Variability of early autumn planktonic assemblages in the strait of Gibraltar: a regionalization analysis

NEREA VALCÁRCEL-PÉREZ, EDUARDO RAMÍREZ-ROMERO, CARLOS M. GARCÍA, JUAN IGNACIO GONZÁLEZ-GORDILLO, FIDEL ECHEVARRÍA

doi: 10.12681/mms.27623

To cite this article:

VALCÁRCEL-PÉREZ, N., RAMÍREZ-ROMERO, E., GARCÍA, C. M., GONZÁLEZ-GORDILLO, J. I., & ECHEVARRÍA, F. (2022). Variability of early autumn planktonic assemblages in the strait of Gibraltar: a regionalization analysis. Mediterranean Marine Science, 23(3), 685–697. https://doi.org/10.12681/mms.27623
**Variability of early autumn planktonic assemblages in the strait of Gibraltar: a regionalization analysis**

Nerea VALCÁRCEL-PÉREZ, Eduardo RAMÍREZ-ROMERO, Carlos M. GARCÍA, Juan Ignacio GONZÁLEZ-GORDILLO and Fidel ECHEVARRÍA

_Mediterranean Marine Science, 23 (3) 2022_

**Table S1**: Average values of physical and biogeochemical parameters defining each cluster during spring and neap tides. Mean, N, standard deviation (SD) and range.

|   | Temperature (°C) | Salinity | Chlorophyll a (mg m\(^{-3}\)) | Chlorophyll > 20 µm (%) | Nitrite (µM) | Nitrate (µM) | Silicate (µM) | Ammonium (µM) |
|---|------------------|----------|--------------------------------|-------------------------|--------------|--------------|---------------|---------------|
| Spring CL1 Mean | 18.67 | 36.27 | 1.67 | 23.52 | 0.59 | 3.38 | 5.19 | 3.31 |
| N | 29 | 29 | 29 | 28 | 29 | 29 | 29 | 29 |
| SD | 1.31 | 0.16 | 0.72 | 16.41 | 0.15 | 4.55 | 3.02 | 1.93 |
| Min - Max | (15.3 - 20.6) | (35.7 - 36.6) | (0.2 - 3.3) | (8.9 - 87.7) | (0.2 - 0.8) | (0.4 - 25.4) | (1.4 - 12.0) | (0.7 - 8.1) |
| CL2 Mean | 18.56 | 36.53 | 0.72 | 10.05 | 0.32 | 1.37 | 3.91 | 1.51 |
| N | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| SD | 1.59 | 0.16 | 0.40 | 5.59 | 0.14 | 1.21 | 2.91 | 0.87 |
| Min - Max | (15.9 - 21.5) | (36.2 - 36.8) | (0.1 - 1.6) | (3.2 - 30.7) | (0.1 - 0.7) | (0.0 - 5.8) | (0.7 - 12.2) | (0.0 - 4.7) |
| Neap CL1 Mean | 18.44 | 36.31 | 1.63 | 24.77 | 0.52 | 2.02 | 4.43 | 3.49 |
| N | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| SD | 1.15 | 0.13 | 1.08 | 18.39 | 0.15 | 2.39 | 2.76 | 1.42 |
| Min - Max | (15.9 - 20.0) | (36.0 - 36.6) | (0.4 - 4.5) | (8.3 - 66.8) | (0.3 - 0.9) | (0.2 - 10.0) | (1.1 - 10.5) | (0.6 - 6.3) |
| CL2 Mean | 18.47 | 36.54 | 0.65 | 11.33 | 0.26 | 0.62 | 5.20 | 1.03 |
| N | 55 | 55 | 55 | 54 | 55 | 55 | 55 | 55 |
| SD | 1.36 | 0.14 | 0.41 | 7.13 | 0.14 | 0.83 | 3.87 | 0.85 |
| Min - Max | (15.5 - 20.7) | (36.2 - 36.9) | (0.1 - 1.6) | (2.2 - 38.4) | (0.1 - 0.6) | (0.0 - 3.5) | (0.7 - 17.3) | (0.0 - 3.2) |
| Total CL1 Mean | 18.59 | 36.29 | 1.65 | 23.99 | 0.52 | 2.88 | 4.91 | 3.38 |
| N | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 |
| SD | 1.24 | 0.15 | 0.86 | 17.03 | 0.16 | 3.95 | 2.92 | 1.75 |
| Min - Max | (15.3 - 20.6) | (35.7 - 36.6) | (0.2 - 4.5) | (8.3 - 87.7) | (0.2 - 0.9) | (0.2 - 25.4) | (1.1 - 12.0) | (0.6 - 8.1) |
| CL2 Mean | 18.51 | 36.54 | 0.68 | 10.75 | 0.28 | 0.96 | 4.62 | 1.24 |
| N | 100 | 100 | 100 | 99 | 100 | 100 | 100 | 100 |
| SD | 1.46 | 0.15 | 0.40 | 6.48 | 0.14 | 1.12 | 3.51 | 0.89 |
| Min - Max | (15.5 - 21.5) | (36.2 - 36.9) | (0.1 - 1.6) | (2.2 - 38.4) | (0.1 - 0.7) | (0.0 - 5.8) | (0.7 - 17.3) | (0.0 - 4.7) |
**Fig. S1:** Average values of physical and biogeochemical variables defining each cluster during spring and neap tides. Purple bars represent CL1, green bars for CL2.
Fig. S2: Picoplankton groups biomass distribution. Synechococcus (A-B), Prochlorococcus (C-D) and Cryptophytes (E-F) biomass (mgC m$^{-3}$) during spring (A, C, E) and neap tides (B, D, F).
Fig. S3: Main microplankton groups biomass (mgC m\(^{-3}\)) distribution during spring (A, C, E, G) and neap (B, D, F, H) tides. A and B represent diatoms, C and D dinoflagellates, E and F correspond to tintinnids, and G and F for silicoflagellates. Note different scales among groups.
### Table S2. Main pico and nanoplankton groups cell densities (cell mL\(^{-1}\)) and biomass

|                  | Spring tides | Neap tides | Total          |
|------------------|--------------|------------|----------------|
|                  | Abundance    | Biomass    | Abundance      | Biomass    | Abundance    | Biomass    |
|                  | Mean ± SD    | Mean ± SD  | Mean ± SD      | Mean ± SD  | Mean ± SD    | Mean ± SD  |
|                  | (cell mL\(^{-1}\)) | (mgC m\(^{-3}\)) | (cell mL\(^{-1}\)) | (mgC m\(^{-3}\)) | (cell mL\(^{-1}\)) | (mgC m\(^{-3}\)) |
| **Synechococcus**| 18258 ± 15337 | 3.3 ± 2.7  | 5928.5 ± 15149.9 | 2.8 ± 3.2  | 11336.2 ± 16362.3 | 3.0 ± 3.0  |
|                  | (394 - 84299) | (0.1 - 15.0) | (0 - 65839) | (0.1 - 13.5) | (0 - 84299) | (0.1 - 15.0) |
| **Prochlorococcus** | 27066 ± 18878 | 0.8 ± 0.5  | 2110.5 ± 4893.2 | 0.7 ± 0.4  | 13055.7 ± 17960.8 | 0.7 ± 0.5  |
|                  | (2877 - 84989) | (0.1 - 2.4) | (0 - 20603) | (0.2 - 1.8) | (0 - 84989) | (0.1 - 2.4) |
| **Cryptophytes**  | 180.8 ± 127.9 | 14.9 ± 10.6| 146.9 ± 127.0 | 14.2 ± 11.2| 164.1 ± 128.1 | 14.6 ± 10.9|
|                  | (2 - 575)     | (0.2 - 47.6)| (3 - 531)   | (1 – 47.2) | (2 - 575)    | (0.2 – 47.6) |
Table S3. Microplankton abundance (cell mL\(^{-1}\)) and biomass (mgC m\(^{-3}\)) by major groups during neap and spring tides.

|                     | Spring tides | Neap tides | Total       |
|---------------------|--------------|------------|-------------|
|                     | Abundance     | Biomass    | Abundance   | Biomass    |
|                     | (cell mL\(^{-1}\)) | (mgC m\(^{-3}\)) | (cell mL\(^{-1}\)) | (mgC m\(^{-3}\)) |
|                     | Mean ± SD     | (Min - Max) | Mean ± SD   | (Min - Max) |
| Diatoms             | 6.15 ± 11.99  | 77.18 ± 70.12 | 2.80 ± 3.22 | 25.36 ± 37.15 |
|                     | (0 - 50.99)   | (0.83 - 86.91) | (0 - 11.36) | (0.07 - 95.79) |
| Single rounded cells| 0.16 ± 0.24   | 0.25 ± 0.45  | 0.06 ± 0.05 | 0.11 ± 0.09  |
|                     | (0.1 - 1.03)  | (0.0 - 1.93) | (0.0 - 1.17) | (0.0 - 1.29) |
| Pennates            | 0.02 ± 0.02   | 0.07 ± 0.12  | 0.01 ± 0.02 | 0.09 ± 0.13  |
|                     | (0.0 - 0.06)  | (0.0 - 0.48) | (0.0 - 0.08) | (0.0 - 0.47) |
| Skeletonema like    | 0.18 ± 0.14   | 0.12 ± 0.15  | 0.15 ± 0.13 | 0.08 ± 0.12  |
|                     | (0.0 - 0.45)  | (0.0 - 0.59) | (0.0 - 0.43) | (0.0 - 0.43) |
| Lineal chains and Rhi-zosolenia like | 0.80 ± 1.49 | 5.8 ± 11.96 | 0.09 ± 0.08 | 0.42 ± 0.41 |
|                     | (0.07 - 6.31) | (0.07 - 47.92) | (0.0 - 1.26) | (0.0 - 6.31) |
| Helical chains      | 4.71 ± 9.79   | 68.02 ± 151.53 | 2.43 ± 2.98 | 23.89 ± 35.94 |
|                     | (0.01 - 41.49) | (0.23 - 610.44) | (0.0 - 10.39) | (0.0 - 45.1) |
| Other diatoms       | 0.27 ± 0.43   | 2.92 ± 6.23  | 0.07 ± 0.09 | 0.78 ± 0.87  |
|                     | (0.1 - 1.75)  | (0.0 - 25.99) | (0.0 - 0.36) | (0.0 - 2.43) |
| Dinoflagellates     | 0.41 ± 0.29   | 3.83 ± 3.33  | 0.45 ± 0.28 | 2.72 ± 2.49  |
|                     | (0.0 - 1.07)  | (0.19 - 10.48) | (0.0 - 0.98) | (0.07 - 6.70) |
| Peridiniales        | 0.39 ± 0.28   | 0.76 ± 0.58  | 0.44 ± 0.28 | 1.03 ± 0.66  |
|                     | (0.1 - 1.06)  | (0.16 - 2.18) | (0.06 - 0.97) | (0.09 - 2.17) |
| Ceratium/Neoceratium| 0.01 ± 0.01   | 3.05 ± 3.07  | 0.01 ± 0.01 | 1.68 ± 2.08  |
|                     | (0.0 - 0.04)  | (0.9 - 9.78) | (0.001 - 0.03) | (0.23 - 8.84) |
| Other dinoflagellates| 0.003 ± 0.01  | 0.03 ± 0.07  | 0.01 ± 0.01 | 0.01 ± 0.04  |
|                     | (0.0 - 0.03)  | (0.0 - 0.24) | (0.0 - 0.02) | (0.0 - 0.15) |
| Tintinnids          | 0.02 ± 0.02   | 0.3 ± 0.3    | 0.02 ± 0.02 | 0.29 ± 0.27  |
|                     | (0.001 - 0.09) | (0.02 - 1.16) | (0.0 - 0.08) | (0.0 - 0.89) |
| Silicoflagellates   | 0.04 ± 0.05   | 0.02 ± 0.02  | 0.016 ± 0.02 | 0.01 ± 0.02  |
|                     | (0.0 - 0.2)   | (0.0 - 0.09) | (0.0 - 0.09) | (0.0 - 0.05) |
| Foraminifers        | 0.003 ± 0.006 | 0.0001 ± 0.0004 | 0.01 ± 0.04 | 0.01 ± 0.02 |
|                     | (0.0 - 0.023) | (0.0 - 0.17) | (0.0 - 0.001) | (0.0 - 1.85) |
| Coccolithophores    | 0.001 ± 0.002 | 0 ± 0       | 0.0015 ± 0.003 | 0 ± 0 |
|                     | (0.0 - 0.011) | (0.0 - 0.01) | (0.0 - 0.01) | (0.0 - 0.01) |
| Others              | 0.07 ± 0.12   | 0.27 ± 0.37  | 0.27 ± 0.38 | 0.04 ± 0.09  |
|                     | (0.0 - 0.45)  | (0.0 - 1.38) | (0.0 - 1.02) | (0.0 - 0.45) |
Table S4. Mesoplankton abundance (ind m\(^{-3}\)) and biomass (mgC m\(^{-3}\)) by major groups during neap and spring tides.

|                | Spring | Neap | Total |
|----------------|--------|------|-------|
|                | Abundance (ind m\(^{-3}\)) | Biomass (mgC m\(^{-3}\)) | Abundance (ind m\(^{-3}\)) | Biomass (mgC m\(^{-3}\)) | Abundance (ind m\(^{-3}\)) | Biomass (mgC m\(^{-3}\)) |
|                | Mean ± SD (Min - Max) | Mean ± SD (Min - Max) | Mean ± SD (Min - Max) | Mean ± SD (Min - Max) | Mean ± SD (Min - Max) | Mean ± SD (Min - Max) |
| Amphipods      | 0.06 ± 0.18 (0 - 0.56) | 0.26 ± 0.06 (0.21 - 0.30) | 0.18 ± 0.31 (0 - 0.53) | 0 | 0.09 ± 0.20 (0 - 0.56) | 0.17 ± 0.16 (0 - 0.30) |
| Appendicularians | 29.33 ± 43.95 (1.14 - 141.31) | 0.72 ± 1.13 (0 - 3.76) | 35.25 ± 10.96 (22.85 - 43.65) | 3.85 ± 2.40 (1.38 - 6.18) | 30.70 ± 38.41 (1.14 - 141.32) | 1.44 ± 1.95 (0 - 6.18) |
| Ascidians      | 0.01 ± 0.03 (0 - 0.09) | 0 | 0.33 ± 0.58 (0 - 1.00) | 0 | 0.08 ± 0.28 (0 - 1.00) | 0 |
| Bryozoans      | 1.31 ± 2.02 (0 - 6.15) | 0.03 ± 0.05 (0 - 0.12) | 1.89 ± 2.23 (0.18 - 4.41) | 0.03 ± 0.04 (0 - 0.08) | 1.45 ± 1.99 (0 - 6.15) | 0.03 ± 0.05 (0 - 0.12) |
| Chaetognats    | 25.19 ± 33.92 (2.38 - 95.38) | 9.66 ± 14.61 (0.44 - 45.95) | 16.73 ± 13.71 (5.43 - 31.98) | 46.36 ± 75.73 (1.74 - 133.80) | 23.24 ± 30.14 (2.39 - 95.38) | 18.13 ± 37.08 (0.45 - 133.80) |
| Cirripedians   | 3.54 ± 5.56 (0 - 18.46) | 0.04 ± 0.09 (0 - 0.26) | 2.14 ± 2.73 (0 - 5.21) | 0.01 ± 0.01 (0 - 0.01) | 3.21 ± 4.98 (0 - 18.46) | 0.03 ± 0.08 (0 - 0.26) |
| Cladocerans    | 204.78 ± 243.19 (7.74 - 697.93) | 7.99 ± 15.18 (0 - 49.11) | 32.74 ± 23.11 (9.84 - 56.06) | 1.29 ± 1.03 (0.10 - 1.89) | 165.08 ± 223.91 (7.74 - 697.93) | 6.44 ± 13.48 (0 - 49.11) |
| Small Copepods | 183.34 ± 255.10 (0 - 883.07) | 0.74 ± 0.91 (0 - 3.08) | 101.28 ± 106.44 (13.52 - 219.67) | 1.25 ± 1.17 (0.14 - 2.48) | 164.41 ± 228.02 (0 - 883.08) | 0.86 ± 0.95 (0 - 3.08) |
| Medium Copepods | 110.04 ± 133.17 (0.75 - 403.49) | 4.90 ± 5.20 (0.05 - 12.55) | 89.78 ± 117.01 (11.64 - 224.31) | 4.14 ± 1.92 (2.47 - 6.24) | 105.36 ± 125.15 (0.75 - 403.49) | 4.72 ± 4.58 (0.05 - 12.55) |
| Large Copepods | 25.09 ± 34.25 (0.15 - 98.69) | 16.18 ± 32.14 (0.61 - 104.20) | 10.19 ± 6.65 (3.11 - 16.30) | 55.36 ± 51.74 (20.29 - 114.78) | 21.65 ± 30.49 (0.15 - 98.70) | 25.22 ± 38.93 (0.61 - 114.78) |
| Cumaceans      | 1.01 ± 0.02 (0 - 0.07) | 0.01 | 0 | 0 | 0.01 ± 0.02 (0 - 0.07) | 0.01 ± 0 (0.01 - 0.01) |
| Decapods       | 9.89 ± 17.65 (0 - 56.39) | 22.23 ± 47.50 (0 - 139.00) | 1.28 ± 2.21 (0 - 3.83) | 0.23 | 8.24 ± 14.47 (0 - 56.40) | 20.23 ± 45.55 (0 - 139.00) |
| Doliolids      | 4.82 ± 8.43 (0 - 28.27) | 0.54 ± 0.51 (0 - 1.34) | 1.10 ± 0.60 (0.41 - 1.47) | 0.33 ± 0.41 (0.07 - 0.81) | 3.96 ± 15.72 (0.28 - 28.28) | 0.48 ± 0.47 (0 - 1.34) |
| Scaphopods     | 0.19 ± 0.49 (0 - 1.53) | 0.72 ± 0.63 (0 - 1.16) | 0.02 ± 0.03 (0 - 0.04) | 0.31 ± 0.55 (0 - 1.54) | 0.01 ± 0.02 (0 - 0.04) |
| Euphausiaceans | 12.34 ± 6.29 (2.33 - 24.44) | 13.58 ± 30.56 (0.02 - 97.66) | 9.78 ± 6.16 (5.04 - 16.75) | 35.16 ± 59.85 (0.56 - 104.27) | 11.75 ± 6.10 (2.34 - 24.45) | 18.56 ± 37.24 (0.02 - 104.27) |
| Gastropods     | 0.40 ± 1.26 (0 - 3.99) | 0.04 | 0 | 0 | 0.31 ± 1.11 (0 - 3.99) | 0.04 |
| Medusas        | 0.08 ± 0.20 (0 - 0.61) | 0.05 ± 0.07 (0 - 0.10) | 0.02 ± 0.04 (0 - 0.07) | 0.03 | 0.07 ± 0.17 (0 - 0.61) | 0.04 ± 0.05 (0 - 0.10) |
| Limaciniidae   | 0.40 ± 1.26 (0 - 3.99) | 0.74 ± 1.27 (0 - 2.21) | 0.02 ± 0 | 0.48 ± 1.22 (0 - 3.99) | 0.01 ± 0.01 (0 - 0.02) |

Continued
Table S4 continued

| Abundance (ind m⁻³) | Biomass (mgC m⁻³) | Abundance (ind m⁻³) | Biomass (mgC m⁻³) | Abundance (ind m⁻³) | Biomass (mgC m⁻³) |
|----------------------|-------------------|----------------------|-------------------|----------------------|-------------------|
| Mean ± SD            | (Min - Max)       | Mean ± SD            | (Min - Max)       | Mean ± SD            | (Min - Max)       |
| Spring               | Neap              | Total                |                   |                      |                   |
| Molluscs             | 0.16 ± 0.27       | 0.02 ± 0.02          | 0.53 ± 0.53       | 0.01 ± 0.02          | 0.25 ± 0.36       | 0.01 ± 0.02       |
|                      | (0 - 0.72)        | (0 - 0.06)           | (0 - 1.05)        | (0 - 0.02)           | (0 - 1.05)        | (0 - 0.06)        |
| Mysidaceans          | 0.25 ± 0.34       | 28.24 ± 53.16 (0.04 - 122.24) | 0                 | 0                 | 0.19 ± 0.31       | 28.24 ± 53.16 (0.04 - 122.24) |
|                      | (0 - 1.03)        | (0 - 0.04 - 122.24)  | (0 - 0.04)        | (0 - 0.04)          | (0 - 1.03)        | (0 - 0.04)        |
| Nauplii              | 2.30 ± 4.91       | 0.03 ± 0.05          | 0.59 ± 0.49       | 0.01 ± 0.01          | 1.91 ± 4.33       | 0.02 ± 0.04       |
|                      | (0 - 15.96)       | (0 - 0.14)           | (0.12 - 1.10)     | (0 - 0.02)           | (0 - 15.96)       | (0 - 0.14)        |
| Ophiuroideans        | 0.15 ± 0.48       | 1.40 ± 2.21          | 0                 | 1.57               | 0.12 ± 0.42       | 1.43 ± 1.98       |
|                      | (0 - 1.52)        | (0 - 5.28)           | (0 - 1.52)        | (0 - 1.52)          | (0 - 1.52)        | (0 - 1.52)        |
| Ostracods            | 14.33 ± 23.21     | 0.24 ± 0.63          | 4.30 ± 6.79       | 0.06 ± 0.09          | 12.02 ± 20.76     | 0.19 ± 0.53       |
|                      | (0 - 64.61)       | (0.01 - 1.79)        | (0.14 - 12.13)    | (0 - 0.16)          | (0 - 64.62)       | (0 - 1.79)        |
| Polychaets           | 1.30 ± 1.70       | 0.07 ± 0.10          | 0.37 ± 0.59       | 0                 | 1.08 ± 1.55       | 0.06 ± 0.09       |
|                      | (0 - 5.67)        | (0 - 0.28)           | (0 - 1.05)        | (0 - 0.28)          | (0 - 5.68)        | (0 - 0.28)        |
| Pteropods            | 0.02 ± 0.07       | 0                    | 0                 | 0                 | 0.02 ± 0.06       | 0                 |
|                      | (0 - 0.21)        | (0 - 0.21)           | (0 - 0.21)        | (0 - 0.21)          | (0 - 0.21)        | (0 - 0.21)        |
| Stomatopoda          | 0.04 ± 0.05       | 13.84 ± 26.40        | 0                 | 0                 | 0.03 ± 0.05       | 13.84 ± 26.40     |
|                      | (0 - 0.12)        | (0.02 - 53.42)       | (0 - 0.12)        | (0 - 0.12)          | (0 - 0.12)        | (0.02 - 53.42)    |
| Unidentified         | 2.48 ± 2.73       | 0.12 ± 0.16          | 1.61 ± 1.57       | 0.01 ± 0.01          | 2.28 ± 2.48       | 0.10 ± 0.15       |
|                      | (0 - 9.23)        | (0 - 0.41)           | (0 - 3.13)        | (0 - 0.01)          | (0 - 9.23)        | (0 - 0.41)        |

Table S5. Summary scheme signing main features defining each cluster.

| Cluster 1                                      | Cluster 2                                      |
|-----------------------------------------------|-----------------------------------------------|
| > Chlorophyll a                               | > Salinity                                    |
| > Chlorophyll > 20 µm                         | > Silicate                                    |
| > Active Chlorophyll                          | > Prochlorococcus                             |
| > Nitrate                                     | > Foraminiferans                              |
| > Nitrite                                     | > Appendicularians                            |
| > Ammonium                                    |                                               |
| > Particles biomass                           |                                               |
| > Presence *Synechococcus*                    |                                               |
| > Presence of coastal diatoms: *Guinardia striata* and *Chaetoceros debilis*, *Rhizosolenia setigera*, etc. |   |
| > Meroplankton                                |                                               |
Table S6. Total abundance of copepods orders (ind m⁻³).

| Order                | Abundance (ind/m³) | (min – max)     |
|----------------------|--------------------|-----------------|
| Calanoida            | 197.04             | (26.61 - 690.77)|
| Cyclopoida           | 45.25              | (1.61 - 286.15) |
| Harpacticoida        | 13.56              | (0 - 96.92)     |
| Poecilostomatoida    | 35.79              | (0 - 179.6)     |
| Other Copepoda       | 3.35               | (0 - 14.49)     |

Fig. S4: Mean temperature, (A) and N₂ (B) profiles averaged for all the stations. The dashed lines represent the 20th and 80th percentiles in both plots.