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TAPHONOMY OF A DEATH ASSEMBLAGE OF THE INVASIVE BIVALVE *Corbicula fluminea* (MÜLLER, 1774), UPPER RIO DE LA PLATA, URUGUAY

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ABSTRACT

The bioinvader bivalve *Corbicula fluminea* (Müller, 1774) is known in the Río de la Plata River since about 35 years ago. This time lapse fills a gap in taphonomical studies, that comprises usually strictly contemporaneous or at best centuries-old phenomena. We sampled shells of this species in one locality in two occasions with the same methodology. Fragmentation, presence of periostracum, corrasion, bioerosion and bioencrustation were studied externally in four sectors of the valve: umbonal, anterior, central, and posterior. We tested the differences in the frequencies of the attributes between the two samples by means of X^2, resulting only significantly different corrasion in the umbonal sector and fragmentation in the central and posterior areas.The umbonal area was the most affected sector, and it was attributed to a higher exposition to corrasive agents (i.e., moving clasts) compared to other areas of the valve. Neither bioerosion nor bioencrustation was recorded, being this attributed to the less prevalence of these taphonomic features in the low salinity conditions of the study area.

Key words: Actualistic Taphonomy, *Corbicula fluminea*, Río de la Plata, Uruguay

RESUMEN

Tafonomía de una concentración de valvas del bivalvo invasor *Corbicula fluminea* (Müller, 1774), Río de la Plata superior, Uruguay. El bivalvo invasor *Corbicula fluminea* (Müller, 1774) es conocido en el Río de la Plata desde hace 35 años. Los estudios tafonómicos que impliquen un lapso de este rango son relevantes, ya que usualmente se tiene acceso a información estrictamente contemporánea o como muy cercano al presente, de cientos de años de antigüedad. Para este trabajo muestreamos en dos ocasiones y con la misma metodología bioclastos de *C. fluminea* en una localidad del Río de la Plata superior. Se estudiaron externamente la fragmentación, presencia de periostraco, corrasión, bioerosión y bioincrustación, en cuatro sectores de la valva: umbonal, anterior, central y posterior. Las frecuencias de estos atributos se compararon mediante el test de X^2, encontrándose diferencias significativas solamente en la corrasión del sector umbonal y en la fragmentación de los sectores central y posterior. El sector umbonal fue el más afectado, atribuyéndose esto a su mayor exposición a los agentes corrasivos (i.e., impacto de clastos) en comparación con otras áreas de la valva. No se registró bioerosión ni bioincrustación, seguramente debido a la ausencia de los organismos habitualmente implicados, debido a la baja salinidad en la que se desarrolla esta especie.

Palabras clave: Tafonomía Actualista, *Corbicula fluminea*, Río de la Plata, Uruguay

INTRODUCTION

Molluscan shells are one of the most frequent protagonists in the study of taphonomical processes, because of their abundance in present and past assemblages along with their high preservation potential (e.g., Parsons and Brett, 1991; Powell, Stanton, Logan and Craig, 1992; Best and Kidwell, 2000 a, b; Erthal and Ritter, 2017). One of the core questions about these taphonomic processes is their duration, i.e., how much time is needed to reach a given taphonomic condition? Until now, the answers have come mainly from two sources: experimental taphonomy, and the evaluation of death assemblages.

Time averaging in death assemblages comprises at best hundreds of years (Kidwell and Bosence, 1991; Flessa, 1993; Flessa, Cutler and Meldahl, 1993; Meldahl, Flessa and Cutler, 1997; Kosnik, Hua, Kaufman and Wüst, 2009), and on the other hand, experimental taphonomy (i.e., artificial conditions) in real-time implies months or a few years of duration (e.g., Flessa and Brown, 1983; Briggs, 1995; Chattopadhyay, Rathie and Das, 2013).

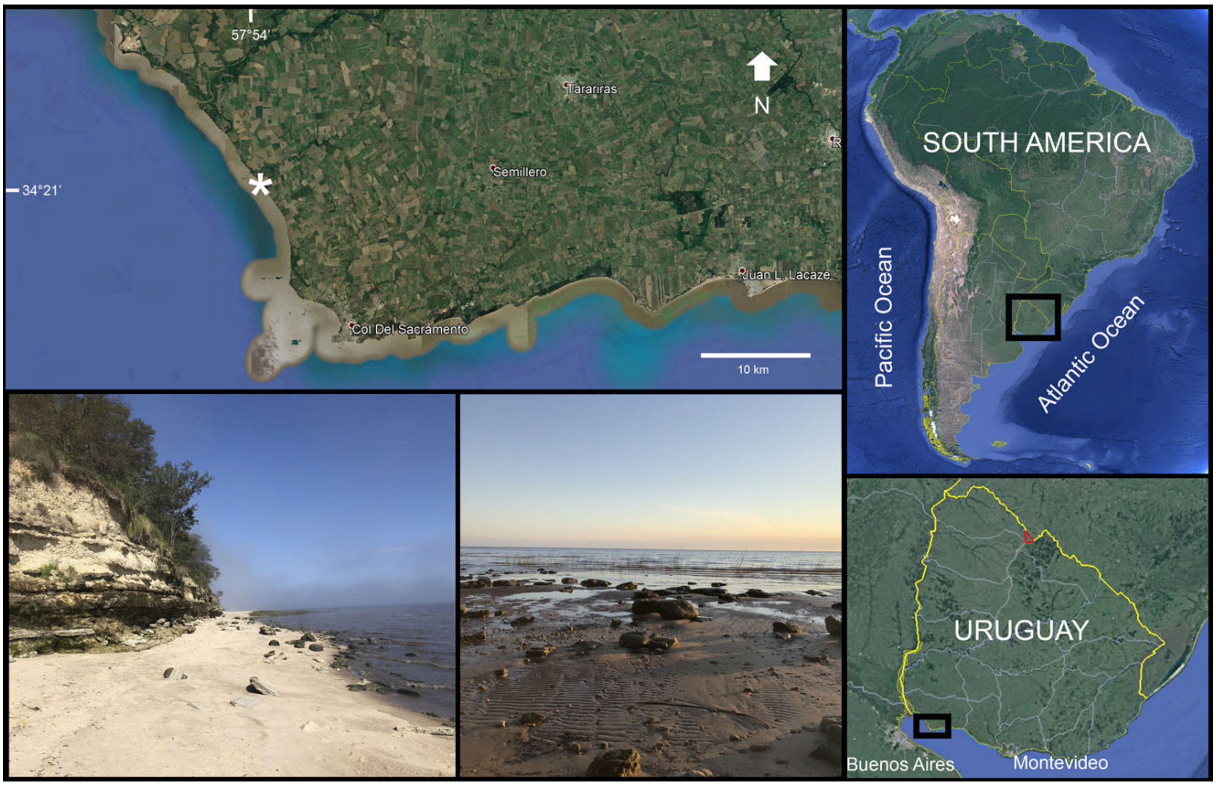

Fig. 1. Sampling location, indicated by the asterisk.

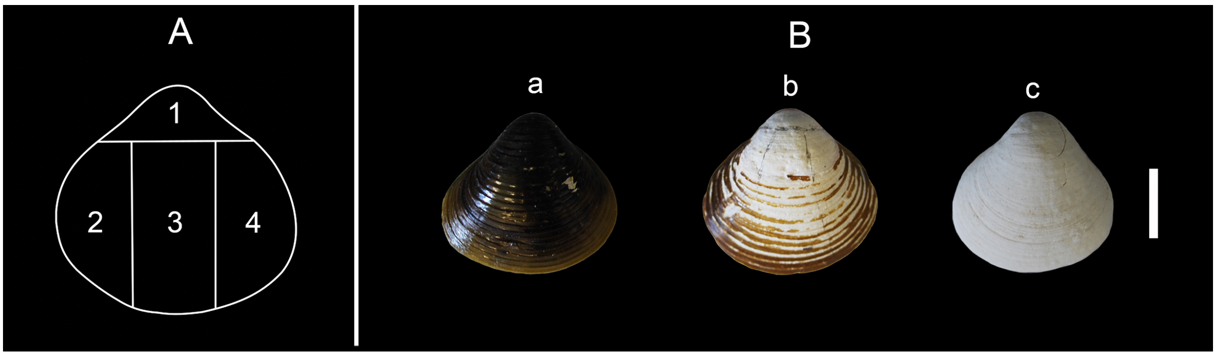

Fig 2. A. Sectors of the valves. 1: umbonal, 2: anterior, 3: central, 4: posterior. B. Shells of *C. fluminea* illustrating the taphonomic grades employed: a) grade 0 of fragmentation, periostracum and corrasion.; b) grade 1 of periostracum and corrasion; c) grade 2 of periostracum and corrasion. Scale bar: 1cm.

The use of a bioinvader with a well-documented time of arrival let us to witness natural taphonomic processes in action in an up to present not accessible time scale when the time of arrival of the invader species is well documented. Martínez, Rojas, Cabrera and Antuña (2020) (see also Antuña et al., this volume) published for the first time the evaluation from a taphonomic point of view of shells of the invader gastropod *Rapana venosa* (Valenciennes, 1846) in Uruguay. Now, we are showing the first results of a similar research but focusing on a bivalve: *Corbicula fluminea* (Müller, 1774). The first populations of *Corbicula fluminea* in Uruguay were signaled by Olazarri (1986), 35 years ago. Thus, we have a decadal scale resolution for the taphonomic processes implied, being the present one the first study of this kind in bivalves.

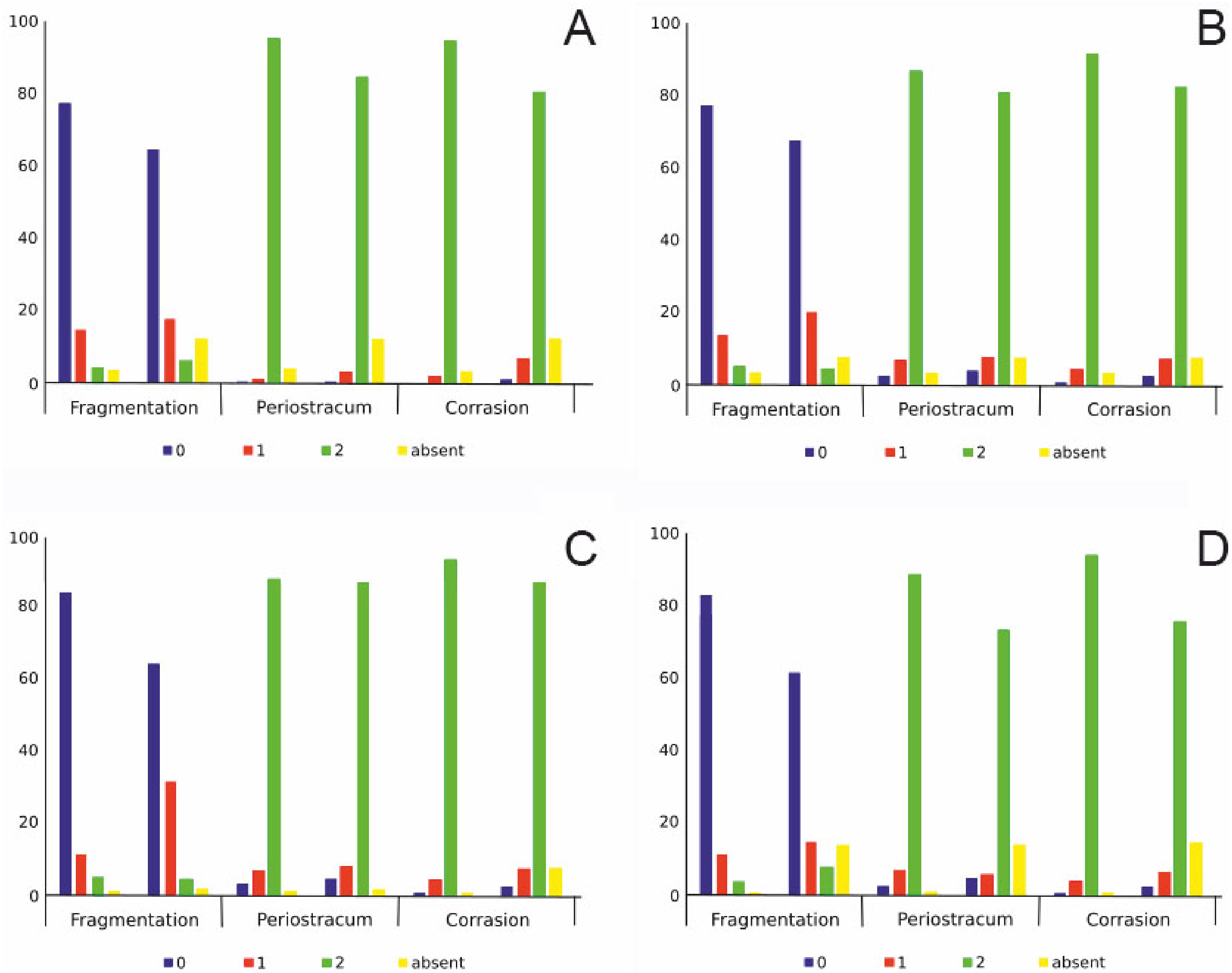

Fig. 3. Frequencies of the taphonomic attributes. A. umbonal sector, B. anterior sector, C. central sector, D. posterior sector. For each sector, there are shown sample 1 and sample 2.

Table 1. Number and percentage (in brackets) of bioclasts according to their taphonomic condition.

	San Pedro1				San Pedro2			
	G.0	G. 1	G. 2	Abs.	G. 0	G. 1	G. 2	Abs.
Umbo								
Fragmentation	245 (77)	47 (15)	14 (4)	12 (4)	194 (64)	53 (17)	19 (6)	37 (12)
Periostracum	1 (0)	3 (1)	302 (95)	12 (4)	1 (0)	9 (3)	256 (84)	37 (12)
Corrasion	0 (0)	6 (2)	300 (94)	12 (4)	3 (1)	20 (7)	243 (80)	37 (12)
Anterior								
Fragmentation	246 (77)	44 (14)	17 (5)	11 (3)	204 (67)	62 (20)	14 (5)	23 (8)
Periostracum	8 (3)	23 (7)	276 (87)	11 (3)	12 (4)	23 (8)	245 (81)	23 (8)
Corrasion	2 (1)	14 (4)	291 (92)	11 (3)	8 (3)	22 (7)	250 (83)	23 (8)
Center								
Fragmentation	265 (83)	36 (11)	14 (4)	3 (1)	192 (63)	94 (31)	13 (4)4 (1)	
Periostracum	9 (3)	22 (7)	284 (89)	3 (1)	12 (4)	25 (8)	262 (86)	4 (1)
Corrasion	3 (1)	13 (4)	299 (94)	3 (1)	8 (3)	22 (7)	269 (89)	4 (1)
Posterior								
Fragmentation	265 (83)	36 (11)	14 (4)	3 (1)	187 (62)	47 (16)	25 (8)	44 (15)
Periostracum	9 (3)	22 (7)	284 (89)	3 (1)	15 (5)	20 (7)	224 (74)	44 (15)
Corrasion	3 (1)	13 (4)	299 (94)	3 (1)	8 (3)	21 (7)	230 (76)	44 (15)

MATERIAL AND METHODS

Sampling was carried out in a Rio de la Plata beach known as Barrancas de San Pedro (34° 21' 1'' S, 57° 54' 60'' W) (Fig. 1). According to López Laborde (2005) this zone is part of the upper and intermediate Rio de la Plata, being its coast part of the "Southwest littoral" landscape (Evia and Gudynas, 2000). The locality is characterized by the presence of sedimentary cliffs, and the beach is composed by coarse sand and gravel. Except during storms, the current and waves have low energy, but the wind-dominated tides are sometimes very wide, reaching the base of the cliffs.

All bioclasts of *C. fluminea* larger than 10 mm were collected by hand in a rectangle limited by the low tide line up to 5 m towards the cliffs, along 30 m parallel to the water line, in two occasions (April 2016, 318 bioclasts, and May 2018, 303 bioclasts).

The following taphonomic attributes were evaluated: fragmentation, presence of periostracum, corrasion, bioerosion and bioencrustation. Corrasion represents the combination of mechanical abrasion and biogeochemical corrosion. Bioerosion refers to the traces left by the action of organisms that remove parts of the shell. Bioencrustation is recognized as the incorporation of biological material to the shell. For this study we only considered as bioencrustation the presence of calcareous remains on the bioclasts. These attributes were registered separately in each of the four areas previously delimited in the valves, named umbonal, anterior, central, and posterior (Fig. 2A), following a three-state scale (Fig 2B):

Fragmentation. 0: more than 80% of the section of the valve is present, 1: between 80% and 20% of the section of the valve is present, 2: less than 20% of the section of the valve is present. Presence of periostracum. 0: periostracum is present in at least 80% of the surface, 1: periostracum is present in 80 to 20% of the surface, 2: periostracum is present in less than 20% of the surface. Corrasion. 0: less than 20% of the surface has signs of corrasion, 1: 80% to 20% of the surface has signs of corrasion, 2: more than 80% of the surface has signs of corrasion. Bioerosion and bioencrustation. 0: less than 20% of the surface has signs of bioerosion or bioencrustation, 1: 80% to 20% of the surface has bioerosion or bioencrustation, 2: more than 80 of the surface has bioerosion or bioencrustation.

Data (Table 1) was summarized in histograms, and compared for independence by a X^2 test, with a $p< 0.05$ significance level. The software used was PAST, version 3.26 (Hammer and Harper, 2006).

RESULTS

The most frequent section of the valve was the central one, being present in ca. 99% of the bioclasts, followed by the anterior (97% and 92%), and the posterior (95% and 85%) ones. The umbonal area was the less frequent, with 65% and 88% of representation, respectively.

The umbonal sector exhibit scarce variation (Fig. 3A), being present in 96% and 88% of the shells in the

Table 2. X^2 and probability (in brackets) values for the comparison between the two samples.

	Fragmentation	Periostracum	Corrasion
Umbo	4.661 (0.12)	4.0145 (0.13)	13.792 (0.001)
Anterior	6.0378 (0.05)	1.4056 (0.05)	7.2584 (0.03)
Center	3.183 (8.43 E-09)	1.0903 (0.58)	5.7585 (0.06)
Posterior	12.687 (0.002)	1.0903 (0.58)	5.7585 (0.06)

first and second sample, respectively. Grade 0 was by far the most frequent (77% and 64%), followed by grade 1 and grade 2. The periostracum was absent in most cases, being grade 2 the most frequent (ca. 95% and 84%). Grade 0 was the less frequent, being less than 1% in both samples. Corrasion followed the same trend as the periostracum, being grade 2 far more frequent than the others (94% and ca. 80%), and grade 0 the less frequent (0% and 1%). Bioerosion and bioencrustation were not recorded in this valve area.

The anterior sector (Fig. 3B) was preserved in 97% and 92% of the first and second samples, respectively. Grade 0 of fragmentation predominated in this sector in both samples (77% and 67%), followed by grades 1 and 2. Periostracum presence exhibited grade 2 mostly (87% and 81%), followed by grades 1 and 0. In the same trend, grade 2 predominated widely regarding corrasion (92% and 83%), followed by grades 1 and 0. Bioerosion and bioencrustation were not recorded in this valve area.

The central section (Fig. 3C) was present in the 99% of the bioclasts. In this area, grade 0 predominated regarding fragmentation (83% and 63%), grade 1 was in second place (31% and 11%), and grade 2 was in both samples in only around 4% of the bioclasts. Periostracum presence was represented in most cases by grade 2 (89% and 86%), with low records of grades 1 and 0. Similar frequencies were obtained for the corrasion, with grade 2 being the 94% and 89%, followed by grade 1, and by grade 0 with extremely low percentages. Bioerosion and bioencrustation were not recorded in this valve section.

The posterior sector (Fig. 3D) was present in 99% and 85% of the first and second samples, respectively. In this area grade 0 predominated regarding fragmentation (83% and 62%), followed by grades 1 and 2. Periostracum presence was represented mostly by grade 2 (89% and 74%), followed by grades 1 and 0. Corrasion followed the same trend, being grade 2 the most frequent (94% and 76%), followed by grade 1, and an extremely low representation of grade 0. Bioerosion and bioencrustation were not recorded in this valve sector.

The frequencies obtained for both samples were compared by means of a X^2 test (Table 2). A significant difference was obtained for corrasion in the umbonal sector, and for fragmentation in the central and posterior sectors. The anterior sector did not exhibit significant differences.

DISCUSSION

Globally, the taphonomic attributes observed in *C. fluminea* showed scarce variability as depicted by the two samples studied. The X^2 test only showed significant differences with respect to corrasion in the umbonal sector, and regarding fragmentation in the central and posterior sectors. These results indicate that the conclusions are reliable, although further sampling would permit refining the discussion and conclusions.

As referred to in Results, the umbonal sector was the less frequent sector in the samples, and by the contrary, the most frequent was the central one. Similar results were obtained for other freshwater bivalves, such as *Unio* sp. (Newell, Gower, Benton and Tverdokhlebov, 2007). The preponderant damaging mechanism proposed by these authors are bedload currents, being the umbo the tallest and most exposed zone to the particle impact, and in consequence the first one to be abraded. Subsequently, with increasing abrasion, the shell becomes more prone to fragmentation. Although in general this sequence is not impossible in our case, the different lifestyles of the species of *Unio* and *Corbicula* preclude to adopt it straightforward; for the moment it can be considered a plausible hypothesis to test. Partly different results were obtained by Kotzian and Simões (2006) in a work globally concerning the molluscan death assemblages of the Touro Passo river in Southern Brazil. Despite as in our case these authors found a general pattern of scarce fragmentation, the most fragmented sector was the posterior one. Contrary to our findings, they reported small levels of corrasion, but this contradiction must be taken with caution, since the identification of corrasion in both works was not done in the same way.

Periostracum loss and corrasion followed the same trends, what is expectable, since the periostracum is the first barrier against abrasion and corrosion (Taylor and Kennedy, 1969; Harper, 1997, among others). The correlation between the size of the clasts, periostracum loss, and corrasion (specifically corrosion) has been signaled many times (e.g., Pereira, Fornari, Erthal, Leme and Giannini, 2021, and literature therein).

The absence of bioerosion structures and bioencrustation may reflect the low salinity conditions in which *C. fluminea* lives. The presence of bioeroding and bioencrusting organisms in freshwater conditions is minimum compared to marine settings. Moreover, as we only considered calcium carbonate bioencrustations, that diminishes notably the probability of finding these structures in freshwater, on the contrary for soft periphyton and ovigerous capsules of different organisms (Kotzian and Simões, 2006; Tietze and de Francesco, 2014). Moreover, in freshwater conditions the low bioturbation diminishes the taphonomic susceptibility of dead remains while the high chemical dissolution may erase the eventual accumulation of taphonomic signals (Tietze and de Francesco, 2014). All these factors certainly played a role in the absence of bioerosion and bioencrustation in the studied bioclasts.

CONCLUSIONS

In a maximum time span of 35 years, the taphonomic attributes most prominent in the shells of *C. fluminea* were periostracum loss and corrasion, which followed similar trends, as expected by the protective function of the periostracum.

The part of the shells best represented was the central sector, and the worst the umbonal area. We attribute this situation to the differential shell sector exposition to the impacts of clasts.

Beyond the details of this primary research, it is clear that in a short time lapse, not exceeding 35 years, taphonomic alterations in this low salinity/freshwater environment are clearly recognized, what has interesting consequences for the interpretation of fossil and death assemblages.

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