

Paleoecological interpretation of a Holocene sand body in the coastal area of Phetchaburi, Gulf of Thailand

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Abstract

Faunal examination is made of 4 samples, 2 from the Recent Ban Laem Phak Bia sand spit, and 2 from the Holocene sand body of Ban Bang Ket. Fossil and modern assemblages are compared on the basis of overall composition, taxa abundances, and of autoecological investigation on life habit, substrate preference, feeding type, depth range and ecological meaning of the identified species. The Holocene assemblage of Ban Bang Ket, compared to the Recent one of Ban Laem Phak Bia, 1) exhibits generally similar overall composition and ecological structure, 2) contains much of the dominant species characterizing the modern assemblage, and 3) includes all taxa that are members of the living molluscan community. On this basis, the molluscan assemblage of Ban Bang Ket results to be the Holocene counterpart of the modern one of Ban Laem Phak Bia, and reflects the same environmental conditions recorded for the latter. Thus, the sand body near Ban Bang Ket is interpreted as a Holocene equivalent of the sand spit of Ban Laem Phak Bia.

Keywords: sand unit, molluscs, Holocene, paleoecology, Thailand.

Introduction

The study examines the molluscan assemblages recovered from a Holocene sand body in the coastal area of Phetchaburi (Fig. 1), and compares them to those occurring on a Recent sand spit located in the Northwestern part of the Gulf of Thailand (Fig. 2), which is regarded to be a modern analog. The purpose is to use this faunal investigation to better interpret the environmental attributes of the Holocene sand body.

Molluscs appear to be notable components of the Holocene marine sequences of Thailand but, to date,

few studies were made, aiming to define molluscan associations and detail their origin. In this respect, reference can be made to Chonglakmani et al. (1983), Dheeradilok et al. (1984), Somboon (1988), Robba et al. (1993), Di Geronimo et al. (2002), Robba et al. (2003) and Di Geronimo et al. (2004). cursory information was provided by Tanabe et al. (2003). Conversely, Holocene taxa were extensively dealt with systematically. A comprehensive treatment of bivalves was compiled by Robba et al. (2002) and a monograph covering scaphopods and gastropods was recently published (Robba et al. 2004). With this as a base, studies were initiated to

define fossil molluscan assemblages and investigate their origin. This is of importance in order to refine the interpretation of the Holocene and most recent environmental evolution of coastal areas of the Northern Gulf of Thailand. In fact, these areas are undergoing very rapid changes because of natural events and accelerated anthropogenic activity.

The fossil taphocoenoses considered herein were obtained in the Phetchaburi coastal plain, at site TH 42 near Ban Bang Ket, along the road connecting Cha Am to Ban Laem Phak Bia (Fig. 2).

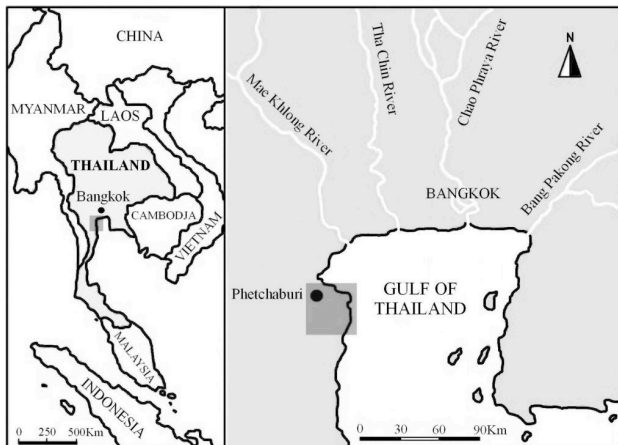


Fig. 1. Map of mainland Southeast Asia showing location of the study area. Details of sample sites are shown in Fig. 2.

There, a 1 m thick deposit is exposed on both sides of an irrigation channel. It consists of 0.90 m of yellow silty sand bearing abundant mollusks, the bivalves often in life position, and sparse pebbles with bivalve borings (sample TH 42A); the silty sand is overlain by 0.10 m of coarse sand with shell heaps and pebbles (sample TH 42B). Calibrated ¹⁴C datings gave an age of 3299±3070 yr BP for sample TH 42A, and of 3070±2977 yr BP for sample TH 42B (Negri 2001). The modern thanatocoenoses (samples 3C and 5C) were collected on the barrier spit east of Ban Laem Phak Bia (Fig. 2). This sand body, stretching southwest-northeast, is approximately 1 km long and reaches a maximum width of 130 m at low tide. Biogenic swash bars parallel to the shoreline were noted along the seaward side, whereas stratified sands with embedded shell layers occur along the northern, lee side (Di Geronimo et al. 2003).

The study focuses on the comparison of the Holocene assemblage recovered near Ban Bang Ket

with the Recent one occurring on the Ban Laem Phak Bia spit. The main underlying principle of this work is that a fossil assemblage similar to a modern one in terms of 1) overall composition and structure, 2) share of dominant species, and 3) presence of all species members of the living community, can be regarded to parallel the latter and its individual taphocoenoses should have formed in basically identical environmental conditions.

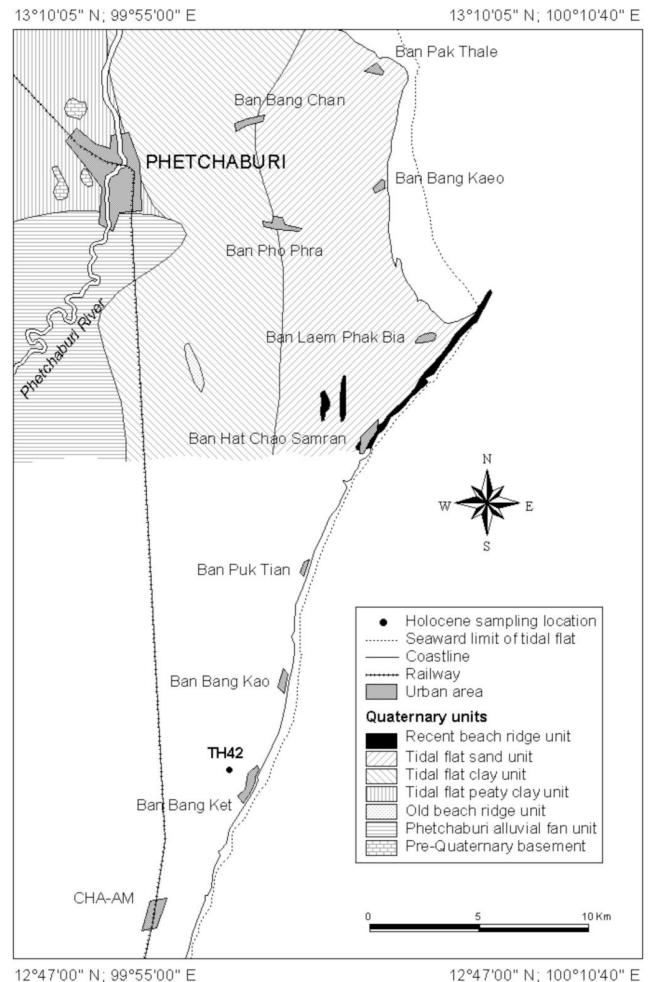


Fig. 2. Position of Holocene sampling site TH 42 and of the modern sand spit (black) northeast of Ban Laem Phak Bia.

Methodology

Faunal examination was made of four samples, two from the modern Ban Laem Phak Bia sand spit, and two from the Holocene sand body of Ban Bang Ket. The Holocene taphocoenoses and Recent thanatocoenoses were bulk-sampled in order to

obtain quantitative data. The mollusks were separated from the terrigenous fraction by means of a 0.5 mm sieve. Shells were identified and the specimens in each taxon were counted following the method proposed by Di Geronimo and Robba (1976). Tables were then prepared, showing the composition of fossil and modern assemblages. In these tables (not included herein), the species are listed with respective abundance (A) and dominance (D) figures recorded in each sample, and ranked according to the decreasing mean dominance (Dm) values calculated for both assemblages. Moreover, observations were made throughout the Ban Laem Phak Bia spit in order to distinguish the living mollusks that colonize the sand. Finally, any available information on the behavioral attributes and some habitat preferences of the considered mollusks was gathered from literature and complemented with personal unpublished data.

Results

This chapter pertains to the description of the fossil and modern assemblages and to the environmental interpretation of the mollusk fauna yielded by the Ban Bang Ket sand body. As shown in the following, the great majority of the species forming the Holocene taphocoenoses and Recent thanatocoenoses are to be considered allochthonous, i.e., they were substantially displaced after death.

Assemblage compositions

The fossil assemblage (187 taxa) and the modern one (150 taxa) exhibit an overall similarity since 98 species are common to both. The Tripartite Similarity Index (Tulloss 1997) provided a significant value of 0.57.

The assemblage of the Holocene sand body (taphocoenoses of samples TH 42A and TH 42B) is mainly composed of free-lying or vagile infaunal species accompanied by members of both attached epifauna and infauna. The taphocoenoses are dominated by suspension-feeders; deposit-feeding and carnivore trophic practices are also important, whereas other feeding groups bear a negligible weight. The bivalves *Bathytormus radiatus*, *Macra luzonica*, *Tellina australis*, *Tellina pallidula*, *Tellina timorensis*, *Gari simplex*, *Donax incarnatus*, *Donax semigranosus*, *Meretrix meretrix*, *Dosinia derupta*, *Corbula modesta*, and the small gastropod

Umbonium vestiarius, that are sand-related and attain together over 36% of cumulative Dm, constitute the most prominent feature of the assemblage. Other characteristic members are the attached epifaunal *Planostrea pestigris* (2,12%), *Dendrostrea rosacea* (9,82%) and *Chama asperella* (1,06%), and the mud-related *Nuculana mauritiana* (5,60%) viewed as indicator for sedimentary instability (Robba et al. 2003). Further dominant species are the gravel-related *Corbula solidula* (1,85%), *Timoclea scabra* (5,68%) that prefers mixed substrates, and *Cardiolucina semperiana* (1,90%), *Tellina semen* (6,66%) and the auger shell *Terebra tantilla* (1,65%) that exhibit a wide ecological range.

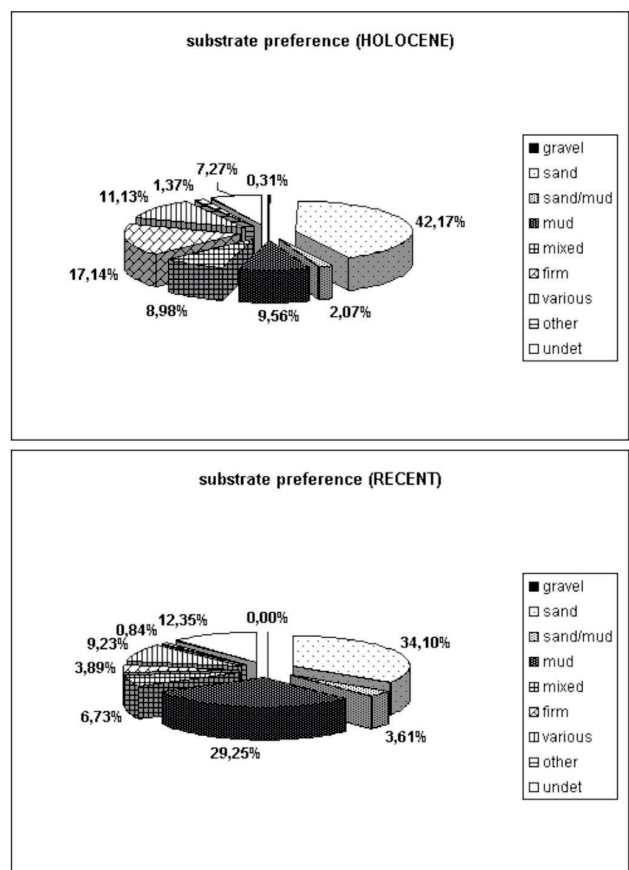


Fig. 3. Relative contribution (cumulative Dm) of substrate influenced categories to the composition of the Holocene (top) and Recent (bottom) assemblages. undet, undetermined.

The Recent assemblage recorded on the Ban Laem Phak Bia sand spit (thanatocoenoses of samples 3C and 5C) is largely composed of infaunal

taxa among which the free-lying shallow burrowers are prevalent. The vagile epifaunal element, primarily pyramidellid gastropods, is also well represented. From a trophic point of view, the thanatocoenoses are dominated by suspension-feeders followed by deposit-feeders and parasites; the other feeding types have negligible cumulative Dm values. The assemblage, as a whole, is similar to that of the Holocene sand body. It is mainly characterized by sand-related taxa, i.e., the bivalves *Scapharca inaequalis*, *Scapharca indica*, *Mactra luzonica*, *Raeta pulchella*, *Tellina pallidula*, *Donax semigranosus*, *Dosinia derupta*, and the tiny gastropods *Cingulina archimedeana* and *Cingulina inaequalis*, that account for over 30% of cumulative Dm.

These taxa are accompanied by the mud-related *Nuculana puellata* (17.18%), *Nuculana mauritiana* (4.03%), *Paphia undulata* (1.24%) and *Chrysallida saurini* (1.10%). Other dominant members, also well represented at Ban Bang Ket, are *Planostrea pestigris* (1.57%), *Cardiolucina semperiana* (5.54%), *Tellina semen* (1.39%) and *Timoclea scabra* (4.86%).

As regards the substrate preference of species, the two assemblages are rather similarly structured and include taxa linked to a variety of bottom types (Fig. 3). The most abundant element is constantly represented by sand dwellers, that attain 42.17% and 34.10% of cumulative Dm respectively in the Holocene and Recent settings. It appears that thanatocoenoses recovered from the Ban Laem Phak Bia sand spit contain a proportion of mud-related species three times as great as that recorded near Ban Bang Ket. This is primarily a function of extensive muddy deposition adjacent to the Ban Laem Phak Bia spit (Di Geronimo et al. 2003), a condition that was probably less so near the Ban Bang Ket sand body.

Concerning the depth range of species (Fig. 4), the assemblages result to be largely composed of shallow water taxa attaining 89.16% and 84.25% of cumulative Dm respectively in the fossil and modern mollusk faunas. It is notable that both assemblages record a basically equivalent proportion, slightly exceeding 10%, of strictly intertidal forms. The lot of species restricted to the intertidal zone or thriving also between tide marks is the most prominent element (61.79%) of the Holocene assemblage; they are followed by the infralittoral taxa that, together, sum up 27.37% of cumulative Dm. In the case of Ban Laem Phak Bia spit, these proportions are in a contrary order: the infralittoral element is more important, with a cumulative Dm that is nearly twice the value recorded for the fossil assemblage and, conversely, the intertidal taxa attain only 39.34% of cumulative Dm. It is manifest that infralittoral mollusks influence the composition of modern thanatocoenoses more than that of Holocene taphocoenoses, likely because of somewhat different wave approach and tidal currents.

The ecological meaning currently refers to the affinity of a species to a given biocoenosis (Pères and Picard 1964; Bernasconi and Robba 1993; Bernasconi and Stanley 1994, 1997). In the present case, since no biocoenoses were defined so far neither in the Gulf of Thailand, nor in Southeast Asian waters, we consider only the affinity of taxa

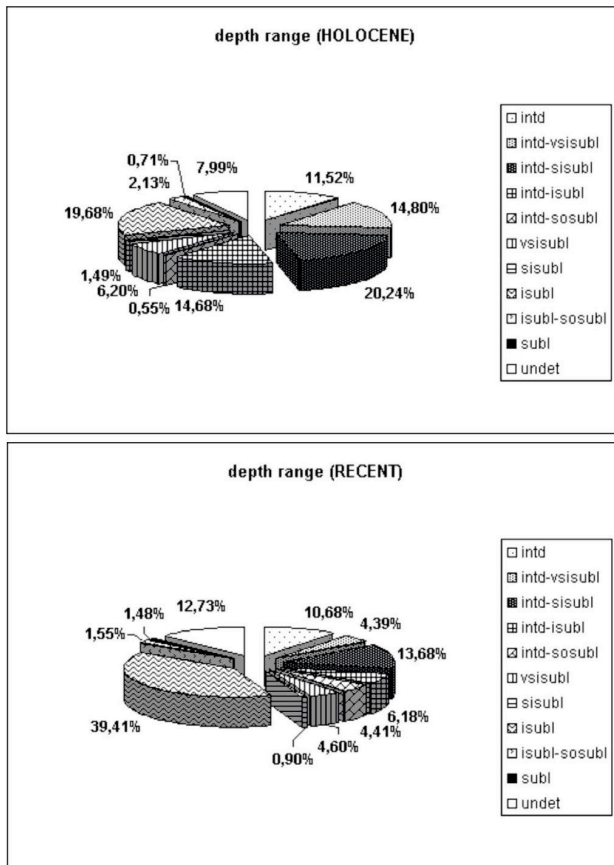


Fig. 4. Relative contribution (cumulative Dm) of depth influenced categories to the composition of the Holocene (top) and Recent (bottom) assemblages. intd, intertidal; vsisl, very shallow inner sublittoral; sisubl, shallow inner sublittoral; isubl, inner sublittoral; sosubl, shallow outer sublittoral; undet, undetermined.

to precise substrate characters, primarily textural features, or to a specific environment. In this context, it is to be noted that the word tolerant applies to species able to endure a small fraction of sediment other than that they are commonly related to. Relative percentages pertaining to ecological categories are depicted in Fig. 5. As expected, strictly sand-related and tolerant sand-related forms appear to be the dominant element in both fossil and modern assemblages. Conversely, strictly mud-related taxa bear negligible values of cumulative Dm, but a greater percentage of tolerant mud-related species was recorded on the Ban Laem Phak Bia spit because of the extensive presence of sandy mud all around that coastal feature. The availability of small hard substrates (pebbles, dead shells) on the seafloor adjacent to the sand accumulation was larger at the Holocene location, as suggested by the greater proportion (12.96%) of species that require this type of ground for attachment. Finally, a slight mangrove influence is to be noticed in both settings (Fig. 5).

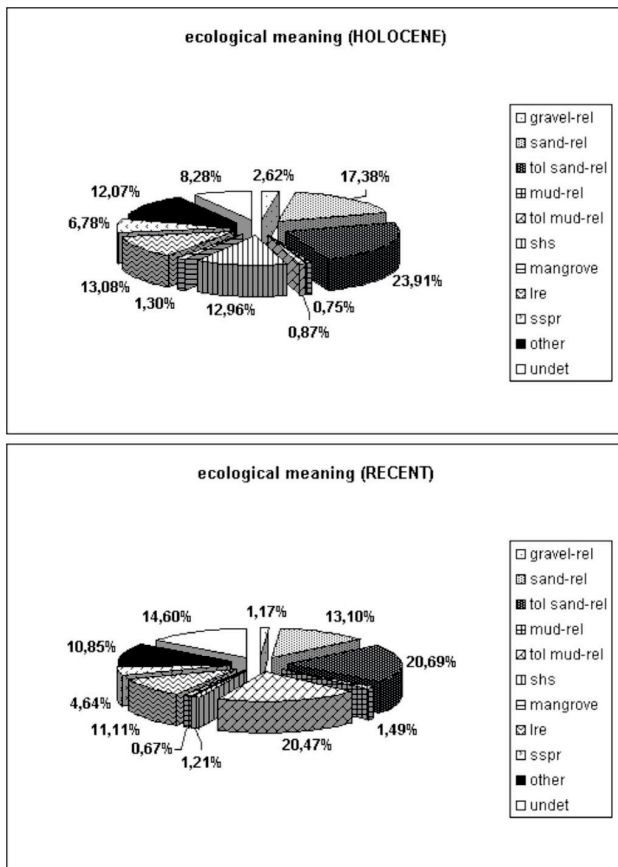


Fig. 5. Relative contribution (cumulative Dm) of ecological categories to the composition of the Holocene

(top) and Recent (bottom) assemblages. rel, related; tol, tolerant; shs, small hard substrates; lre, wide ecological range; sspr, no precise ecological meaning; undet, undetermined.

DOMINANT SPECIES (Dm ≥ 1,00%)	Ban Laem Phak Bia (RECENT)		Ban Bang Ket (HOLOCENE)	
	Am	Dm	Am	Dm
<i>Nuculana puellata</i>	1540	17,18		
<i>Donax semigranosus</i>	640	9,60	75,5	5,62
<i>Dosinia derupta</i>	466,5	6,74	149,5	11,08
<i>Cardiolucina semperiana</i>	547	5,54	26,5	1,90
<i>Timoclea scabra</i>	424,5	4,86	76,5	5,68
<i>Chemnitzia nodai</i>	378	4,53		
<i>Nuculana mauritiana</i>	324	4,03	73,5	5,60
<i>Maetra luzonica</i>	176,25	2,83	51,5	3,82
<i>Tellina pallidula</i>	241	2,71	14,5	1,06
<i>Scapharca inaequivalvis</i>	142	2,30		
<i>Raeta pulchella</i>	114	2,06		
<i>Scapharca indica</i>	81,5	1,68		
<i>Planostrea pestigris</i>	62	1,57	27,0	2,12
<i>Lucidestea sp.</i>	92	1,53		
<i>Tellina semen</i>	146	1,39	87,5	6,66
<i>Cingulina inaequalis</i>	104	1,25		
<i>Paphia undulata</i>	75,5	1,24		
<i>Chrysallida melvilli</i>	98	1,11		
<i>Chrysallida saurini</i>	72	1,10		
<i>Dosinia tumida</i>	68	1,09		
<i>Cingulina archimedeae</i>	56	1,07		
<i>Dendostrea rosacea</i>			139,5	9,82
<i>Umbonium vestiarium</i>			45,5	3,40
<i>Meretrix meretrix</i>			32,0	2,30
<i>Gari simplex</i>			28,0	2,17
<i>Corbula solidula</i>			25,0	1,85
<i>Lucina vemusta</i>			24,5	1,77
<i>Terebra tantilla</i>			23,5	1,65
<i>Corbula modesta</i>			20,5	1,51
<i>Tellina australis</i>			17,5	1,47
<i>Bathytormus radiatus</i>			16,0	1,20
<i>Tellina timorensis</i>			14,5	1,20
<i>Donax incarnatus</i>			15,0	1,14
<i>Chama asperella</i>			14,0	1,06

Tab. 1. Dominant species (mean dominance ≥ 1.00%) in the recovered assemblages. Taxa are ranked according to the decreasing Dm values calculated for the modern assemblage.

It is recalled that the Ban Laem Phak Bia sand spit is a coastal structure with a considerable input

of dead shells and shell debris from the surrounding marine environments (Di Geronimo et al. 2003).

The largely allochthonous nature of the thanatocoenoses, suggested by their composition, is consistent with that peculiar environmental setting, and the same would be true as regards the sand accumulation of Ban Bang Ket. Except for minor differences that are a response to moderate variations of physical and biogenic depositional processes, the Holocene assemblage appears to be generally similar to the Recent one, and statistically comparable to it.

The dominant taxa

In this study, taxa having a Dm value equal to 1.00% or greater are regarded as dominant. A total of 22 and 21 species fulfill this requirement, respectively, in the fossil and modern assemblages, together accounting for 75.41% and 74.08% of cumulative Dm, and are considered to describe adequately the assemblage they belong to. The dominant species are listed in Tab. 1, and ranked according to the decreasing Dm values calculated for the Recent assemblage. Nine taxa, i.e., *Nuculana mauritiana*, *Planostrea pestigris*, *Cardiolumina semperiana*, *Mactra luzonica*, *Tellina pallidula*, *Tellina semen*, *Donax semigranosus*, *Timoclea scabra* and *Dosinia derupta* are dominant in both assemblages. Respective Dm figures in the fossil and modern mollusk faunas are either comparable or can be quite different. Another 18 taxa, i.e., the bivalves *Scapharca inaequalis*, *Scapharca indica*, *Chama asperella*, *Lucina venusta*, *Bathytormus radiatus*, *Raeta pulchella*, *Tellina australis*, *Tellina timorensis*, *Gari simplex*, *Donax incarnatus*, *Meretrix meretrix*, *Paphia undulata*, *Dosinia tumida*, *Corbula solidula*, and the gastropods *Umboonium vestiarium*, *Terebra tantilla*, *Chemnitzia nodai* and *Cingulina archimedeana* resulted to be dominant only in one assemblage (Holocene or Recent), but are significantly present (Dm > 0.1) also in the other. The rest of the dominant species (7 taxa) were recorded in one assemblage, whereas they are absent from the other.

The high proportion (over 79%) of key species common to the considered assemblages, and often dominant in both, provides evidence for the remarkable similarity of these latter. By taking into account also the findings of the previous section, it appears that the individual taphocoenoses and thanatocoenoses that compose respectively the fossil

and modern assemblages have the same nature, and reflect basically similar environmental settings.

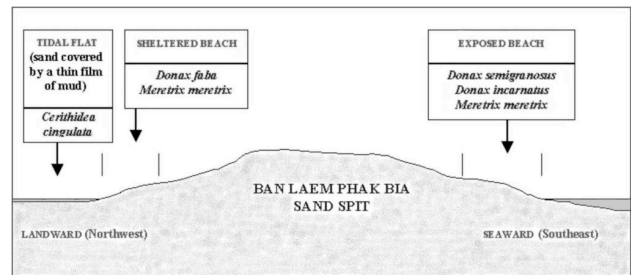


Fig. 6. Distribution of live species across the Ban Laem Phak Bia sand spit.

The living molluscan community

Observations made throughout the modern sand spit of Ban Laem Phak Bia have shown that a living molluscan community does exist there (Fig. 6), formed by few taxa adapted to reside in this intertidal, highly dynamic environment. The exposed beach along the seaward side of the spit houses a rather rich population of the surf clam *Donax semigranosus*. Uncommon live specimens of *Donax incarnatus* and of the venerid clam *Meretrix meretrix* were noted to co-occur with *Donax semigranosus*. The sheltered landward beach is dwelled by *Donax faba* accompanied by *Meretrix meretrix*. The latter taxon, that is remarkably large-sized, is collected for food by local villagers all along this beach. It is notable that the distribution of *Donax semigranosus* and *Donax incarnatus* seems not to overlap that of *Donax faba*. These findings appear to agree with the results of other surveys carried out at several coastal locations in the Indo-West Pacific (Baissac et al. 1962; Reys and Reys 1966; Picard 1967; Pichon 1967; Purchon and Purchon 1981; Ansell 1985). The sheltered beach grades into a vast tidal flat, predominantly muddy, and bounded landward by extensive mangrove swamps. At the transition, where the sand is floored by a thin film of mud, abundant specimens of the cerithioidean gastropod *Cerithidea cingulata* were observed to crawl about on the surface of the mud. This snail is a common mangrove swamp dweller (Robba et al. 2003), but can occur in abundance outside the mangrove, on sheltered tidal flats rich in plant debris. Other molluscan taxa, such as *Atactodea glabrata*,

Caecella chinensis and *Umbonium vestiarius*, were reported to currently inhabit sandy intertidal substrates (Purchon and Purchon 1981; Ansell 1985; Al Bakri et al. 1997). Our investigation, however, recovered only dead shells of *Umbonium vestiarius*. Thus, we focus on the first 5 species cited above, that are also present in the Holocene sand body of Ban Bang Ket, and are supposed to compose the molluscan community living there at that time.

In order to refine the comparison, the dominance (D) pertaining to these 5 species, in both fossil and modern assemblages, was recalculated as the proportion of the cumulative abundance relative only to the considered forms. The result of this elaboration is shown in Tab. 2, where taxa are ranked according to the decreasing Dm values. Besides the identical composition, it is worthy of note that each species has the same rank in both Holocene and Recent assemblages and this provides further evidence in support of the close similarity of the two mollusk faunas.

Ban Bang Ket (HOLOCENE)	TH 42A		TH 42B		Am	Dm
	A	D	A	D		
<i>Donax semigranosus</i>	63	60,58	88	55,00	75,5	57,79
<i>Meretrix meretrix</i>	21	20,19	43	26,88	32,0	23,53
<i>Donax incarnatus</i>	14	13,46	16	10,00	15,0	11,73
<i>Donax faba</i>	5	4,81	9	5,63	7,0	5,22
<i>Cerithidea cingulata</i>	1	0,96	4	2,50	2,5	1,73
totals	104		160		132	

Ban Laem Phak Bia (RECENT)	3 C		5 C		Am	Dm
	A	D	A	D		
<i>Donax semigranosus</i>	1074	93,88	206	95,81	640,0	94,85
<i>Meretrix meretrix</i>	20	1,75	9	4,19	14,5	2,97
<i>Donax incarnatus</i>	24	2,10			12,0	1,05
<i>Donax faba</i>	22	1,92			11,0	0,96
<i>Cerithidea cingulata</i>	4	0,35			2,0	0,17
totals	1144		215		680	

Tab. 2. Recalculated D and Dm values pertaining to the species living on the Ban Laem Phak Bia sand spit (bottom) and assumed to have resided also on the Holocene sand body (top).

Summary and conclusions

This study represents an attempt to use modern molluscan assemblages in reconstructing the

environmental meaning of Holocene assemblages recovered inland in the coastal areas of the Northern Gulf of Thailand. This approach has proved to be efficient as regards other Holocene assemblages from various localities in the Lower Central Plain of Bangkok (Robba et al. 2003).

Fossil taphocoenoses and modern thanatocoenoses were compared on the basis of overall composition, taxa abundances, and of an autoecological investigation that provides information on life habit, substrate preference, feeding type, depth range and ecological meaning for the identified species. Dominant taxa, accounting for over 70% of cumulative mean dominance (Dm) in both assemblages, were considered to be relevant to describe and compare the assemblages, as is the stock of species that form the living community and occur in the fossil one as well.

Findings of the present study show that the Holocene assemblage of Ban Bang Ket, compared to the Recent one of Ban Laem Phak Bia, has 1) generally similar overall composition and ecological structure, 2) contains much of the dominant species characterizing the modern assemblage, and 3) includes, with comparable proportions, all taxa that are members of the living molluscan community. Thus, it is manifest that the basic principles cited in a previous section of this paper are fulfilled. We conclude that the molluscan assemblage of Ban Bang Ket is the Holocene counterpart of the modern one recovered at Ban Laem Phak Bia and reflects the same environmental conditions recorded for the latter. Accordingly, the sand body near Ban Bang Ket is interpreted as a Holocene equivalent of the sand spit of Ban Laem Phak Bia.

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Riassunto

[Interpretazione paleoecologica di un corpo sabbioso olocenico nell'area costiera di Phetchaburi, Golfo di Thailandia]

Il presente lavoro si propone di analizzare le tanatocenosi a molluschi rinvenute in sedimenti sabbiosi nell'area costiera della Provincia di Phetchaburi, nella parte settentrionale del Golfo di Thailandia. Due campioni provenienti da depositi olocenici nei pressi di Ban Bang Ket, con un'età radiometrica di circa 3000 anni, sono stati confrontati con altrettanti campioni prelevati su una barra sabbiosa di neoformazione davanti a Ban Laem Phak Bia; sono state prese in considerazione la composizione faunistica, l'abbondanza dei singoli taxa e la relativa autoecologia. Quest'ultima comprende

informazioni relative al modo di vita, al trofismo, alle esigenze di substrato, all'intervallo batimetrico e al significato ecologico delle specie considerate.

L'associazione olocenica di Ban Bang Ket, che conta 187 taxa, mostra significative somiglianze con quella attuale di Ban Laem Phak Bia (150). Entrambe le faune possiedono una composizione tassonomica generalmente simile, con ben 98 specie in comune. Nove taxa risultano dominanti in entrambi i casi, mentre 18 lo sono in una sola associazione ma sono comunque significativamente presenti anche nell'altra. Inoltre, l'associazione olocenica comprende, in proporzioni paragonabili, tutti i taxa che fanno oggi parte della biocenosi, vale a dire i donacidi *Donax semigranosus*, *D. incarnatus* e *D. faba*, il veneride *Meretrix meretrix* ed il gasteropode *Cerithidea cingulata*. Le informazioni disponibili circa le esigenze ecologiche delle specie rinvenute mostrano sostanziali analogie tra le strutture delle due associazioni, con lievi discrepanze dovute all'influenza di fattori locali (diverso apporto di sedimenti fini, differenti regimi di marea e moto ondoso).

Sulla base di questi dati, si può considerare l'associazione di Ban Bang Ket come l'analogo olocenico di quella attualmente presente sulla barra sabbiosa di Ban Laem Phak Bia. L'associazione fossile riflette quindi le medesime condizioni ambientali di quella attuale, e il corpo sabbioso costiero olocenico può essere considerato un equivalente dello spit sabbioso oggi in formazione.