Living benthic foraminiferal species as indicators of cold-warm water masses interaction and upwelling areas

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Abstract

The western South Atlantic continental margin, between 27° and 37° S, is dominated by three main water masses: cold-fresh Subantarctic Shelf Water (SASW), warm-salty Subtropical Shelf Water (STSW) and fresh Plata Plume Water (PPW). Despite the large seasonal variability of PPW extension along the shelf, an intense and relatively stable temperature-salinity gradient separates the SASW and the STSW forming the Subtropical Shelf Front (STSF) around 32°S. These two dominant shelf water masses arise from the process of mixing of oceanic waters. The SASW originates from the dilution of Subantarctic Water due to excess precipitation and continental runoff, and the STSW consists of modified warm tropical waters and South Atlantic Central Water (SACW) diluted below PPW. A previous article demonstrates the distribution of *Bulimina marginata*, a shelf environment and deep-sea species of benthic foraminifera, is influenced by the front location and it can be used as a proxy of the STSF in sediment core analysis. Here we show three other infaunal living species inhabiting at the Continental margin: *Buccella peruviana*, *Globocassidulina subglobosa* and *Uvigerina peregrina* and their distribution limits show the interaction of Subantarctic Shelf Water, Subtropical Shelf Water,

Plata Pluma Water and upwelling of SACW, respectively, in the bottom sediment of coastal studied areas.

Keywords: Benthic Foraminifera, Subantarctic Shelf Water (SASW), Subtropical Shelf Water (STSW), South Atlantic Central Water (SACW), upwelling areas

1. Introduction

The western South Atlantic continental margin, between 27° and 37° S, is dominated by three main water masses: cold-fresh Subantarctic Shelf Water (SASW), warm-salty Subtropical Shelf Water (STSW) and Plata Plume Water (PPW). Despite the large seasonal variability of PPW extension along the shelf, a narrow and intense frontal zone with relatively stable temperature-salinity gradient, separates the SASW and the STSW water masses forming the Subtropical shelf front (STSF) around 32°S (Piola et al., 2000; Piola et al., 2008). The SACW is formed by sinking within the Subtropical Convergence area, with subsequent spreading along its proper density surface (Sverdrup et al., 1942; Stramma and England, 1999), and there is periodical intrusion of cold, nutrient-rich SACW onto the continental shelf regarded as upwelling phenomenon. This periodical intrusion was associated to a major enrichment of marine communities (Pires-Vanin et al., 1993). Upwelling of SACW tends to occur preferably during the spring and summer for both Cape Frio (23°S) (e.g. Emílson, 1961; Matsuura, 1986; Rodrigues and Lorenzzetti, 2001) and Santa Marta Cape (29°S) (Castello and Möller, 1977; Eichler et al., 2008). Upwelling is bound to happen off Cape Polônio in Uruguay (34°S); however, the presence of Plata plume requires a significant wind impulse for upwelling to occur (Framinan et al., 1999; Pimenta et al., 2008).

The presence of fresher and colder Subantarctic Water (SASW: 4°C < T < 15°C, 33.7 < S < 34.15) (Miranda and Castro, 1979; Guerrero and Piola, 1997), originated from the dilution of SASW due to excess precipitation and continental runoff (Piola et al., 2000); and STSW, warmer and more saline (T > 20 °C, S > 36) as a branch of Tropical Water (TW) (Emílson, 1961;

Miranda and Castro, 1979; Silveira et al., 2000) in the South Atlantic continental margin between 27° and 37°S reflects the distribution of two foraminifera species *Buccella peruviana* and *Globocassidulina subglobosa*, respectively (Eichler et al., 2012). Boltovskoy in 1959 established *Buccella peruviana* as benthic indicator species for cold subantarctic waters, and Boltovskoy et al. (1980) defined *Globocassidulina subglobosa* as species carried by the warm Brazil Current.

The two dominant shelf water masses arise from the process of mixing of oceanic waters, and the STSW consists of modified warm tropical waters and SACW below Plata Pluma Water (PPW) (Piola et al., 2000; Möller et al., 2008; Eichler et al., 2012). Figure 1 shows a temperature-salinity diagram with three distinctive water masses PPW, STSW, SASW in the study region in summer and winter.

Figure 1: Temperature-Salinity diagram showing the presence of three distinctive water masses in summer and winter (PPW, STSW, SASW).

In an earlier study, Eichler et al. (2014) tracked distribution of *Bulimina marginata* to be primarily controlled by the presence of the Subtropical Shelf Front (STSF) and secondarily by presence of South Atlantic Central Water (SACW). Our study builds on this one; we now consider further details on the distribution of *Buccella peruviana* and *Globocassidulina subglobosa* as indicators of warm-cold water mass interaction (SASW and STSW) and *Uvigerina peregrina* as indicator of mixing of STSW and upwelling coastal areas of SACW. All species have critical morphological characters easily observed; and future studies will not face icons of taxonomical ambiguity.

2. Material and Methods

2.1 Sample Collection

During two oceanographic cruises, 120 surface sediment samples were collected in austral winter (August, 20th to September, 2nd 2003, 64 samples) and summer (February, 1st to 19th 2004, 56 samples); data on living foraminifera from these samples were used. A Van Veen Grab sampler was used in 11 transects in water depths from 10 and 250 m. These transects from south to north were as follows: Mar del Plata , Punta Medanos, Plata River, Punta del Este, Punta del Diablo, Albardão, Rio Grande, Solidão, Torres, Santa Marta and Itajaí (Figure 2). Oceanographic data were obtained for all stations.

Figure 2a: Transects from south to north are as follows: (1) Mar del Plata, (2) Punta Medanos, (3) Plata River, (4) Punta del Este, (5) Punta del Diablo, (6) Albardão, (7) Rio Grande, (8) Solidão, (9) Torres, (10) Santa Marta, and (11) Itajaí collected in winter and summer. 2b: Bathymetric map of the area.

2.2. Laboratory procedures

After collection, the uppermost layer of the sediment sample (about 5 mm) was scraped off and kept in ethanol. A solution of Rose Bengal in ethanol was used for staining live specimens (Eichler et al., 2007). After staining for 48hs, a fixed volume of 10 cm³ of sediment was washed through a 0.063 mm sieve. This fraction was floated using trichloroethylene to separate shells from rocks. The quantitative analysis of the primary data set is based on counts of living specimens. If sample had too many tests, the content was split with a micro splitter, but a minimum of 100 tests of foraminifera Fatela and Taborda (2002) was obtained, when quartering samples. Some stations, even counted in total, did not meet the 100 tests, but they were taken into account. Taxonomy identification and counting of dry specimens were done under an optical microscope. Scanning electron micrographs were taken to help with some problematic identification. Absolute and relative abundances were computed for each species.

3. Results

1 The relative abundance of foraminiferal species in the 63 winter samples and 54
2 summer samples are in the supplementary data (tables 1 and 2). Hydrographic and
3 hydrochemical data (depth, salinity, temperature, dissolved oxygen and nutrients) of the
4 bottom water in the winter and the summer is illustrated in Figure 3, and it is given on
5 supplementary data (tables 3 and 4).

7 Figure 3: Bottom hydrographical data: salinity, temperature, oxygen and three
8 distinguished Costal Water (CW), Subantartic Shelf Water (SASW), Subtropical Shelf Water
9 (STSF) (taken from Eichler et al, 2008).

10 Eichler et al. (2008) described lower salinity in winter closer to the coast, in the
11 shallowest stations, as Continental Water (CW) under direct influence of the Plata River plume.
12 In summer, this pattern is observed as far as the northernmost limit of Albardão. Towards
13 north it is observed increase of the salinity. Temperature shows clear separation between
14 north and south parts, being both limited for cold water in the north and warm water in the
15 south in Rio Grande at 50 m deep. The shallowest stations in the south of Rio Grande present
16 cold waters and the deepest stations of Punta del Diablo and Albardão present warmer
17 temperatures. In summer, temperature presents higher values closer to the coast, and in Rio
18 Grande, warmer temperature follows the deepest stations of this transect. In winter, oxygen
19 pattern also presents clear separation between oxygenated waters in the south close to Rio
20 Grande and lower values of oxygen in the north part, mainly in the deepest regions. In the
21 summer, this clear separation pattern is not evidenced, but it follows the temperature pattern
22 for the current limits. According to the abovementioned authors, it was possible to delimit
23 three water masses in the region, in winter: CW, well oxygenated, cold with lower salinity;
24 SASW, well oxygenated, cold with low salinity and high silicate; and STSW, less oxygenated,
25 warmer and more saline than CW and SASW (Figure 3). The clear differentiation of water
26 masses pattern observed in the winter is less apparent in the summer, but the presence of

warmer, less saline and less oxygenated water, characteristic of the STSW was detected all over the region.

Figure 4 shows *Globocassidulina subglobosa* and *Uvigerina peregrina* inhabit mainly to the north of Rio Grande (31.5° S) in areas deeper than 20 m. In Torres, in winter, in the shallowest station, the absence of this species indicates low accumulation of coastal water in this site. In summer, similar patterns with peaks of occurrence, further south in deepest stations of Punta del Este and Punta Medanos indicates penetration of warm currents down south in deeper parts. In winter, *U. peregrina* abundance is higher in Albardão (59.5%), at 53 m deep, and the southern limit of its occurrence is in Punta del Este, at 64 m deep. In summer, the occurrence of *Globocassidulina subglobosa* is similar to *U. peregrina* (Figure 4), however, an increase of *U. peregrina* in summer mainly in Santa Marta Cape, indicates the presence of colder water.

Figure 4: Relative frequency of *Globocassidulina subglobosa*, *Buccella peruviana*, and *Uvigerina peregrina*.

G. subglobosa and *Uvigerina peregrina* present peaks of occurrence (56.4%, and 47.6%, respectively) in summer, in Mar del Plata, and in deepest stations of P. Medanos, also suggesting reach of the STSW as south as this transect. By the other hand, *Buccella peruviana* is dominant south of Punta del Diablo, in winter and summer, however, in winter, its distribution occurs closer to the coast in practically all transects, except in Santa Marta (28° S), which it occurs in the deepest stations (105 and 130 m). In both seasons, more than 30% of *Buccella peruviana* indicates the presence of cold SASW, from 33.5 to 38.3° S, south of Punta del Este (Transect 4). In summer, however, at stations deeper than 100 m, the abundance of this species decreases to less than 15%, around 37.5-38.9°S, closer to the southernmost transect, Mar del Plata, where *Globocassidulina subglobosa*, *Uvigerina peregrina* take over. In the winter, the south limit of the STSW seems to be the shallowest stations of Torres (28.5° S).

4.1. Temperature-Salinity Diagram (TS diagram)

The TS diagram of Figure 5 is based on data from CTD (conductivity-temperature-depth) casts for the winter of 2003 and summer of 2004 (Campos et al., 2008; Möller et al., 2008) and from inner-shelf and estuarine casts derived from the RioPla Project for the winter of 1999 and summer of 2000 (Framiñan, 2005; Pimenta et al., 2008).

We observe that the distribution of *Buccella peruviana* present peaks of occurrence where salinity and temperature are characteristic of both cold-water masses: Subantarctic Shelf Water (SASW), ($T < 15^{\circ}\text{C}$ and $33.7 < S < 34.1$) and Plume Plata Water (PPW) (Figure 5). *Globocassidulina subglobosa* and *Uvigerina peregrina* are characteristic of warm Subtropical Shelf Water (STSW) ($T > 12^{\circ}\text{C}$ and $S > 34.5$), and of upwelled SACW ($5.0 < T < 18.0^{\circ}\text{C}$ and $34.3 < S < 35.8$).

Figure 5: Temperature-Salinity diagrams and relative density of three characteristic species *Buccella peruviana* (top), *Globocassidulina subglobosa* (middle) and *Uvigerina peregrina* (bottom). Each point in the graph represents a sample with its axis representing its *in-situ* salinity (abscissa) and temperature (ordinate). Colored dots indicate the CTD sample depth. Solid circles represent relative abundance of foraminiferal species from Tables 1 and 2, according to the scale shown on the left.

4. Discussion

Our study shows a very dynamic area under the influence of at least four water masses: cold Subantarctic Shelf Water (SASW), warm Subtropical Shelf Water (STSW), upwelled cold Atlantic Central Water (SACW) and fresh Pluma Plata Water (PPW) in the bottom marine sediment favoring distribution of *Buccella peruviana*, *Globocassidulina subglobosa* and *Uvigerina peregrina*.

1 In the Subtropical Shelf Water (STSW) (where $T > 12^{\circ}\text{C}$ and $S > 34.5$) the main species
2 are *Globocassidulina subglobosa* and *Uvigerina peregrina*, mainly to the north of Rio Grande
3 (31.5°S) in areas deeper than 20 m. In the winter, the south limit of the STSW seems to be the
4 shallowest stations of Torres (28.5°S). Boltovskoy et al. (1980) have described these species as
5 carried by the Brazil Current. In summer, higher incidence of this water mass is observed
6 penetrating further south. In the winter, the south limit of the STSW seems to be the
7 shallowest stations of Torres (28.5°S), and in summer, *Globocassidulina subglobosa* and
8 *Uvigerina peregrina* present peaks of occurrence in deepest stations of Mar del Plata (38°S),
9 suggesting reach of the STSW as south as this transect. In summer, higher incidence of this
10 water mass is observed in the south. Earlier studies on recent distribution of uvigerinids reveal
11 relationships of certain species with water depth (Schnitker, 1979; Streeter & Lavery, 1982;
12 Caralp, 1987), and its paleo bathymetric trackers in deep-water masses (Balsam, 1981; Pekari
13 & Kominz, 2001), and more recently Eichler et al., (2014) has showed *U. peregrina* as a reliable
14 indicator of bottom-water temperatures. As *U. peregrina* is, also an indicative of high primary
15 productivity species (Mulitza et al., 2004; Schmiedl et al., 2004) we can correlate its occurrence
16 with the presence of the SACW at least in in Santa Marta Cape in the summer. Foraminiferal
17 responses to upwelling variations in the South China Sea over the last 220000 years have
18 shown high productivity species such as *U. peregrina* displayed high abundance during
19 interglacial and glacial periods (Huang and others, 2003). In a different approach, Vergnaud-
20 Grazzini et al (1991) studying the highly productive upwelling along the northwestern margin
21 of the Alboran basin, on the glacial to postglacial reconstruction, showed that $\delta^{13}\text{C}$ differences
22 between endobenthic *U. peregrina* species from the Alboran basin and from other
23 Mediterranean basins are changes in the fertility during the last deglaciation. Jian and others
24 (1991) have selected four upwelling proxies (BF-Flux, Corg-Flux, relative abundance of *U.*
25 *peregrina*) for the variability of monsoonal intensity, indicating differential responses of this
26 species to the changes in C_{org} flux induced by upwelling intensity.

1 In Callao, Peru, *Buccella peruviana* was described as being carried to the Atlantic via
2 subantarctic waters (Boltovskoy, 1950) and our results showed that this species is indeed a
3 characteristic species of the Subantarctic Shelf Water (SASW) ($T < 15^{\circ}\text{C}$ and $33.7 < S < 34.15$)
4 dominant mainly further southward than Punta Del Diablo (33°S). Stevenson et al. (1998)
5 describe this species as a temperate water species typical of Argentine Province and they
6 concluded that the Subantartic waters have reached lagoonal areas situated in the
7 northernmost part of Rio de Janeiro, Brazil (22°S).

8 Despite of Moller et al. (2008) findings, which suggest that SASW does not reach areas
9 beyond 32°S , the occurrence of *Buccella peruviana* in these deeper layers suggests that this
10 species may have been transported to lower latitudes in winter. Such phenomenon called for
11 further detailed studies (Eichler et al., 2008; Eichler et al., 2012a) because the presence of
12 *Buccella peruviana* during the winter at Santa Marta Cape (28°S) suggest that this species was
13 passively transported by prevailing northward shelf currents in the present study. This species
14 was also described in Eichler et al. (2012b) as indicators of marine pollutant contamination on
15 the inner continental shelf of southern Brazil and its occurrence was mostly regulated by
16 temperature, depth, salinity, and percentage of sand other than percentage of clay and total
17 coliforms.

19 5. Conclusions

20 Our study show three species: *Buccella peruviana*, *Globocassidulina subglobosa*, and
21 *Uvigerina peregrina* probably tracking distinct temperature and salinity averages oscillations in
22 the continental shelf of Brazil. Two foraminiferal species: *Globocassidulina subglobosa* and
23 *Uvigerina peregrina* are characteristic of warm Subtropical Shelf Water (STSW), and of
24 upwelled South Atlantic Central Water (SACW). *Buccella peruviana* is mainly indicator of
25 Subantarctic Shelf Water (SASW), and secondly as a Pluma Plata Water (PPW) tracker.

1 We conclude that the stratigraphic distribution of *Buccella peruviana*, *Globocassidulina*
2 *subglobosa*, and *Uvigerina peregrina* in sediment cores might track subtle changes of
3 temperature and salinity like warming or cooling of these water masses in the past due to their
4 relatively easy taxonomy, and its bottom water masses tracking power.

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21 References

- 22 Balsam, W., 1981, Late Quaternary sedimentation in the western North Atlantic: stratigraphy
23 and paleoceanography: *Palaeogeography, Palaeoclimatology, Palaeoecology*, v. 35, p.
24 215–240.
- 25 Barmawidjaja, D. M., Jorissen, F. J., Puskaric, S, and van der Zwaan, G. J. 1992. Microhabitat
26 selection by benthic foraminifera in the northern Adriatic Sea; *J. Foram. Res.*22: 297–317.
- 27 Boltovskoy, E. 1959. Foraminifera as biological indicator in study of ocean currents.
28 *Micropaleontology*, vol. 5, no. 4, p. 473-481.
- 29 Boltovskoy, E., Giussani, G., Watanabe, S. and Wright, R. 1980. Atlas of benthic shelf
30 foraminifera of Southwest Atlantic. Junk, The Hague, 147 pp.

- 1 Burone, L., Mello e Sousa, S. H., Mahiques, M. M., Valente, P., Ciotti, A., Yamashita, C. 2011.
2 Benthic foraminiferal distribution on the southeastern Brazilian shelf and upper slope.
3 Marine Biology vol. 158 issue 1, p. 159 - 179
- 4 Campos, E., Piola, A., Matano, R., Miller, J. 2008. PLATA: A synoptic characterization of the
5 southwest Atlantic shelf under influence of the Plata River and Patos Lagoon outflows.
6 Continental Shelf Research, Vol. 28, No. 13, pp. 1551-1555, doi:10.1016/j.csr.2008.03.007
- 7 Campos, C.P., Möller, O.O., Piola, A.R. and Palma, E.D., 2013. Seasonal variability and coastal
8 upwelling near Cape Santa Marta (Brazil). Journal of Geophysical Research, 118, 1-14,
9 doi:10.1002/jgrc.20131.
- 10 Caralp, M., 1987, Deep-sea circulation in the northeastern Atlantic over the past 30,000 years:
11 the benthic foraminiferal record: Oceanologica Acta, v. 10, p. 27–40.
- 12 Castello, J.P. and Möller O.O., 1977. Sobre as condições oceanográficas no Rio Grande do Sul.
13 Atlântica, Rio Grande, 2 (2), 25-110.
- 14 Donnici, S., and Barbero, R.S., 2002. The benthic foraminiferal communities of the northern
15 Adriatic continental shelf. Mar. Micropaleontol. 44, 93-123.
- 16 De Leo, F.C., and Pires-Vanin, A.M.S. 2006. Benthic megafauna communities under the
17 influence of the South Atlantic Central Water intrusion onto the Brazilian SE shelf: A
18 comparison between an upwelling and a non-upwelling ecosystem. Journal of Marine
19 Systems, 60 (3-4), pp. 268-284.
- 20 Eichler, P. P. B.; Eichler, B. B.; De Miranda, L. B.; Rodrigues, A. R. 2007. Modern foraminiferal
21 facies in a subtropical estuarine channel, Bertioga, São Paulo, Brazil. Journal of
22 Foraminiferal Research, 37: 234 - 247
- 23 Eichler, P.P.B., Sen Gupta, B.K., Eichler, B.B., Braga, E.S., and Campos, E.J.D, 2008. Benthic
24 foraminiferal assemblages of the South Brazil: Relationship to water masses and nutrient
25 distributions. Continental Shelf Research, 28:1674-1686.
26 <http://dx.doi.org/10.1016/j.csr.2007.10.012>
- 27 Eichler, P.P.B., Eichler, B.B., Sen Gupta, B., Rodrigues, A.R., 2012. Foraminifera as indicators of
28 marine pollutant contamination on the inner continental shelf of southern Brazil. Marine
29 Pollution Bulletin 64 (1), 22--30.
- 30 Eichler, P.P.B., Rodrigues, A.R., Eichler, B.B., Braga, E.S., Campos, E.J.D. 2012. Tracing latitudinal
31 gradient, river discharge and water masses along the subtropical South American coast

- using benthic Foraminifera assemblages. *Braz. J. Biol.* [online]., vol.72, n.3, suppl., pp. 723-759. ISSN 1519-6984. <http://dx.doi.org/10.1590/S1519-69842012000400010>.
- Eichler, P. P., Billups, K., Vital, H., & De Moraes, J. A. 2014. Tracing thermohaline properties and productivity of shelf-water masses using the stable isotopic composition of benthic foraminifera. *The Journal of Foraminiferal Research*, 44(4), 352-364.
- Emílson, I., 1961. The shelf and coastal waters off Southern Brazil. *Brazilian Journal of Oceanography*, 17 (2), 101-112.
- Fatela, F. and Taborda, R. 2002. Confidence limits of species proportions in microfossil assemblages. *Marine Micropaleontology*, 45:169-174.
- Framinan, M.B., Etala, M.P., Acha, E.M., Guerrero, R.A., Lasta, C. and Brown, O.B. 1999. Physical characteristics and processes of the Rio de la Plata Estuary. In: *Estuaries of South America*, G.M. Perillo; M.C. Piccolo & M. Pino (Eds), Springer-Verlag, Ch.8, 161-194.
- Framiñan, M. B. 2005, On the physics, circulation and exchange process of the Rio de la Plata estuary and adjacent shelf. Ph.D. thesis, University of Miami, Coral Gables, Florida, USA, 486 pp.
- Guerrero, R.A., Piola, A.R., 1997. Masas de agua en la plataforma continental. In: Boschi, E. (Ed.), *El Mar Argentino y sus Recursos Pesqueros*, Instituto Nacional de Investigación y Desarrollo Pesquero. Mar del Plata, Argentina, 107–118.
- Huang, B., Jian, Z. Cheng, X., Wang, P. 2003. Foraminiferal responses to upwelling variations in the South China Sea over the last 220 000 years, *Marine Micropaleontology*, Volume 47, Issues 1–2, Pages 1-15, ISSN 0377-8398, [http://dx.doi.org/10.1016/S0377-8398\(02\)00045-2](http://dx.doi.org/10.1016/S0377-8398(02)00045-2).
(<http://www.sciencedirect.com/science/article/pii/S0377839802000452>)
- Jian, Z. Huang, B. Kuhnt, W., Lin Hui, L. 2001. Late Quaternary Upwelling Intensity and East Asian Monsoon Forcing in the South China Sea. *Quaternary Research* 55, 363–370 doi:10.1006/qres.2001.2231, available online at <http://www.idealibrary.com> on
- Klitgaard-Kristensen, D. and Sejrup, H. F. 1996. Modern benthic foraminiferal biofacies across the northern North Sea. *Sarsia* 81:97-106. Bergen. ISSN 0036-4827.
- Klitgaard-kristensen, D., Sejrup, H. F., Hafliðason, H. 2002. Distribution of recent calcareous benthic foraminifera in the northern North Sea and relation to the environment. *Polar Research*, North America, 21, jan. 2002. Available at: <http://www.polarresearch.net/index.php/polar/article/view/6488>

- 1 Lutze, G.F., Coulbourn, W.T., 1984. Recent benthic foraminifera from the continental margin
2 off Northwest Africa: community structure and distribution. *Mar. Micropaleontol.* 8, 361–
3 401.
- 4 Martins, V., Jouanneau, J.M., Weber, O., Rocha, F. 2006. Tracing the late Holocene evolution of
5 the NW Iberian upwelling system, *Marine Micropaleontology*, Volume 59, Issue 1, 22,
6 Pages 35-55, ISSN 0377-8398, 10.1016/j.marmicro.2005.12.002.
7 (<http://www.sciencedirect.com/science/article/pii/S0377839806000028>)
- 8 Matano, R.P., Palma E.D., Piola, A.R., 2010. The influence of the Brazil and Malvinas Currents
9 on the Southwestern Atlantic Shelf circulation. *Ocean Science*, 6, 983-995.
- 10 Matsuura, Y., 1986. Contribuição ao Estudo da Estrutura Oceanográfica da Região Sudeste
11 entre Cabo Frio (RJ) e Cabo de Santa Marta Grande (SC). *Ciência e Cultura*, 38 (8), 1439-
12 1450.
- 13 Miranda, L.B., 1972. Propriedades e variáveis físicas das águas da plataforma continental do Rio
14 Grande do Sul. Ph.D. Thesis, Instituto Oceanográfico da Universidade de São Paulo, São
15 Paulo, Brazil.
- 16 Miranda, L.B., Castro, B.M., 1979. Aplicação do diagrama T-S estatístico-volumétrico à análise
17 das massas de água da plataforma continental do Rio Grande do Sul. *Brazilian Journal of*
18 *Oceanography*, 28 (1), 185-200.
- 19 Möller, O., Piola, A.R., Freitas, A.C., Campos, E.J.D., 2008. The effects of river discharge and
20 seasonal winds on the shelf off Southeastern South America. *Continental Shelf Research*,
21 vol. 28, p. 1607-1624.
- 22 Mojtahid, M., Jorissen, F., Durrieu, J., Galgani, F., Howa, H., Redois, F., Camps, R. 2006. Benthic
23 foraminifera as bio-indicators of drill cutting disposal in tropical east Atlantic outer shelf
24 environments, *Marine Micropaleontology*, Volume 61, Issues 1–3, 20, Pages 58-75, ISSN
25 0377-8398, 10.1016/j.marmicro.2006.05.004.
26 (<http://www.sciencedirect.com/science/article/pii/S0377839806001022>)
- 27 Pekari, S. F., and Kominz, M. A., 2001, Two-dimensional paleoslope modeling: a new method
28 for estimating water depths of benthic foraminiferal biofacies and paleoshelf margins:
29 *Journal of Sedimentary Research*, v. 71, p. 608–620.
- 30 Phleger, F.B., Soutar, A., 1973. Production of benthic foraminifera in three east Pacific oxygen
31 minima. *Micropalaeontology* 19 (1), 110-115.

- 1 Pimenta, F.M., Campos, E.J.D., Miller, J.L. and Piola, A.R. 2005. A numerical study of the Plata
2 River plume along the Southeastern South American continental shelf: Brazilian Journal of
3 Oceanography, vol. 53. no. 3, p. 129-146.
- 4 Pimenta F. M., Garvine R., Münchow A. 2008. Observations of coastal upwelling off Uruguay
5 downshelf of the Plata estuary, South America. Journal of Marine Research, v. 66, p. 835-
6 872.
- 7 Piola, A.R.; Campos, E.J.D.; Möller Jr., O.O.; Charo, M. Martinez, C.M. 2000. Subtropical shelf
8 front off eastern South America. Journal of Geophysical Research, 105 (C3), pp. 6566–
9 6578
- 10 Piola, A.R., Möller Jr., O.O., Guerrero, R.A., Campos, E.J.D., 2008. Variability of the Subtropical
11 Shelf front off eastern South America: winter 2003 and summer 2004. Continental Shelf
12 Research, doi:10.1016/j.csr.2008.03.013.
- 13 Pires-Vanin, A. M. S. 1993. A macrofauna bêmica na plataforma continental ao largo de
14 Ubatuba, São Paulo, Brasil. Publicação esp. Inst. oceanogr., (10):137-158
- 15 Rodrigues, R.R., Lorenzetti, J.A., 2001. A numerical study of the effects of bottom topography
16 and coastline geometry on the Southeast Brazilian coastal upwelling. Continental Shelf
17 Research, 21, 371-394.
- 18 Schnitker, D., 1979, The deep waters of the western North Atlantic during the past 24,000
19 years, and the reinitiation of the Western Boundary Undercurrent : Marine
20 Micropaleontology, v. 4, p. 265–280.
- 21 Stevenson, MR., Dias-Brito, D., Stech, JL. and Kampel, M., 1998. How do cold water biotas
22 arrive in a tropical bay near Rio de Janeiro, Brazil? Continental Shelf Research, vol. 18, no.
23 13, p. 1595-1612.
- 24 Stramma, L., and England, M. 1999, On the water masses and mean circulation of the South
25 Atlantic Ocean, J. Geophys. Res., 104(C9), 20863–20883, doi:10.1029/1999JC900139.
- 26 Streeter, S., and Lavery, S. A., 1982, Holocene and latest glacial benthic foraminifera from the
27 slope and rise off eastern North America: Geological Society of America Bulletin, v. 93,p.
28 190–199.
- 29 Sverdrup, H.U., Johnson, M.W., Fleming, R.H., 1942. The Oceans. Their Physics, Chemistry, and
30 General Biology. Prentice-Hall, Englewood Cliffs, NJ, 1087 pp.

- Villanueva-Guimerans, P. and Canudo, I. 2008. Assemblages of recent benthic foraminifera from the northeastern gulf of Cadiz. 2008. *Geogaceta*, 44 (2008), 139-142. ISSN: 0213683X
- Vivier, F., Provost, C., 1999. Direct velocity measurements in the Malvinas Current. *Journal of Geophysical Research*, 104, 21083–21103.
- Vergnaud-Grazzini, C.; Pierre, C. (1991): High fertility in the Alboran Sea since the last glacial maximum. *Paleoceanography*, 6(4), 519-536, doi:10.1029/91PA00501
- Walton, W.R., 1952. Techniques for recognition of living foraminifera. *Contributions of the Cushman Foundation for Foraminiferal Research*, 3: 56-60.

Figure 1

Figure 2

Figure 3

Winter

Summer

Figure 4

Figure 5

Table 1

Winter/2003	0	1	2	3	4	5
Ammonia becarrii	97.5	9.2	6.7	0.0	8.0	0.0
Ammonia rolshauseni	0.0	0.0	0.0	0.0	0.0	0.0
Amphicoryna scalaris	0.0	0.0	0.0	0.0	0.0	0.0
Anglogerina angulosa	0.0	0.0	0.0	0.0	0.0	0.0
Astacolus crepidulus	0.0	0.0	0.0	0.0	0.0	0.0
Bigenerina irregularis	0.0	0.0	0.0	0.0	0.0	0.0
Bolivina pulchella	0.0	0.0	0.0	0.0	0.0	0.0
Bolivina striatula	0.0	15.4	1.4	0.0	0.0	0.0
Buccella peruviana	0.6	29.2	17.8	48.3	6.0	55.0
Bulimina elongata	0.0	0.0	3.9	2.4	0.0	0.0
Bulimina marginata	1.3	3.1	11.8	4.1	0.0	0.0
Buliminella elegantissima	0.0	1.5	0.4	0.6	0.0	0.0
Cancris sacra	0.0	0.0	0.2	0.0	0.0	0.0
Cassidulina crassa porrecta	0.0	0.0	0.0	0.0	0.0	0.0
Cassidulina subglobosa	0.0	4.6	2.2	0.6	0.0	8.4
Cassidulinoides parkerianus	0.0	0.0	0.0	0.0	0.0	0.0
Cibicides fletcheri	0.0	0.0	0.0	0.0	0.0	0.0
Cibicides mackannai	0.0	0.0	2.2	9.0	0.0	10.7
Cibicides refulgens	0.0	0.0	0.0	0.0	0.0	0.0
Cibicides variabilis	0.0	0.0	0.4	0.0	0.0	0.0
Cibicides sp	0.0	0.0	0.0	0.0	0.0	0.0
Cornuspyra involves	0.0	0.0	0.0	0.0	2.8	0.0
Dentalina sp.	0.0	0.0	0.0	0.0	0.0	0.0
Discorbis peruvianus	0.0	0.0	0.6	0.2	0.0	0.0
Discorbis williamsoni	0.6	16.9	4.3	6.4	40.2	1.5
Discorbis bertheloti	0.0	0.0	0.0	0.0	0.0	0.0
Ehrenbergina pupa	0.0	0.0	0.0	0.0	0.0	0.0
Elphidium discoidale	0.0	0.0	0.2	0.0	0.0	0.0
Elphidium excavatum	0.0	0.0	4.5	0.0	0.0	0.0
Elphidium gunteri	0.0	0.0	0.4	0.0	0.0	0.0
Elphidium poeyanum	0.0	0.0	0.2	0.0	0.0	0.0
Fissurina laevigata	0.0	0.0	0.2	0.4	0.0	0.0
Fursenkoina pontoni	0.0	0.0	0.2	0.2	0.0	0.8
Fursenkoina sp.	0.0	0.0	0.0	0.0	0.0	0.0
Gutulina sp.	0.0	0.0	0.0	0.0	0.0	0.0
Gypsina vesicularis	0.0	0.0	0.0	0.0	0.0	0.0
Hanzawaia boueana	0.0	0.0	0.0	0.0	0.0	0.0
Hoeglundina elegans	0.0	0.0	0.0	0.0	0.0	0.0
Hopkinsina pacifica	0.0	0.0	0.0	0.0	0.0	0.0
Lagena caudata	0.0	0.0	0.0	0.2	0.0	0.0
Lagena digitale	0.0	0.0	0.2	0.2	0.0	0.0
Lagena distoma	0.0	0.0	0.0	0.0	0.0	0.0
Lagena striata	0.0	0.0	0.0	0.6	0.0	0.0
Lenticulina sp.	0.0	0.0	0.0	0.0	0.0	0.0
Marginulina spp.	0.0	0.0	0.0	0.0	0.0	0.0
Miliolinella subrotunda	0.0	0.0	0.0	0.0	0.0	0.0
Nonionella opima	0.0	0.0	0.0	0.0	0.0	0.0
Oolina melo	0.0	0.0	0.0	0.2	0.0	0.0
Oolina vilarboana	0.0	0.0	0.0	0.0	0.0	0.0
Oolina universa	0.0	0.0	0.0	0.0	0.0	0.0
Orthomorphina filiformis	0.0	0.0	0.0	0.0	0.0	0.0

Table 2

Summer 2004	0	1	2	4	5	6
<i>Ammonia becarii</i>	8.1	0.0	2.1	0.0	0.0	0.0
<i>Ammonia rolshauseni</i>	0.0	0.0	0.0	0.6	0.0	0.0
<i>Amphicoryna scalaris</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Angulogerina angulosa</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Astacolum crepidulus</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Bigennerina irregularis</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Bolivina compacta</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Bolivina doniezi</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Bolivina ligularia</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Bolivina ordinaria</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Bolivina striatula</i>	2.7	0.0	0.7	4.8	3.2	0.0
<i>Bolivina pulchella</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Buccella peruviana</i>	5.4	31.4	46.9	23.8	21.5	12.0
<i>Bulimina elongata</i>	0.0	0.0	15.4	0.0	1.1	0.0
<i>Bulimina marginata</i>	0.0	0.0	0.7	0.0	3.2	0.0
<i>Bulimina patagonica</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Buliminella elegantissima</i>	0.0	0.0	1.4	0.0	0.0	0.0
<i>Cancris sacra</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Cassidulina crassa porrecta</i>	0.0	0.0	0.0	8.4	2.7	2.3
<i>Cassidulina subglobosa</i>	0.0	0.0	3.5	0.0	32.3	19.8
<i>Cassidulinoides parkerianus</i>	0.0	0.0	0.0	0.0	0.0	5.2
<i>Cibicides sp</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Cibicides fletcheri</i>	0.0	0.0	0.0	0.0	2.2	0.0
<i>Cibicides mackannai</i>	0.0	0.0	0.7	0.0	3.2	6.3
<i>Cibicides refulgens</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Cibicides variabilis</i>	0.0	0.0	2.1	0.0	0.0	0.0
<i>Cornuspyra involves</i>	40.5	0.0	0.0	0.0	0.0	0.0
<i>Discorbis williamsoni</i>	0.0	21.6	3.5	0.3	0.0	0.0
<i>Discorbis peruvianus</i>	0.0	0.0	0.0	0.0	0.5	0.0
<i>Dentalina sp.</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Ehrenbergina pupa</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Elphidium discoidale</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Elphidium excavatum</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Elphidium gunteri</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Elphidium poeyanum</i>	0.0	1.0	1.4	2.2	0.5	0.0
<i>Fissurina laevigata</i>	0.0	0.0	0.0	1.3	0.0	1.7
<i>Fursenkoina pontoni</i>	0.0	0.0	0.0	1.3	0.0	0.0
<i>Fursenkoina sp.</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Hanzawaia boueana</i>	0.0	0.0	0.7	7.9	2.2	0.0
<i>Gutulina sp.</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Hoeglundina elegans</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Hopkinsina pacifica</i>	0.0	0.0	0.7	0.0	0.0	0.0
<i>Lagena caudata</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Lagena distoma</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Lagena laevis</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Lagena striata</i>	0.0	0.0	0.0	0.3	0.5	0.0
<i>Lenticulina sp.</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Marginulina spp.</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Miliolinella subrotunda</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Nonionella opima</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Oolina melo</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Oolina vilarboana</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Oolina universa</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Orthomorphina filiformis</i>	0.0	0.0	0.0	0.6	0.0	0.0
<i>Poreoponides lateralis</i>	0.0	0.0	0.0	0.0	0.0	0.0

Table 3

Winter station	Longitude	Latitude	Depth	Salinity	Temperature	Oxygen	% Gravel	% Sand
1	-57.44997	-38.14007	24.0	33.8	10.0	6.4	10.4	89.6
2	-57.2308	-38.2478	44.0	33.8	10.4	6.2	0.4	98.1
3	-56.91072	-38.39175	80.0	33.6	8.1	6.3	0.0	97.0
4	-56.51508	-38.59362	87.0	33.6	7.6	6.2	0.2	99.8
5	-56.08967	-38.7843	80.0	33.9	6.7	6.7	0.0	100.0
6	-55.6968	-38.9813	117.0	34.0	5.5	3.4	0.0	99.4
11	-55.14273	-37.58727	110.0	33.8	7.0	6.8	0.0	100.0
12	-55.56437	-37.3847	78.0	33.5	8.4	6.3	0.8	99.2
13	-55.82952	-37.283	72.2	33.6	9.7	6.4	0.3	98.9
14	-56.08	-37.1705	37.0	33.7	10.3	6.4	1.0	99.0
15	-56.27648	-37.05445	31.0	33.7	10.4	6.5	0.0	100.0
16	-56.4977	-36.91655	17.5	33.7	10.2	6.5	10.9	89.1
17	-55.88463	-35.8815	15.0	33.2	10.8	6.3	0.0	100.0
18	-55.60422	-36.00225	21.0	33.8	10.8	6.4	46.7	53.3
19	-55.31548	-36.1371	21.0	33.7	10.8	6.4	0.0	100.0
20	-55.0393	-36.28013	38.3	33.6	10.6	6.4	30.6	69.4
21	-54.70898	-36.41817	52.6	33.6	9.8	6.4	0.4	99.6
22	-54.28122	-36.61295	100.0	33.6	8.1	6.4	0.0	100.0
26	-53.02571	-35.90835	217.0	35.1	13.3	4.7	0.0	92.8
27	-53.35	-35.6845	64.7	33.6	8.7	6.4	0.0	99.1
28	-53.6645	-35.4793	53.0	33.6	10.1	6.4	0.7	99.3
29	-53.9072	-35.3185	22.6	33.7	10.6	6.4	0.0	100.0
30	-54.0652	-35.2007	26.4	33.7	10.8	6.4	0.0	95.6
31	-54.285	-35.04	37.2	34.0	11.0	6.2	0.0	96.8
32	-54.4633	-34.89	30.6	32.6	11.2	5.5	0.0	97.5
33	-53.22217	-33.79833	20.2	26.5	11.3	6.4	0.0	96.3
34	-52.99767	-33.9165	28.0	31.4	11.4	5.8	16.9	83.1
36	-52.62533	-34.12634	61.9	33.5	10.8	6.2	0.0	95.8
37	-52.4085	-34.24267	41.0	33.5	10.6	6.4	0.0	100.0
38	-52.07784	-34.42883	102.0	35.9	17.4	4.7	0.0	93.4
42	-51.03983	-33.58967	137.8	35.7	16.4	4.4	0.0	87.9
43	-51.3095	-33.43283	89.0	35.4	17.3	5.0	0.0	95.6
44	-51.51978	-33.31593	58.0	33.1	11.7	5.7	0.0	92.1
45	-51.737	-33.16117	54.9	33.0	11.6	5.8	0.8	98.8
46	-51.99965	-33.00543	37.0	29.7	11.8	6.4	32.2	67.8
47	-52.1545	-32.93017	20.0	27.9	11.4	6.6	0.6	99.4
48	-52.33	-32.8205	11.7	27.0	11.6	6.6	3.7	96.3
49	-51.8475	-32.04433	15.0	27.8	12.5	6.3	0.0	100.0
50	-51.54	-32.2085	20.1	30.4	12.0	5.5	1.0	99.0
51	-51.35683	-32.32533	53.0	32.8	12.8	6.1	0.0	97.8
52	-51.14067	-32.43616	67.0	34.5	16.4	4.7	0.0	99.8
53	-50.9015	-32.55967	61.0	35.4	18.0	4.4	0.0	99.7
54	-50.62583	-32.70867	85.0	35.9	17.8	4.7	0.0	100.0
58	-49.82467	-31.36417	144.0	35.7	16.4	4.5	15.5	84.5
59	-50.04198	-31.23618	130.0	35.9	17.6	4.3	3.1	96.5
60	-50.19167	-31.1592	108.0	35.8	17.7	5.6	0.2	93.4
61	-50.3675	-31.08318	75.0	35.0	18.2	4.3	0.0	96.1
62	-50.48867	-30.99883	36.6	32.8	14.5	5.1	0.0	97.4
64	-48.84467	-30.49083	157.7	35.6	15.6	4.5	1.5	96.3
65	-49.03083	-30.25333	136.0	35.8	17.2	4.3	4.5	90.9

Table 4

Summer station	Longitude	Latitude	Depth	Salinity	Temperature	Oxygen	MES(mg/L)	MO(mg/L)	SiO ₄	NO ₂
1	-38.0567	-57.4583	24	33.57	16.69	3.82	7.9	4.0	3.4	0.2
2	-38.253	-57.2447	47	33.59	11.83	4.19	22.0	3.9	3.9	0.1
3	-38.3947	-56.9118	82	33.57	8.59	5.26				
4	-38.5937	-56.5142	85	33.59	7.62	5.81	8.5	0.9	6.3	0.1
5	-38.785	-56.0857	82	33.63	7.11	5.65	7.7	0.6	3.3	0.1
6	-38.9758	-55.709	117	33.69	6.41	5.24	16.4	3.1	5.3	0.1
12	-37.6176	-55.1683	112	33.67	7.05	5.16	11.8	4.4	2.7	0.1
13	-37.4035	-55.5863	82	33.64	7.32	4.59	15.0	5.2	2.9	0.1
14	-37.2758	-55.8508	74	33.59	8.34	4.89	10.5	4.9	0.9	0.1
15	-37.1698	-56.0767	40	33.58	11.56	4.12	1.9	2.3	2.4	0.4
16	-37.0647	-56.2825	26	29.71	19.42	4.31	34.0	10.2	3.2	0.6
17	-36.953	-56.425	23	32.79	18.19	4.03	18.4	2.5	6.0	0.1
19	-35.9028	-55.9285	14	29.1	24.11	5.31	16.0	2.5	3.6	0.1
20	-36.0022	-55.6067	22	30.24	23.22	4.99	14.0	3.2	2.5	0.1
21	-36.1362	-55.3187	25	33.15	17.83	4.26	15.7	3.4	5.8	0.2
22	-36.276	-55.0393	39	33.61	16.92	5.05	15.3	3.4	1.1	0.1
23	-36.4113	-54.7167	49	33.55	12.15	4.19	17.8	3.8	2.3	0.3
24	-36.6155	-54.2765	95	33.62	7.4	4.72	5.7	3.4	1.2	0.1
30	-35.6195	-53.469	65	33.56	12.8	4.16	59.0	19.0	1.9	0.4
31	-35.5237	-53.7187	54	33.59	15	5.16	25.0	12.3	1.3	0.1
32	-35.3262	-53.94	28	33.15	17.69	4.27	22.0	41.6	1.7	0.1
33	-35.2613	-54.1255	27	32.06	21.88	4.42	21.0	18.5	1.0	0.1
34	-35.0422	-54.3573	40	32.61	16.7	2.57	34.0	38.7	10.1	0.2
37	-34.0708	-53.4207	23	31.85	20.89	4	19.0	24.5	3.6	0.2
38	-34.252	-53.0892	34	32.64	17.16	3.81	20.0	14.7	6.7	0.2
39	-34.368	-52.938	66	33.04	14.87	2.93	32.0	21.3	5.6	1.2
40	-34.47	-52.781	36	32.82	17.13	4.05	21.4	10.4	4.9	1.5
41	-34.5347	-52.633	60	33.43	15.4	4.04	32.0	9.5	5.6	0.1
42	-34.7087	-52.3923	97	34.88	14.57	3.61	19.3	6.3	4.6	0.0
48	-32.9602	-52.429	15	32.17	23.98	5.02	13.7	2.8	3.8	0.3
49	-33.0675	-52.303	19	32.94	23.27	5.1	22.3	7.7	18.7	0.3
50	-33.2367	-52.107	42	33.36	15.66	3.34	21.3	8.0	10.9	0.2
51	-33.3735	-51.88	64	34.72	17.44	2.65	22.5	8.0	2.3	0.1
52	-33.4723	-51.72	54	34.75	15.93	3.56	13.8	5.1	1.6	0.2
53	-33.6137	-51.5175	92	35.85	17.47	4.81	23.9	8.3	6.8	0.2
57	-32.9748	-50.5658	103	35.13	19.34	4.44	17.1	3.8	3.3	0.3
58	-32.8575	-50.7777	84	35.97	18.4	3.86	26.1	13.5	3.8	0.4
59	-32.7272	-51.0577	64	35.95	18.23	4.15	18.7	5.0	7.2	0.5
60	-32.6003	-51.3515	56	35.95	18.6	4.31	26.3	10.5	7.4	0.2
61	-32.4962	-51.5115	46	35.74	18.54	3.44	23.7	6.6	4.0	0.1
62	-32.3833	-51.7102	27	35.2	20.45	4.28	17.6	2.2	11.7	0.4
63	-32.3193	-52.048	19	34.582	24.29	4.78	15.7	3.2	5.6	0.2
64	-30.982	-50.5362	30	35.82	18.36	3.76	22.0	8.5	3.0	0.1
65	-31.0915	-50.3847	74	35.73	16.76	4.39	18.2	6.1	5.0	0.1
66	-31.1692	-50.2295	104	35.62	15.99	3.8	13.6	4.5	4.6	0.6
73	-30.0237	-49.232	104	35.61	16.01	4.09	15.2	5.0	7.9	0.4