



The Oudierin Drainage Archaeological Project: New Perspectives on the Saloum Delta Shell Middens (Senegal)

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Abstract Archaeological research on the Saloum Delta (Senegal) shell middens has had relative highs and lows since the first half of the twentieth century, but they are one of the most investigated regional clusters in West Africa. Research has been structured along three main thematic axes: mortuary archaeology (investigating burial mounds); taphonomy (assessing the rhythm and speed of shell midden formation); and ethnoarchaeology (contributing to the construction actualistic references). The Oudierin Drainage Archaeological Project was designed to shift perspective from single sites to the “region”—in this case, the Bolon Oudierin drainage—by investigating the long-term dynamics of the local shellfish economy via fine-tuned “motorboat” and pedestrian surveys, detailed site-mapping and recording, and excavation at two key sites. The research reported here presents new details on the structure of large shell middens, including detailed stratigraphic sections, activity areas, and material culture. The analysis of shell size variations along the stratigraphic column of the largest midden allows for modeling the reasons for the punctuated nature of shell middens formation—relatively short periods of exploitation followed by longer periods of abandonment. Finally,

it is shown that shellfish exploitation started some 10,000 years ago during the early Holocene, much earlier than the formation of the Saloum Delta as known today. The formation of cemeteries with burial mounds occurred early in the second millennium (AD 1000–1300), supporting the Diorom-Boumak sequence.

Résumé Les recherches archéologiques sont menées sur les amas coquilliers du delta du Saloum (Sénégal) depuis la première moitié du XXe siècle. Toutes proportions gardées, ils sont à ce jour l’ensemble régional le plus étudié en Afrique de l’Ouest. Les recherches menées sont structurées selon trois principaux axes thématiques: l’archéologie funéraire (avec les fouilles des tumuli); la taphonomie (évaluant le rythme et la vitesse de formation des amas coquilliers); et l’ethnoarchéologie (contribuant à la construction de référentiels actualistes). Le projet archéologique du Bolon Oudierin, conçu dans une perspective régionale, explore la dynamique à long terme de l’économie conchylicole locale via une prospection systématique, la cartographie et enregistrement détaillés du site, et fouilles à ce stade de 2 sites clés. Les résultats préliminaires rapportés ici présentent pour la première fois des détails fins de la structure de grands amas coquilliers, y compris une stratigraphie précise et rigoureuse, les aires d’activité insérées et la culture matérielle. L’analyse des variations de taille des coquilles le long de la colonne stratigraphique du plus grand amas coquillier permet de modéliser les raisons du caractère

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« ponctué » de la formation des amas coquilliers – période d'exploitation relativement courte suivie de périodes d'abandon beaucoup plus longues -. Il est démontré en effet que l'exploitation des coquillages a commencé beaucoup plus tôt, il y a environ 10 000 ans au cours de l'Holocène Ancien, dans ce qui n'était clairement pas encore le delta du Saloum tel qu'on le connaît aujourd'hui. La formation de cimetière avec des tumulus a eu lieu pendant le 1^{er} tiers du II^e millénaire [1000–1300 CE] confirmant ainsi la séquence de Diorom-Boumak.

Keywords Shellfish · Mangrove oyster · Bloody cockle · Early Holocene · Burial-mounds · Bolon Oudierin · Saloum delta · Senegal · West Africa

Introduction

Shell middens are recorded along the Atlantic coast of Africa from Mauritania to South Africa. The oldest cases of relatively intensive exploitation of marine resources in general, and shellfish in particular, are documented in Middle Stone Age South African sites (Klein & Steele, 2013). Most of the remaining cases are dated from the early Holocene to the present (Bailey et al., 2013; Bailey & Hardy, 2021; Camara et al., 2017; Chenorkian, 1983; Hardy et al., 2016; Vernet & Tous, 2004). As far as West Africa is concerned, the Saloum Delta is the most investigated regional complex of shell middens. Initial archaeological probes were launched in the first half of the twentieth century, with the first excavations carried out in 1939 by M. Yvetot, T. Monod, and J. de Saint-Seine at Dioron-Boundaw and Dioron-Boumak. H. Bessac, R. Mauny, and J. Figuié excavated the same sites a few years later in 1951 and 1956. G. Thilmans and C. Descamps conducted additional and larger research projects there in 1971–73. Ba et al. (1997) excavated the Ndiamon-Badat shell midden near Dionewar in the Gandoul islands. Additional excavations were carried out at Faboura (Descamps et al., 1977), Bangalere (Elouard et al., 1974), and Soukouta (Descamps & Thilmans, 1979) in the Nombato, the continental portion of the delta.

So far, archaeological field research has focused on a relatively small number of shell middens: three tested sites (Faboura, Bangalere, and Soukouta) in the continental portion of Nombato; the twin complex of Dioron-Boumak and Dioron-Boundaw at the northeastern tip of the Betanti Islands; and finally, Ndiamon-Badat

near Dionewar in the Gandoul Islands. The most recent research focuses on the ethnoarchaeological investigation of Saloum Delta shellfishing traditions to interpret the local archaeological record (Camara et al., 2017; Descamps, 1989, 1994; Diouf, 2010; Hardy et al., 2016; Mbow, 1997).

The chronology obtained for the human exploitation of shellfish and anthropic shell middens formation in the Saloum Delta so far spans nearly 2000 years, from about 450 BC to AD 1500. The archaeological remains unearthed, including weapons and ornaments in iron and alloyed copper and glass and carnelian beads, attest to the insertion of the Saloum Delta in the long-distance exchange networks that crisscrossed West Africa during the past two millennia. The archaeological research conducted in the delta is essentially based on a single-site approach structured along two thematic axes: mortuary archaeology through the excavation and analyses of burial mounds (Descamps & Thilmans, 2006; Thiam, 2013) and shell midden taphonomy (Descamps et al., 1977; Elouard et al., 1974) focusing on the assessment of the rhythm and speed of site formation. Taking advantage of the research conducted so far, the Oudierin Drainage Archaeological Project initiates a shift from this single-site approach to a regional one. The delimitation of the study area is accordingly the product of an elaborate research strategy that is spelled out below.

The Saloum Delta

The Saloum estuary along the West African coast of Senegal, between Joal in the north and the Gambia River in the south, is an original mangrove environment crossed by multiple watercourses and tidal channels (Fig. 1). The delta *stricto sensu*, located between 13°40' and 14°20' N latitude, comprises three major sedimentary units—thick green mud, silty sand, and silty and sandy clay—accumulated during the Holocene in five evolutionary stages (Diara, 1999). These include a submerged postglacial ria, then a funnel-like estuary, a barred estuary, a cusped delta, and finally, a reversed estuary (Ausseil-Badie et al., 1991, p. 178). The Saloum estuary was an open bay around 4000 BC. It was gradually filled in by the sediments deposited by the Saloum River, with a geomorphological configuration close to the current one established between 50 BC and AD 450 (Azzoug et al., 2012).

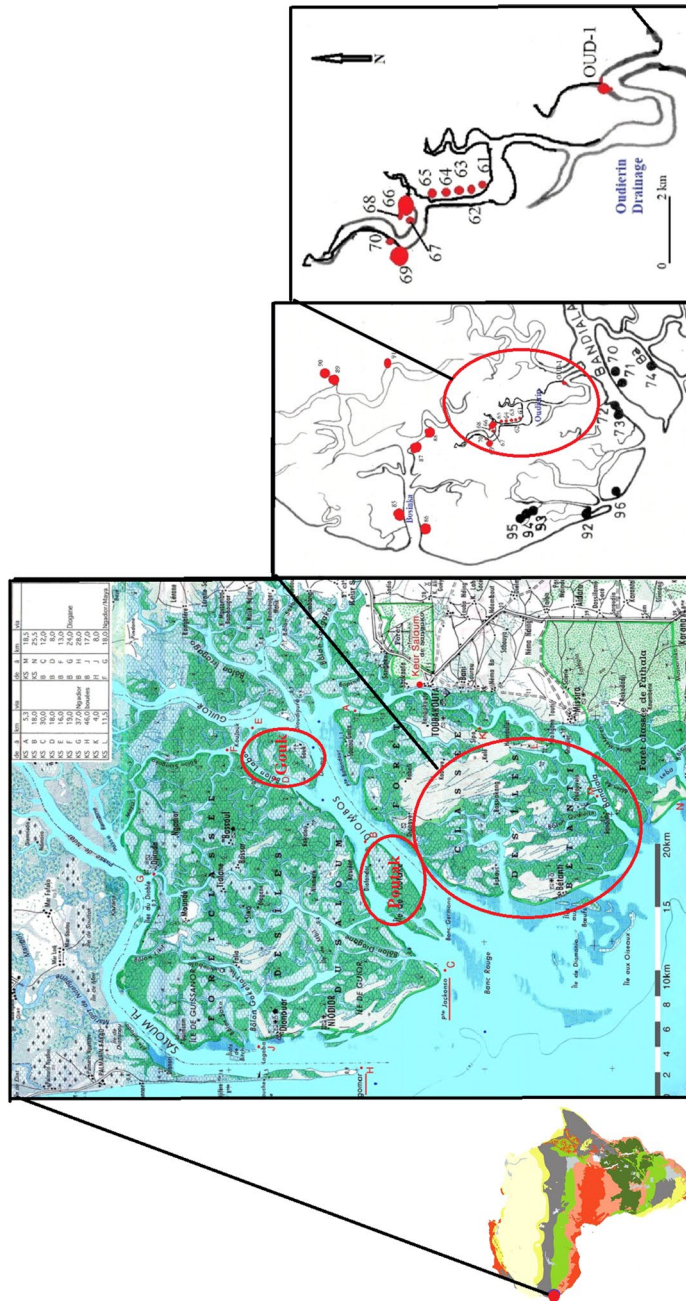


Fig. 1 The Saloum Delta: location map, surveyed area and the Oudierin Drainage

The last phase of degradation took place between AD 450 and AD 1350.

The mangrove, so characteristic of the delta landscape, essentially comprises three species, *Rhizophora mangle*, *Avicennia nitida*, and, more rarely, *Rhizophora racemosa*. Old and current shell middens and villages are colonized by *Adansonia digitata* (baobabs) and, in some cases, oil palms (*Elaeis guineensis*). The herbaceous layer comprises bands of different species depending on the salt content: “The borders are populated with halophytes (*Sesuvium*), the sandy soils with little salt concentrate the *Andropogonae*. The dominant soils under mangrove are acid sulfate, the acidification of which is due to the oxidation of sulphids” (Leprun et al., 1976, p. 14). The Saloum Delta, extending over a little more than 2,500 square kilometers, has three main watercourses: the Saloum in the north; the Diombos in the center; and the Bandiala in the east. These three rivers are connected to a dense network of channels, called *bolons* in the local idiom. The delta has two large groups of islands separated by the Diombos River, including the Gandoul islands in the northwest and the Betanti islands in the southeast, with the islets of Gouk and Poutak in the Diombos (Fig. 1).

Shellfish exploitation and processing

The patterns of exploitation and processing of shellfish have been investigated in the region of Joal-Fadiouth, the Saloum Delta, and Casamance (Camara et al., 2017; Descamps, 1989, 1994; Hardy et al., 2016; Kantoussan, 2006; Linares de Sapir, 1971; Mbow, 1997). The “actualist” approach (ethnoarchaeology) is a method of investigation developed over the past decades, based on the observation of current cultural practices to assist in the interpretation of archaeological situations. Properly conducted, ethnoarchaeology provides an understanding of shell-mound formation processes and facilitates archaeological interpretation. Ethnoarchaeological investigations by Hardy et al. (2016), Camara et al. (2017), and Mbow (1997) have outlined the versatile nature of Saloum Delta shell middens whose diverse functions—monuments, dumps, villages, foraging locations, religious places, or burial sites—can change over time. Accordingly, the Saloum Delta cultural landscape is constantly shaped and reshaped by the shifting exploitation of shellfish resources, the formation of

shell middens, and the practical and symbolic meanings assigned to all these places.

The muddy environments of mangrove estuaries, particularly rich in organic matter, are the preferred habitats for certain mollusks, including bloody cockles (*Anadara senilis*) and oysters (*Crassostrea gasar*), the main species exploited in the Saloum Delta. The patterns for exploitation of the former have been investigated at several localities in the Joal-Fadiouth region, the Saloum estuary, and the Gandoul Islands, specifically at Fadiouth, Missirah, Betanti, Niodor, Djirnda, Dionewar, Falia, Diogane, Siwo, Bassar, Mounde, Bassoul, and Tialane. As described by Kantoussan (2006, p. 79), bloody cockles (*Anadara senilis*) have a “pair of valves, heavy and thick externally marked with radiating ribs and fine increment ridges. The valve is white to black depending on whether the bivalve evolves in a sandy, muddy or intermediate environment.” Bloody cockles breed in the tidal flow zone, between the intertidal and upper infra-tidal levels, but they live in sandbanks below the surface in intertidal zones. Living up to ten years, the bloody cockles are abundant in the Saloum region: According to Hardy et al. (2016, p. 23), “Some of the islands in the delta are partly based on vast amounts of naturally accumulated bloody cockle shells....”

As its name suggests, the mangrove oyster (*Crassostrea gasar*) forms colonies that feed on the microorganisms reproducing on the stilt roots of mangrove trees (*Rhizophora* type) in the intertidal zone. Low current *bolons* are the most suitable for the development of oyster colonies because the spat can easily attach to the mangrove rhizophores here: “The species is a continuous breeder in lagoons and a seasonal one in estuaries. Size at maturity is 8 mm for males and 10 mm for females. This suggests that most oysters differentiate sexually and spawn first as males. The proportion of females increases with the size until the sex ratio is approximately 1:1 in oysters measuring 30 mm” (Otchere, 2020, p. 54). The dynamics of the ecosystem generate variations in the nature and rates of sediment accumulation along the *bolons*. There may be significant changes in the distribution of the optimal areas for different shellfish species in the medium and long term. The amplitude, speed, and frequencies of these changes are difficult to predict, but they explain the geographic distribution and chronology of shell mounds in most cases.

Today’s shellfish gathering is a seasonal activity typically carried out by women during the dry

season, from December to June. *Mbissa*, the most favorable period for collecting bloody cockles, “corresponds to the tide of dead water” (Mbow, 1997, p. 239). The so-called *Sarre* bloody cockles can be seen at low tide. The daily collection lasts about four hours for a maximum of 15 to 20 days per month during the dry season. The collection locality is changed when the deposit is exhausted, which generally occurs after two or three months of exploitation. The collected bloody cockles are washed and boiled for 20–30 min. The flesh is removed from the shells, washed, and left to dry. The shells are thrown away, forming heaps that gradually become clumps of shells. As with bloody cockle gathering, oyster exploitation is also women’s work and seasonal, taking place in the dry season, from January to June. The oysters are scalded or smoked, then flesh is removed and left to dry in the sun. The shells are discarded in heaps that will gradually become shell middens.

The products of shellfish exploitation, be they bloody cockles, oysters, or other species, are still part of the local economy, just like the exploitation of fish, oil palm, textiles, sea salt, and metals. Part of the production was intended for domestic and local consumption. It is, however, highly likely that at a later stage of long-term socio-economic evolution, the intensity of shellfish exploitation would have been driven by regional supply–demand economic imperatives. The emergence of Tekrur along the lower reaches of the Senegal River in the eleventh century AD and the circulation of gold during the peak of ancient Ghana illustrate the complex exchange networks that developed in West Africa at the end of the first millennium AD (Bovill, 1968). Trade items found in the Saloum Delta and the presence of delta shells and pottery at interior megalithic sites and south along the coast in the Casamance and Rio Cacheu in Guinea-Bissau point to the integration of long-distance commodities into local and regional exchange networks (Holl & Bocoum, 2013, 2017).

The “Territoriality Hypothesis”

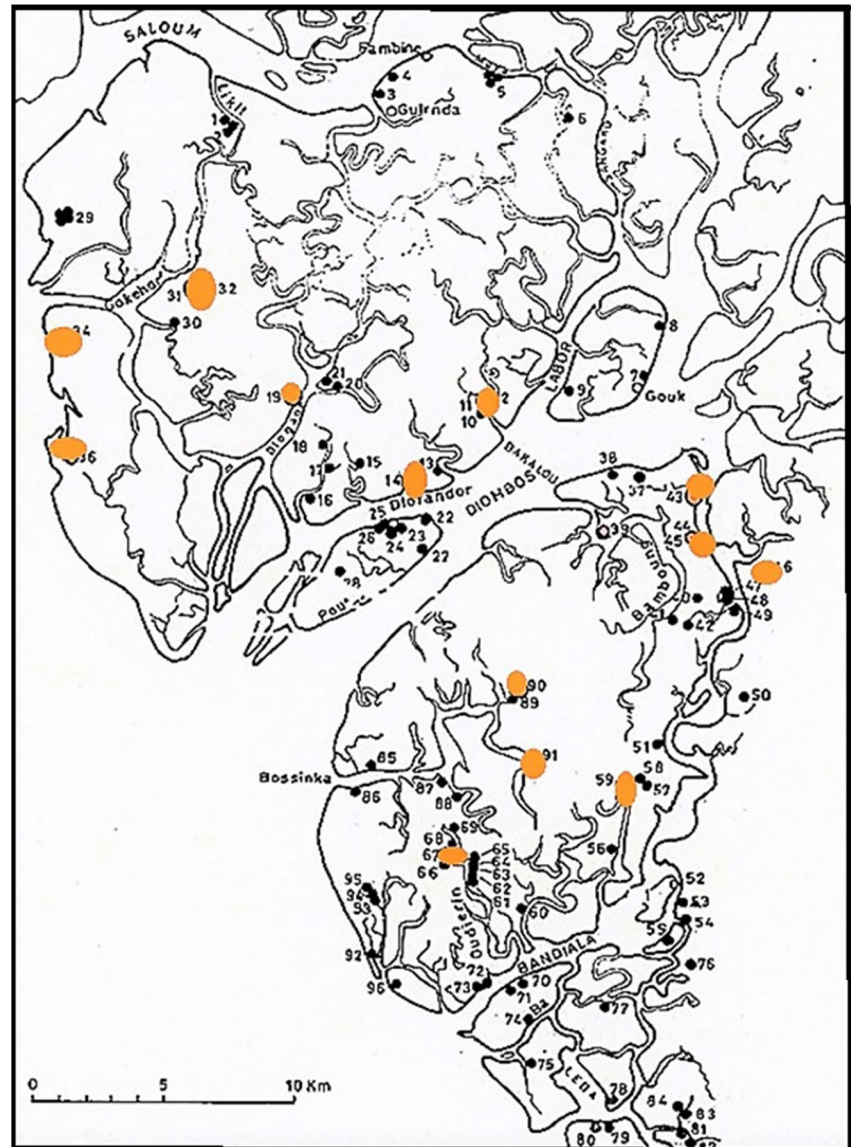
The environmental and human dimensions of shellfish exploitation are in a constant state of flux. In the

past, the control (or attempted control) of collection areas could have been done in subtle ways, first by implementing the “customary” rights of the first operators. With population growth and shellfishing intensification, one would expect highly visible territorial markers such as tumuli cemeteries. Overall, a careful analysis of variations in the characteristics and locations of tumuli cemeteries can yield insights into the implementation of these past “territorial” strategies (Fig. 2).

The cemeteries of the Gandoul Islands are divided into two distinct areas, the Southeast and the West. The number of tumuli varies from four (Site 19 on the Diogane *bolon*) to 77 (Site 14 on the north bank of the Diombos River) in the Southeast area. In the West area, there are seven tumuli sites with the number of burial mounds ranging from 168 (Tioupane-Boumak) to 11 (Ndiar, Site 35 at the Dionewar SSE). If these sites are grouped by locality, Ndiamon-Badat (Site 34) and Ndiar (Site 35) are part of the Dionewar funeral complex; Ndafafe (Site 31), Tioupane-Boumak (Site 32a), and Tioupane-Boundaw (Site 32b) are part of the Falia Cemetery complex. In other words, there are six cemetery complexes in the Gandoul Islands. Quite surprisingly, the cemeteries’ nearest neighbor spacing oscillates around 5 km. This is the case between Site 11/12 of Bolon Bakalou and Site 14 of the Diombos tributary, Site 14 and Site 19 of Bolon Diogane, Ndafafe (Site 19) and Tioupane (Site 31/32) of Bolon Gokehor, Tioupane (Site 31/32) and Ndiamon-Badat (Site 34) of *bolon* Gokehor, and finally Ndiamon-Badat (Site 34) and Apatch (Site 36). Cemeteries in both the Southeast and West areas of the islands are relatively equidistant from the central Site 19 on Bolon Diogane (Fig. 2).

Sites with burial mounds present a different spatial logic in the Betanti Islands. In the northeast, there are three equidistant cemeteries with six (Site 39) to 125 tumuli (Dioron-Boumak) directly on the west bank of the Bandiala River (Fig. 2). Dioron-Boundaw (Site 44) and Site 45 form a single complex. Site 39, Dioron-Boumak (Site 43), and Soukouta (Site 46) form a triangular arrangement with localities set 4 km apart. A different arrangement is found in the central part of the islands with four cemeteries in a triangular pattern around the central Site 91 on the east bank of Bolon Bossinka south tributary. Their location presents the same regularity as found in the rest of the islands. The “emerging” cemetery of Site 95 with a

Fig. 2 Distribution of cemeteries in the Saloum Delta



single tumulus on the littoral cordon is located 5 km to the south of Site 67 of Bolon Oudierin. The same distance separates Site 67 from Site 91 of the southern arm of Bolon Bossinka, as well as Site 59 of Bolon Hamdallaye from Site 52 of islet Kator on the Bandiala River. Sites 59 and 91 are only 3 km apart. The Betanti Islands are smaller than Gandoul, but have a higher density of shell middens and cemeteries. The exploitation areas controlled by the different groups tended to be smaller. The geometry of the cemeteries' spatial distribution is remarkable. The mesh of sites with burial mounds is highly constrained, averaging

one cemetery per *bolon* drainage. Such a pattern does not seem to derive from random locational decisions. The issues seem to revolve around “territoriality” based on the control of productive shellfish habitats.

With the exception of Ndiamon-Badat being the only instance of a comprehensive project (Ba et al., 1997; Van Neer, 1997), archaeological fieldwork has focused so far on two main issues: burial mounds excavations (Bessac, 1953; Descamps & Thilmans, 1979, 2006; Thiam, 2013; Thilmans & Descamps, 1982) and the assessment of the pace of shell midden formation (Descamps et al., 1974, 1977; Elouard et al., 1974). All the tested sites are

clustered in the same area along the banks of the Bandiala River, north of the Betanti Islands. In addition, “the purpose and significance of the wide range of different size and type of archaeological shell middens in the Saloum Delta remain unclear, and there is little understanding of their stratigraphy or methods of construction” (Hardy et al., 2016, p. 23). The Oudierin project was crafted to explore shell middens in the interior west flank of the Betanti Islands and address research issues that arose from previous works, but from a regional perspective.

The Oudierin Drainage: Survey Methods and Site Characteristics

Survey operations were conducted in the Gandoul and Betanti Islands and the islets of the Diombos River to test the accuracy of the distributional patterns outlined above. The first survey, focusing on selected parts of this region, was conducted in 2009 as part of the field investigations needed to nominate the Saloum Delta for UNESCO World Heritage listing. The second survey in 2017 was geared toward delineating a comprehensive, coherent, and manageable study area. It focused on the west-central Betanti Island and the Blombos River islets of Gouk and Poutak (Fig. 1). The survey method relied on motorboat pilots familiar with the Saloum Delta landscape and intricate hydrographic network, combined with a pedestrian survey as allowed by the mangrove. The goal of these operations was to conduct a fine-grained survey to fill some gaps, geo-reference the sites with hand-held GPS devices, and take systematic measurements of the recorded shell middens. Four field seasons of two to six weeks were organized, with the last two (2018 and 2019) serving as archaeology field courses for students from Xiamen and Cheikh Anta Diop Universities. These successive field surveys helped to delineate the Oudierin drainage as an optimal study area (Table 1).

Eighteen new shell middens of different sizes and shapes were recorded on the Poutak islet, in addition to the seven previous ones published by Thilmans and Descamps (1982), while six additional sites were found on Gouk islet (Table 1). Of these, the Bolon Oudierin has the highest concentration of shell middens, numbering 12 in total (Fig. 3). This *bolon*, located in the Betanti Islands, connects the Bandiala

River in the southeast to the Bolon Bossinka in the northwest. It is oriented north–south and measures approximately 10 km. The shell middens vary in size from 0.03 ha (Oudierin 70A) to 12.56 ha (Oudierin 66 or Oudierin-Boumak). The largest shell middens, Oudierin 66 and Oudierin 69, are located along two parallel branches at the head of the Oudierin drainage (Fig. 3).

Oudierin 1, one of the newly recorded sites made exclusively of oyster shells, is located at the confluence of the Bolon Oudierin and the Bandiala River (Fig. 3). The remaining sites are concentrated along the northern half of the drainage: Oudierin 61–65 along the east bank; Oudierin 66–68 clustered along the east branch; and finally, Oudierin 69, 70A, and 70B set along the west bank of west branch. Except for Oudierin 1, the recorded shell middens include bloody cockles and oysters’ shells. Two of the sites, Oudierin 67 and 68, located along the west flank of Oudierin 66, are not shell middens, strictly speaking. They have relatively shallow archaeological deposits containing some pottery, with surface scatters of shells. They appear to have been used for residential purposes during shellfish gathering and processing episodes. All the recorded sites were sampled with vertical columns. Columns of sediment and shells were collected where the whole shell-mound stratigraphy was exposed by erosion, generally along channel banks. Although these sites were all scheduled for further testing, the Covid-19 pandemic disrupted the work plan for two years.

It is, nonetheless, possible to look at the sedimentary bases of the shell middens to figure out aspects of initial site location decisions (Fig. 4). Oudierin 61–65, with surface extents in the range of 0.04 ha (Oudierin 63) to 0.32 ha (Oudierin 65), form a south–north string along the east bank of Bolon Oudierin. They are located on sand/silty-sand formations delineating the western edge of an extensive intertidal zone, a favored habitat for bloody cockles, with patches of mangrove rich in oysters’ colonies (Fig. 4). The site profiles feature a sharp demarcation between the sand/sandy-silt base sedimentary formations and the anthropic shell accumulation containing ash deposits and scattered rock fragments. These shell middens are accordingly “located on silty sand layers with a low clay content (5–10%). A large silt and fine sand population in the polymodal assemblage is

Table 1 List of shell middens from the Saloum Delta 2009 and 2017 surveys

Site	Latitude (North)	Longitude (West)	Elevation (m asl)	Length (m)	Width (m)	Height (m)	Surface (Ha)	Species	Others
Bolon Bossinkan									
Bossinkang 88	13°43.568'	16°35.214'	13	370 (N-S)	260 (E-W)	12.67	9.62	C, O	Baobab
Bossinkang 90	13°45.679'	16°34.155'	4	350 (N-S)	300 (E-W)	6.00	10.50	C, O	Baobab
Bossinkang 91	13°44.196'	16°33.552'	4	95 (N-S)	95 (E-W)	3.00	0.70	C, O	Trees
Bolon Oudierin									
Oudierin 1	13°39.043'	17°25.853'	3	24 (N-S)	24 (E-W)	6.00	0.045	O	-
Oudierin 61	13°41.718'	16°34.913'	5	75 (N-S)	29 (E-W)	3.00	0.21	C, O	-
Oudierin 62	13°41.759'	16°34.899'	6	55 (N-S)	25 (E-W)	7.00	0.13	C, O	-
Oudierin 63	13°41.823'	16°34.897'	8	32 (N-S)	11 (E-W)	2.50	0.035	C, O	-
Oudierin 64	13°41.865'	16°34.910'	4	65 (N-S)	45 (E-W)	3.00	0.29	C, O	-
Oudierin 65	13°41.922'	16°34.934'	4	68 (N-S)	48 (E-W)	3.00	0.32	C, O	-
Oudierin 66	13°42.012'	16°34.954'	7	400 (N-S)	400 (E-W)	2.50	12.56	C, O	Baobab
Oudierin 67	13°42.041'	16°35.049'	7	60 (N-S)	35 (E-W)	<0.5	0.21	shallow	Habitation
Oudierin 68	13°42.023'	16°35.054'	2	125 (N-S)	125 (N-S)	<1.00	1.22	Shallow	Habitation
Oudierin 69	13°41.537'	16°35.223'	7	237 (E-W)	128 (N-S)	4.50	3.03	C, O	Baobab
Oudierin 70A	13°42.010'	16°35.252'	6	38 (N-S)	8 (E-W)	<0.20	0.030	C, O	Surface
Oudierin 70B	13°42.016'	16°35.251'	6	61.5 (N-S)	14.5 (E-W)	<0.20	0.89	C, O	Surface
Gouk Islet (Diombos River)									
Gouk 7	13°52.416'	16°31.169'	?	100 (N-S)	50 (E-W)	1.00	0.50	C	-
Gouk I	13°52.399'	16°31.192'	?	?	?	?	?	C, M	-
Gouk II	13°52.452'	16°31.269'	?	?	?	?	?	C, O	-
Gouk III	13°52.401'	16°31.189'	?	?	?	?	?	C	-
Gouk IV	13°52.324'	16°31.216'	?	?	?	?	?	O	-
Gouk V	13°52.321'	16° 31.237'	?	?	?	?	?	C	Recent
Gouk VI	13°52.283'	16°31.250'	?	?	?	?	?	O	Boiling Site
Poutak Islet (Diombos River)									
Poutak 22	?	?	?	100	50	4	0.50	C	Baobab
Poutak 23	?	?	?	100	50	?	0.50	C	-
Poutak 24	?	?	?	<50	?	2.5	?	C	Baobab
Poutak 25	?	?	?	<50	?	1.5	?	C	Baobab
Poutak 26	?	?	?	100	?	1.5	0.50	C	Baobab
Poutak 27	?	?	?	100	50	1.5	0.50	C	Baobab
Poutak 28	?	?	?	?	?	?	?	?	?
Poutak I	13°49.613'	16°36.622'	?	?	?	?	?	?	?
Poutak II	13°49.578'	16°36.617'	?	?	?	?	?	C, Cy	-
Poutak III	13°49.539'	16°36.623'	?	?	?	?	?	C, O	-
Poutak IV	13°49.541'	16°36.648'	?	?	?	?	?	C	-
Poutak V	13°49.550'	16°36.652'	?	?	?	?	?	O	-
Poutak VI	13°49.548'	16°36.706'	?	?	?	?	?	O	Recent Midden

Table 1 (continued)

Site	Latitude (North)	Longitude (West)	Elevation (m asl)	Length (m)	Width (m)	Height (m)	Surface (Ha)	Species	Others
Poutak VII	13°49.542'	16°36.721'	?	?	?	?	?	O, Cy	-
Poutak VIII	13°49.519'	16°36.820'	?	?	?	?	?	O	-
Poutak IX	13°49.476'	16°36.889'	?	?	?	?	?	C	-
Poutak X	13°49.464'	16°36.903'	?	?	?	?	?	C, O	-
Poutak XI	13°49.443'	16°36.900'	?	?	?	?	?	C	-
Poutak XII	13°49.602'	16°36.640'	?	?	?	?	?	C	-
Poutak XIII	13°49.580'	16°36.673'	?	?	?	?	?	C	-
Poutak XIV	13°49.476'	16°36.727'	?	?	?	?	?	O	-
Poutak XV	13°49.446'	16°36.752'	?	?	?	?	?	O	-
Poutak XVI	13°49.549'	16°36.612'	?	?	?	?	?	O	-
Poutak XVII	13°49.527'	16°36.629'	?	?	?	?	?	O	-
Poutak XVIII	13°49.541'	16°36.657'	?	?	?	?	?	O	-

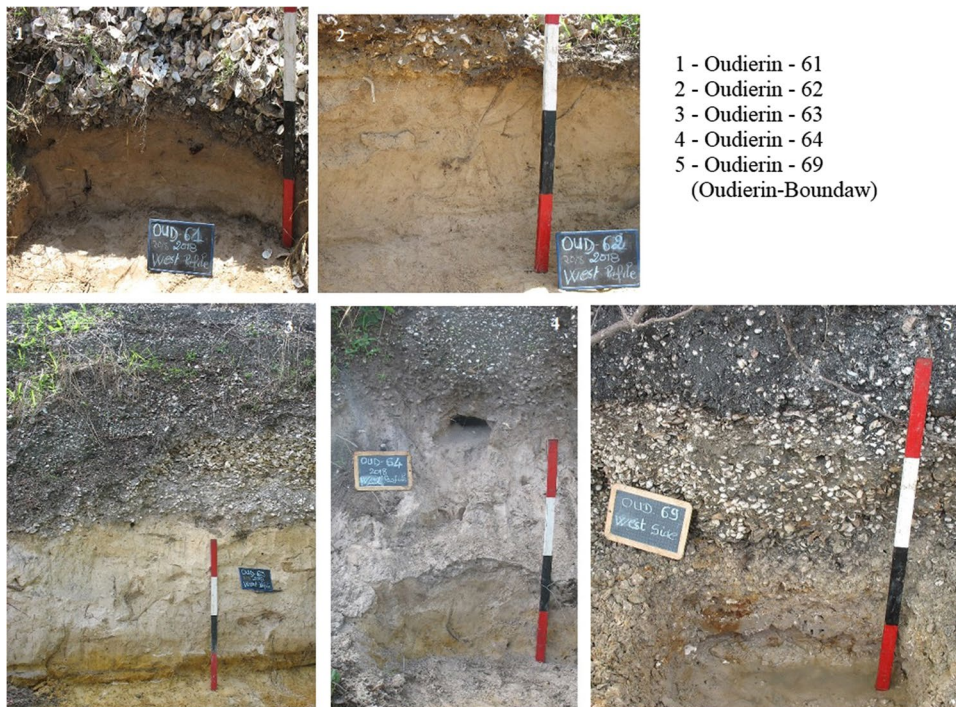
Key: C = *Anadara senilis*; Cy = *Cymbium neptuni*; O = *Crassostera gasar*

Fig. 3 Oudierin drainage surveyed sites

evidence of a prominent eolian input” (Ausseil-Badie et al., 1991, p. 182).

The situation is radically different for Oudierin 66 (Oudierin-Boumak) and Oudierin 69 (Oudierin-Boundaw), the largest shell middens of the study area, measuring 12.59 ha and 3.03 ha, respectively, with deposits 3–5 m thick. The anthropic shell deposits accumulated initially on extensive natural beds of

dead bloody cockles (Fig. 5). The early shellfish gatherers who entered the Bolon Oudierin drainage picked the exposed consolidated bloody cockle shell areas as shellfish processing locales. The exploration of the channel drainage and the exploitation of its resources (shellfish, fish, wood, etc.) may have proceeded from there and expanded irregularly to the entire Bolon Oudierin drainage. As will be shown later, the earliest



- 1 - Oudierin - 61
- 2 - Oudierin - 62
- 3 - Oudierin - 63
- 4 - Oudierin - 64
- 5 - Oudierin - 69
(Oudierin-Boundaw)

Fig. 4 Sedimentary bases of Bolon Oudierin shell middens

anthropogenic shell accumulations are made exclusively of mangrove oyster shells. Oysters, growing on mangrove roots, have different habitat requirements and do not form extensive compact deposits. Humans accumulated their shells in deposits that include ash, charcoal, and coarse pieces of rock (sandstone) used as “hearthstones” and introduced from the hinterland. The remaining part of this paper will focus on the excavations carried out at Oudierin-Boumak and Oudierin-Boundaw.

Excavations at Oudierin-Boumak

The excavation program carried out at Oudierin-Boumak in July–August 2018 as the Xiamen University Saloum Delta archaeological project included two complementary components. First, an archaeological component sought to unveil behavioral features and material culture items contained in the relatively large Oudierin-Boumak shell midden, and delineate its formation history. Second, an “environmental assessment” component addressed the dynamics of shellfish populations via systematic sampling and analyses of the size of collected shells.

The Trench

The archaeological exploration of Oudierin-Boumak was implemented through an inverted L-shaped trench, 3 m wide and 12 m long east–west, and 3 m long north–south (Fig. 6). The trench revealed a 2-m thick occupation deposit of discontinuous exploitation episodes, comprising bedded layers of oyster and bloody cockle shells, with the former largely predominant throughout the sequence. The lower segment of the midden stratigraphic sequence, 1.4–2.0 m below the ground surface, was accumulated by early Holocene foragers as shown by ash floors; this deposit dates from 8551–8329 cal BC to 8091–7882 cal BC (Table 2).

The shellfish processing area (and possibly the site) was abandoned for a few millennia, almost 4000 years, and reused during distinct episodes in the mid-Holocene. The first segment, dated to 4343–4151 cal BC, resulted in the accumulation of the 1.1–1.2-m level of the deposit. The second segment, dated almost 1000 years later, was documented in the 0.9–1.2-m level and featured the formation of a thick, hard ash floor exposed at 1.0 m below the surface (Fig. 6). The locale was abandoned again for

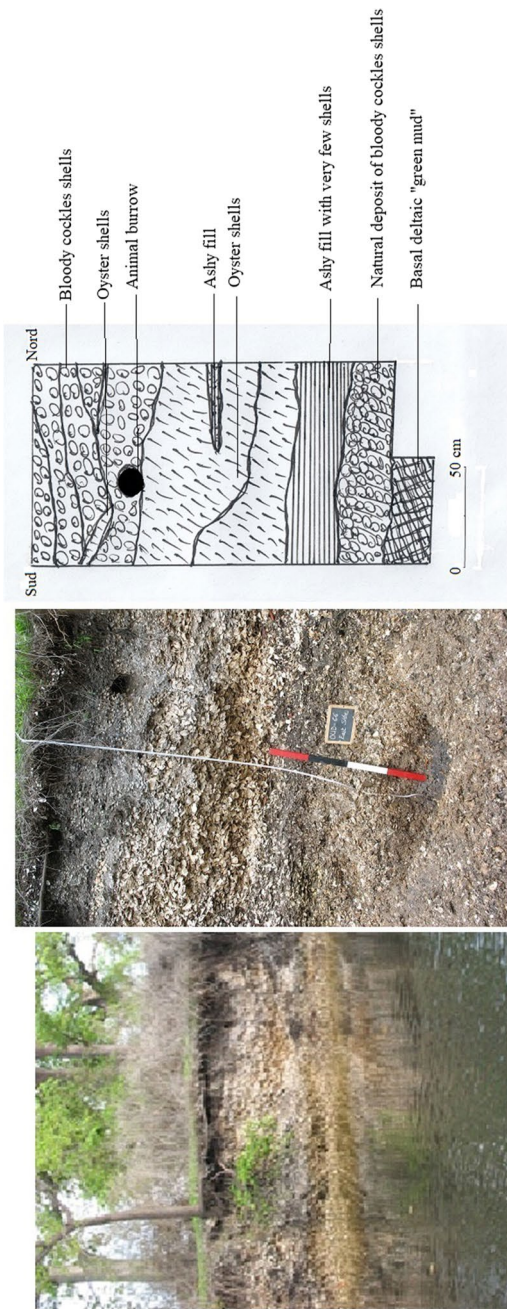


Fig. 5 Oudierin-Boumak (Oudierin-66) East flank and profile

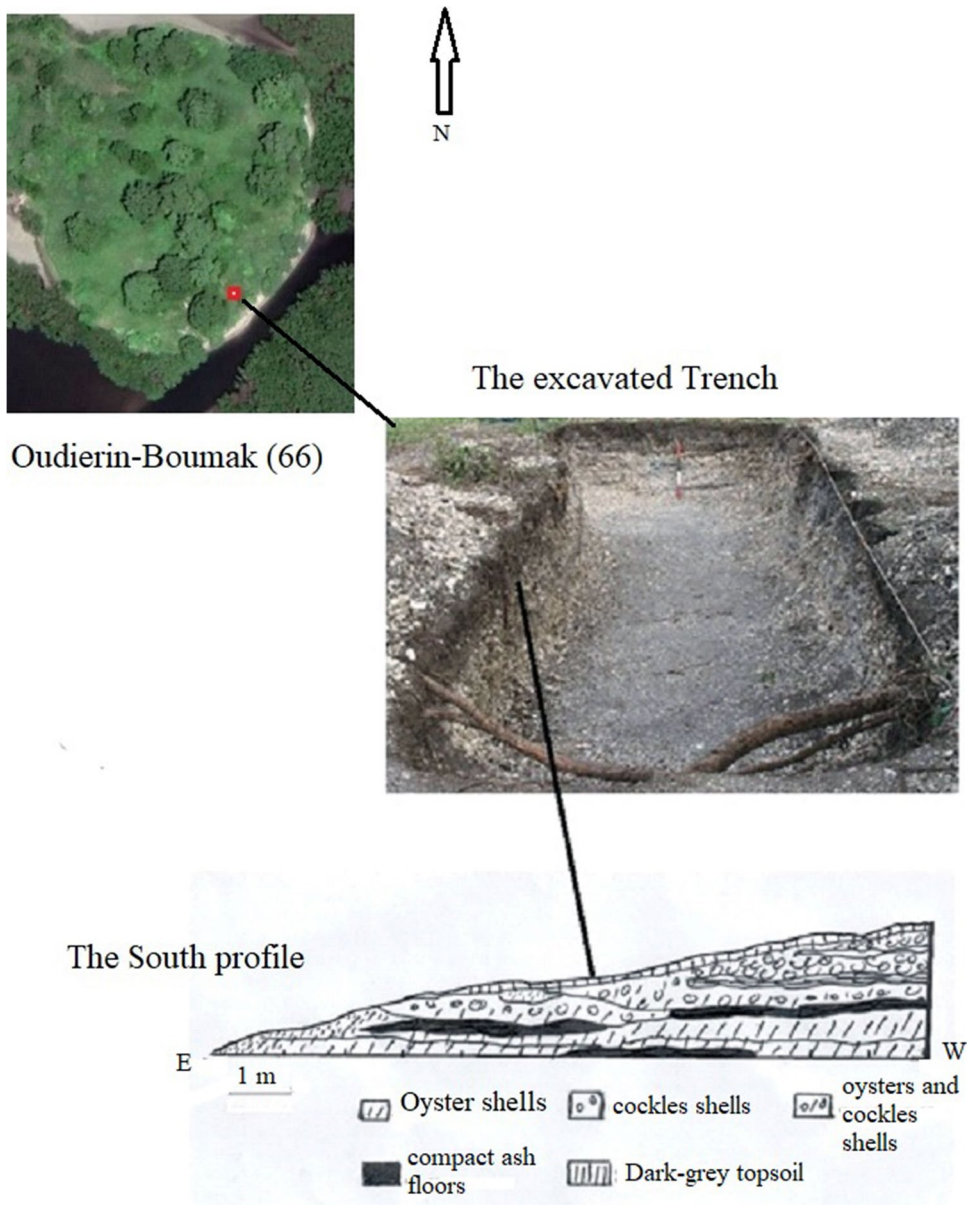


Fig. 6 Oudierin-Boumak: Excavated units and south wall stratigraphic profile

more than 2000 years before being revisited around 763–546 cal BC during the Late Holocene. Then, another abandonment phase lasted for more than 1500 years before it was reoccupied during the eleventh through the mid-thirteenth century AD.

The storage bin recorded at the top of the north section (Fig. 7) is intrusive and points to a post-thirteenth-century use of the site. Successive and super-imposed thick and hardened ash surfaces, resulting from shellfish boiling operations, were

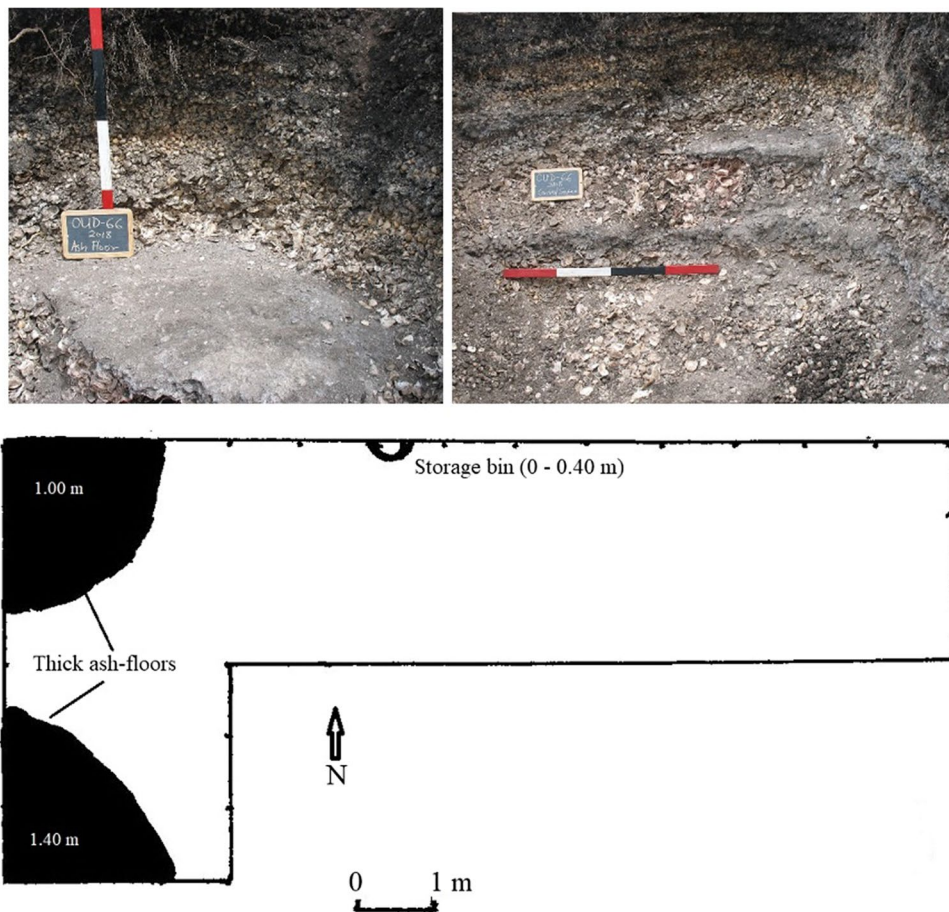
exposed in the west end of the trench at depths of 1.0–1.4 m below the surface (Fig. 7). The largest of these features, found in the northwest and southwest trench corners, have exposed dimensions of 2.0–2.5 m.

Oudierin-Boumak Material Culture

The sample of material culture collected from the excavated trench is relatively modest. It consists of

Table 2 Radiocarbon chronology of Oudierin-Boumak (Site 66)

Context	Sample material	Laboratory number	Date BP	Calibrated BCE/CE	
				1 sigma	2 sigma
Second Millennium CE					
OU D-66, 0.0–0.6 m	Bone	DK052018AH	714 ± 27	cal AD 1208: cal AD 1246	cal AD 1193: cal AD 1268
OU D-66, 0.4–0.8 m	Charcoal/Bone	DK082018AH	804 ± 30	cal AD 1137: cal AD 1172	cal AD 1193: cal AD 1268
OU D-66, 0.4–0.8 m	Shell	DK042018AH	998 ± 24	cal AD 970: cal AD 1013	cal AD 945: cal AD 1029
Late Holocene					
OU D-66, 0.8 m	Charcoal	DK102018AH	2559 ± 40	cal BC 714: cal BC 604	cal BC 763: cal BC 546
Mid-Holocene					
OU D-66, 0.9–1.0 m	Bone	DK032018AH	4236 ± 42	cal BC 2937: cal BC 2824	cal BC 3010: cal BC 2779
OU D-66, 1.1–1.2 m	Charcoal	DK02018AH	5227 ± 43	cal BC 4284: cal BC 4191	cal BC 4343: cal BC 4151
Early Holocene					
OU D-66, 1.4 m	Charcoal	DK092018AH	7276 ± 41	cal BC 6913: cal BC 6832	cal BC 6956: cal BC 6791
OU D-66, 1.6 m	Bone	DK06018AH	8116 ± 43	cal BC 8027: cal BC 7923	cal BC 8091: cal BC 7882
OU D-66, 2.0 m	Charcoal	DK072018AH	8417 ± 34	cal BC 8496: cal BC 8383	cal BC 8551: cal BC 8329

**Fig. 7** Oudierin-Boumak activities areas: Ash floors and storage pit

potsherds, fired rock fragments, clay blocks used as “hearth-stones,” and a sun-dried clay potter’s tool for smoothing partly dried vessels prior to firing (Table 3, Fig. 8). Pottery is represented in two discrete occupation segments: the mid-Holocene dated to 3000–2800 cal BC in the 0.90–1.20 m segment of the archaeological deposit, and the early second millennium AD (950–1250 cal AD) in the upper level, 0.00–0.80 m. Seventy-seven potsherds were retrieved from the mid-Holocene level and 743 sherds from the early second millennium AD, with bodysherds largely predominant in all the collected samples (Table 3A). The proportion of decorated sherds shifts from 28% to 34.45% from the mid-Holocene to the early second millennium AD (Table 3B). Sherds from the mid-Holocene were so worn out, probably following long exposure to the elements, that it was challenging to identify the motifs and decoration techniques. The twisted roulette impression is predominant in the early second millennium AD deposit (Table 3C). Both pottery series feature four sherd thickness classes with similar distribution patterns. Thin-walled vessels (< 5 mm thick) are marginally represented (Table 3C). Cooking, food/beverage consumption, and daily life wares (5.5–15 mm thick) are largely predominant, with the last thickness class (> 15.5 mm) representing storage vessels.

The recorded pottery material was highly fragmented, likely because of a high degree of trampling. Some vessel shapes could nonetheless be reconstructed based on larger rimsherds. The mid-Holocene ceramic complex features short-necked globular vessels (Fig. 8A), predominantly decorated with a horizontal band of twisted roulette impression on the shoulder. Vessel shapes are more diverse during the early second millennium. They include hemispheric and footed bowls and short-necked globular pots with straight or everted rims (Fig. 8B and 8D). The systematic inspection of the large sherds shows that pottery-making was based on coiling techniques, with crushed shells used for tempering.

In summary, the data available from the Oudierin-Boumak trench reveals the beginning of shellfish exploitation in the Saloum Delta during the early Holocene and continuing for millennia, with several significant interruptions (Table 2). The first early–mid-Holocene interruption lasted for more than 3700 years, while the second mid–late Holocene abandonment lasted for over two millennia.

Finally, the third interruption lasted for about 1500–1700 years, from the late Holocene to the early second millennium AD.

A word of caution is, however, required. Oudierin-Boumak is a large 12.54-ha shell midden. The absence of evidence in the excavated trench does not necessarily mean human absence from the whole site or area. Shellfish processing may have shifted elsewhere to different spots on the site. Additional units will need to be excavated in other parts of the shell mound to build a more accurate chronological outline. This being said, the data obtained so far can help to formulate new hypotheses. The interruptions in occupation were long enough that they likely did not form parts of the social memories of past populations. Can they be explained by significant climate change, which may have impacted shellfish reproduction and distribution? Or did human exploitation deplete local shellfish populations?

Environmental Assessment at Oudierin-Boumak

The Oudierin-Boumak environmental assessment was implemented to probe the possible reasons for the successive abandonment of the site as documented in the excavated sequence. The project was carried out through a sampling column set on the east flank of the midden exposed by the east branch of the Bolon Oudierin, a few meters east of the excavated trench. Relatively equal size shell samples were collected every 10 cm in the column of the human-made deposit. The samples were sorted in the laboratory, and complete shells (at least 100 per sample) of represented species were selected for further measurements (e.g., width, length). The analytical rationale is anchored on the biology and growth patterns of shellfish, specifically bloody cockle and oyster.

In West Africa, bloody cockles generally live in the upper 5–10 cm of the sandy mud in lagoons and estuaries. They can live up to ten years (Hardy et al., 2016) and “reach sexual maturity and spawn for the first time when they are 6-months old and about 20 mm long” (Otchere, 2020, p. 54). Their maximum length ranges 100–150 mm. Meanwhile, mangrove oysters are seasonal breeders in estuaries and continuous ones on lagoons, with size at maturity ranging from 8 mm for males and 10 mm for females. According to Otchere (2020, p. 54), “the majority of oysters differentiate sexually and spawn first as males. The proportion of females increases with size until the sex

Table 3 Oudierin-Boumak pottery

A – Vessels body parts frequency distribution

Context	Weight (kgs)	N	Rim	Body	Base	Other					
Surface	0.95	50	4	46	-	-					
<i>Second Millennium (950–1250 cal AD)</i>											
0.00–0.40 m	1.25	60	3	56	1	-					
0.40–0.60 m	9.80	496	30	450	17	-					
0.60–0.80 m	4.30	187	14	162	12	-					
Total	15.35	743	47	668	30	-					
<i>Mid-Holocene (3000–2800 cal BC)</i>											
0.90–1.00 m	0.90	22	1	19	2	-					
1.00–1.20 m	1.50	53	3	47	3	-					
Total	2.40	77	4	66	5	-					
Total	18.70	868	55	780	35	-					
B—Distribution of decorated and undecorated sherds											
Context	Decorated				Undecorated				Total		
	n	Rim	Body	Base	n	Rim	Body	Base			
Surface	42	4	38	-	58	4	54	-	100		
<i>Second Millennium (950–1250 cal AD)</i>											
0.00–0.40 m	26	2	23	1	33	1	32	1	59		
0.40–0.60 m	163	8	152	3	333	18	296	19	496		
0.60–0.80 m	67	4	62	1	121	10	101	10	188		
Total	256	14	237	5	487	29	429	30	743		
<i>Mid-Holocene (3000–2800 cal BC)</i>											
0.90–1.00 m	8	1	7	-	14	-	13	1	22		
1.00–1.20 m	13	-	13	-	40	3	34	3	53		
Total	21	1	20	-	54	3	47	4	75		
Total	319	19	295	5	599	36	530	34	918		
C—Frequency distribution of decoration techniques and sherd thickness classes											
Context	Decoration techniques						Thickness classes (mm)				
	TR	ZZ	CI	In	Comp	Undet	<5	5.5–10	10.5–15	> 15.5	
Surface	15	2	1	-	-	3	6	26	2	-	
<i>Second Millennium (950–1250 cal AD)</i>											
0.00–0.40 m	23	-	1	1	1	-	1	47	11	1	
0.40–0.60 m	159	-	4	-	3	7	11	383	82	23	
Total	60	2	-	1	1	-	4	119	54	11	
Total	242	2	5	2	4	7	16	549	147	35	
<i>Mid-Holocene (3000–2800 cal BC)</i>											
0.90–1.00 m	-	-	-	-	-	-	-	14	8	-	
1.00–1.20 m	-	-	-	-	1	-	1	33	17	2	
Total	-	-	-	-	1	-	1	47	25	2	
Total	257	4	6	2	6	10	23	622	174	37	

Key: TR = Twisted Roulette; ZZ = zigzag; CI = Comb Impression; In = Incision; Comp = Composite; Undet = Undetermined

ratio is approximately 1/1 in oysters measuring over 30 mm.” There are, however, many factors that may influence shellfish size: “Water temperature, salinity,

turbidity, nutrient availability, species population density, and overall community composition all affect intertidal molluscan growth rates and may contribute

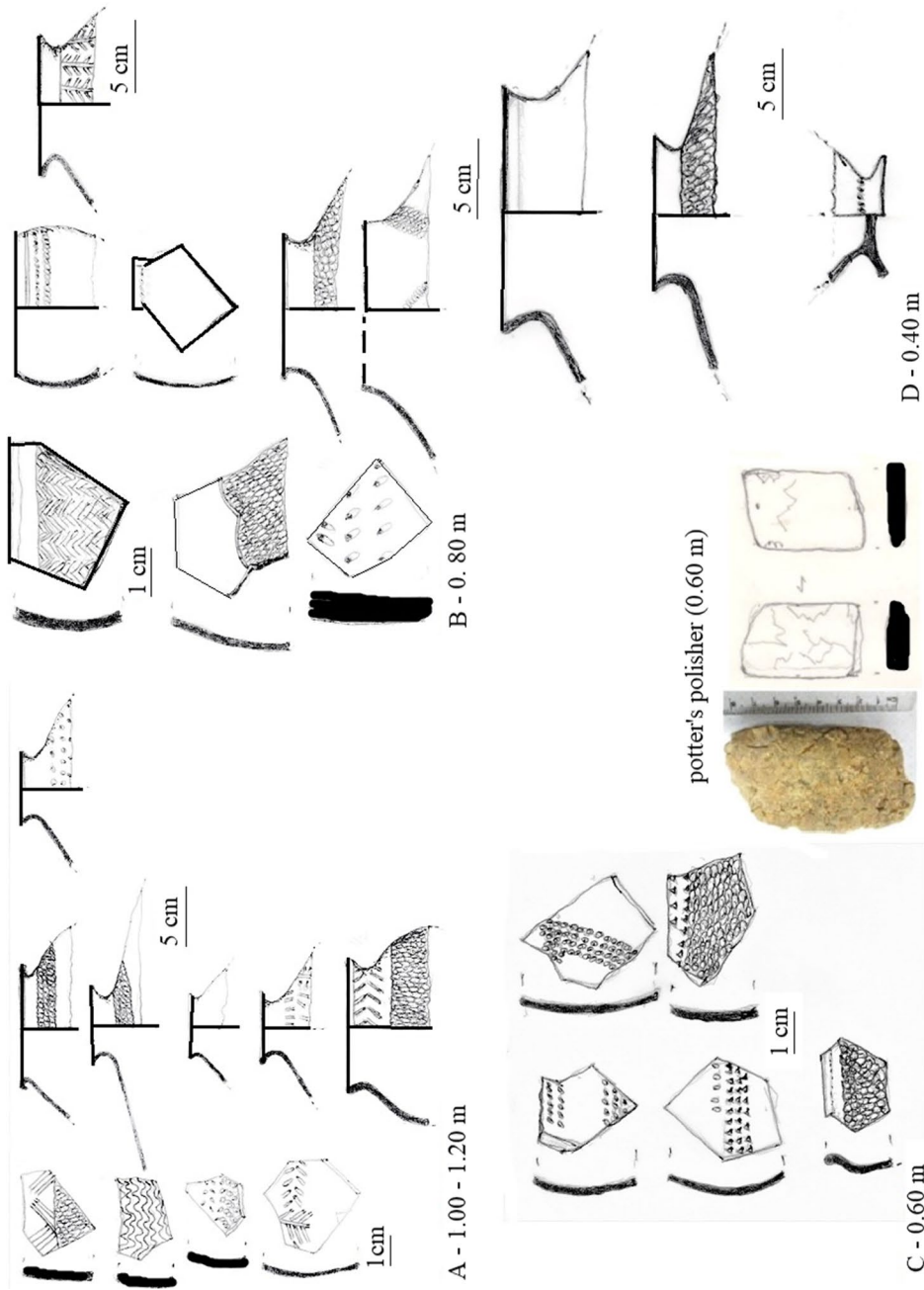


Fig. 8 Oudierin-Boumak material culture

to geographic or temporal variation in average size within a molluscan species” (Klein & Steele, 2013, p. 10,911).

Samples Composition and Shells’ Population Structure

It is important to emphasize that each of the samples collected very likely represents a “snapshot” of an actual discrete episode of shellfish processing, providing an insight into the exploited shellfish population structure. A total of 16 samples (0.7–2.0 kg) were collected along the stratigraphic column. The early Holocene (8550–7000 BC) segment was represented by levels 0.40–0.80 m, from which 452 shells (6.2 kg), predominantly oysters, were collected. A handful of cockle shells appeared in the upper deposit (Fig. 9; Table 4). The first (0.40–0.50 m), third (0.60–0.70 m), and fourth (0.70–0.80 m) levels of the early Holocene are radiocarbon dated to 8551–8329 cal BC, 8091–7882 cal BC, and 6956–6791 cal BC respectively.

After a significant occupation gap (0.10 m devoid of shells), the mid-Holocene deposit (0.90–1.20 m) built up between ca. 4350 BC and 2800 BC (Fig. 7, Table 4). A total of 393 shells were collected. As is the case for the early Holocene, there are important chronological gaps in the mid-Holocene deposit. Its lower part (1.10–1.20) dates to 4343–4150 cal BC, and the upper part (0.90–1.00 m) to ca. 3010–2800 cal BC. The late Holocene portion of the deposit (700–500 BC), 1.20–1.50 m, accumulated after more than 2000 years of the cultural gap. Oysters are again predominant. The lower part of the late Holocene (1.20–1.30 m) is dated to 763–546 cal BC. The upper late Holocene deposits (1.30–1.50 m) are not directly dated, but they suggest episodes of

shellfish exploitation and processing that may have stretched across the second half of the first millennium BC.

The early second millennium AD deposit (AD 950–1300), recorded at 1.50–2.00 m, accumulated after a depositional gap of approximately 1500 years. The deposit features the highest representation of bloody cockle shells, predominant in the uppermost 1.90–2.00 m of the deposit (Fig. 9, Table 4). In summary, the collected shell samples point to the principal exploitation of mangrove oysters, complemented throughout most of the depositional sequence by the collection of bloody cockles. The latter became dominant in the last deposition level.

Shell Size, Collection Pressure, or Environmental Adjustment?

According to Klein and Steel (2013, p. 10910), “smaller [shell] size implies more intense collection and more intense collection is most readily attributed to growth in the number of human collectors.” In other words, sustained collection pressure affects growth patterns in shellfish populations. During initial pristine conditions, one can expect larger specimens to be optimally picked first, with a tendential process resulting in the decreasing size of the catches. Keeping in mind that mollusk size is influenced by a broad array of factors described above, one would expect shellfish gathering to be shifted elsewhere following a significant drop in the average size of the catches, resulting in the abandonment of collection areas and processing sites. Therefore, measurements of the maximum length and width of complete oyster and bloody cockle shells can be used to assess size fluctuations and their relations to cycles of use and abandonment of shellfish processing sites. More specifically,

Fig. 9 Frequency distribution of shellfish (shell) species in the Oudierin-Boumak sequence

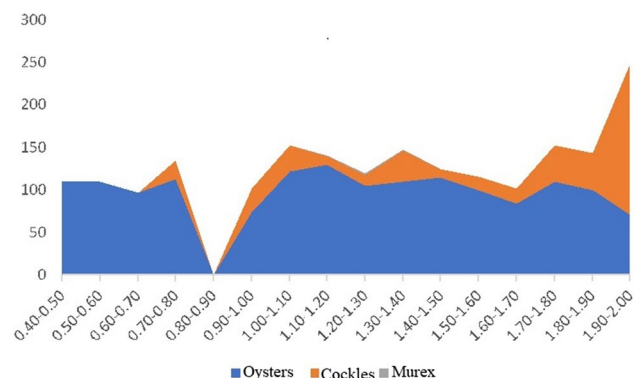


Table 4 Oudierin-Boumak shell samples

Stratigraphy (m)	Sample weight (kg)	# of shells	Oysters	Bloody cockle	Murex
IV – Early-Second Millennium AD (950–1300)					
16—1.90–2.00	1.5	248	71	177	-
15—1.80–1.90	1.5	144	100	44	-
14—1.70–1.80	2.0	153	110	43	-
13—1.60–1.70	0.7	102	84	18	-
12—1.50–1.60	0.8	116	100	16	-
1.50–2.00	6.5	763	465	298	-
III – Late Holocene (700–500 BC)					
11—1.40–1.50	1.0	125	115	10	-
10—1.30–1.40	0.7	147	110	37	1
9—1.20–1.30	0.8	120	105	13	2
1.20–1.50	2.5	392	330	60	3
II—Mid-Holocene (4350–2800 BC)					
8—1.10–1.20	0.7	141	130	10	1
7—1.00–1.10	0.9	153	122	31	-
6—0.90–1.00	1.2	102	74	28	-
0.90–1.20	2.8	393	316	69	1
5—0.80–0.90	-	-	-	-	-
I—Early Holocene (8550–7000 BC)					
4—0.70–0.80	1.2	135	113	22	-
3—0.60–0.70	1.2	97	97	-	-
2—0.50–0.60	1.9	110	110	-	-
1—0.40–0.50	1.9	110	110	-	-
0.40–0.80	6.2	452	430	22	-
Total	18	2,000	1,541	449	4

length/width correlations provide a tool for assessing long-term variations in shellfish size. However, lumping the shell measurements into aggregated chronological segments (e.g., early, middle, and late Holocene) would result in a significant loss of information. Therefore, the analysis proceeds from sample to sample using scatter diagrams and emphasizing the beginning and end of these chronological segments.

The Early Holocene

The samples from the early Holocene are predominantly oyster shells (Fig. 10). Oyster sizes from the earliest level (0.40–0.50 m) range from 1.5–6.0 cm (length) and 0.5–3.5 cm (width), with the bulk of the specimens clustered between 2.0–5.0 cm (length) and 1.0–3.0 cm (width). This shell size range contrasts the samples from the 0.50–0.60-m level: the length shrinks to 1.5–4.5 cm, and the width increases to

0.5–4.5 cm (Fig. 10). Level 3 has a relatively good proportion of specimens measuring 5.0–7.0 cm long, but most range from 2.0–5.0 cm (length) and 0.5–3.0 cm (width). Level 4, representing deposits from the end of the early Holocene, displays an overall drop in average oyster size: 2.0–4.0 cm (length) and 0.5–4.0 cm (width). Data from cockle shells support this trend in oysters. Most of the recorded specimens measure 1.5–2.7 cm (length and width), pointing to the collection of very young specimens (Fig. 10). The abandonment of the processing locality at the end of the early Holocene appears to be a logical consequence of the depletion of shellfish populations in the collection zones.

The Mid-Holocene

When shellfish exploitation resumes a few thousand years later in the mid-Holocene, the collected

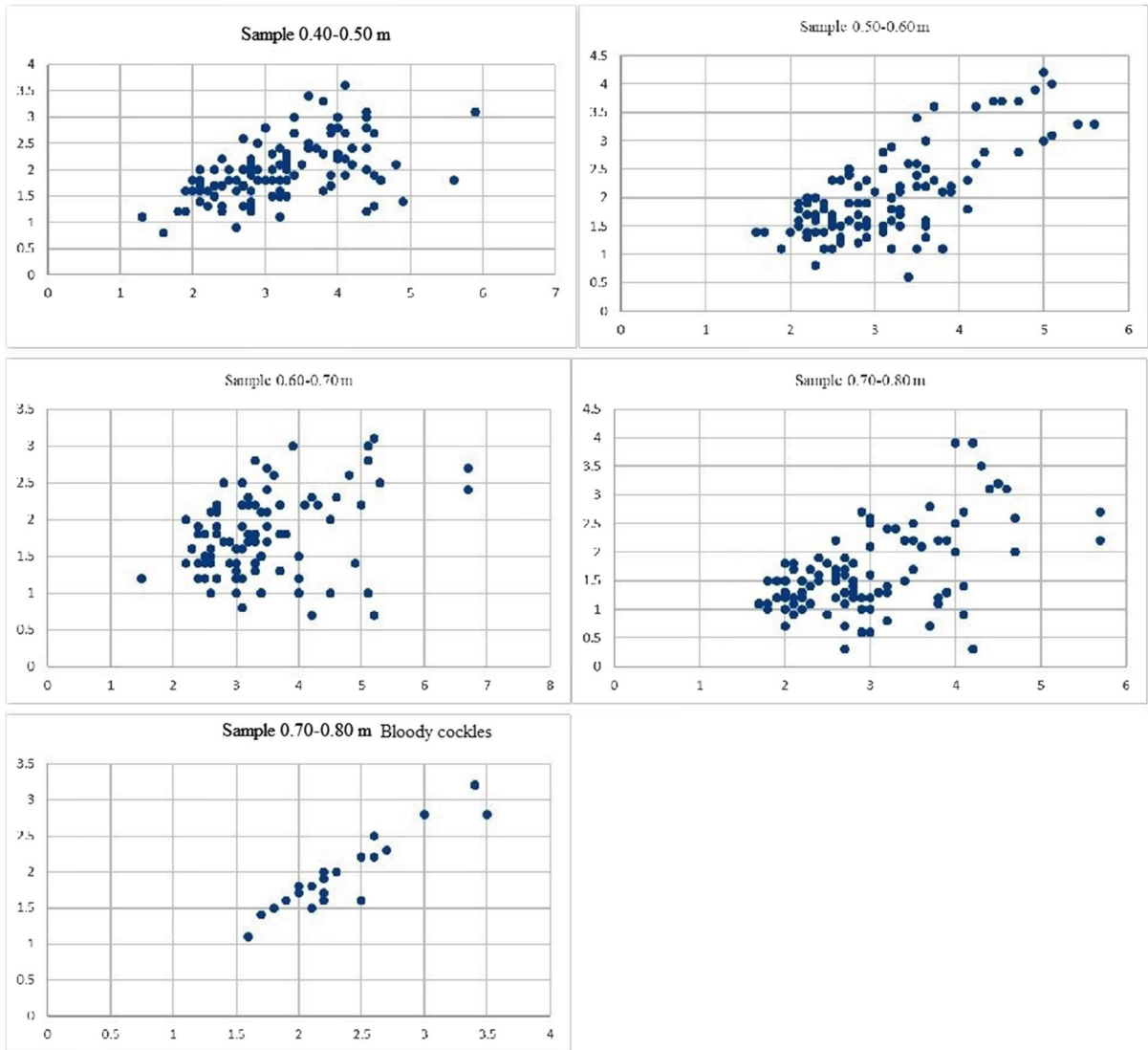


Fig. 10 Scatter diagram of early Holocene shell measurements

oysters and cockles are larger. There is a significant proportion of longer oyster shells (4.0–6.0 cm) and cockle shells (2.5–5.0 cm) (Fig. 11.1). However, most recorded cockle shells are small (1.5–2.5 cm). On average, oyster shell size increases in level 1.00–1.10 m, with some specimens measuring 5.0–7.5 cm (length) (Fig. 11.2). The collected cockle shell sizes also increase slightly, with a good proportion measuring 2.5–4.0 cm (length). The last mid-Holocene level (1.10–1.20 m) features a broader size range for oysters. There is an increase at both ends of the size spectrum, including specimens measuring 5.0–8.0 cm and

2.0–3.0 cm (length). Most of the cockle population ranges 2.0–4.0 cm (length), continuing a trend from the 1.00–1.10 m level. Overall, there is an interesting contrast between the sizes of oyster and cockle shells. On the one hand, oyster size increases from 1.5–6.0 cm×0.5–4.0 cm in level 0.90–1.00 m, to 1.8–7.5 cm×0.7–4.6 cm in level 1.00–1.10 m, and reaches 1.5–8.0 cm×0.5–4.9 cm in level 1.10–1.20 m. Cockle shell size, on the other hand, follows an opposite trend, from 1.3–4.8 cm×1.0–3.7 cm in the lower level to 1.5–3.7 cm×1.5–3.5 cm in the middle, and finally, to 1.7–2.9 cm×0.7–2.6 cm in the upper level. It is as if

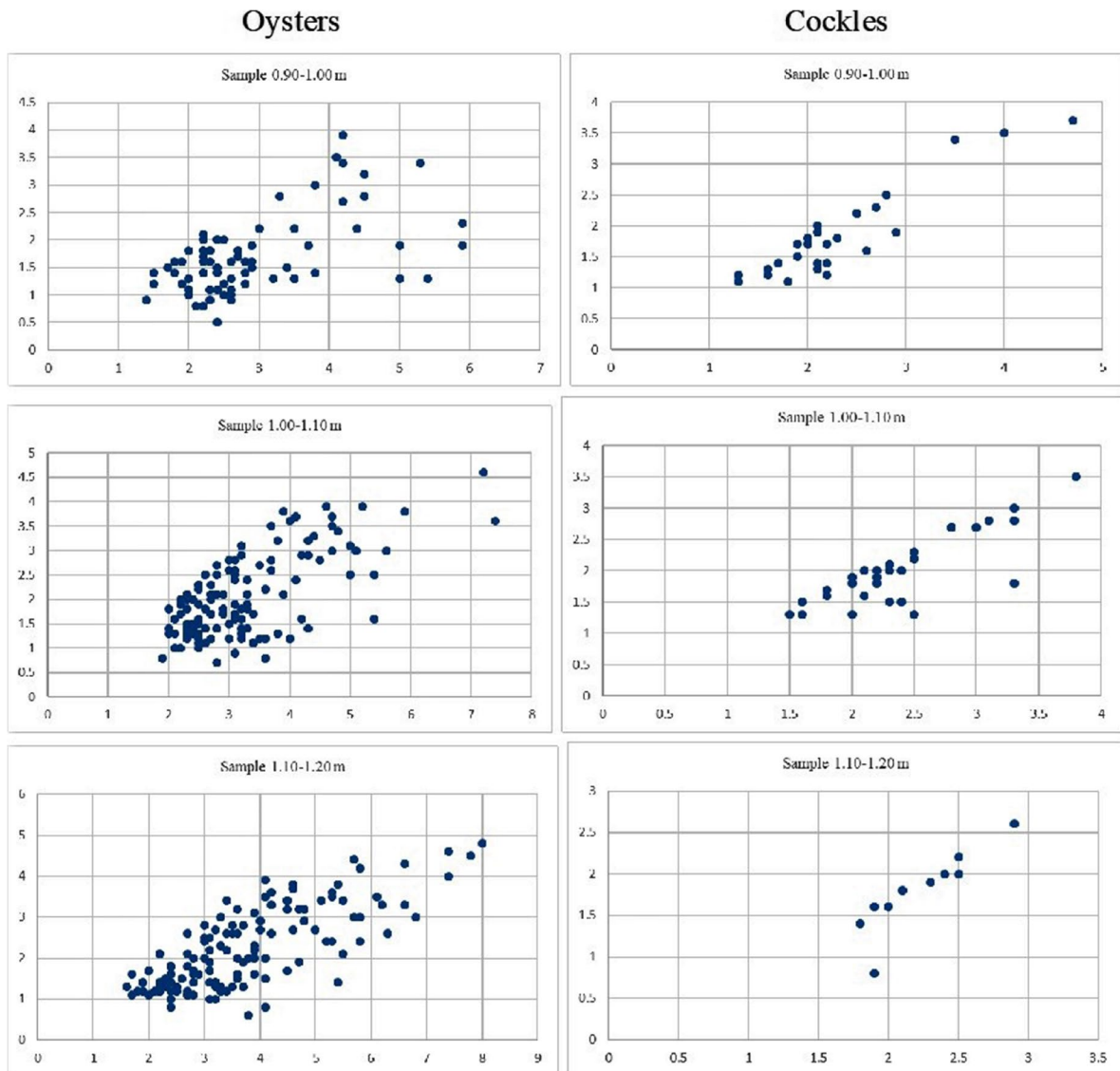


Fig. 11 Scatter diagram of mid-Holocene shell measurements

the mangrove had expanded and colonized the intertidal zones, impacting the local bloody cockle habitat.

The Late Holocene

Shellfish collection and processing resumed some 2500 years later. Oyster sizes in level 1.20–1.30 m range 2.0–7.0 cm (length) and 0.5–4.5 cm (width). The recorded shells are distributed into two relatively equal subsets, below and above the 2.5 cm width line (Fig. 12). The lower subset includes specimens 2.0–4.1 cm (length)

and 0.7–2.5 cm (width), while the upper one includes shells measuring 4.0–7.0 cm (length) and 2.5–4.5 cm (width). There is a significant increase in the range of oyster shell sizes at level 1.30–1.40 m. The length varies from 1.7 cm to almost 10 cm, and the width from 0.5 cm to 5.5 cm (Fig. 12). However, the bulk of the recorded shells is confined to the 1.5–5.0×1.0–4.0 cm size range. Finally, the average oyster shell size increases in the final Late Holocene phase (1.40–1.50 m) with a relatively even distribution, ranging from 2.2–7.5 cm in length and 1.0–4.0 cm in width (Fig. 12).

Cockle shell sizes present three equal and “discrete” subsets with four specimens each: 1.3–2.0 cm×1.0–1.6 cm for the smallest; 2.4–2.5 cm×2.0–2.3 cm for the intermediate; and 2.8–2.9 cm×2.3–2.7 cm for the largest, found in level 1.20–1.30 m (Fig. 12). The size ranges 1.0–3.6 cm (length) and 1.0–3.6 cm (width) in level 1.30–1.40 m, with the bulk of specimens measuring 1.5–2.8 cm (length) and 1.4–2.5 cm (width). And finally, there is a significant shrinkage of the shell size range in level 1.40–1.50 m, with a handful of specimens measuring

2.0–2.7 cm (length) and 1.4–2.4 cm (width) (Fig. 12). On average, cockle shells are small, featuring young specimens. Oyster shells are larger in comparison, suggesting preferential exploitation of richer mangrove areas at the expense of interstadial sandy mud.

The Early Second Millennium AD

The exploitation and processing of shellfish resumed in the early second millennium AD after more than five centuries of interruption. The

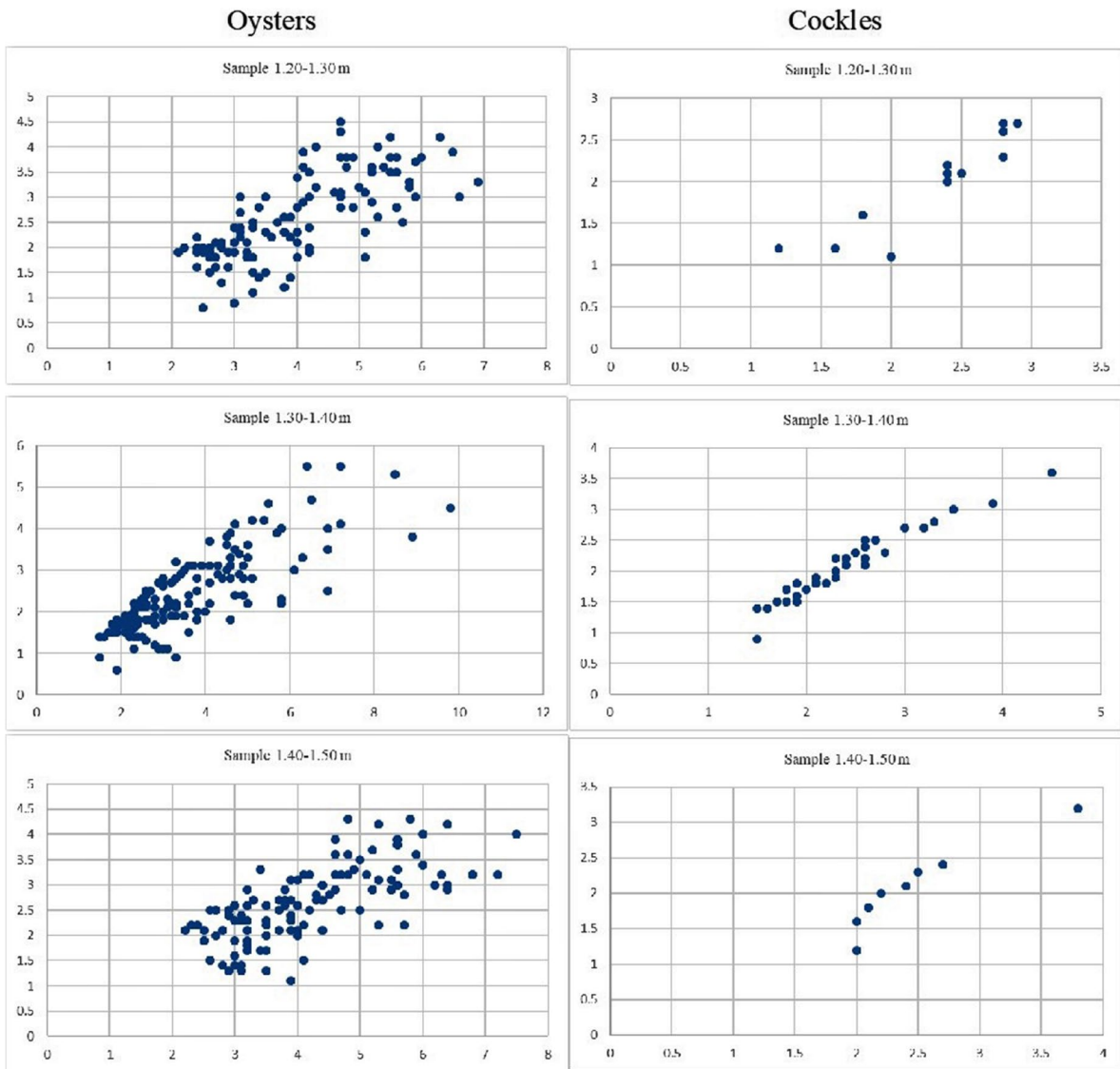


Fig. 12 Scatter diagram of late Holocene shell measurements

oyster shells from level 1.50–1.60 m have a wide size range of 2.0–10.2 cm in length and 1.0–5.0 cm in width (Fig. 13). Most of the shells cluster between 2.0–5.5 cm × 1.0–4.0 cm, with an outlier set of four specimens measuring 8.1–10.2 cm (length) and 2.0–4.7 cm (width), and an intermediate set of specimens measuring 4.5–6.5 cm (length) and 3.0–5.0 cm (width). Shell length shrinks to 2.2–8.0 cm, while width increases to 1.0–6.0 cm at level 1.60–1.70 m. However, a narrower length range (3.0–8.0 cm) with an even distribution is documented in level 1.70–1.80 m. At 1.80–1.90 m depth, the width range remained constant, but the length range grew to 1.8–8.0 cm, featuring a shift toward smaller oysters. Finally, in level 1.90–2.00 m, the width range remained constant, while the length range shrunk to 2.1–7.1 cm, with the bulk of collected specimens in the 2.2–4.5 cm × 1.0–3.0 cm size range (Fig. 13). All the cockle shell levels present the same characteristics and distribution patterns. They are small, measuring 1.2–4.0 cm (length) by 1.0–4.0 cm (width) (Fig. 13). The shellfish population sampled from the Oudierin-Boumak shell midden clearly points to over-exploitation and depletion in the first half of the second millennium AD, leading to the final abandonment of the excavated part of the site.

Keeping in mind that these samples are snapshots of discrete subsistence episodes, the detailed analysis of shell populations suggests different scenarios for the multiple millennia-long interruptions in shellfish processing in the excavated area of the Oudierin-Boumak shell midden. These scenarios range from environmental processes like the extension of oysters' mangrove habitat at the expense of bloody cockles' intertidal sand mud habitat to the human-enhanced depletion of shellfish resources. The impact of the abrupt late Holocene climate change documented worldwide is difficult to document with the data at hand, but this topic deserves sustained investigation in future research.

Excavation of Oudierin-Boundaw Cemetery

Oudierin-Boundaw (Site 69, 13°41.537' N, 16°35.223' W), the second-largest site of the drainage (3.3 ha), is an elongated shell midden, oriented NE-SW along the west bank of the west branch of the Bolon Oudierin. Its

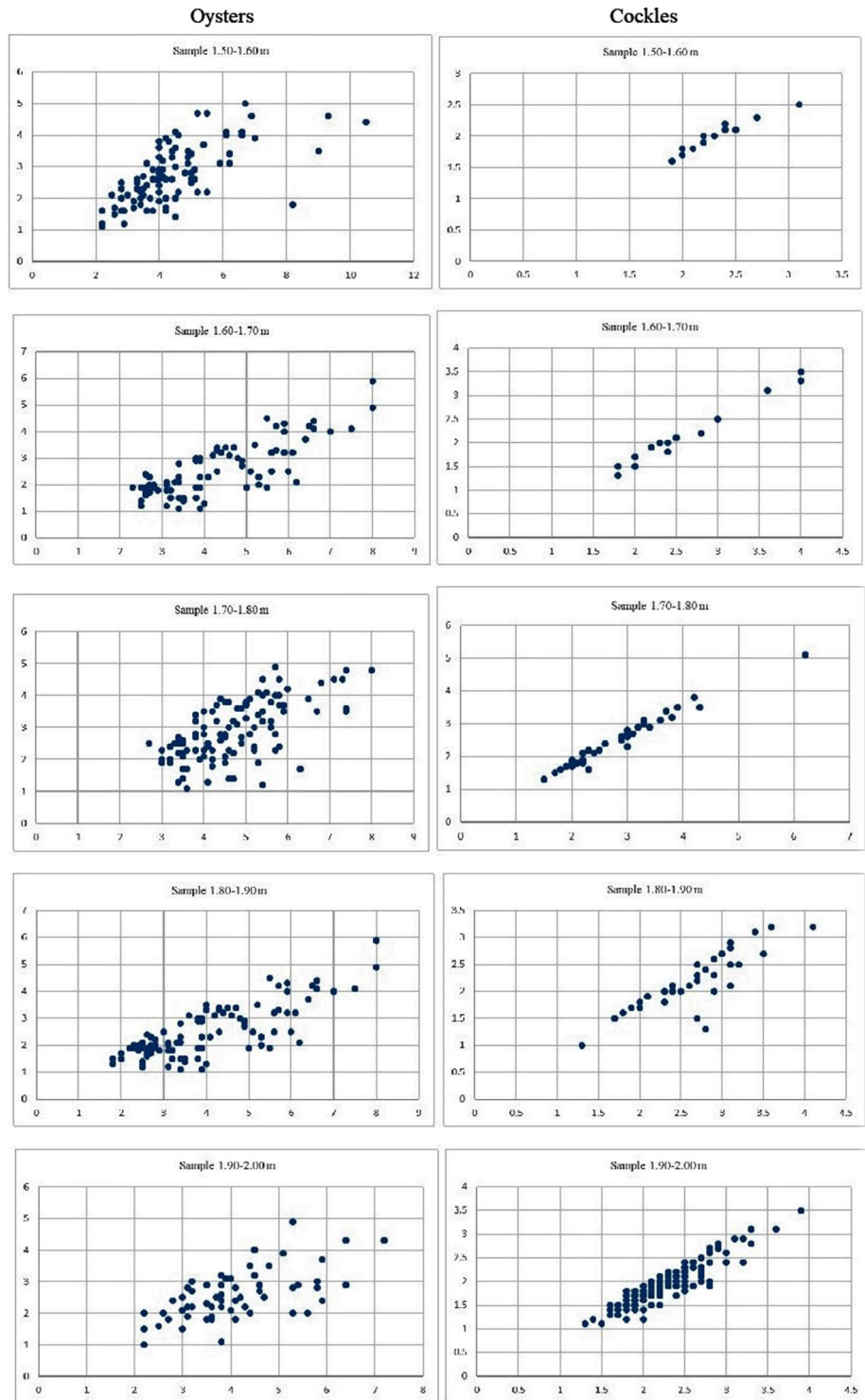
northeastern flank has been steadily eroded by the river to expose a 3–4 m deposit, and there is a cemetery with 35 burial mounds located at the north end of the site (Table 5, Fig. 14). The excavation program focused exclusively on these mounds built with shells dug from previously accumulated deposits. The shell midden itself has not yet been tested but is certainly older than the excavated burials.

The recorded burial mounds, spread over 1 ha, have diameters ranging from 16 m (T-16, T-29) to 5 m (T-08, T-35) and heights ranging from 0.2 m (T-35) to 2 m (T-21, T-22) (Table 5). The northeastern portion of the cemetery overlooking the Bolon Oudierin was selected for further study. An excavation grid of 5 × 5 m cells was set over a 50 × 50 m sampling unit containing ten burial mounds. In general, the diameters of the sampled burial mounds range from 5 m (T-08) to 10.5 m (T-02), and their heights from 0.3 m (T-06) to 1.8 m (T-10) (Table 5). Three out of the four largest burial mounds, measuring 9.5–10.5 m in diameter (T-07, T-02, T-03), are set along a relatively central north–south axis (Fig. 14). The smaller ones, measuring 5.0–8.4 m in diameter, are arranged along a west–east axis from T-09 to T-06. All three large central axis burial mounds (T-02, T-03, T-07) and two additional smaller ones (T-04, T-06) were tested.

T-02

T-02 is located at the gravity center of the sampled unit. It is a dome-shaped burial mound, 10.5 m in diameter and 1.0 m in maximum height. Half of the mound, around 43 m² was excavated with two opposite quadrants (Table 6, Fig. 14). Heavily disturbed remains of three individuals (based on skull count) were exposed at 0.80–1.00 m below the surface in the southeast quadrant (Fig. 15). The poor preservation of the skeletal remains makes the reconstruction of the burial protocol difficult. The individuals appear to have been buried simultaneously. One individual was oriented north–south based on the location of feet bones and skull. A second individual, oriented east–west, was laid on the left side with slightly flexed legs and buried with three spiral-shaped tinkles in alloyed copper and an iron rod placed at the ankle. The implemented inhumation protocol can be reconstructed as follows: (1) The burial location was selected; (2) The deceased was laid crisscrossed on the shell deposit without special preparation; (3) A

Fig. 13 Scatter diagram of early second millennium AD shell measurements



dome-shaped mound made of shells was finally piled above the deceased.

One piece of red ochre, two animal bones, and 210 sherds were collected in the sampled mound deposit. The faunal remains consist of one left calcaneum of

Table 5 Measurements and geographic coordinates of Oudierin-Boundaw burial mounds

Number	Diameter	Height	Latitude	Longitude
Excavated Area (50 m N-S; 50 m E-W)				
T-01	8.00 m	0.50 m	13° 41' 57.1" N	16° 35' 20.6" W
T-02	10.50 m	1.00 m	13° 41' 57.1" N	16° 35' 20.4" W*
T-03	9.50 m	1.50 m	13° 41' 56.7" N	16° 35' 20.0" W*
T-04	6.20 m	1.20 m	13° 41' 57.0" N	16° 35' 19.8" W*
T-05	7.00 m	0.80 m	13° 41' 57.3" N	16° 35' 19.8" W
T-06	6.90 m	0.30 m	13° 41' 57.3" N	16° 35' 20.4" W
T-07	9.50 m	1.50 m	13° 41' 57.3" N	16° 35' 20.6" W*
T-08	5.00 m	0.60 m	13° 41' 57.4" N	16° 35' 19.4" W
T-09	8.40 m	0.45 m	13° 41' 57.1" N	16° 35' 21.0" W
T-10	9.60 m	1.80 m	13° 41' 56.9" N	16° 35' 20.6" W
Other Burial Mounds				
T-11	12.00 m	1.80 m	13° 41' 93.0" N	16° 35' 36.0" W
T-12	8.00 m	1.00 m	13° 41' 32.0" N	16° 35' 35.0" W
T-13	7.50 m	0.50 m	13° 41' 91.0" N	16° 35' 36.0" W
T-14	10.50 m	1.20 m	13° 41' 90.0" N	16° 35' 36.0" W
T-15	8.50 m	1.40 m	13° 41' 89.0" N	16° 35' 35.0" W
T-16	16.00 m	1.65 m	13° 41' 90.0" N	16° 35' 35.0" W
T-17	9.20 m	1.75 m	13° 41' 88.0" N	16° 35' 34.0" W
T-18	6.00 m	0.35 m	13° 41' 87.0" N	16° 35' 33.0" W
T-19	6.00 m	0.40 m	13° 41' 87.0" N	16° 35' 33.0" W
T-20	11.00 m	1.35 m	13° 41' 88.0" N	16° 35' 32.0" W
T-21	11.00 m	2.00 m	13° 41' 88.0" N	16° 35' 33.0" W
T-22	14.80 m	2.00 m	13° 41' 89.0" N	16° 35' 34.0" W
T-23	14.00 m	1.60 m	13° 41' 90.0" N	16° 35' 34.0" W
T-24	12.00 m	1.10 m	13° 41' 91.0" N	16° 35' 34.0" W

Table 5 (continued)

Number	Diameter	Height	Latitude	Longitude
T-25	8.00 m	0.80 m	13° 41' 90.0" N	16° 35' 34.0" W
T-26	10.00 m	1.00 m	13° 41' 90.0" N	16° 35' 33.0" W
T-27	9.00 m	0.60 m	13° 41' 91.0" N	16° 25' 33.0" W
T-28	12.00 m	1.35 m	13° 41' 91.0" N	16° 35' 33.0" W
T-29	16.00 m	1.75 m	13° 41' 92.0" N	16° 35' 34.0" W
T-30	14.00 m	1.30 m	13° 41' 92.0" N	16° 35' 34.0" W
T-31	13.00 m	1.10 m	13° 41' 92.0" N	16° 35' 34.0" W
T-32	13.00 m	1.65 m	13° 41' 92.0" N	16° 35' 33.0" W
T-33	13.00 m	1.20 m	13° 41' 92.0" N	16° 35' 33.0" W
T-34	10.00 m	0.90 m	13° 41' 92.0" N	16° 35' 32.0" W
T-35	5.00 m	0.20 m	13° 41' 92.0" N	16° 35' 32.0" W

* Excavated burial mounds

sheep/goat (*Ovis/Capra*) and one cattle molar (*Bos taurus*). The pottery sample comprises 46 rims and 149 bodysherds, including 95 decorated and 106 non-decorated sherds. Interestingly, there are 22 beveled rims in the analyzed sample (Table 7). Such sherds are assigned to the “Diorom-Boumak Culture” (Thilmans & Descamps, 1982) dating to the early second millennium AD. They are found as far inland as the Senegambian megaliths zone (Holl & Bocoum, 2013, 2017). They are assumed to be linked to the development of extensive long-distance trade networks in coastal West Africa. A charcoal sample collected beneath the skeletal remains at 1.00 m below the surface dates to 1046–1084/1040–1182 cal AD (Gif A20242) (Table 8).

T-03

T-03, the southernmost of the tested burial mounds (Fig. 14), is located a few meters south of the previous one. It measures 9.5 m in diameter and 1.5 m in maximum height (Table 6). Three-quarters of

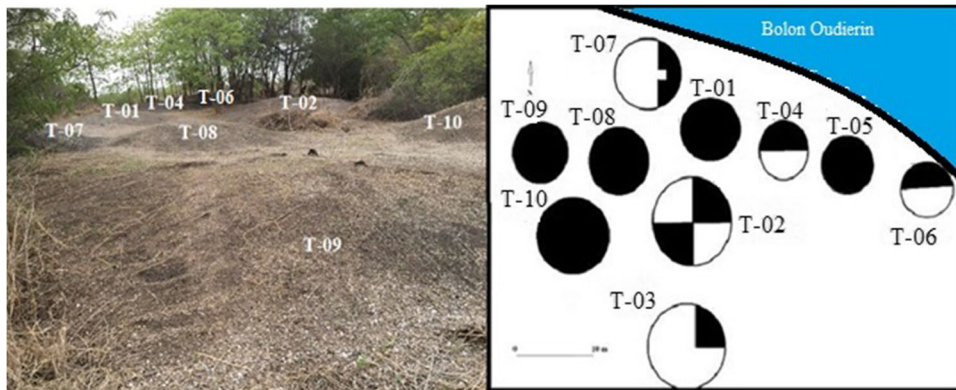


Fig. 14 Partial view from the northwest and map of the sampled portion of Oudierin-Boundaw cemetery

Table 6 Parameters of Oudierin-Boundaw excavated burial mounds

Burial Number	Diameter (m)	Height (m)	Probe size (m ²)	Number of burials	Pottery	Metals	Others
T-02	10.50	1.00	43	3	210	4	2
T-03	9.50	1.50	53	7	519	10	5
T-04	6.20	1.20	24	2	-	-	-
T-06	6.90	0.30	24	-	-	-	-
T-07	9.50	1.50	57	2	166	-	-

the mound (about 53 m²) was excavated, revealing two superimposed inhumation episodes: the earlier one at 1.5–1.8 m below the surface and the latter at 0.4–0.5 m. The first inhumation episode 1 consists of the simultaneous burial of three individuals oriented southeast–northwest (Fig. 15). Individual 1, on the east flank, is an adult male (based on the chin shape), 1.85 m tall, laid in dorsal decubitus, arms and legs extended, the skull crushed, and overlaid by an iron spearhead. A bundle of nine additional iron spearheads was deposited along the right shoulder (Fig. 16). Individual 2, on the west flank, is an adult, likely female, 1.60 m tall, also laid in dorsal decubitus position, arms and legs extended, the skull crushed, with an iron knife blade along the left arm (Fig. 15). And finally, Individual 3, in the middle, is a juvenile, 6–9 years old, based on tooth eruption. The individual is also laid in a dorsal decubitus position in direct contact with Individual 2. The latter’s right arm rested on the child’s remains. At the same time, the child’s right hand was in contact with the forearm of Individual 1. Individual 3 was buried with an alloyed

copper ring at the left wrist and a miniature alloyed copper bell as a pendant (Fig. 16).

The second inhumation episode (0.4–0.5 m) features a complex sequence involving four adult persons—two complete skeletons and two skulls. Both complete skeletons, sharing a similar depositional syntax, were oriented southeast–northwest, buried successively face up in dorsal decubitus, with legs and right arm extended, and left arm slightly flexed. The skulls were added to the initial set of two primary burials. The artifacts from this burial complex include metal objects and pottery. The pottery sample comprised 519 sherds, including 114 rims (75 beveled), 386 bodysherds, and 26 baseshersds. Of these, 330 are non-decorated, while 164 are decorated (Table 7). The iron spearheads present at least four distinct variants of barbed and non-barbed specimens, with alloyed copper items represented by a small arm-ring and a miniature bell (Fig. 16). The few faunal remains consist of two distal ends of the right metapodial and one sheep/goat (*ovis/capra*) molar, one large cattle molar (*Bos taurus*), and a fish cranial fragment. A charcoal sample

Fig. 15 Views of the best-preserved burials from Oudierin-Boundaw Cemetery



Table 7 Pottery distribution from Oudierin-Boundaw burial mounds

Burial Number (kg)	Weight	N	Rim	Beveled Rim	Body	Base	Decorated	Non-Decorated
T-02	3.4	201	46	22	150	6	95	106
T-03	12.6	519	114	75	386	27	164	330
T-07	2.3	166	16	2	148	2	48	118
Total	18.3	876	176	99	684	35	307	554

Table: Potsherds distribution T-07

Sample	Weight (kg)	n	Rim	Bev Rim	Body	Base	Decorated	N. Decorated
0.30–0.60	1.2	66	6	-	58	2	24	42
0.60–0.70	1.1	100	10	2	90	-	24	76

Table 8 Radiocarbon chronology of Oudierin-Boundaw burial mounds

Burial	Sample	Lab Number	Date BP	Calibrated BC/AD	
				1 sigma	2 sigma
Tumulus 02, 1.0 m	Charcoal	Gif A20242	915 ± 25	cal AD 1046: cal AD 1084	cal AD 1040: cal AD 1182
Tumulus 03, 1.3 m	Charcoal	Gif A20243	945 ± 20	cal AD 1115: cal AD 1154	cal AD 1036: cal AD 1158
Tumulus 04, 0.60 m	Charcoal	Gif A20244	850 ± 20	cal AD 1176: cal AD 1224	cal AD 1162: cal AD 1231
Tumulus 06, 0.50 m	Charcoal	Gif A20245	895 ± 20	cal AD 1055: cal AD 1221	cal AD 1150: cal AD 1219
Tumulus 07, 0.50 m	Charcoal	Gif A20246	725 ± 20	cal AD 1272: cal AD 1286	cal AD 1266: cal AD 1297

Fig. 16 Samples of Oudierin-Boundaw metal artifacts

collected at 1.30 m between inhumation episodes 1 and 2 dates the mound to 1115–1154/1036–1158 cal AD (Gif A20243) (Table 8). It is tempting to read the T-03 burial protocols as a high-ranking family group with insignia of status and prestige buried with some of their dependents—an assumption frequently made in the archaeology of the Senegambia (Gallay, 2012; Thilmans et al., 1980). However, this is very difficult to back rigorously with archaeological data (Holl & Bocoum, 2013, 2017).

T-04

T-04 is located in the east-central part of the sampled cemetery area (Fig. 14). It measures 6.2 m in diameter and 1.2 m in maximum height. Three-quarters of the mound (around 24 m²) was sampled, revealing two heavily disturbed and superficial burials. Because of their proximity to the surface, the skeletal remains were significantly affected by bush fires, blackening all the bones. Both skeletons, located at the center of the mound and initially complete, were also extensively trampled and fragmented. The earlier burial at 0.50 m below the surface was oriented east–west, laid in left lateral decubitus, facing south, with legs slightly flexed and arms folded. The deceased was deposited on the shell midden surface, followed by mounding. The later burial at 0.20–0.30 m below the surface was represented by a few long bones, suggesting a north–south orientation. The preservation was so bad that the bones crumbled on the slightest touch. No material culture was recorded. A charcoal sample beneath the early burial at 0.60 m below the surface dates the mound to 1176–1224/1150–1219 cal AD (Gif A20245) (Table 8).

T-06

T-06 measures 6.9 m in diameter with an eroded tumulus some 0.3 m in height (Table 6). It is located at the eastern end of the sampled area overlooking the Bolon Oudierin (Fig. 14). Two-thirds of the burial mound was excavated, including a central test pit probed down to 1.50 m below the surface in the shell midden. Neither material culture nor human

skeletal remains were recorded (Table 7). A charcoal sample collected at 0.50 m below the surface, most likely from the top deposit of the shell midden, provided a reading of 1055–1221/1150–1219 cal AD (Gif A20245) (Table 8). The burial mound was located at the edge of the shell middens, where extensive river erosion probably washed away all its contents.

T-07

T-07 is the northernmost burial mound of the studied cluster (Fig. 14). It measures 9.5 m in diameter and 1.5 m in maximum height. Three-quarters of the mound was excavated, revealing two central burials at 0.55 m below the surface (Table 6, Fig. 13). The excavation proceeded through a central test pit to 1.50 m below the surface to avoid missing a lower series of cultural evidence. There is no physical contact between the exposed skeletons, suggesting that the deceased were buried sequentially. The outline of the skeletons was exposed as accurately as possible. Because of the graves' shallow depth, all the bones were highly fragmented. The northern individual is oriented east–west, laid on the left side, facing south, with arms extended forward and slightly flexed legs. The southern individual is also oriented east–west, laid on the back, the right arm slightly folded, the left one extended forward, the right leg extended, and the left one slightly flexed (Fig. 15); a fragmented but complete pottery vessel was set upside-down next to the skull.

The material culture consisted of a fragmented but complete vessel and 166 potsherds (Table 7). The sherds include 16 rimsherds, two of which are beveled, and 148 bodysherds and two bas sherds; 48 of the sherds are decorated. The complete vessel is a large, open, straight-rimmed bowl decorated with vertical bands of twisted roulette impression delineated by grooved lines. A charcoal sample associated with the burials at 0.50 m below the surface dates these inhumations to 1272–1286/1266–1297 cal AD (Gif A20246) (Table 8).

Summary

The Oudierin-Boundaw cemetery was used around AD 1000–1300 (Table 8). The implemented burial protocol had four main steps: (1) selection of the

burial spot on the shell midden surface; (2) deposition of the deceased on the shell surface; (3) deposition of grave goods where applicable; and finally, (4) construction of a mound above the deceased bodies using the shell midden material. T-03 and T-04 featured successive burial episodes. Simultaneous or near-simultaneous inhumations occurred in T-02 and T-07. All the recorded individuals are adults of unknown age and sex—except the adult male from the early T-30 burial cluster and the child from T-03.

The deceased are predominantly oriented east–west (T-02, T-04, T-07), then north–south (T-02, T-04), and finally southeast–northwest (T-03). The position of the bodies varies considerably but was difficult to outline in some cases. T-03 appears to be the most elaborately choreographed burial with “impressive” sets of iron tools and weapons and jewelry in alloyed copper (Fig. 16). T-02 follows with more modest material remains in alloyed copper and iron. The north–south central axis is made of burial mounds with multiple primary inhumations. The recorded grave goods consist of iron tools and weapons and items of personal adornment in copper, all imported through long-distance trade networks in the region. It is worth mentioning that the excavated burial mounds were all backfilled and returned, as much as possible, to their initial shape and volume.

As documented at Dioron-Boumak (Thilmans & Descamps, 1982), and now supported by additional evidence from Oudierin-Boundaw, the creation of burial mound cemeteries kicked off at the very beginning of the second millennium AD. That period corresponds to the rise of Tekrur, the apex and collapse of the Ghana Kingdom (AD 1000–1200), and the rise and expansion of the Mali Empire (AD 1250–1400), which reached coastal Senegal and the Saloum Delta. The intensification of shellfish exploitation and processing triggered by the development of local, regional, and long-distance trade set the stage for such a dramatic burial practice, a symbolic materialization of claims to the exclusive control of resources from the rich *bolon* drainages.

Conclusion

Unfortunately, the Oudierin Bolon Archaeological Project was significantly disrupted by the Covid-19 pandemic. The initial program to test-excavate and

date (C-14) all the recorded shell middens could not yet be implemented. Samples collected for laboratory processing and analyses must wait for the lifting of international research travel limitations. The results obtained so far open exciting new perspectives on the archaeology of the Saloum Delta shell middens. The exploitation of shellfish started in the early Holocene, some 10,000 years ago. The long-term patterns of their exploitation, obtained from the trench at Oudierin-Boumak, reveal punctuated use, with short periods of relatively intensive collection/processing followed by long periods of abandonment. Four such periods of different durations have been recorded: the early Holocene, mid-Holocene, late Holocene, and early second millennium AD. However, one must remember that shellfish processing could have shifted elsewhere on the large Oudierin-Boumak shell midden (12.5 ha). Therefore, additional probing is necessary to confirm, add nuance to, or falsify the above inference. It is equally plausible that shellfish processing could have shifted to other areas and sites along the *bolon* drainage during the abandonment periods evidenced in the Oudierin-Boumak sequence. This hypothesis will be tested in future fieldwork. A program of systematic archaeological testing and extensive radiocarbon dating of all shell midden sites recorded in the Bolon Oudierin will provide more precise and accurate information and a greater chronological resolution on the dynamics of the regional shellfish economy.

Both Oudierin-Boumak and Oudierin-Boundaw, the largest shell middens in the Oudierin drainage, were contemporaneous during the first quarter of the second millennium AD. The latter was consecrated as a cemetery. Interestingly, there is no single beveled rimsherd characteristic of the so-called “Diorom-Boumak Culture” in the early second millennium AD pottery sample from Oudierin-Boumak shell mounds. In contrast, almost 18% of pottery sherds from the Oudierin-Boundaw burial mounds have beveled rims. The simplest explanation may be that some communities exploiting the Bolon Oudierin shellfish resources were connected to long-distance trade networks, while others were not. Keeping in mind the low chronological resolution of the current archaeological analytical grid, it is important to start moving away from generalizations about stable “cultures” in order to understand better the systemic fluctuations

of past relationships between humans and their environments.

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