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Shallow water ostracods near the Mae Khlong river mouth (NW Gulf of Thailand)

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ABSTRACT – *The study of the ostracod fauna of shallow marine environments strongly influenced by human activity off the Mae Khlong river mouth (NW Gulf of Thailand, north of Phetchaburi) allows the identification of 34 species, belonging to thanatocoenosis and, subordinately, to biocoenosis. The relationships between ostracods and water depth and substrate are discussed in order to identify species which are tolerant of the changes in these environmental parameters. Ostracod distributions are also related to salinity, pH and dissolved oxygen. Moreover, using the Shannon Weaver index as a measure of ecosystem health, it has been possible to highlight the deterioration of environmental conditions at the investigated sampling stations and to identify the species which are tolerant of human-induced environmental changes.*

RIASSUNTO – [Ostracodi costieri di fronte la foce del fiume Mae Khlong (Golfo della Thailandia nord-occidentale)] – *Lo studio dell'ostracofauna di ambienti marini costieri fortemente antropizzati, di fronte la foce del Mae Khlong, a nord di Phetchaburi (Golfo di Thailandia nord-occidentale) ha consentito l'identificazione di 34 specie appartenenti a tanatocenosi e, in subordine, biocenosi. Questa area risulta fortemente influenzata dal Mae Khlong, il secondo fiume della Thailandia, che drena inquinanti e nutrienti. Le relazioni ostracodi-profondità e ostracodi-substrato mettono in evidenza specie più o meno tolleranti le variazioni di questi fattori ambientali. La diffusione degli ostracodi è messa anche in relazione alla salinità, pH e ossigeno disciolto. L'utilizzo dell'indice di Shannon-Weaver evidenzia nelle stazioni di campionatura condizioni ambientali convenzionalmente definite cattive, intermedie e cattive. Sulla base di questi dati è possibile identificare ostracodi caratteristici delle condizioni ambientali suddette. Ne consegue, che tra le specie si può individuare una differente capacità di tollerare cambiamenti delle condizioni ambientali, tanto da riconoscere forme che potrebbero essere molto utili nel monitoraggio ambientale di ambienti costieri della Thailandia.*

INTRODUCTION

The investigated coastal area, north of Phetchaburi (NW Gulf of Thailand), is strongly influenced by several rivers including the Mae Khlong, which is the second largest river of Thailand in terms of discharge (Text-fig. 1). This sector of the Gulf experiences high levels of pollutants and nutrients due to the high level of development along the coast. Thus, the human impact allows us to consider this coastal area as one in which ostracods can play a role in determining the quality of environmental conditions. The aims of this study are: 1) to identify the ostracod species, 2) to determine the links between ostracods and environmental parameters, focusing mainly on depth and substrate, as well as salinity, pH and dissolved oxygen, 3) to recognize ostracod species indicating possible deterioration of environmental conditions in the area, and 4) to highlight species which are tolerant of environmental variations.

THE MAE KHLONG RIVER DELTA ENVIRONMENT

The littoral area off the Mae Khlong mouth is a fragile ecosystem due to its very variable environmental conditions, caused by the influence of fresh water influx, pollutants and nutrients, a high tidal range (2 m) and its proximity to coastal mangrove habitats.

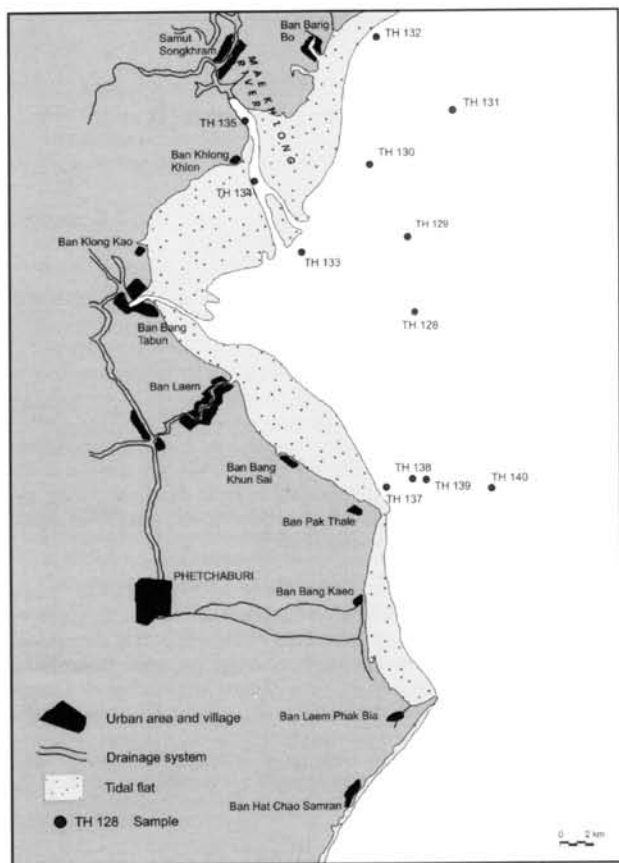
The sampling stations for this study are located in channels within the tidal flat and in the shallow shelf. The tidal flat shows different widths along the area. Northwards, in the front of the Mae Khlong river mouth, it spans over 4 km (Text-fig. 1). Southward, it is narrow with its minimum (0.5 km) south of Ban Pak Thale. The investigated bottoms are included in the depth range 1-15 m.

This sector of the Gulf of Thailand is affected by the sediment discharge of the Mae Khlong, Tha Chin, and Chao Phraya rivers. The discharge is influenced by the coastal morphology and by the direction and strength of the local winds which control the sediment longshore drift.

Northeast of the Mae Khlong river mouth, the benthic habitats are characterized seawards by subparallel belts of silty sand (tidal flat), slightly sandy silt and silt; moreover, sandy silt bottoms characterize the channels of the tidal flat and of some northeastern sectors.

The southern area, between Ban Laem to Ban Bang Kaeo, is characterized seawards by subparallel irregularly outlined belts of silt, sandy silt, slightly sandy silt and silt.

The fresh water influence is strong in the area and causes wide variations of the environmental parameters, such as temperature, salinity, pH, and dissolved oxygen. The measurements of these parameters are re-



Text-fig. 1 - Location map of the sampling stations in front of Mae Khlong river mouth (after Chaimanee *et al.*, 1999, modified).

ported by Chaimanee *et al.* (1999) for the period 23-31 March 1996. Moreover, similar values for these parameters are confirmed for May 2001 (Di Gerónimo *et al.*, in progress). Although these measurements denote a seasonal value, they may indicate a trend for the environmental conditions of this coastal area. Thus, it is possible to observe that:

1) surface temperature varies from 30.8°C, near Ban Bang Bo, to 28.7°C southeast of the cape near Ban Pak Thale. The lowest temperatures are recorded in front of the Mae Khlong river mouth and along the transect southeast of Ban Pak Thale. Bottom temperatures range from 30.6°C to 27.1°C at these same sites. Minimal bottom and surface temperatures coincide in the same location. Southwards, just above a sandy spit, the coldest water in the area occurs, characterized also by low salinity values, caused by a submarine spring;

2) salinity experiences remarkable variability mainly related to the distance from the river mouth. For example, it ranges from 6‰, in the surface waters at the river mouth, to 32‰ in distal coastal waters. In front of the river mouth, the low-density continental fresh waters flowing at the surface causes very low

salinity values. The influence of the fresh waters, drained by the Mae Khlong river in the Gulf, is evident throughout the area north of the sandy spit, whereas its influence is minor southward, where salinity is always higher than 30‰ in both surface and bottom waters. Finally, in front of the sandy spit, the previously mentioned low salinity water body strongly affects the surrounding area causing reduced salinity;

3) dissolved oxygen values are low, seemingly due to the strong human influence on the coastal area. Surface and bottom conditions present the same exiguous values. In the northernmost area, the surface and bottom values are almost constant at 3.6 ml/l. In the transect between the cape near Ban Pak Thale and the sandy spit, the bottom waters show values ranging from 3.4 ml/l to 4 ml/l. They denote the influence of less contaminated waters coming from the south, meanwhile the surface waters are charged in organic and industrial pollutants;

4) pH values follow the same trend as dissolved oxygen. In the north, the values are low and range from 5.0 to 6.6 whereas in the south, the range is between 7.0 and 8.2. The minimal value of 5.8 is recorded in front of the sandy spit, linked to the fresh water body trapped into the loop of currents coming from the south.

MATERIALS AND METHODS

We studied 12 grab-samples collected at depths ranging from 1 to 15 m during May 2002. Most samples belong to the upper infralittoral zone, while two samples (TH 134 and TH 135) are included in the mesolittoral one.

For each sample, a standard volume 25 cc was washed through a 63 µm mesh. Subsequently, the ostracods of a half sample were picked taking into account the adult and the presence of young specimens, belonging to biocoenosis and thanatocoenosis. Moreover, the adult specimens were counted, while the juveniles were only recorded. Particular attention was made to the recognition of autochthonous and displaced specimens. Species were considered as autochthonous in a sample when represented by living specimens and/or by the contemporarily presence of adults and juveniles, males and females. Displaced species are considered those characterized by the exclusive presence of juveniles and/or bad-preserved specimens.

From the sedimentological point of view, the samples TH 138, TH 137, and TH 131 are sandy silts, the samples TH 128, TH 129, TH 130, and TH 140 are silts, the samples TH 133 and TH 139 are fairly sandy silts, the samples TH 134 and TH 135 are sands, and the sample TH 132 is silty sand (Chaimanee *et al.*, 1999).

OSTRACOD FAUNA

The ostracod fauna consists of 34 species (Tab. 1);

among them 19 species are considered autochthonous at least at one sampling station (Pls 1, 2). Table 1 also lists the living species. Thirteen species are in open nomenclature. The ostracod diversity varies from 1 (TH 135) to 14 species (TH 138). In general, the samples characterized by a high/reduced number of species show abundant/sparse specimens.

Most of the species have already been recorded in the Indo-Pacific region (Carbonel & Hoibian, 1988; Hussain, 1998; Hussain & Mohan, 2000; Shreeyansh, 1978; Titterton *et al.*, 2001; Whatley & Zhao, 1987, 1988; Yassini *et al.*, 1993; Zhao & Whatley, 1989, 1993, *inter alia*).

Three groups of species can be recognized on the basis of their number of specimens. The first group includes 6 species which are usually very abundant: *Stigmatocythere bona* (61 specimens), *Neomonoceratina iniqua* (62 specimens), *Keijella gonia* (76 specimens), *Sinocytheridea impressa* (58 specimens), *Neocyprideis* sp. 1 (80 specimens), and *Keijella multisulcus* (106 specimens). The above mentioned species show their maximum values in samples TH 137 and TH 138 (the first three species), in sample TH 140 (the fourth spe-

cies), in samples TH 132 and TH 137 (the fifth species) and samples TH 128 and TH 130 (the sixth species). The second group consists of 6 species, which show a low abundance and occur occasionally: *Gerdocypris* sp. (14 specimens), *Cytherella hemipunctata* (14 specimens), *Hemicytheridea cancellata* (20 specimens), *Tanella gracilis* (23 specimens), *Hemikrithe peterseni* (24 specimens), and *Hemikrithe orientalis* (24 specimens). The third group is constituted by rare species, always represented by a few specimens: *Phlyctenophora* cf. *P. orientalis*, *Bairdia* sp. 1, and *Pontocypris attenuata* (1 specimen), *Stigmatocythere indica* (6 specimens), and *Neosinocythere elongata* (7 specimens).

OSTRACODS AND ENVIRONMENTAL PARAMETERS

The following sections deal with a discussion of the relationships between autochthonous ostracods and environmental parameters. The discussion concerns the species which are considered autochthonous in at least two samples.

For species already recorded in the region, it has been possible to compare environmental data obtained

SAMPLING STATIONS	TH 132	TH 128	TH 133	TH 129	TH 135	TH 138	TH 137	TH 130	TH 139	TH 140	TH 134	TH 131
DEPTH in m	1.5	9	1	9	4	5	1.5	5	7	15	1	5
SUBSTRATE	sS	s	sl Ss	s	S	Ss	Ss	s	sl Ss	s	S	Ss
<i>Bairdia</i> sp.		1x								x		
<i>Carinocythereis</i> sp.	1											
<i>Cistacythereis</i> sp.							x					
<i>Copysus posterosulcus</i> Wang						1x			4x	2x		
<i>Cytherella hemipuncta</i> Swanson	1x + 1b			x		4x	x	1x	1x	x	x	6x
<i>Cytherella</i> spp.										x		x
<i>Cytherois</i> sp.										x		
<i>Foveoleberis cypraeoides</i> (Brady)										x		
<i>Gerdocypris</i> sp.	x	3		x		x	2	8x	2x	4x		x
<i>Hemicytheridea cancellata</i> (Brady)	1x + 1b	1				2x	8x	1x	x	x		7x
<i>Hemicytheridea</i> sp.1												x
<i>Hemikrithe orientalis</i> van den Bold		1				8	3x	3	9x	4x		1
<i>Hemikrithe peterseni</i> Jain						10 + 1b	2		7x	2x		4x
<i>Keijella gonia</i> Zhao & Whatley	6x	9x	1	1x		10x + 13b	12x + 2b	5x + 2b	6x	2x		8x
<i>Keijella multisulcus</i> Whatley & Quanhong	6x + 2b	21x	8 x	12x + 1b	x	2 + 3b	6x + 2b	18x + 1b	9x	7x		8x
<i>Keijella papuensis</i> (Brady)										x		x
<i>Malaycythereis trachodes</i> Zhao & Whatley			1									
<i>Neocytheretta multilineata</i> Zhao & Whatley						1x	3x					
<i>Neocytheretta</i> sp.							x					
<i>Neocyprideis</i> sp.1	32x + 5b		6 x	1	4r	3x	30x + 4b	x	x		x	
<i>Neomonoceratina iniqua</i> (Brady)	1x + 3b	9x+1b		1x		16x+1b	5x + 8b	1x + 6b	4x	3x		3x
<i>Neosinocythere elongata</i> (Hu)			1b						1	6x		
<i>Paracytherois</i> sp.		x										
<i>Paradoxostoma</i> sp.	x							x		x		
<i>Phlyctenophora orientalis</i> (Brady)						1x			x			
<i>Pontocypris attenuata</i> Brady		1x										
<i>Propontocypris</i> spp.		x		x		x		x	x	x		x
<i>Pseudopsammocythere</i> sp.										x		
<i>Sclerochilus</i> sp.		x										
<i>Sinocytheridea impressa</i> (Brady)	3	4+1b		1x		8x + 2b	10x	x	10x	17x	x	5x
<i>Stigmatocythere bona</i> Chen	3x	2		3x + 1b		11x + 3b	28x + 3b	3x + 1b	2x	2x		1x
<i>Stigmatocythere indica</i> (Jain)	x	1				2 + 1b			2x	8x		1
<i>Stigmatocythere roesmani</i> (Kingma)										x		
<i>Tanella gracilis</i> Kingma	1x		1b				20x + 1b			x	x	

Tab. 1 - Ostracods of the investigated area. 1 = specimen of thanatocoenosis; 1b = specimen of biocoenosis; x = presence of juveniles; r = reworked. Legend for the substrate: S) sand; sS) silty sand; Ss) sandy silt; sl Ss) slightly sandy silt; s) silt.

here with those derived from other Indo-Pacific regions.

OSTRACODS VERSUS DEPTH

The autochthonous ostracods occur in the infralittoral sampling stations, only. Two groups of species can be separated in relation to their distribution, the former with a wide and the latter with a limited depth range (Tab. 2):

1) species having a wide depth range: *Keijella multisulcus* and *Neosinocythere elongata* (1-15 m); *Keijella gonia*, *Hemikrithe orientalis*, *Neomonoceratina iniqua*, *Sinocytheridea impressa*, and *Stigmatocythere bona* (1.5-15 m); *Copypus posterosulcus*, *Gerdocypris* sp., *Hemikrithe peterseni*, and *Stigmatocythere indica* (5-15 m).

2) species having a limited depth range: *Tanella gracilis* (1-1.5 m); *Hemicytheridea cancellata*, *Neocyprideis* sp. 1, and *Neocytheretta murilineata* (1.5-5 m); *Cytherella hemipunctata* (1.5-7 m).

The first group comprises *Neosinocythere elongata*, which occurs along the China Sea (estuaries, tidal flats, subtidal settings <20m of depth) as reported by Zhao & Whatley (1993), and in the Jason Bay, SE Malay at depths <20m (Zhao & Whatley, 1989). *Keijella gonia* is present at 7 m in the Jason Bay (Zhao & Whatley, 1989); *Copypus posterosulcus* and *Stigmatocythere indica* live in the Malacca Strait at 28-29 m (Whatley & Zao, 1987, 1988).

Among the species of the second group *Hemicytheridea cancellata* is present between 0 and 20 m in the Mannar Gulf (Hussain, 1998) and from 25 to 38 m in the Malacca Strait (Whatley & Zhao, 1987, 1988); *Neocytheretta murilineata* occurs between 0 and 20 m in the Mannar Gulf (Hussain, 1998) and from 6 to 20 m in the Jason Bay (Zhao & Whatley, 1989); *Tanella gracilis* is present in Malacca Strait from 25 to 45 m (Whatley & Zhao, 1987, 1988).

It appears obvious that the data obtained in this study generally agree with the ostracod distribution of nearby geographic areas, since the species occur always at shallow depth. The only exception is *Cytherella hemipunctata*, which was previously known from 75 to 100 m in the Malacca Strait (Whatley & Zhao,

1987, 1988). Its distribution depth is here widened to shallower waters.

OSTRACODS VERSUS SUBSTRATE

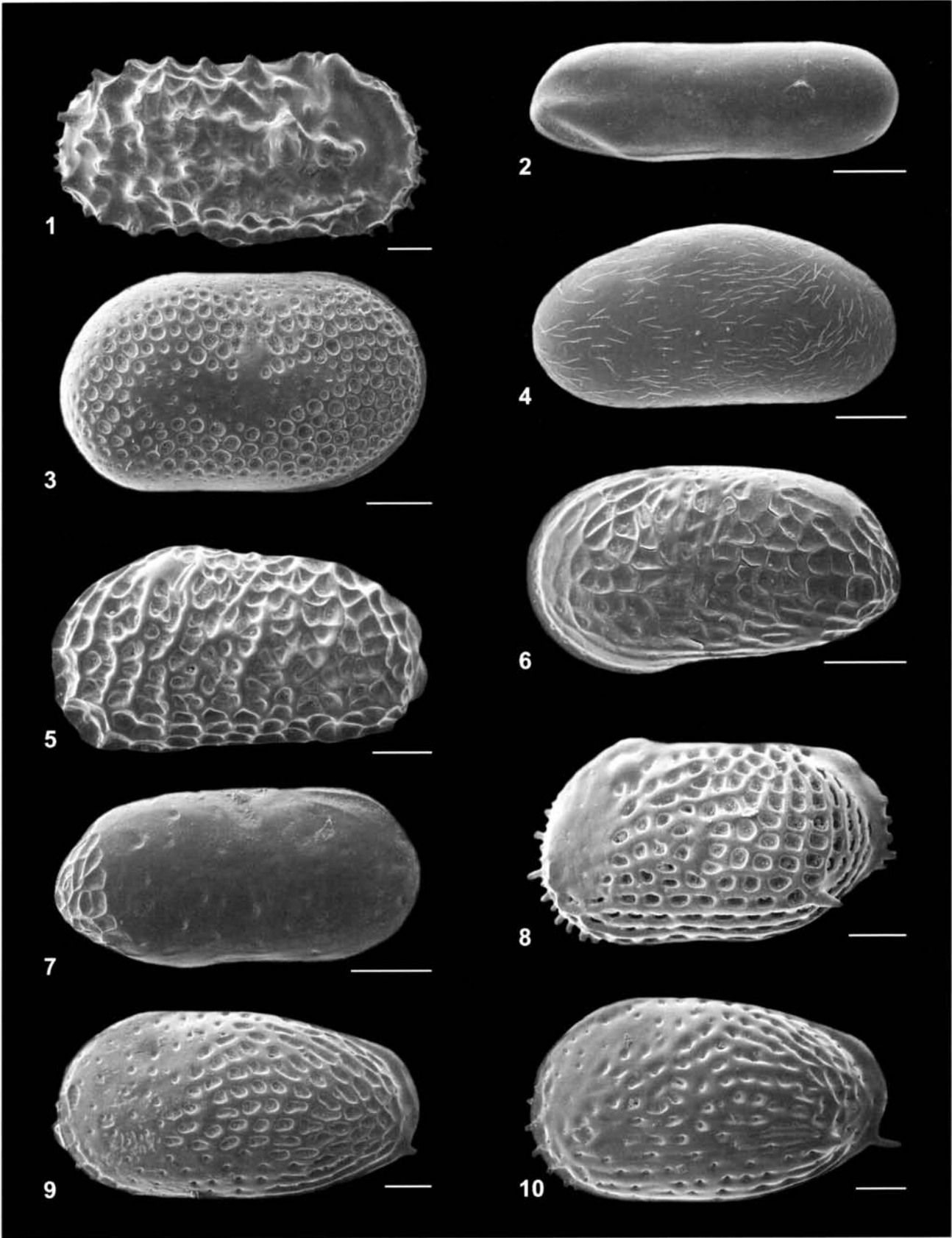
Data in Tab. 3 shows that the ostracods usually avoid the coarsest sediments and prefer the finest ones being absent or very rare on sandy bottoms, as in mesolittoral samples TH 134 and TH 135. The ostracod fauna shows a higher diversity (9 species) and abundance (66 specimens) in the silty sands (sample TH 132). The diversity and abundance generally increase in sandy silts (TH 131, TH 137, TH 138), reaching their maximum in stations TH 138 (14 species, 103 specimens) and TH 137 (11 species, 148 specimens). In slightly sandy silts the diversity may be low (TH 133: 2 species) or high (TH 139: 12 species) and the abundance is generally low (TH 133: 14 specimens; TH 139: 57 specimens). Diversity generally shows intermediate values (from 6 to 11 species) in silty bottoms (stations TH 130, TH 128, TH 129, and TH 140), while abundance varies from 21 to 50 specimens. Thus, in this area ostracods show a preference towards bottoms characterized by silty sediments with a high sandy content.

Nevertheless some species show a wide tolerance for substrate grain size: *Cytherella hemipunctata*, *Hemicytheridea cancellata*, *Keijella gonia*, *Keijella multisulcus*, *Neomonoceratina iniqua*, *Sinocytheridea impressa*, and *Stigmatocythere bona* thrive in bottoms varying from silty sand to silt; *Hemikrithe orientalis*, *H. peterseni*, and *Stigmatocythere indica* from sandy silt to silt. Other species denote a reduced capacity to tolerate different types of substrate: *Gerdocypris* sp. and *Neosinocythere elongata* (from slightly sandy silt to silt); *Copypus posterosulcus* (from sandy silt to silt); *Neocytheretta murilineata* (sandy silt), and *Neocyprideis* sp. 1 and *Tanella gracilis* (from sandy silt to slightly sandy silt).

In the Indo-Pacific region, data on the relationships between ostracods and substrate are scarce. The few available data usually agree with those obtained in this study. In the Malacca Strait, Whatley & Zhao (1987, 1988) reported *Hemikrithe orientalis*, *Keija demissa*, *Keijella multisulcus*, and *Neomonoceratina ini-*

EXPLANATION OF PLATE 1

- Fig. 1 - *Carinocythereis* sp., right valve in exterior view;
 - Fig. 2 - *Copypus posterosulcus*, right valve in exterior view;
 - Fig. 3 - *Cytherella hemipunctata*, right valve in exterior view;
 - Fig. 4 - *Gerdocypris* sp., left valve in exterior view;
 - Fig. 5 - *Hemicytheridea cancellata*, left valve in exterior view;
 - Fig. 6 - *Hemikrithe orientalis*, left valve in exterior view;
 - Fig. 7 - *Hemikrithe peterseni*, right valve in exterior view;
 - Fig. 8 - *Keijella gonia*, left valve in exterior view;
 - Fig. 9 - *Keijella multisulcus*, left valve in exterior view (male);
 - Fig. 10 - *Keijella multisulcus*, left valve in exterior view (female).
- Scale bar = 100 μ m.



SAMPLING STATIONS	TH 134	TH 133	TH 132	TH 137	TH 135	TH 138	TH 131	TH 130	TH 139	TH 128	TH 129	TH 140
DEPTH in m	1	1	1,5	1,5	4	5	5	5	7	9	9	15
<i>Bairdia</i> sp.						1			4			2
<i>Copytus posterosulcus</i>						4	6	1	1			
<i>Cytherella hemipunctata</i>			2					8	2			4
<i>Gerdocypris</i> sp.						2	7	1				
<i>Hemicytheridea cancellata</i>			2	8								
<i>Hemikritha orientalis</i>				3		8	1	3	9	1		4
<i>Hemikritha peterseni</i>				2		11	4		7			2
<i>Keijella gonia</i>			6	14		23	8	7	6	9	1	2
<i>Keijella multisulcus</i>		8	8	8		5	8	19	9	21	13	7
<i>Neocytheretta murilineata</i>				3		1						
<i>Neocyprideis</i> sp. 1		6	37	34		3					1	
<i>Neomonoceratina iniqua</i>			4	13		17	3	7	4	10	1	3
<i>Neosinocythere elongata</i>									1			6
<i>Phlyctenophora orientalis</i>						1						
<i>Pontocypris attenuata</i>										1		
<i>Sinocytheridea impressa</i>			3	11		10	5		10	5	1	17
<i>Stigmatocythere bona</i>			3	31		14	1	4	2		4	2
<i>Stigmatocythere indica</i>						3	1		2	1		1
<i>Tanella gracilis</i>			1	21								

Tab. 2 - Ostracods and depth distribution in the investigated area.

SAMPLING STATIONS	TH 134	TH 135	TH 132	TH 137	TH 138	TH 131	TH 133	TH 139	TH 130	TH 128	TH 129	TH 140
SUBSTRATE	S	S	sS	Ss	Ss	Ss	sl Ss	sl Ss	s	s	s	s
<i>Bairdia</i> sp.										1		
<i>Copytus posterosulcus</i>					1			4				2
<i>Cytherella hemipunctata</i>			2		4	6		1	1			
<i>Gerdocypris</i> sp.								2	8			4
<i>Hemicytheridea cancellata</i>			2	8	2	7			1			
<i>Hemikritha orientalis</i>				3	8	1		9	3	1		4
<i>Hemikritha peterseni</i>				2	11	4		7				2
<i>Keijella gonia</i>			6	14	23	8		6	7	9	1	2
<i>Keijella multisulcus</i>			8	8	5	8	8	9	19	21	13	7
<i>Neocytheretta murilineata</i>				3	1							
<i>Neocyprideis</i> sp. 1			37	34	3		6				1	
<i>Neomonoceratina iniqua</i>			4	13	17	3		4	7	10	1	3
<i>Neosinocythere elongata</i>								1				6
<i>Phlyctenophora orientalis</i>					1							
<i>Pontocypris attenuata</i>										1		
<i>Sinocytheridea impressa</i>			3	11	10	5		10		5	1	17
<i>Stigmatocythere bona</i>			3	31	14	1		2	4		4	2
<i>Stigmatocythere indica</i>					3	1		2		1		1
<i>Tanella gracilis</i>			1	21								

Tab. 3 - Ostracods and substrate distribution in the investigated area. Legend for the substrate as in Tab. 1.

qua on fine-to-coarse sands, *Cytherella hemipunctata* and *Stigmatocythere bona* on medium-to-coarse sands, and *Tanella gracilis*, *Phlyctenophora orientalis*, *Hemicytheridea cancellata*, and *Copytus posterosulcus* on medium-to-fine sands. Moreover, in Jason Bay, Zhao & Whatley (1989) found *Keijella gonia* and *Neocytheretta murilineata* on mud and fine sand, respectively.

OSTRACODS VERSUS SALINITY, DISSOLVED OXYGEN, AND pH

Although the measurements of salinity, dissolved oxygen and pH are scarce and limited to short periods in the year, some trends suggest links between these factors and the occurrence of ostracods. For example, at stations with salinity of 20-22‰ (TH 134 and TH 135) there is not autochthonous ostracod fauna; stations with salinity of 22-30‰ of salinity (TH 132, TH 139, TH 138, TH 140, TH 137, and TH 131) contain the highest number of species and specimens.

Stations with salinity >30‰ (TH 130, TH 128, TH 129, and TH 133) show relatively high numbers of species and specimens. Among the latter stations, TH 133 is anomalous in that it contains a poor ostracod fauna in high salinity environment.

Sampling stations TH 134 and TH 135 experience very low dissolved oxygen content (3-3.1 ml/l) corresponding to a very rare or absent ostracod fauna. Other sampling stations with dissolved oxygen content >3.1 ml/l show a rich ostracod fauna both in number of species and specimens. On the contrary, the sampling stations TH 129 (3.5 ml/l) and TH 133 (3.2 ml/l) contain poor ostracod faunas even though they have high values of dissolved oxygen.

The sampling stations with pH 5.7-5.8 denote a very poor or absent ostracod fauna (TH 133, TH 134, and TH 135). Other sampling stations with pH 5.9-6.8 present a richer ostracod fauna, particularly in those with pH 5.9 (TH 137) and 6.2 (TH 138) and in correspondence with a high dissolved oxygen content.

SAMPLING STATIONS	TH 134	TH 135	TH 129	TH 133	TH 132	TH 128	TH 130	TH 131	TH 137	TH 140	TH 138	TH 139
SHANNON WEAVER index (H')	/	/	1.51	1.53	2.02	2.03	2.32	2.83	2.96	2.97	3.1	3.17
<i>Bairdia</i> sp.						1						
<i>Copysus posterosulcus</i>										2	1	4
<i>Cytherea hemipuncta</i>					2		1	6			4	1
<i>Gerdocypris</i> sp.							8			4		2
<i>Hemicytheridea cancellata</i>					2		1	7	8		2	
<i>Hemikritha orientalis</i>									3	4		9
<i>Hemikritha peterseni</i>								4		2	11	7
<i>Keijella gonia</i>			1		6	9	7	8	14	2	23	6
<i>Keijella multisulcus</i>			13	8	8	21	19	8	8	7	5	9
<i>Neocyprideis</i> sp. 1				6	37				34		3	
<i>Neocytheretta murilineata</i>									3		1	
<i>Neomonocerotina iniqua</i>			1		4	10	7	3	13	3	17	4
<i>Neosinocythere elongata</i>				1						6		
<i>Phlyctenophora orientalis</i>											1	
<i>Pontocypris attenuata</i>						1						
<i>Sinocytheridea impressa</i>			1			5		5	10	17	10	10
<i>Stigmatocythere bona</i>			4		3		4	1	31	2	14	2
<i>Stigmatocythere indica</i>										1	3	2
<i>Tanella gracilis</i>				1	1				21			

Tab. 4 - Ostracods and Shannon Weaver (H') index in the investigated area.

Combining the data on salinity, dissolved oxygen and pH, it is possible to recognize that the poorest ostracod faunas occur at the lowest values of salinity, dissolved oxygen content and pH. Conversely, the richest ostracod fauna is present at the highest values of salinity, dissolved oxygen content and pH. This does not preclude some exceptions, as observed in sampling station TH 133, where the poor ostracod fauna might be linked to reduced pH and a relatively coarser grain size of the sediments.

OSTRACODS VERSUS SHANNON – WEAVER INDEX

The Shannon-Weaver (H') index can be an useful tool to evaluate the quality of the ostracod fauna (Shannon & Weaver, 1949). In the study area, the H' index is not calculated in the stations without ostracods, while in the other ones its values vary from 1.51 to 3.327 (Tab. 4). It is assumed by us that: index not calculated (no fauna) corresponds to stressing environmental conditions; values $H' > 2.5$ correspond to equitable environmental conditions; values $1.5 < H' < 2.5$ correspond to intermediate environmental conditions. Text-fig. 2 reports these environmental conditions in the area, which are discussed below.

Stressing conditions: H' index not calculated (sampling stations TH 134 and TH 135)

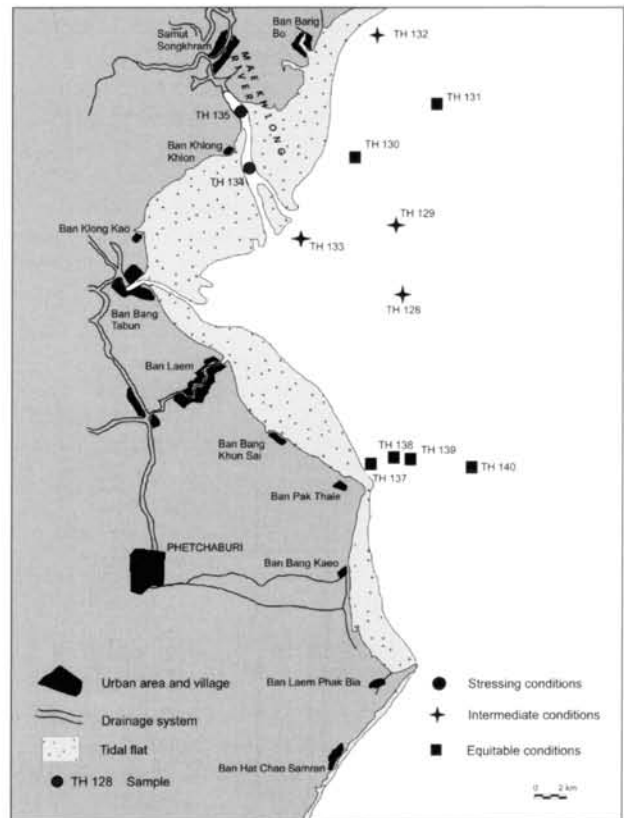
These conditions are placed in correspondence to shallow waters, from 1 m to 4 m depth, in sandy sediments, at salinity values between 20 and 22‰, at values of dissolved oxygen from 3 to 3.2 ml/l and at pH values ranging between 5.7 and 5.8.

This situation corresponds to the channel flowing across the tidal flat in front of Mae Khlung river mouth. There, the ostracods are exclusively represented by displaced specimens from nearby environments. Among them, *Neocyprideis* sp. 1 is the most common species.

Intermediate conditions: $1.5 < H' < 2.5$ (sampling sta-

tions TH 128, TH 129, TH 132, and TH 133)

The intermediate H' values correspond to stations between 1 and 9 m of depth, with substrate ranging from silty sand to silt, salinity between 22 and 32‰, dissolved oxygen ranging from 3.2 to 3.7 ml/l and pH from 5.7 to 6.6.



Text-fig. 2 - Environmental conditions in the investigated area.

These conditions occur in the northern sector of the studied area, off the Mae Khlong mouth. The most critical situation occurs in front of the river mouth (TH 133), where only *Keijella multisulcus* and *Neocyprideis* sp. 1 occur. In general, the autochthonous species are *Keijella multisulcus*, *Neocyprideis* sp. 1 (dominant at a salinity of 22‰), *Keijella gonia*, *Neomonoceratina iniqua* and *Sinocytheridea impressa*. Other scattered species are *Cytherella hemipunctata*, *Hemicytheridea cancellata*, *Hemikrithe orientalis*, *Hemikrithe peterseni*, *Neosinocythere elongata*, *Stigmatocythere bona*, and *Tanella gracilis*.

Equitable conditions: $H' > 2.5$ (samplings stations TH 130, TH 131, TH 137, TH 138, TH 139, and TH 140)

The highest H' values are found between 1.5–15 m water depths, in substrates ranging from sandy silt to silt, at salinities from 27 to 32‰, dissolved oxygen values from 3.2 to 4.2 ml/l and pH values from 5.6 to 6.8.

The conditions yielding the highest diversity occur in two sectors of the investigated area: 1) northwards, off the tidal flat, where they improve with the increasing distance from the Mae Khlong mouth and, thus, with the increasing depth and pH, and with the substrate grain size decreasing; 2) southwards, along the seawards transect in front the locality Ban Pak Thale, where they roughly improve with the increasing depth, pH and dissolved oxygen. The autochthonous species *Keijella gonia*, *Keijella multisulcus*, *Hemikrithe orientalis*, *Neomonoceratina iniqua*, *Sinocytheridea impressa*, and *Stigmatocythere bona* are there present, being the most common. Subordinate species include *Neocyprideis* sp. 1 and *Tanella gracilis* (dominant in TH 137) together with *Stigmatocythere bona*, *Cytherella hemipunctata*, *Copytus posterosulcus*, *Hemicytheridea cancellata*, *Neocytheretta murilineata*, *Neosinocythere elongata*, and *Stigmatocythere indica*.

CONCLUSIONS

The study of the shallow water ostracod fauna of the coastal area in front of Mae Khlong mouth allowed us to identify 34 species. Some species are left

in open nomenclature and might represent undescribed new species (*Neocyprideis* sp. 1).

The presence of the ostracods is strongly influenced by the Mae Khlong river fresh water outflow. Together with other minor rivers and channels, the Mae Khlong also drains organic and industrial pollutants, controlling the presence of ostracods able to tolerate differently variations of salinity, dissolved oxygen and a generally low pH.

The Shannon-Weaver index is useful to characterize the diversity and evenness of the ostracod fauna, revealing species able to live in different environmental conditions. The stressing conditions correspond to the absence of autochthonous ostracod fauna. The autochthonous species characterizing intermediate-equitable conditions are: *Keijella gonia*, *Keijella multisulcus*, *Neocyprideis* sp. 1, *Neomonoceratina iniqua*, *Sinocytheridea impressa* and, subordinately, *Cytherella hemipunctata*, *Hemicytheridea cancellata*, *Hemikrithe orientalis*, *Neosinocythere elongata*, *Stigmatocythere bona*, and *Tanella gracilis*. The species *Copytus posterosulcus*, *Hemikrithe peterseni*, *Neocytheretta murilineata*, and *Stigmatocythere indica* are recorded in equitable conditions.

The ostracod species ability to tolerate wide environmental variability, also related to pollution, will be further investigated in the area. However, these preliminary data suggest that further research would allow us to develop a classification of ostracod species which are most tolerant of impaired coastal environments and extreme environmental variability. Thus, these markers might become useful tools for the monitoring of a coastal area showing particular conditions linked to strong river influence and pollution.

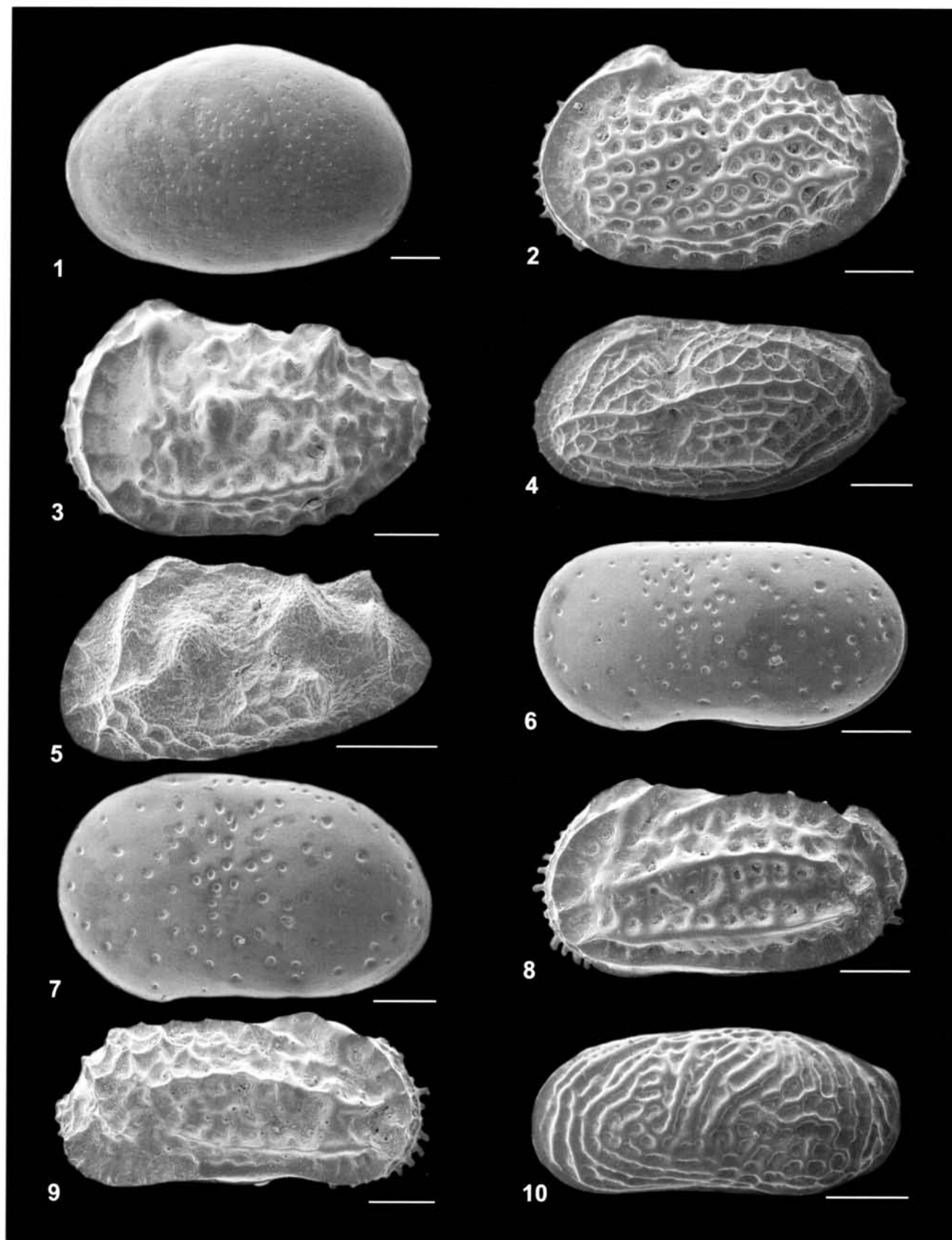
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EXPLANATION OF PLATE 2

- Fig. 1 - *Neocyprideis* sp. 1, left valve in exterior view;
 - Fig. 2 - *Neocytheretta murilineata*, left valve in exterior view;
 - Fig. 3 - *Neocytheretta* sp., left valve in exterior view;
 - Fig. 4 - *Neomonoceratina iniqua*, left valve in exterior view;
 - Fig. 5 - *Neosinocythere elongata*, left valve in exterior view;
 - Fig. 6 - *Sinocytheridea impressa*, left valve in exterior view (male);
 - Fig. 7 - *Sinocytheridea impressa*, left valve in exterior view (female);
 - Fig. 8 - *Stigmatocythere bona*, left valve in exterior view;
 - Fig. 9 - *Stigmatocythere indica*, right valve in exterior view;
 - Fig. 10 - *Tanella gracilis*, left valve in exterior view.
- Scale bar = 100 μ m.



bution and ecology of the Holocene modern foraminifers and ostracods in the coastal area near Phetchaburi, Thailand" (Dir. N. Pugliese; National leader: E. Robba).

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