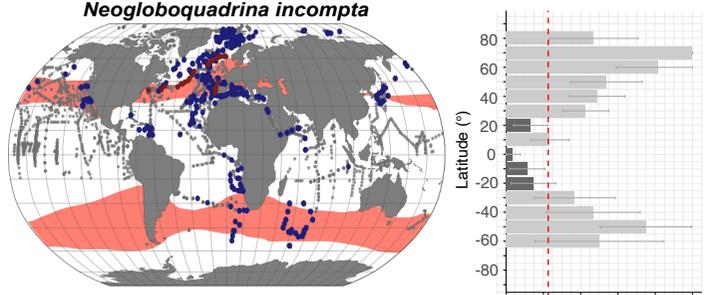
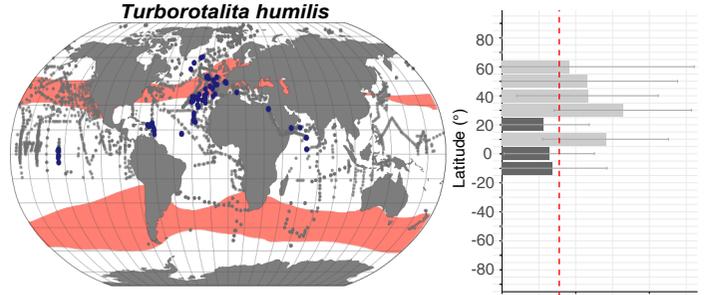
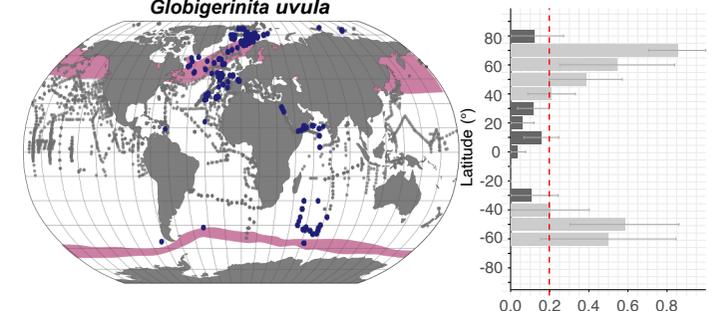
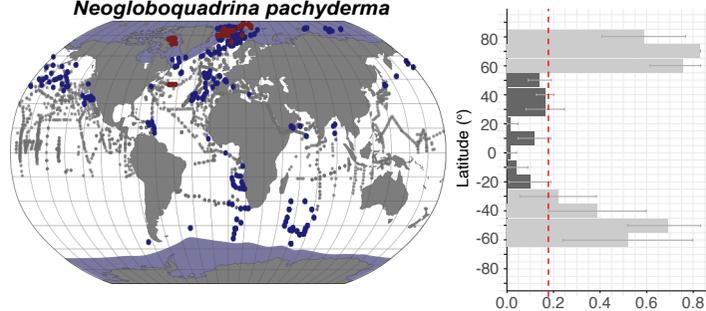
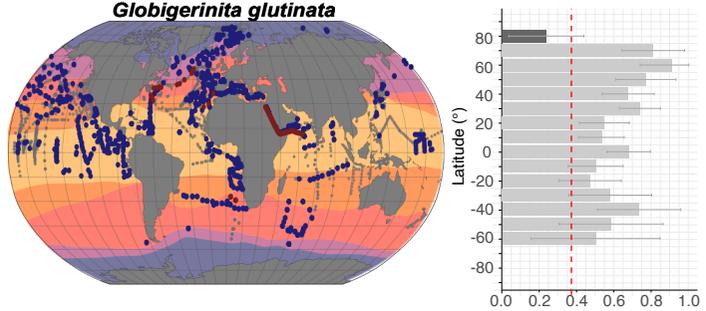
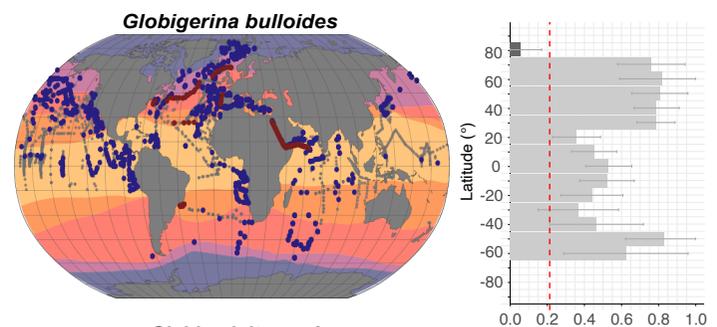
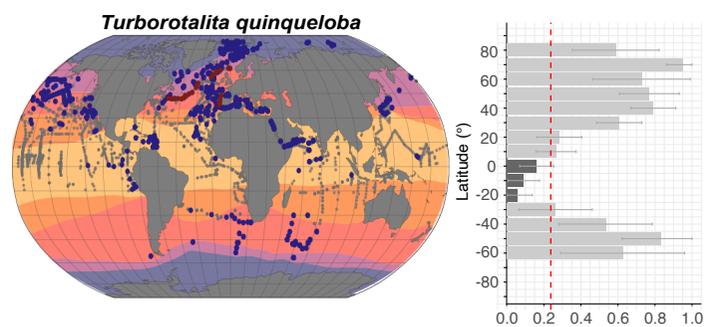
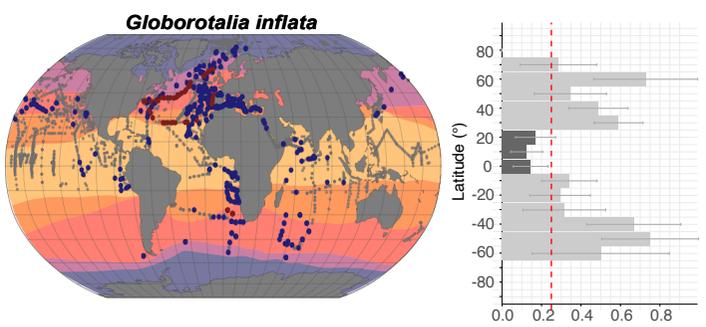
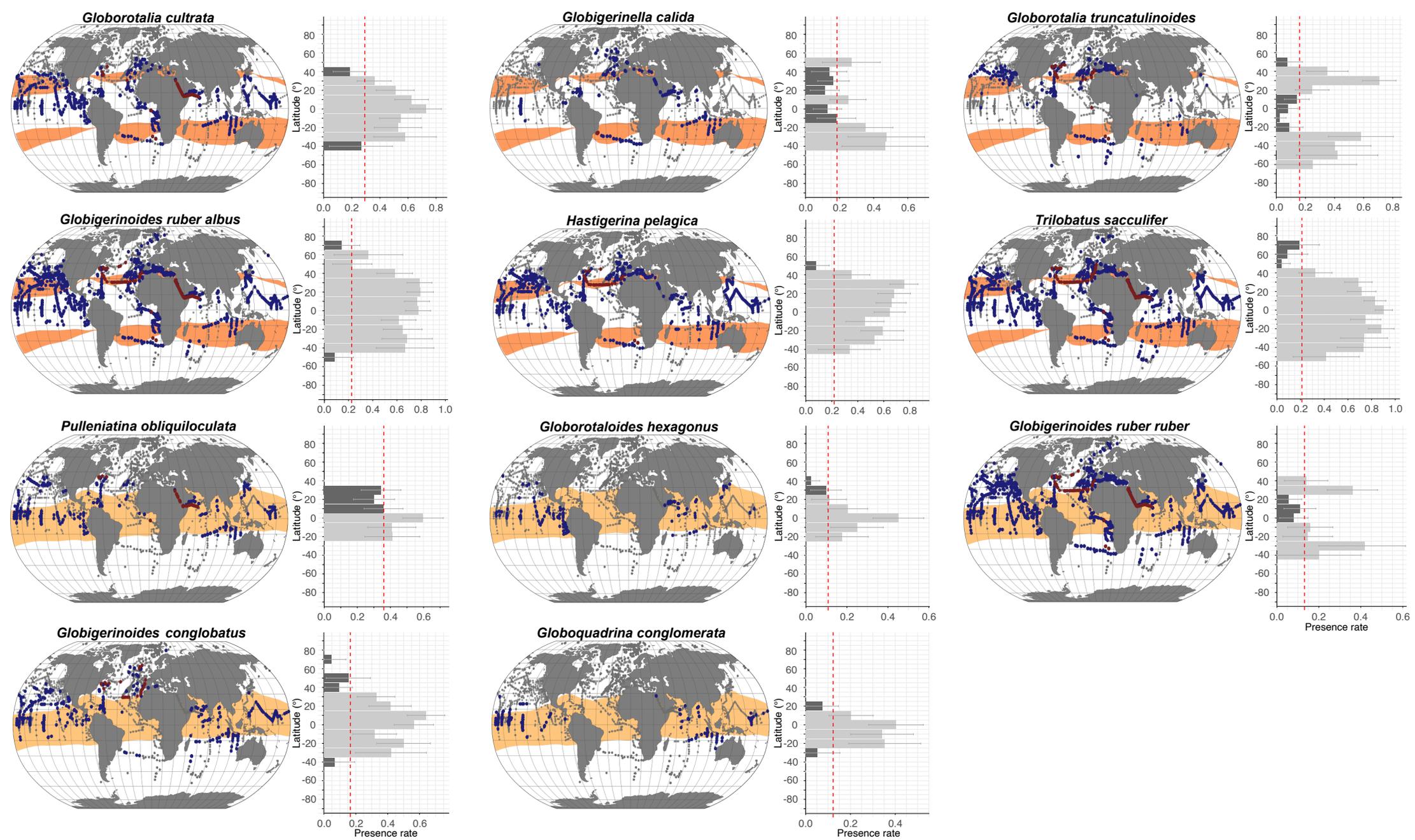


Fig. S2





Bé and Tolderlund, 1971

Polar

Subpolar

Temperate

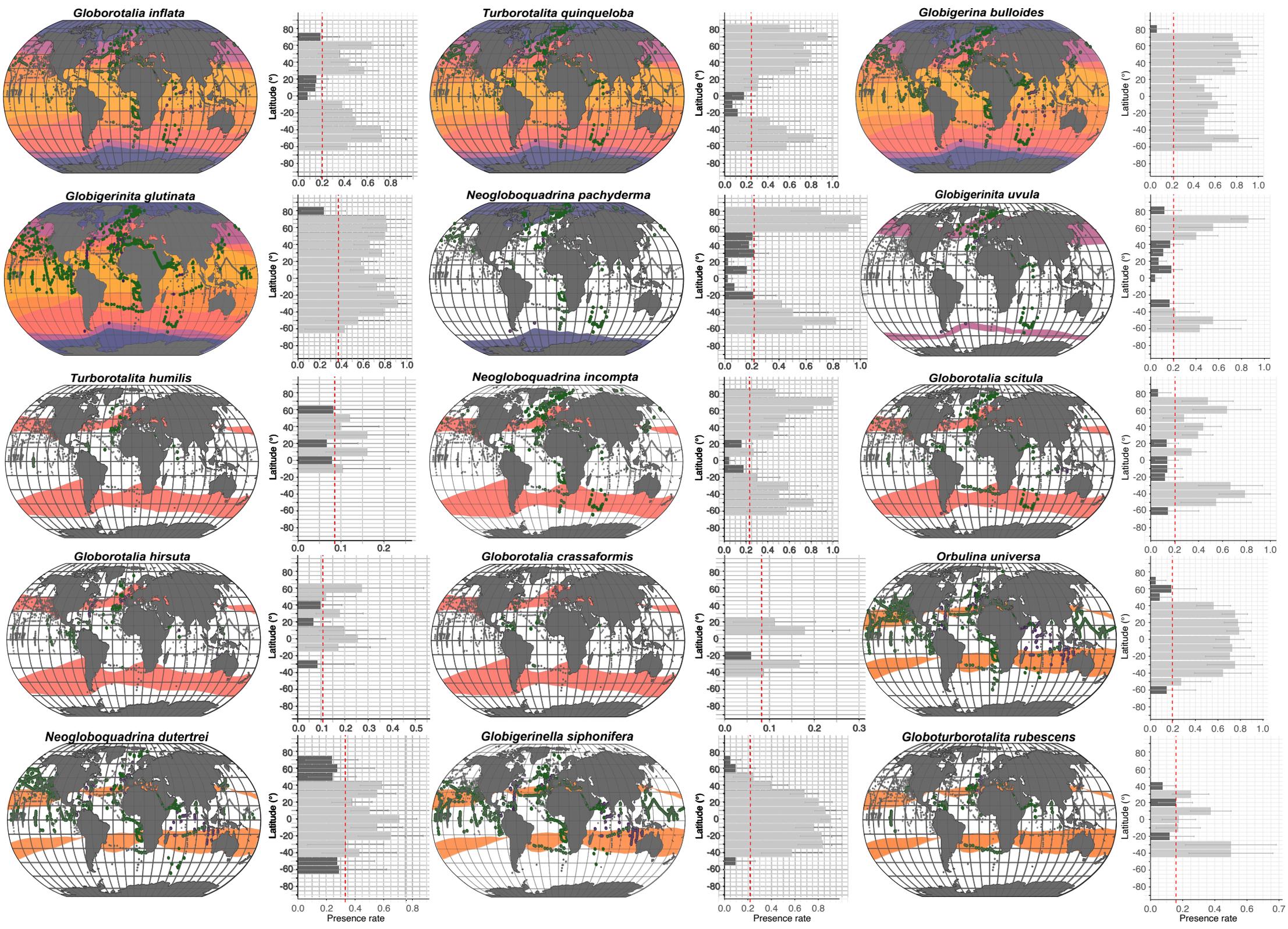
Subtropical

Tropical

● Samples all shells were counted

● Samples all shells were not counted

Fig. S3



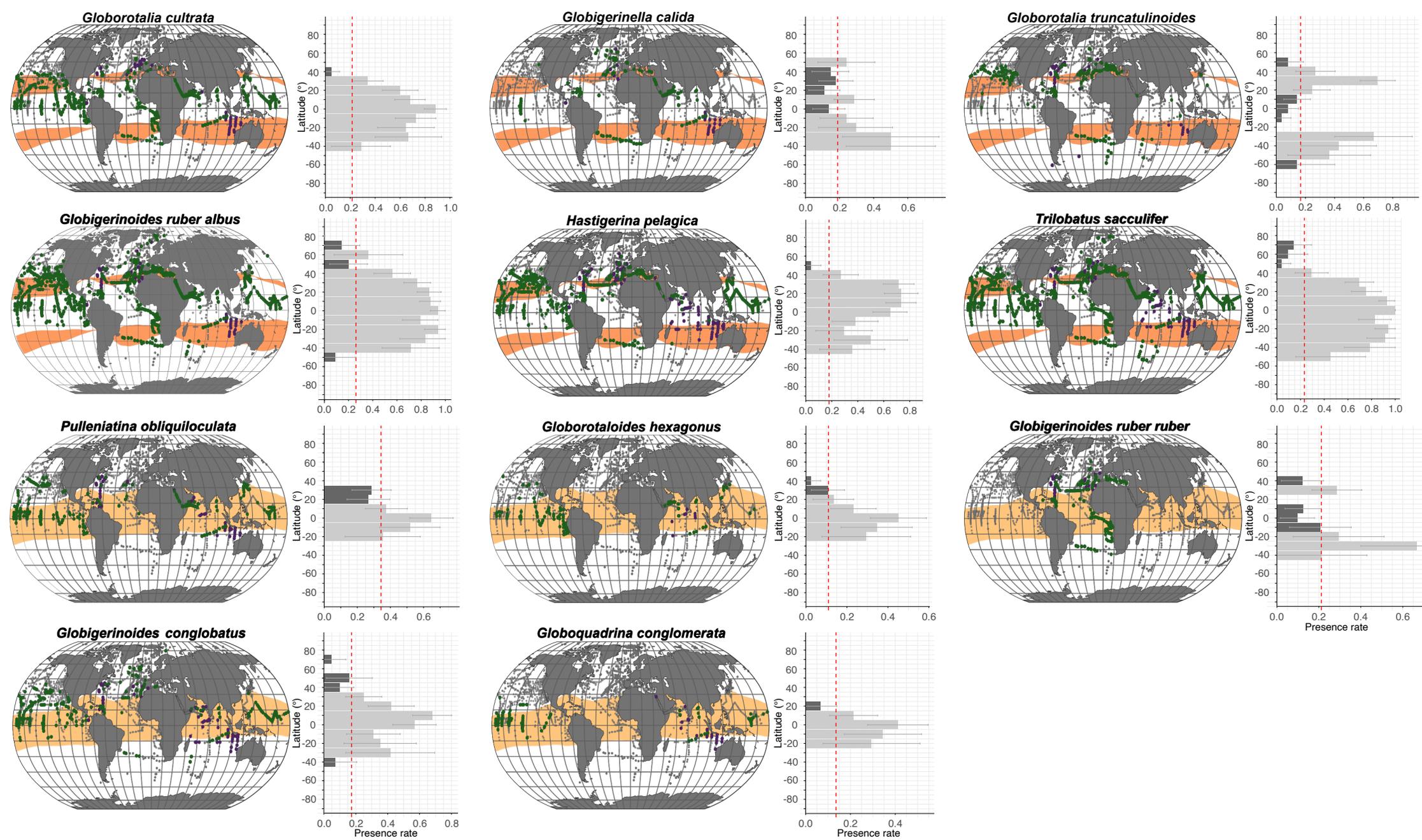
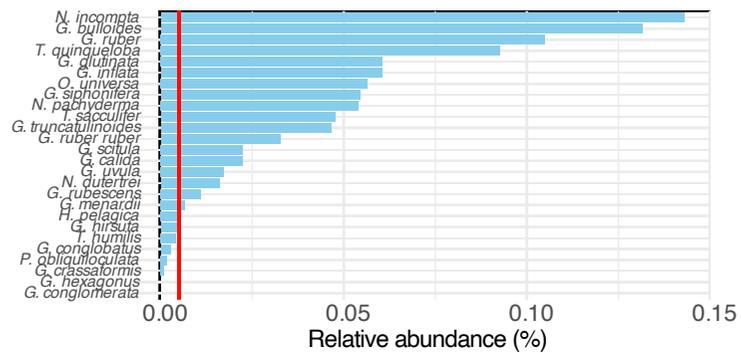
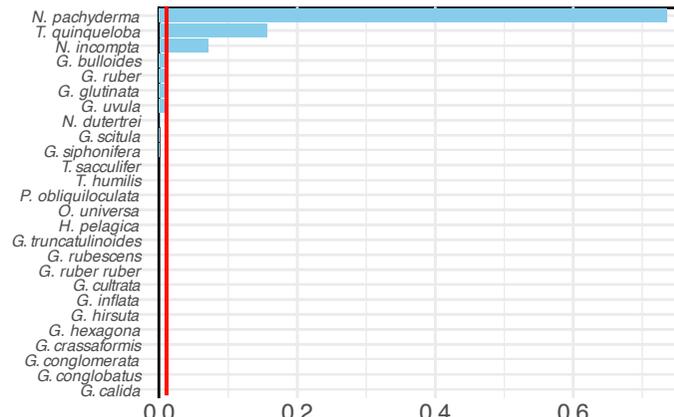


Fig. S4

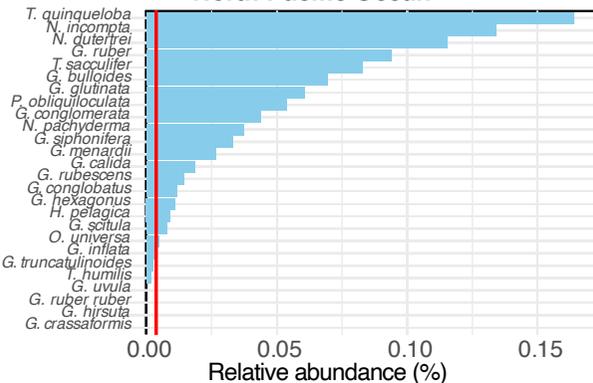
North Atlantic Ocean



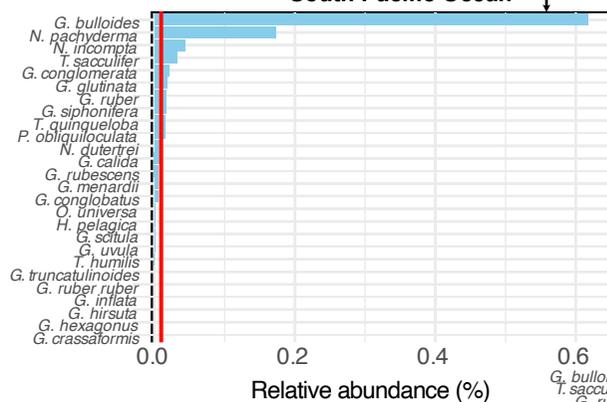
Arctic Ocean



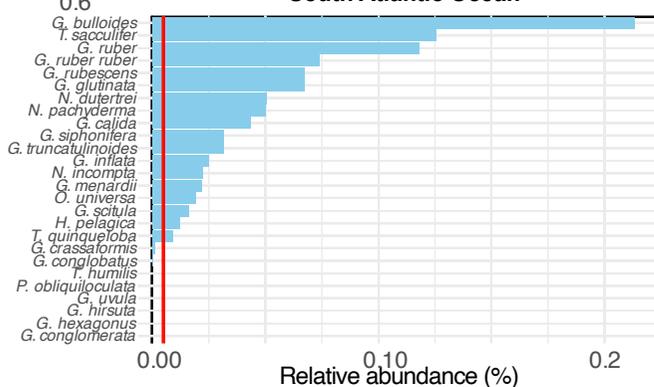
North Pacific Ocean



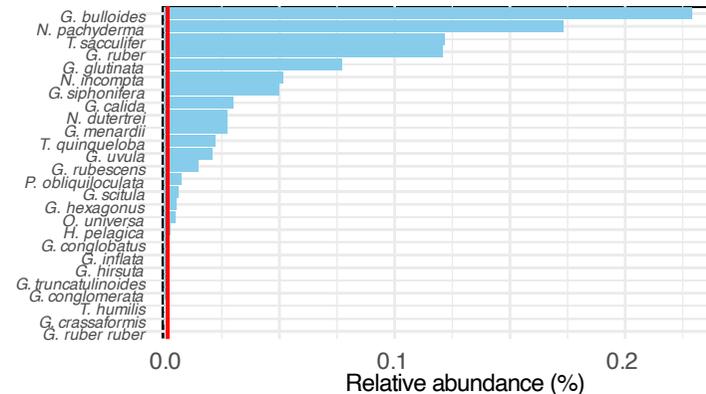
South Pacific Ocean



South Atlantic Ocean



Indian Ocean



Southern Ocean

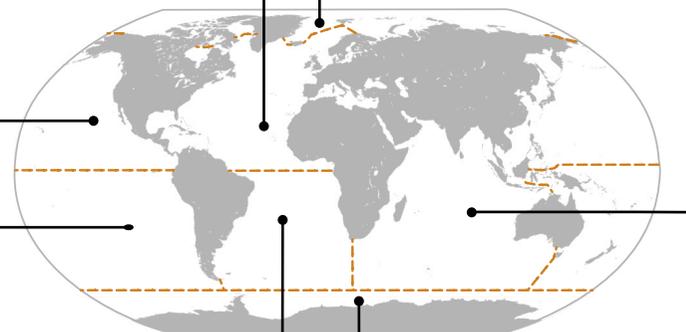
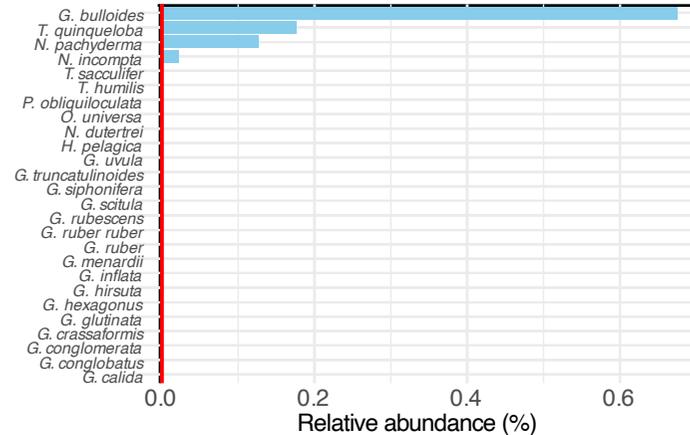


Fig. S5

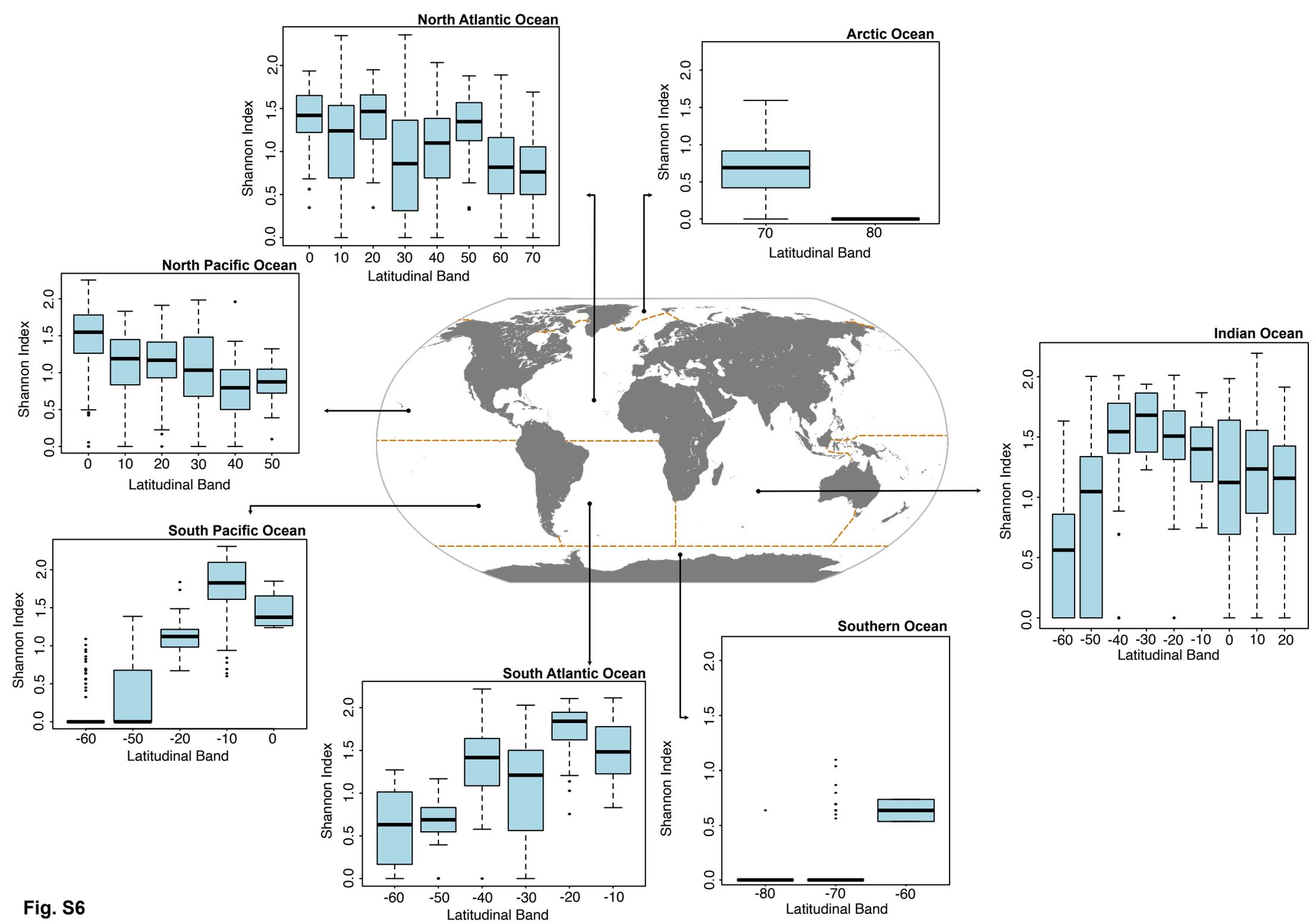


Fig. S6

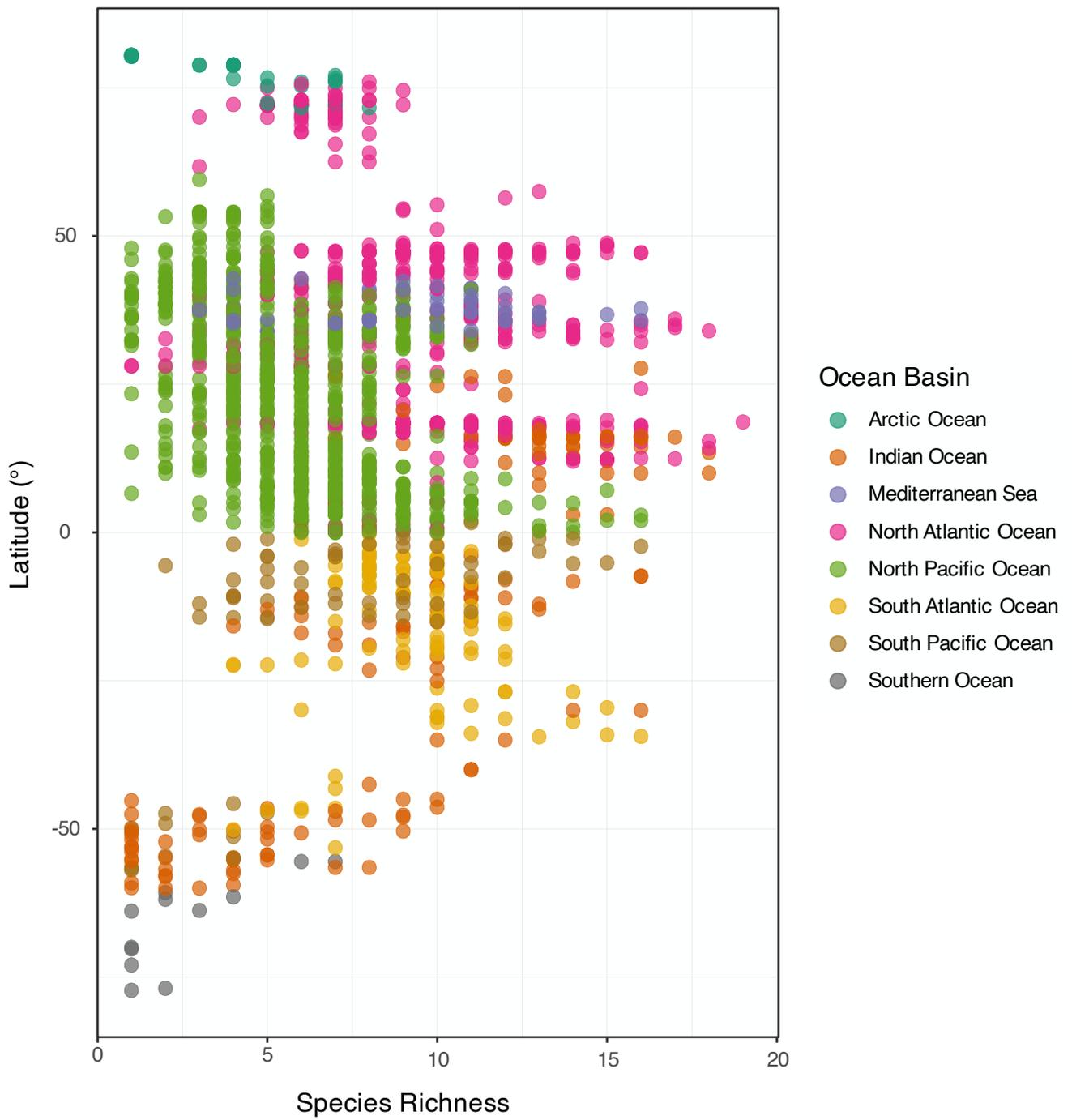


Fig. S7

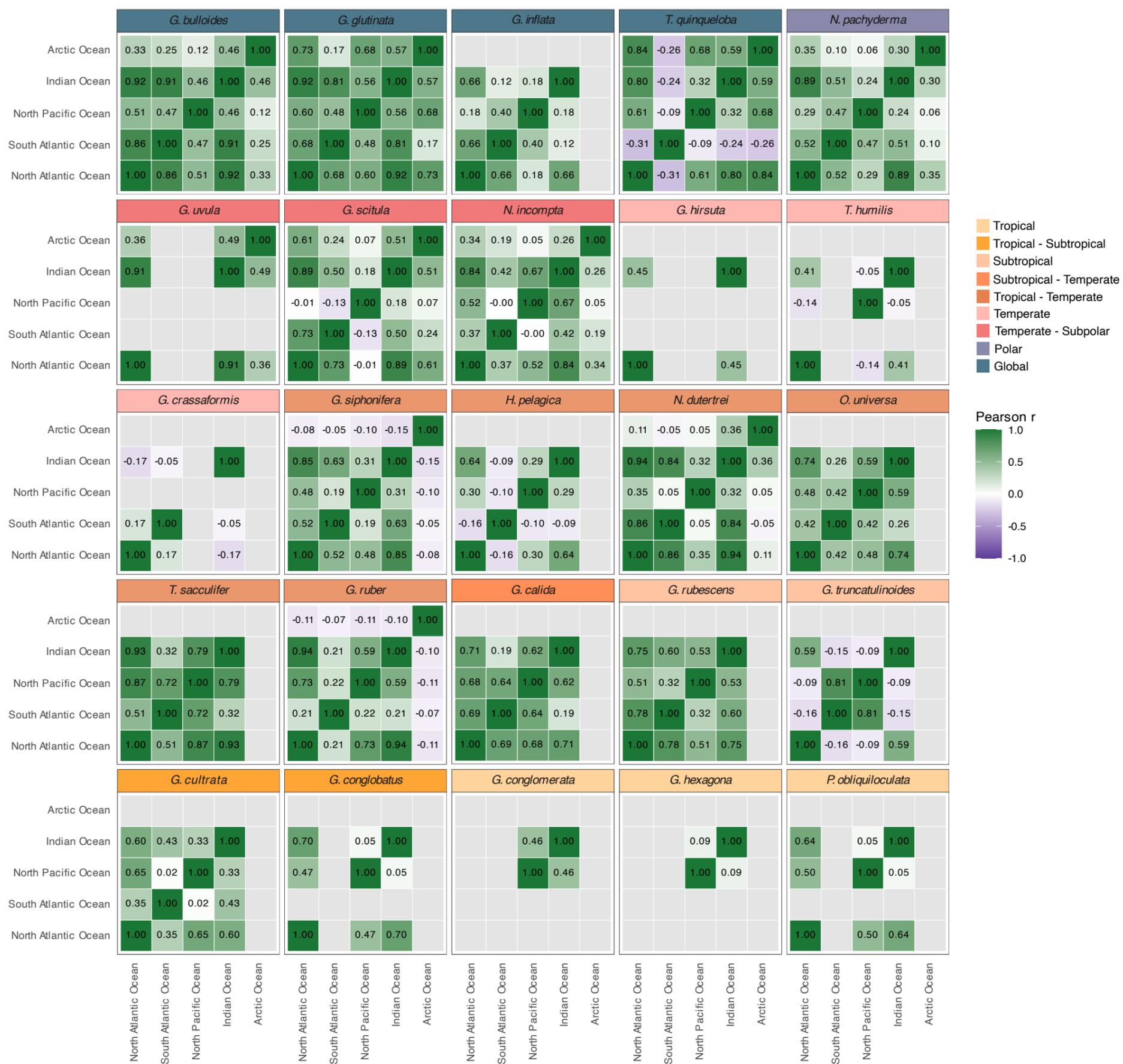


Fig. S8

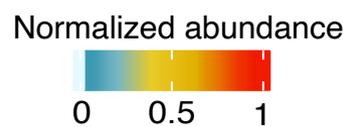
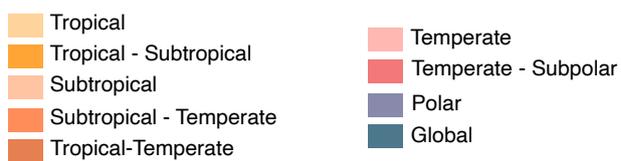
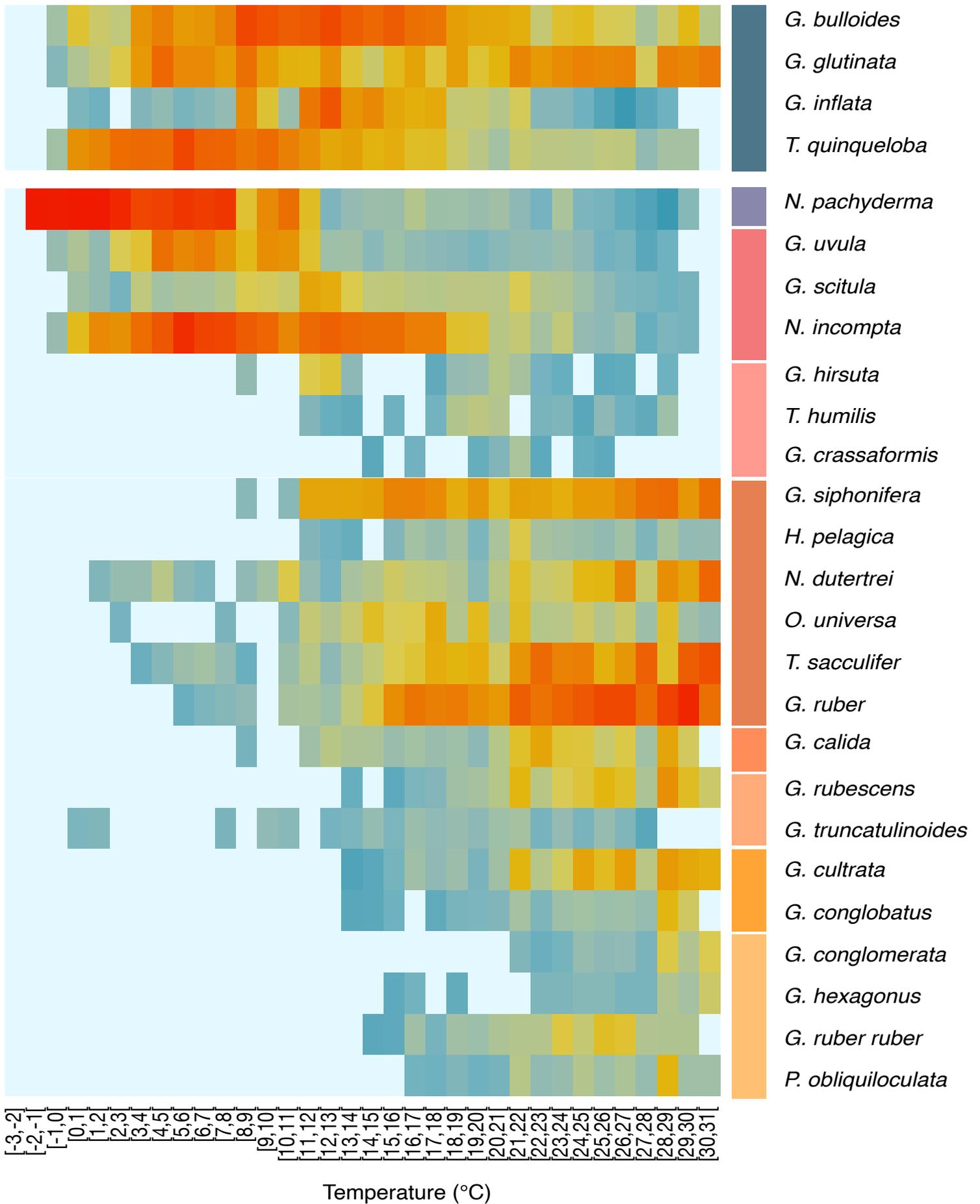


Fig. S10

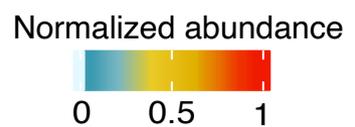
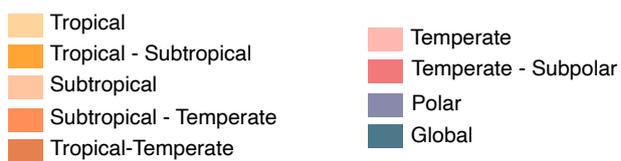
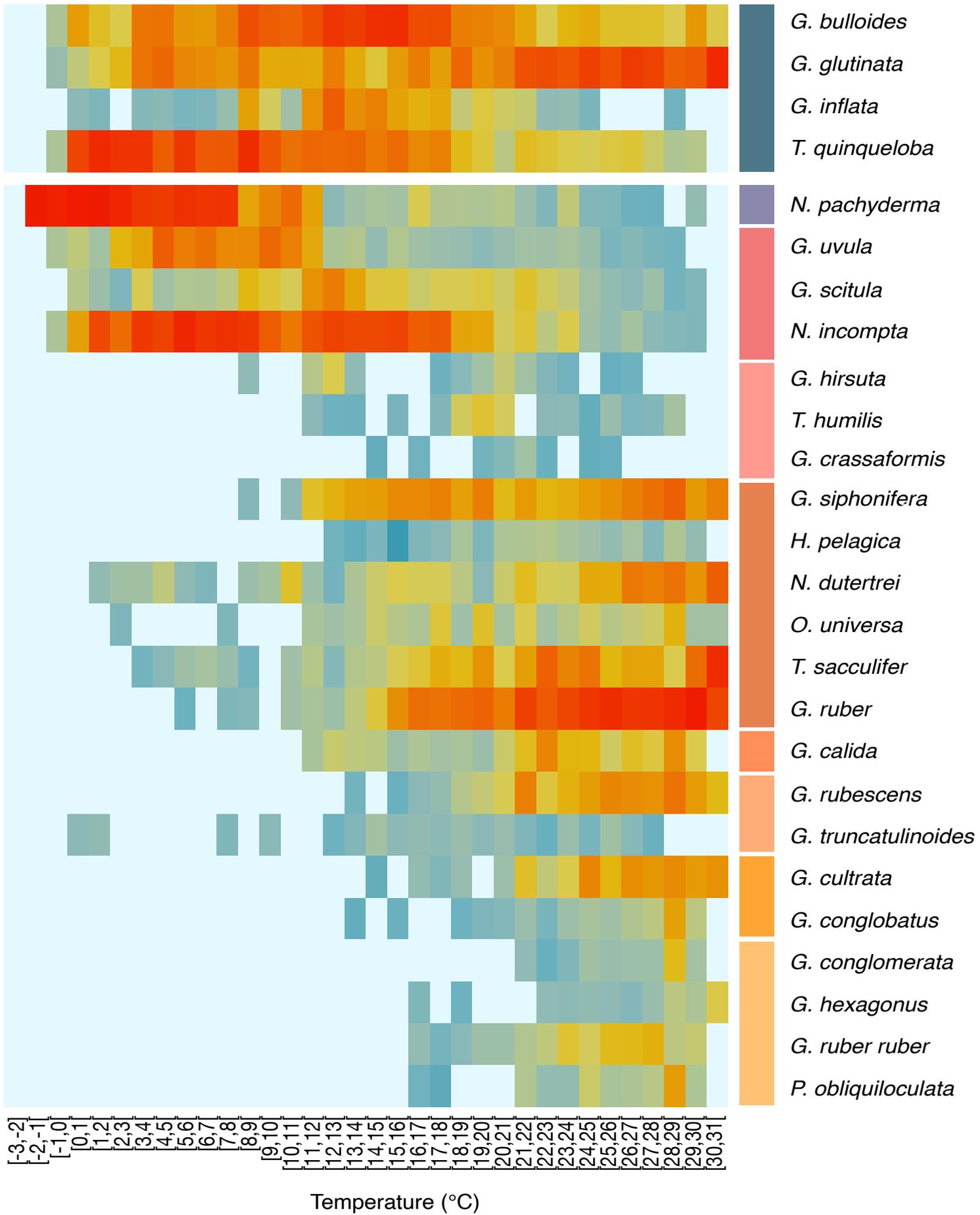


Fig. S11