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NOTA
BENTHIC DIATOMS FROM SHALLOW ENVIRONMENTS DEPOSITED AT 300 m DEPTH IN A SOUTHERN GULF OF CALIFORNIA BASIN

Diatomeas bentónicas de ambientes someros depositadas a 300 m de profundidad en una cuenca del sur del Golfo de California

RESUMEN. Se registraron diatomeas bentónicas recolectadas con una trampa Technicap modelo PPS-3/3 con una abertura de 0.125 m^2, la cual consta de un carrusel programable motorizado con doce botellas de 250 mL instalada a 300 m de profundidad en Cuenca Alfonso, Bahía de La Paz. Se contrastó la hipótesis de que diatomeas depositadas en la trampa de sedimento estarían relacionadas a ambientes de manglar de la Bahía de La Paz. Así, con el objetivo de identificar las diatomeas bentónicas e inferir su procedencia, se revisó una muestra del período diciembre de 2011 a enero de 2012. La identificación se realizó a partir de imágenes tomadas con un microscopio electrónico de barrido Zeiss Supra Vp55. Se identificaron 38 taxa de diatomeas, 32 de las cuales fueron formas bentónicas entre las que se incluyen las especies: *Actinoptychus vulgaris, Halamphora coffeaeformis, Delphineis surirella, Fragilariopsis doliolus* y *Nitzschia amabilis*. Como éstas, las diatomeas observadas corresponden principalmente a taxa bentónicos comúnmente representadas en hábitats de las zonas intermareal y submareal someras. Aunque la hipótesis fue respaldada, la composición de especies de diatomeas no permitió mayor precisión sobre el ambiente de procedencia.

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Studies using sediment traps from different environments have been focused on understanding the different processes that affect settled particles, and variations of total masses fluxes and their components (Thunell *et al*., 2007; Silverberg *et al*., 2014). In a recent study using sediment traps deployed at a 300 m depth on Alfonso basin, Bahía de La Paz, benthic foraminifera were observed in samples from September 2011 to September 2012, showing highest fluxes in the December 2011-January 2012 sample (Rochín-Bañaga, 2014). Along with these, benthic diatom taxa were also observed in the sample from December 2011 to January 2012. These were identified in order to develop a reference for the recorded benthic foraminifera and the transport of particles in the area.

The record of benthic diatoms on marine sediments may provide evidence of displacement of shallow-water material or, when said diatoms are autochthonous, they may indicate the depth of the sea floor at the time of sediment deposition (Martínez López *et al*., 2004). For this reason, the aim of this study was to identify the benthic diatoms represented in the trap, and to infer their most likely provenance assessing the feasibility of transport from their original location to Alfonso basin.

Previous data suggested that in the winter 2011 the highest fluxes of benthic foraminifera collected at a 300 m depth could suggest re-depositing of material in Alfonso basin, related to the period of strongest gust of wind promoting the suspension of material, as well as to transporting by streams (Rochín-Bañaga, 2014). According to this, our hypothesis proposes that benthic diatoms deposited in the sediment traps are related to sediments from shallow mangrove ecosystems found in Bahía de La Paz and thus, the main taxa represented are expected to be species of *Actynopthychus*, *Amphora*, *Diploneis*, *Lyrella*, previously identified (Siqueiros Beltrones, 2002; 2006) as common elements of the diatom assemblages in the region.

Method. Alfonso Basin (2635 km^2) is located in the northern part of Bahía de La Paz, (24º 39’ N and 110º 36’ W), and reaches a depth of 420 m (Fig. 1). The communication with the Gulf of California occurs mainly through Boca Grande located north of the bay where depths vary between 220 and 320 m. To the south, communication is through the San Lorenzo Channel with depths no greater than 20 m (Cruz Orozco *et al*., 1996; Obeso Nieblas *et al*., 2008; Salinas González *et al*., 2003). A combination of diurnal currents from 1851 (cm/s)^2 at a depth of 20 m, to 42 (cm/s)^2 at a depth of 30 m (Zaytsev *et al*., 2010), and the more sluggish currents over the sea floor make it a natural depositional environment.

One sample from the Dec 2011 to Jan 2012 period was analyzed in order to identify the benthic diatoms and infer their origin, and to assess the feasibility for their transportation from a close by location to Alfonso basin. Settling particles were collected with a Technicap model PPS-3/3 sediment trap with a 0.125 m^2 opening, and a programmable motor-driven carousel containing twelve 250 mL bottles. The sample bottles contained a 4% formaldehyde solution with filtered (0.45 µm) seawater to which high purity NaCl was added to a practical salinity of 40, dense enough to limit exchange with the ambient seawater (Silverberg *et al*., 2014). The resolution of the sample was 30 days. The instrument was installed approximately at 24º39′ N,

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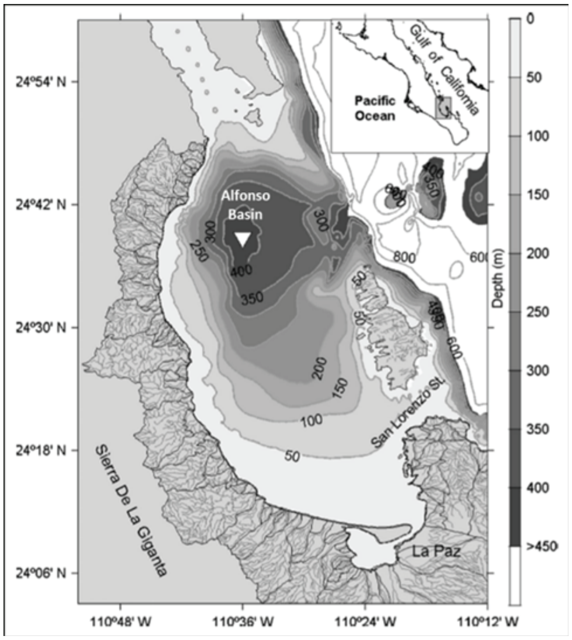

Figure 1. Bathymetry of Bahía de La Paz and location of the sediment trap mooring over Alfonso basin. After Silverberg *et al*. (2014)..

110º36′ W, at a depth of 300 m, and 100 m above the sea floor (Aguirre-Bahena, 2007; Silverberg *et al*., 2014). The bulk sample (without swimmers) was divided into 10 subsamples (splits) using a rotary splitter. Organic matter was removed according to Bairbakhish *et al.* (1999). The sample was then filtered through 0.8 µm Nucleopore membranes (Bollmann *et al*., 2002). Images were automatically taken using a Zeiss Supra Vp55 scanning electron microscope (Bollmann *et al*., 2004), with a magnification of 1500x. Benthic diatoms (and others) were identified based on regional studies, regarding the particular species composition of the represented habitats: Siqueiros Beltrones & Hernández Almeida (2006), López Fuerte & Siqueiros Beltrones (2006), López Fuerte *et al*. (2010), Siqueiros Beltrones (2002); Siqueiros Beltrones (2006); Siqueiros Beltrones *et al.* (2014), Siqueiros Beltrones & Argumedo Hernández (2014).

Observations. Overall, 38 diatom taxa were identified, including 32 benthic and 6 planktonic forms. The recorded number of identified benthic diatom taxa falls within the typical interval for benthic diatom samples (Siqueiros Beltrones, 2002) which commonly includes also planktonic forms, and usually depicts a specific area and date. In accordance with our hypothesis all diatom taxa from table 1 have been previously recorded in floristic studies of benthic diatoms carried out in the surrounding areas. The identified taxa (Table 1; Figs. 2-3) are commonly represented in assemblages from the intertidal and shallow subtidal habitats (planktonic forms included), comprising various benthic substrata, such

Table 1. Diatom taxa collected in the sediment trap set in Alfonso basin at a depth of 300 m from December 2011 to January 2012. Planktonic taxa commonly observed in benthic samples*.

1. *Actinoptychus aster*	Brun
2. *Actinoptychus vulgaris*	Schumann (Fig. 2G)
3. *Alveus marinus*	(Grunow) Kaczmarska & Fryxell
4. *Amphora proteus* var. *contigua*	Cleve (Fig. 2C)
5. *Amphora spectabilis*	Gregory
6. *Amphora wisei*	(Salah) Simonsen (Fig. 2A)
7. *Amphora holsaticoides*	T. Nagumo & H. Kobayasi
8. *Asteromphalus heptactis*	(Brébisson) Ralfs *
9. *Azpeitia nodulifera*	(AWF Schmidt) GA Fryxell & PA Sims* (Fig. 3H)
10. *Cocconeis* cf. *distans*	Gregory
11. *Cocconeis* cf. *californica*	Grunow (Fig. 2F)
12. *Cyclotella striata*	(Kützing) Grunow
13. *Delphineis* cf. *minutissima*	(Hustedt) Simonsen
14. *Delphineis surirella*	(Ehrenberg) Andrews
15. *Diploneis littoralis*	(Donkin) Cleve
16. *Diploneis papula*	(AWF Schmidt) Cleve
17. *Diploneis smithii*	(Brébisson) Cleve
18. *Fallacia vittata*	(Cleve) DG Mann (Fig. 2E)
19. *Fragilariopsis doliolus*	(Wallich) Medlin & Sims
20. *Halamphora coffeaeformis*	(Agardh) Levkov
21. *Haslea spicula*	(Hickie) L. Bukhtiyarova (Fig. 3I)
22. *Mastogloia* cf. *mauritiana*	Brun
23. *Mastogloia* sp.	(Fig. 3J)
24. *Navicula* cf. *pennata*	A. Schmidt
25. *Navicula diserta*	Hustedt
26. *Navicula* sp.	(Fig. 2D)
27. *Neodelphineis* cf. *pelagica*	Takano
28. *Nitzschia bicapitata*	Cleve
29. *Nitzschia amabilis*	Suzuki
30. *Nitzschia sicula*	(Castracane) Hustedt (Fig. 3K)
31. *Nitzschia* sp.	
32. *Odontella aurita*	(Lyngbye) C. Agardh *
33. *Perissonoë cruciata*	(Janisch & Rabenhorst) Andrews & Stoelzel
34. *Psammodictyon* cf. *constrictum*	(Gregory) DG Mann
35. *Roperia tesselata*	(Roper) Grunow* (Fig. 3L)
36. *Stephanopyxis* cf. *palmeriana*	(Greville) Grunow*
37. *Thalassiosira eccentrica*	(Ehrenberg) Cleve*
38. *Tryblionella acuminata*	W. Smith

as rock, sediments and macroalgae (López Fuerte & Siqueiros Beltrones, 2006; López Fuerte *et al*., 2010; Siqueiros Beltrones, 2002; 2006; Siqueiros Beltrones & Argumedo Hernández, 2014).

Alfonso Basin is located more than 10 km away from the shoreline. This is a considerable distance for particles such as diatoms, with an approximate density of 2.1 g cm^{-3}, to reach into the trap considering physical aspects such as particle sedimentation. However, it is feasible that when the speed of tidal currents and greater wind gusts, which can exceed 5 m s^{-1} (Silverberg *et al*., 2014), the displacement of particles such as foraminifera and diatoms among

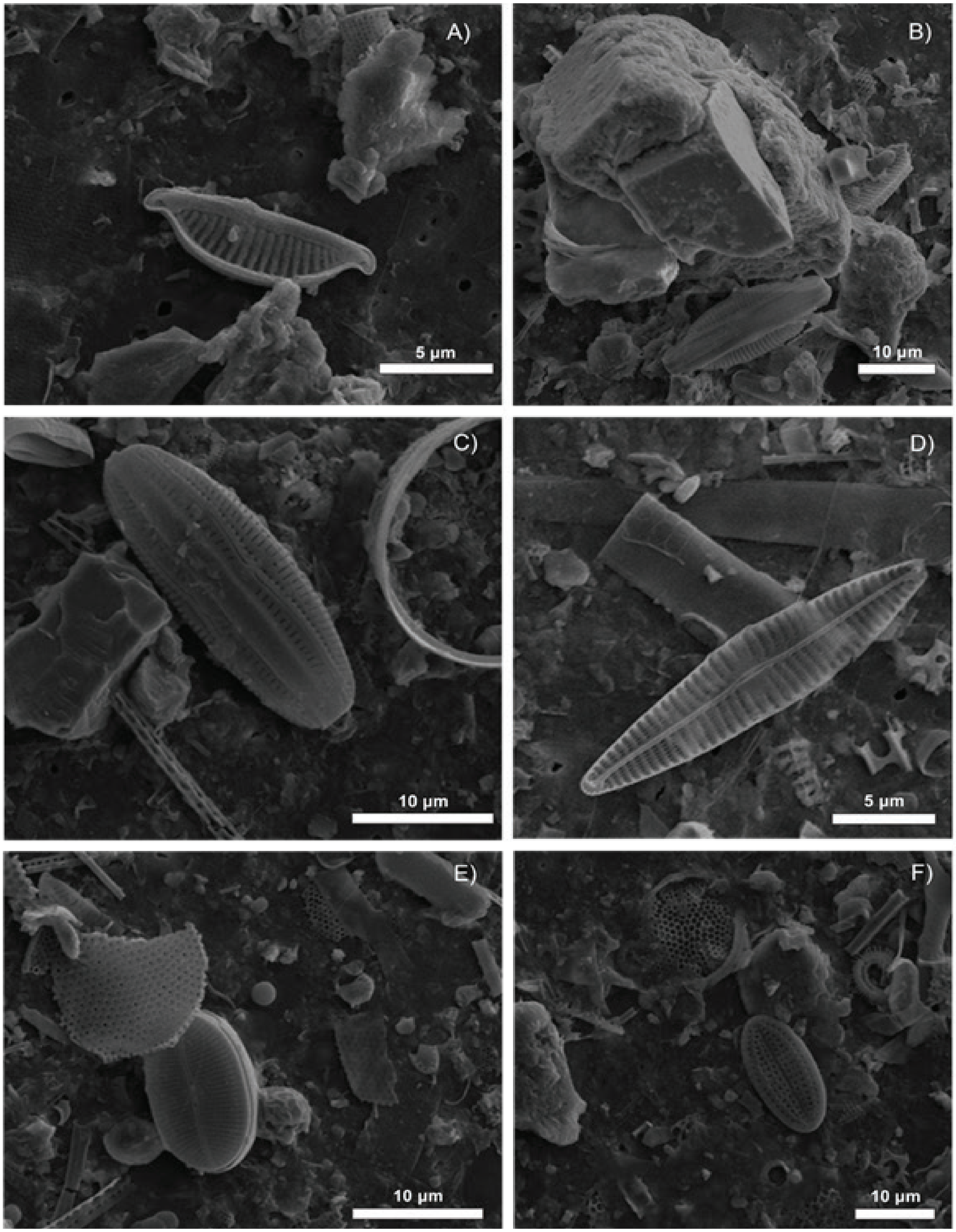

Figure 2. Benthic diatoms collected in Alfonso basin, La Paz bay at a depth of 300 m (December 2011 - January 2012). A) *Amphora wissei*, B) *Halamphora coffeaeformis,* C) *Amphora proteus* var. *contigua,* D) *Navicula* sp.*,* E) *Fallacia vittata*, F) *Cocconeis* cf. *californica*.

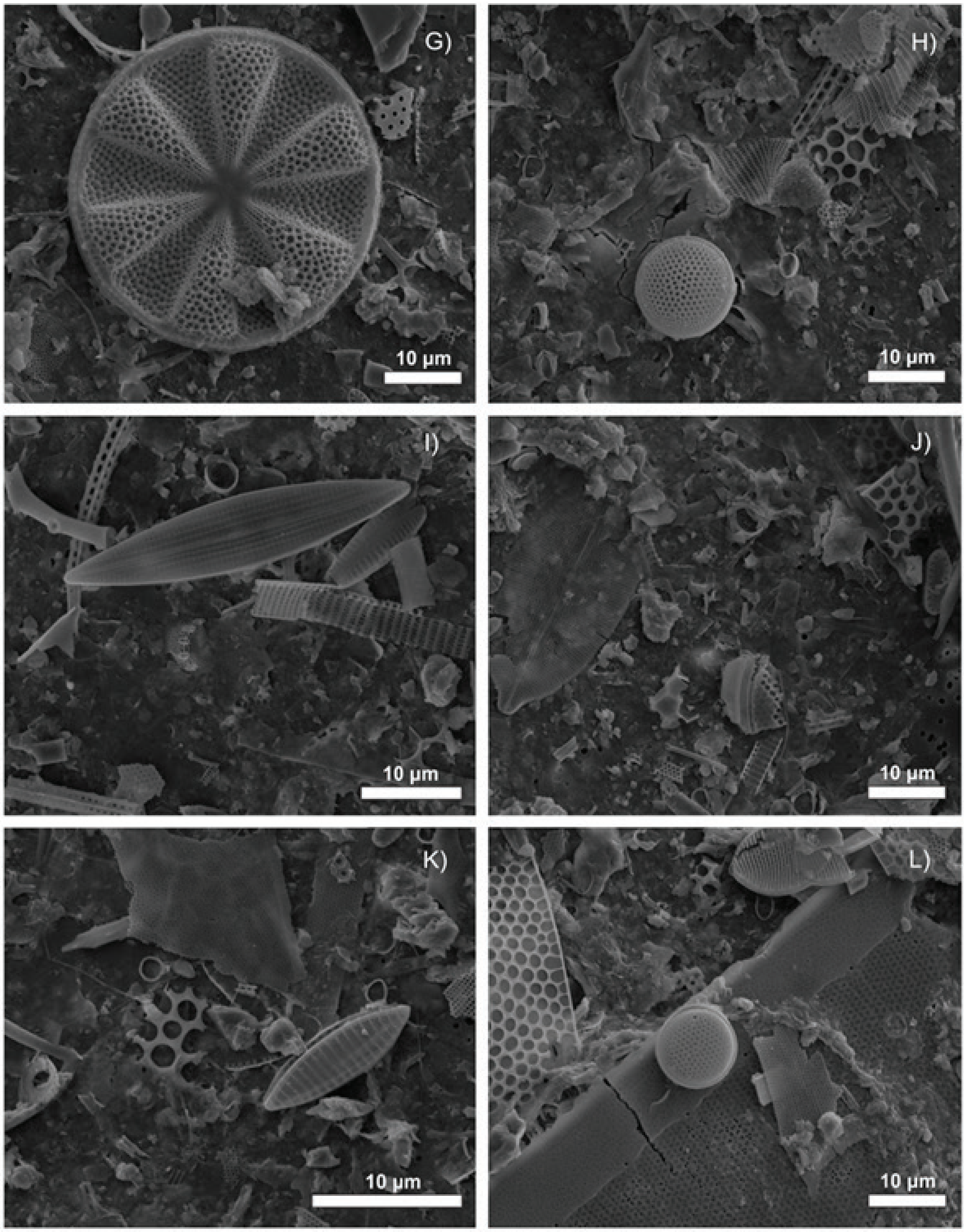

Figure 3. Benthic diatoms collected in Alfonso basin, La Paz bay at a depth of 300 m (December 2011 - January 2012). G) *Actinoptychus vulgaris*, H) *Azpeitia nodulifera,* I) *Haslea spicula,* J) *Mastogloia* sp. (top left)*,* K) *Nitzschia sicula*, L) *Roperia tesselata.*

others into the basin may occur.

Highly productive diatom mats on the continental shelf have been detected down to water depths of 40 m, caused by the successful establishment of benthic diatoms transported from inshore sediments (Cahoon *et al.*, 1990); these grow well even under low light levels, <0.03% surface incident radiation, possibly down to depths of 200 m to where the potential limits of benthic primary production extends (MacGee *et al.,* 2008). However, no record of benthic diatoms existed hitherto for La Paz bay from depths of 100-200 m, although seven taxa from the first 100 m depth in Alfonso Basin have been recorded earlier using light microscopy by Villegas-Aguilera (2009). Results from laboratory experiments on re-suspension of benthic diatoms by Delgado *et al.* (1991) show that the presence of a diatom film increases sediment stability, thereby suppressing re-suspension of sediment and diatoms; however, if the sediment contains many fine particles and much detritus, sediment stability decreases, leading to increased re-suspension. Therefore, turbulent water currents generated by winds greater than 5 m s^{-1} govern the re-suspension, particularly in shallow environments, and consequently the displacement of microphytobenthic populations. The presence of benthic diatoms in the sediment trap, such as those depicted in table 1 and figures 2-3, most likely indicates a re-deposition process from shallow environments to the deeper portion of the bay. In a similar study off Bahía Magdalena, B.C.S. (Martínez López *et al*., 2004), the recorded species assemblage also included species such as *Actinoptychus vulgaris, Halamphora* (*Amphora*) *coffeaeformis, Delphineis surirella, Fragilariopsis doliolus* and *Nitzschia* (*laevis*) *amabilis*, all of which were found to be components of assemblages found in mangrove environments, albeit also in nearby rocky coastlines. Lateral transport of benthic diatoms from the coastal zone was suggested to be an important phenomenon at that site. Likewise, the assemblage from the Alfonso basin traps could be related to those found in mangrove environments from different localities in La Paz bay (Siqueiros Beltrones & Morzaria Luna, 1999; Siqueiros Beltrones & Sánchez Castrejón, 1999; Siqueiros Beltrones, 2006). However, the species composition found in the sediment trap does not allow to pin-point any precise location or specific environment. This requires an *ex profeso* sampling design. We can assert only that the taxa are common in the currently studied lacunar systems of the southern coasts of the Baja California peninsula. Thus, it is still uncertain if all of the benthic diatoms were from the bay, or if some diatoms came from more distant localities.

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