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THE SYSTEMATICS AND ECOLOGY OF CRABS BELONGING TO THE GENERA *CLEISTOSTOMA* DE HAAN AND *PARACLEISTOSTOMA* DE MAN ON KUWAIT MUDFLATS

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INTRODUCTION

Apart from the taxonomic studies by Stephensen (1945) on Brachyura collected from Iranian waters, there have been few reports in the literature on this group from the Arabian Gulf, and none from Kuwait. Basson et al. (1977) describe the distribution of crabs on Saudi Arabian Gulf shores, but many of the species in their collections remain unidentified.

Collections of shore animals taken from mud and sand flats during a shore survey, initiated under a Royal Society Leverhulme-Kuwait University visiting Professorship research programme, produced twelve species of ocypodid crabs including new species of *Cleistostoma* De Haan and *Paracleistostoma* De Man. A third species *Cleistostoma dotilliforme* Alcock was also common. Quantitative transects together with the collection of physical data including temperature, salinity and sediment analysis, allow aspects of the ecology of these genera on Kuwait shores to be described.

METHODS

During the survey of Kuwait shores some 27 soft sediment shores ranging from salt marshes and mudflats to open coast beaches were visited for faunal collections (fig. 1). Shore profiles were measured at 14 sites and quantitative surveys of macrofauna were undertaken by sieving 25 × 25 × 15 cm deep areas of sediment through 1 and 2 cm mesh sieves. Air, sea and sediment temperatures were taken during January-June 1981 and additional data were supplied by the Kuwait Institute for Scientific Research. Salinities were measured using a refractometer (American Optical Co.), and interstitial salinities were measured in water draining into holes dug at various levels on the sand and mudflats.

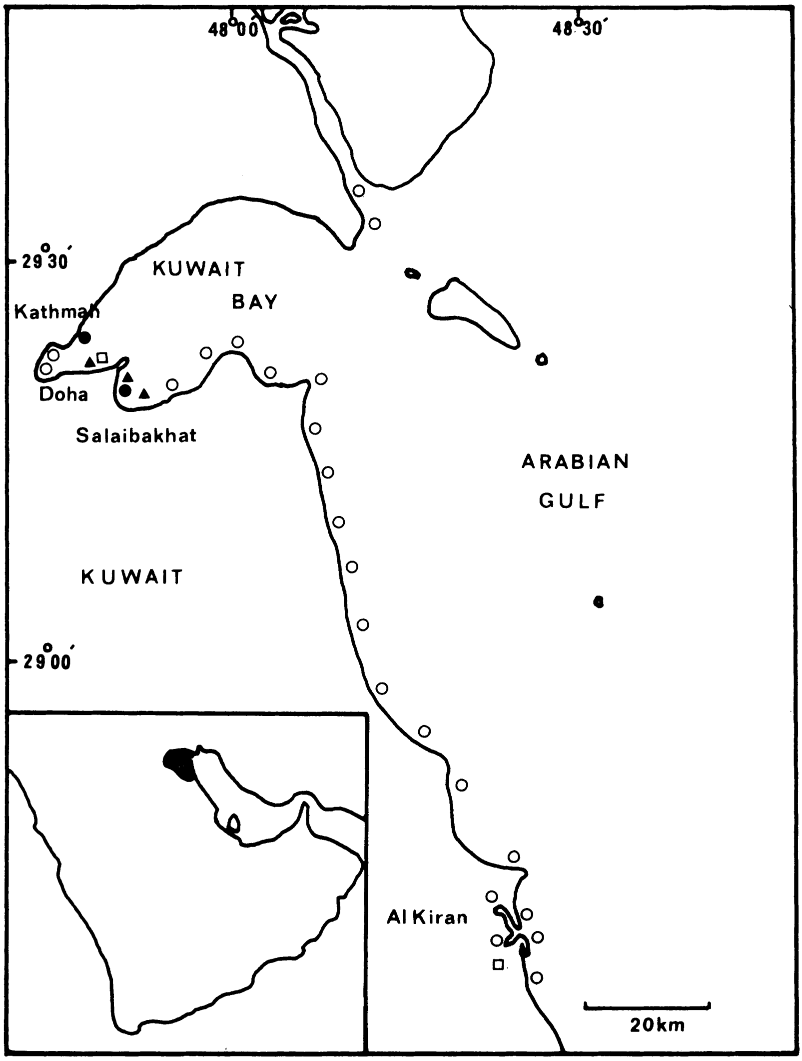

Fig. 1. Distribution of *Paracleistostoma* and *Cleistostoma* species on Kuwait shores. ● *C. kuwaitensis*, ▲ *C. dotilliforme*, □ *P. arabicum*, ○ all species absent.

Present work concentrates on the 6 transects containing crabs of the genera *Cleistostoma* and *Paracleistostoma*. Population densities were estimated by counting the burrows of each species once these had been identified, and are recorded as numbers m^{-2} for the smaller species and 10 m^{-2} for larger species. Sand and mud samples taken at intervals on transects were analysed following the methods of Holme & McIntyre (1971) to estimate medium particle size and clay-silt fractions. The estimation of the organic content of sediment samples was obtained by loss of weight on ignition at 600°C of dried sediment samples from which carbonates had previously been removed. Tests showed that the sulphide content of samples was less than 1% of the organic content in all cases.

SYSTEMATICS

Cleistostoma kuwaitense sp. n. (fig. 2)

Material examined. — ♂♂, ♀♀ and juveniles collected between February-June 1981 from mudflats at Kathmah and Salaibakhat, Kuwait Bay, Kuwait. 1 ♂ holotype 2.5 cm carapace width (cw) in British Museum (Natural History) B.M.(N.H.) registration number 1981: 498. 1 ♂ paratype 4.0 cm cw (damaged) B.M.(N.H.) registration number 1981: 499. 2 ♀♀ paratypes 2.8 and 2.6 cm cw, latter ovigerous B.M.(N.H.) registration number 1981: 499 all from Kathmah, Kuwait 10.iii.1981, the type locality.

Description of male holotype. — A young adult with carapace broader than long (width 1.36 times length), maximum width 2.5 cm across gastric region and narrowing anteriorly, lateral margins with single external orbital tooth (fig. 2a). Carapace smooth with shallow transverse groove in mesogastric region and scattering of short setae on branchial regions, these becoming denser posteriorly. Lateral, supra- and infra-orbital margins minutely granulate (fig. 2a, b). Front approximately one third of the width of the anterior border of the carapace, deflexed with antero-lateral angles quadrate (fig. 2b).

Orbits transverse containing stout eyestalks bearing well developed cornea. Epistome with median ventral tooth producing a bilobed buccal cavity. Pterygostomial regions granulate with a sulcus originating at the edge of the buccal cavity which runs laterally and ventrally (fig. 2b). Third maxillipeds almost meet in the mid line, merus longer than ischium, latter with internal distal angle strongly produced and bearing an oblique row of setae (fig. 2c). Carpus articulates with the external angle of the merus and all articles, together with exopod, are covered to some extent by the ischium and merus.

Chelae of holotype small, elongate, and equal; propodus with a short row of denticles on the lower border and on the outer border (fig. 2e). Dactylus and propodus bearing rows of setae, both terminating in rounded slightly spatulate tips; dactylus bearing a small peg-like tooth on the inner surface near the base. Female chelae very similar (fig. 2g) but rather more elongate and with more pronounced rows of setae. Chelae of large (4.0 cm cw) ♂ much more robust (fig. 2f) with propodus quadrate and coarsely granulate on the outer surface. Dactylus with pronounced tooth and opposable surfaces of chelae granulate and irregular, setae absent.

Legs broad and robust, third and fourth longest, fifth shortest. Length of merus of third and fourth leg 2.5 times width, with serrated anterior and posterior margins. The dorsal surfaces bear rows of small tubercles (fig. 2a). The outer surfaces of the carpus and propodus of legs 3 and 4, and carpus of leg 5 are covered with thick mats of short brown setae which almost completely obscure the joints. On large ♂♂ (circa 4.0 cm cw) the third leg is longest with

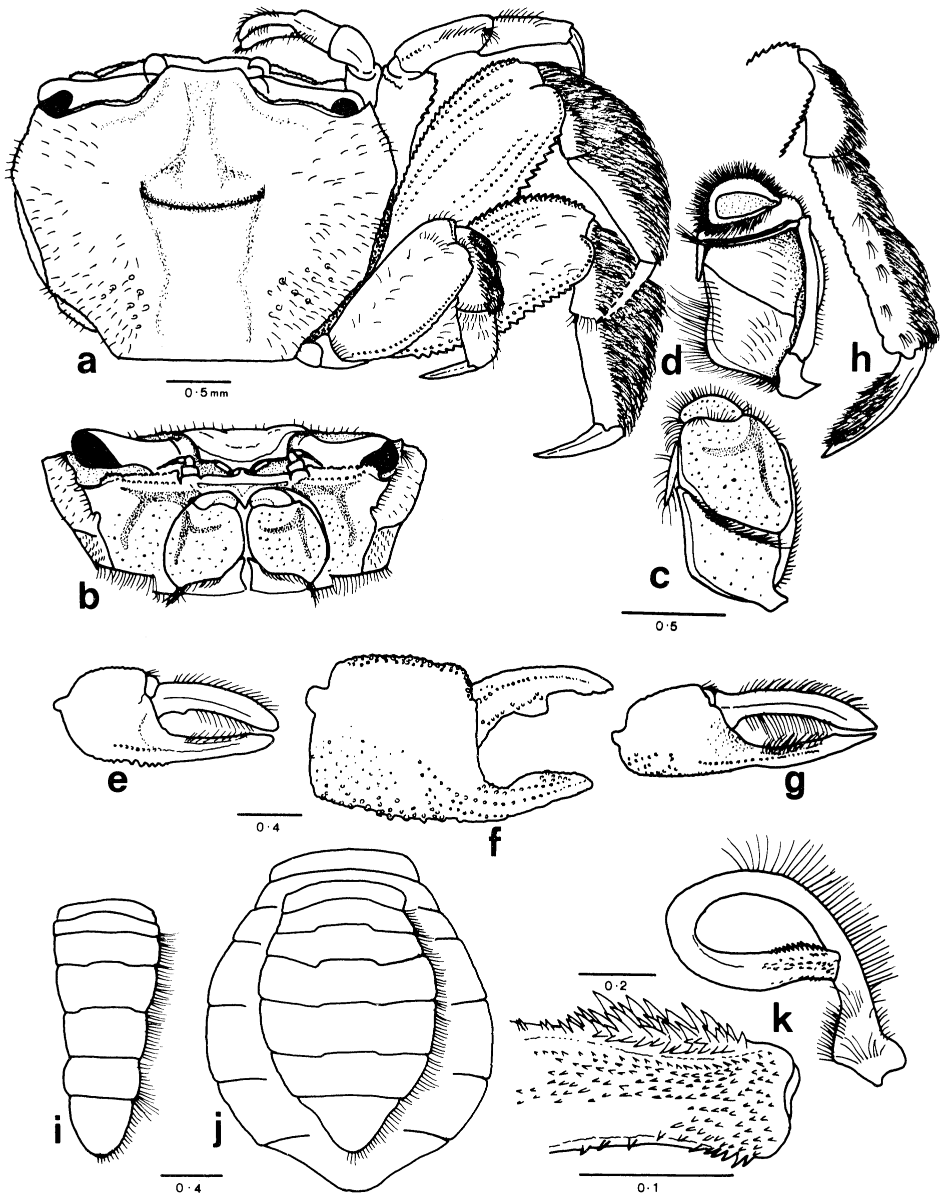

Fig. 2. *Cleistostoma kuwaitense* new species, ♂ holotype. a, dorsal view; b, anterior view; c, third maxilliped anterior view; d, third maxilliped posterior view; e, chela anterior view; f, ♂ paratype chela anterior view; g, ♀ paratype chela anterior view; h, ♂ paratype third leg; i, abdomen of ♂; j, abdomen of non-ovigerous and ovigerous ♀♀; k, first pleopod of ♂.

the propodus 5 times longer than wide (as opposed to twice as long as wide in ♂ holotype). In addition a large tuft of setae is present on the inner surface of the dactyl (fig. 2h). All dactyls terminate in sharp tips and are otherwise glabrous.

Abdomen of ♂ (fig. 2i) narrow and evenly tapering with segments 1 and 2 short and segment 7 longest, as broad as long, all segments free. Non-ovigerous ♀ with abdomen 1.5 times longer than wide, ovigerous ♀ almost as broad as long (fig. 2j). First pleopod of ♂ completely reflexed upon itself with tip armed with a series of spine rows (fig. 2k), these show an identical arrangement in all ♂♂ examined.

Colour. — Live specimens have a green and yellow mottled carapace with yellow legs, in formalin the carapace becomes uniform blue-grey, the legs light brown. The legs and chelae of large ♂♂ are a striking bright yellow and are used in display behaviour patterns.

Remarks. — Guinot & Crosnier (1963) briefly reviewed the genera *Cleistostoma* De Haan and *Paracleistostoma* De Man concluding that the characters used to distinguish them are at times so indistinct as to scarcely warrant their separation. Nevertheless until such time as all the widely scattered type material can be brought together for comparison, *Cleistostoma* and *Paracleistostoma* remain valid genera.

Cleistostoma kuwaitense conforms with the generic diagnosis (De Haan, 1835; Tesch, 1918; Barnard, 1950; Guinot & Crosnier, 1963) in the convex lateral margins of the carapace which is broader than long; the operculiform 3rd maxillipeds with the merus as long as, or longer than ischium; stout chelae in ♂♂; absence of tufts of setae between legs; reflexed ♂ pleopod and abdomen of 7 segments. It may be separated from *Paracleistostoma* as the antero-lateral corners of the front are rounded rather than angular, although it must be said that *C. kuwaitense* virtually presents an intermediate form of this condition (fig. 2b).

The relative dimensions and shape of the carapace enables *C. kuwaitense* to be separated from the other 6 species in the genus. *C. dilatatum* De Haan and *C. wardi* Rathbun are much broader, and *C. dotilliforme* Alcock, *C. edwardsi* McLeay, *C. algoense* Barnard and *C. macneilli* Ward all show different tooth configurations on the lateral margins of the carapace (Alcock, 1900; Ward, 1933; Barnard, 1950). In addition the shape of the tip of the ♂ pleopod 1, together with the spine arrangement, are characteristic and differ from those of all other species so far figured, including *Paracleistostoma* species.

The ♂ appendage of *Cleistostoma wardi*, *C. macneilli*, *Paracleistostoma eriophorum* Nobili and *P. dentatum* Tesch have yet to be figured.

C. kuwaitense would appear to fit well into the homogeneous group formed by *C. dilatatum*, *C. wardi*, *C. dotilliforme* and *C. edwardsi*. However, the shape of the antero-lateral carapace margins, toothed chelae, and heavily setose legs are reminiscent of some species of *Paracleistostoma* cf. *C. leachi* (Audouin), *P. depressum* De Man and *P. longimanum* Tweedie.

It is interesting to note that whilst juvenile *C. kuwaitense* upto 0.8 cm cw show the adult carapace outline, the heavily setose leg patches are absent and only appear on crabs with a carapace width of over 0.9 cm. The setae on the dactylus of the third leg of the ♂ do not appear until crabs reach 2.5 cm cw. Similarly, the small claws seen in both ♂ and ♀ (fig. 2e, g) are only present on ♂♂ below 2.5 cm cw, above this size ♂ chelae grow rapidly to reach the large size (fig. 2f) seen on crabs of 4.0 cm cw and above.

Cleistostoma dotilliforme Alcock (fig. 3)

Clistostoma dotilliforme Alcock, 1900: 373; Alcock & McArdle, 1902, pl. 64 fig. 1.
Cleistostoma dotilliforme Tesch, 1918: 61; Stephensen, 1945: 194.

Material examined. — ♂♂, ♀♀ and juveniles collected between February and June 1981 from mudflats in Kuwait Bay. British Museum (Natural History) collections from Saudi Arabia, Abu Dhabi and Trucial coast in the Arabian Gulf, and Karachi in the Arabian Sea.

The original description of a single ovigerous ♀ by Alcock (1900) is brief and even when taken together with the figures (Alcock & McArdle, 1902) does not allow adequate separation of this species from *C. kuwaitense* (fig. 2). Fig. 3a illustrates a ♂ *C. dotilliforme* cw 1.16 cm from Salaibakhat, Kuwait Bay, and is representative of collections of *C. dotilliforme* taken from other sites in the Arabian Gulf and Karachi, the type locality.

Relative dimensions of the carapace do not differ significantly from the original figure (Alcock & McArdle, 1902), but the lateral carapace margins bear an indentation behind the orbital tooth (fig. 3a). This indentation is often obscure in large specimens (circa 1.8 cm cw) and is not shown in the original figure (Alcock & McArdle, 1902). The front is deflexed with the antero-lateral angles smoothly rounded (fig. 3b). Third maxillipeds with merus slightly longer than ischium, latter with internal distal angle only moderately produced (fig. 3c).

Chelae of all specimens examined small, ♂ with chelae subequal, dactylus and propodus bearing dorsal and ventral rows of setae, both terminating in strongly spatulate tips (fig. 3d). Female chelae similar to those of ♂ (fig. 3e) but less spatulate. Dactylus without teeth in both sexes.

Abdomen of ♂ (fig. 3f) with all segments free, narrow and evenly tapering, segment 7 longest, longer than broad. Non ovigerous ♀ with abdomen 1.25 times longer than wide (fig. 3g). First pleopod of ♂ completely reflexed upon itself with tip armed with a characteristic arrangement of spines and tip of sperm duct protruding (fig. 3h).

Colour. — Live specimens with dark or light sand coloured carapace often obscured by detritus trapped amongst setae, unchanged in formalin.

Remarks. — Specimens from Karachi and various sites in the Arabian Gulf show considerable uniformity. Large specimens which tend to lose the indentation behind the orbital tooth on the lateral margins of the carapace may be con-

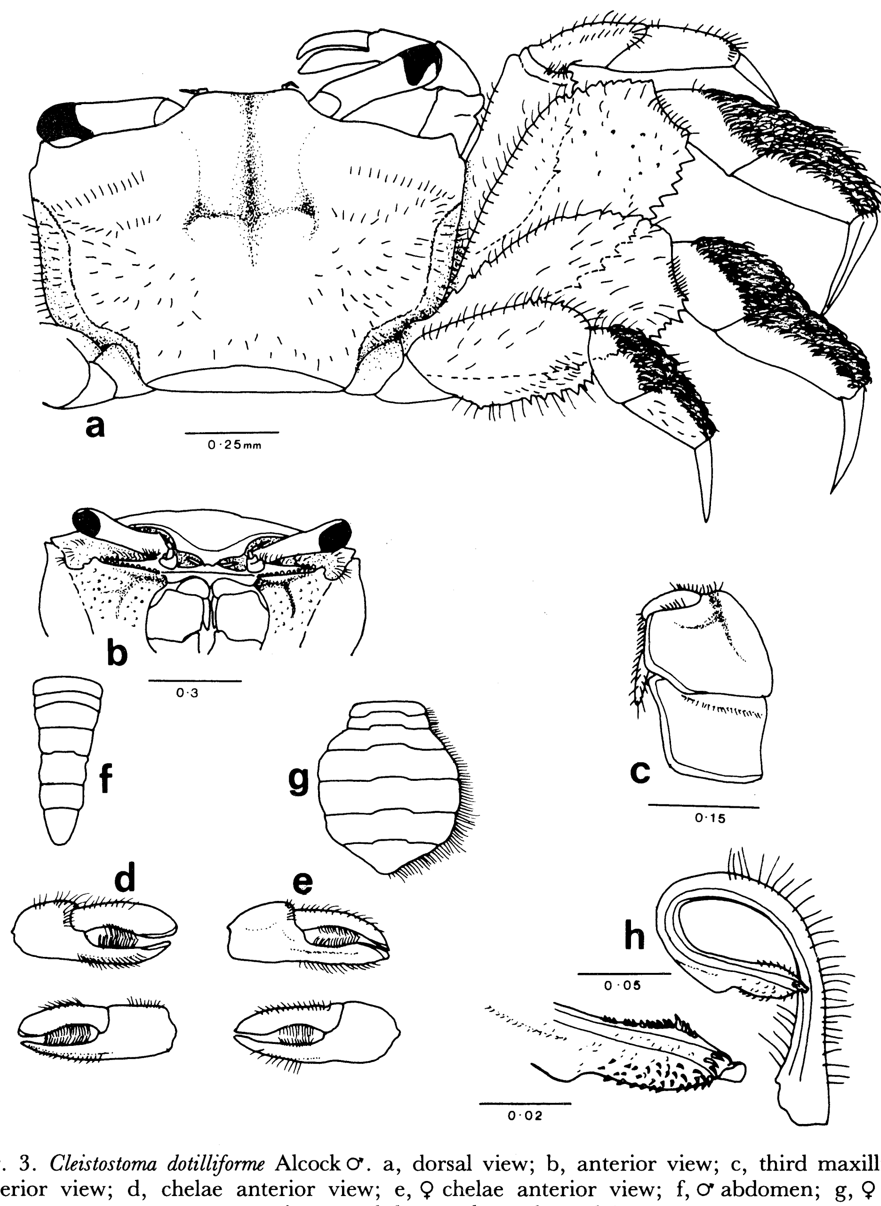

Fig. 3. *Cleistostoma dotilliforme* Alcock ♂. a, dorsal view; b, anterior view; c, third maxilliped anterior view; d, chelae anterior view; e, ♀ chelae anterior view; f, ♂ abdomen; g, ♀ non ovigerous abdomen; h, ♂ pleopod 1.

fused with young *C. kuwaitense.* However, comparison of the third maxillipeds, abdomen, and particularly the ♂ pleopod 1 enables separation of species. *C. dotilliforme* may be separated from other *Cleistostoma* and *Paracleistostoma* species by use of the key provided by Tesch (1918).

Paracleistostoma arabicum sp. n. (fig. 4)

Material examined. — ♂♂ ♀♀ and juveniles collected between February and June 1981 from sandy mud flats at Doha and Al Kiran, Kuwait. 1 ♂ holotype 0.9 cm cw in British Museum (Natural History) B.M.(N.H.) registration number 1981: 496; 2 ♂ paratypes 0.7 cm cw B.M.(N.H.) registration number 1981: 497; 3 ♀ paratypes 0.8, 0.65, 0.7 cm cw, latter ovigerous B.M.(N.H.) registration number 1981: 497; all from Al Kiran 8.iv.81, the type locality.

Description of male holotype. — The largest adult found, carapace broader than long (width 1.7 times length), maximum width 0.9 cm across gastric region; front, at junction with supra-orbital margins, 0.3 of maximum carapace width (fig. 4a). Carapace glabrous with slightly raised epigastric, protogastric, and mesogastric lobes, distinct grooves present to either side of intestinal lobe. Antero-lateral margins convex and minutely denticulate, lateral margins showing 2 feeble indentations and continuing posteriorly as granulate ridges over part of the branchial region (fig. 4a). Supra-orbital margins deeply inset and sinuous, sloping obliquely backwards. Front deflexed with antero-lateral angles acute and produced into lobes (fig. 4b). Orbits transverse containing stout eyestalks, denticulate ridge present running from outer end of infra-orbital border to the base of the antenna. Infra-orbital border bearing a row of setae which increase in length towards the outer edge, covering the cornea (fig. 4b). Gastric cavity bilobed with epistome bearing well developed median tooth and row of minute denticles on the upper surface. Pterygostomial regions smooth bearing scattered setae. Slight gap present between third maxillipeds, merus of which is marginally shorter but wider than ischium (fig. 4c). Carpus articulates with the external angle of merus which is slightly raised; carpus and all other articles, including the exopod, partially concealed behind merus and ischium. Outer surfaces of the latter are smooth but sparsely setose; oblique line of setae present on ischium.

Chelae equal, propodus quadrate in lateral aspects (fig. 4d), smooth and bearing a short row of setae on the inner surface (fig. 4a). Dactylus bears a peg-like tooth on the lower surface and narrows distally to meet the fixed finger with a forceps action. Chelae of male and female paratypes (0.7 cm and 0.8 cm cw) small and elongate (fig. 4e, f), with dactylus curved but of consistent width, ♂ bearing small peg-like tooth, dactyl tips slightly expanded and spatulate.

Legs relatively short and stout, lacking thick tufts of setae (fig. 4a). Third leg longest, fifth shortest, merus of legs 3 and 4 expanded laterally with granulate rows on anterior margin and dorsal surface. All leg articles including the dactylus sparsely setose. Abdomen of ♂ with all segments free, narrow and slightly waisted with segment 6 broader than segment 5, segment 2 shortest and segment 5 longest (fig. 4g). Non-ovigerous ♀ with abdomen as broad as long (fig. 3h, i). First ♂ pleopod (fig. 4j) almost completely reflexed with distal third armed with spine rows and terminating in a square tip. A series of 7 or 8 large hooked spines are present on the distal inner surface.

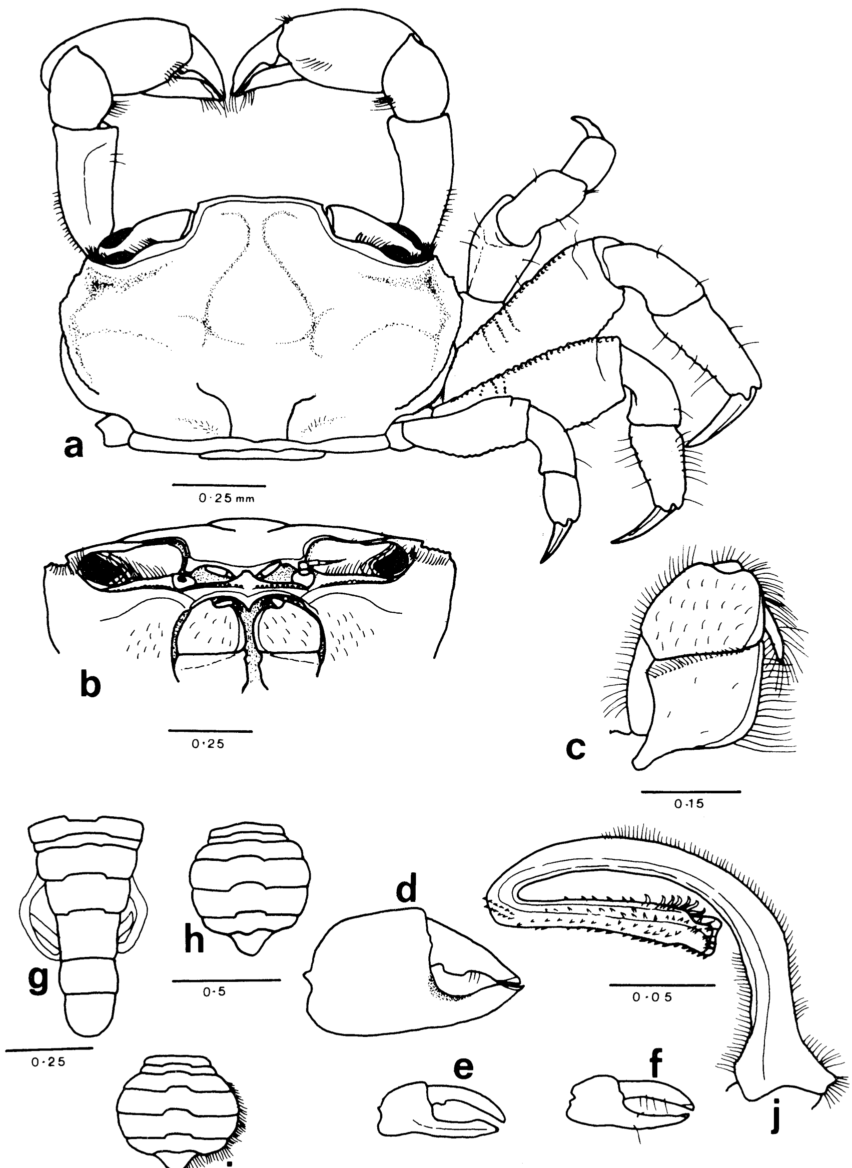

Fig. 4. *Paracleistostoma arabicum* new species ♂ holotype. a, dorsal view; b, anterior view; c, third maxilliped anterior view; d, chela anterior view; e, ♂ paratype chela; f, ♀ paratype chela; g, abdomen of ♂; h, abdomen of non ovigerous ♀ paratype; i, abdomen of ovigerous ♀ paratype; j, first pleopod of ♂.

Colour. — Live specimens are a uniform sandy yellow, lightening to creamy white in formalin.

Remarks. — *P. arabicum* agrees with the general diagnosis outlined above for *C. kuwaitense*, but is retained in the genus *Paracleistostoma* as the antero-lateral angles of the front are acute (fig. 4a). Although the merus of the third maxilliped is just less than equal in length to the ischium, and thus does not strictly conform to the generic diagnosis (Tesch, 1918; Barnard, 1950), this character appears to have been disregarded by several authors. In *P. longimanum* and *P. microcheirum* Tweedie (Tweedie, 1937) and *P. fossulum* Barnard (Barnard, 1955) the merus is also considerably shorter than the ischium.

The carapace of *P. arabicum* is much broader relative to its length than is seen in all other species of *Paracleistostoma*, and the indented antero-lateral carapace margins also separate this species from all but *P. fossulum* and *P. japonicum* Sakai. However, in the former species the posterolateral margins are expanded, and in the latter the carapace is quadrate. In addition the shape and ornamentation of the chelae, legs and mouth parts, together with the spine arrangement on the ♂ pleopod 1 serve to separate *P. arabicum* from all other species of *Paracleistostoma* and *Cleistostoma*.

P. arabicum forms part of a group including *P. cristatum* De Man, *P. dentatum*, *P. depressum*, *P. eriophorum* and *P. longimanum*, all of which show the typical general characters (Guinot & Crosnier, 1963).

The range of sizes present in collected material reveals that, apart from chelae and sexual characters, juveniles and ♀♀ resemble adult ♂♂. Growth of the large chelae seen in adult ♂♂ again appears to be rapid, and to some extent unrelated to overall crab size. Large chelae are found on ♂♂ with carapace widths ranging from 0.6 to 0.9 cm, small chelae on ♂♂ with carapace widths of 0.5 to 0.75 cm. However, all ♂ specimens over 0.5 cm cw possess the characteristic pleopod 1.

ECOLOGY

Physical environment

Kuwait is situated at the northern end of the Arabian Gulf (fig. 1) in a semi-arid region subjected to air temperatures which range in extreme from 0 to 55°C annually. Fig. 5a shows mean monthly sea surface temperatures for Kuwait Bay during 1980. High evaporation rates together with little rainfall produce high salinities (38-42‰) in the Gulf, although these may be moderated in northern Gulf waters by the outflow from the Tigris and Euphrates (fig. 5b).

In semi-enclosed bays and intertidal areas salinities may rise drastically and table I shows that interstitial water commonly reaches over 100‰. During the summer *C. kuwaitense* was found in burrows containing water ranging from 70-120‰, *C. dotilliforme* in salinities reaching 70‰, and *P. arabicum* in salinities of 75‰ (table I).

TABLE I

Quantitative distribution of *Cleistostoma* and *Paracleistostoma* species on sand and mudflats in Kuwait, together with physical data

		Tidal					Levels				
Transect 1	HAT	MHHW			MHLW		Surface water table	MSL	HLW	MLLW	
AL KIRAN											
Median particle size (MPS)	145		135	190	145		150		205	150	138
% silt and clay	18.5		17.8	13.5	9.6		12.6		11.2	14.2	18.9
% organic content	0.95		1.70	1.47	1.09		0.51		1.76	2.28	0.89
Paracleistostoma arabicum (Nos m^{-2})				100	120	32	10				
Transect 3											
M.P.S.	130			140					131		
% silt and clay	10.0			16.4					14.6		
% organic content	0.95			1.52					1.74		
P. arabicum (Nos m^{-2})				20	60						
DOHA											
Interstitial salinity (‰)		132				75		65			
M.P.S.	160			153	190	180		165			
% silt and clay	29.2			11.4	21.6	18.6		20.8			
% organic content	3.69			2.71	2.63	2.88		2.5			
P. arabicum				4	44	20					
Cleistostoma dotilliforme (Nos m^{-2})				2	16	22		14			
SALAIBAKHAT INFILL											
Interstitial salinity (‰)			55		40			55			
M.P.S.					50		55	52			
% silt and clay					52.4		47.7	49.4			
% organic content					5.76		4.04				
C. dotilliforme				2	48		46	10			
SALAIBAHKAT SEA CLUB											
Interstitial salinity (‰)	160+	122	110		70	70		55			
M.P.S.			59						125		
% silt and clay			41.2						31.8		
% organic content			4.77						5.67		
Cleistostoma kuwaitensis (Nos 10 m^{-2})		10	51	29	47						
C. dotilliforme (Nos m^{-2})						46		2			
KATHMAH											
M.P.S.	148	101	80		125	87	120		58		
% silt and clay	14.4	4.4	14.6		11.8	20.9	15.4		42.7		
% organic content	0.43	1.0	1.33		0.82	1.67	2.68		3.61		
C. kuwaitensis (Nos 10 m^{-2})		30	48	61							

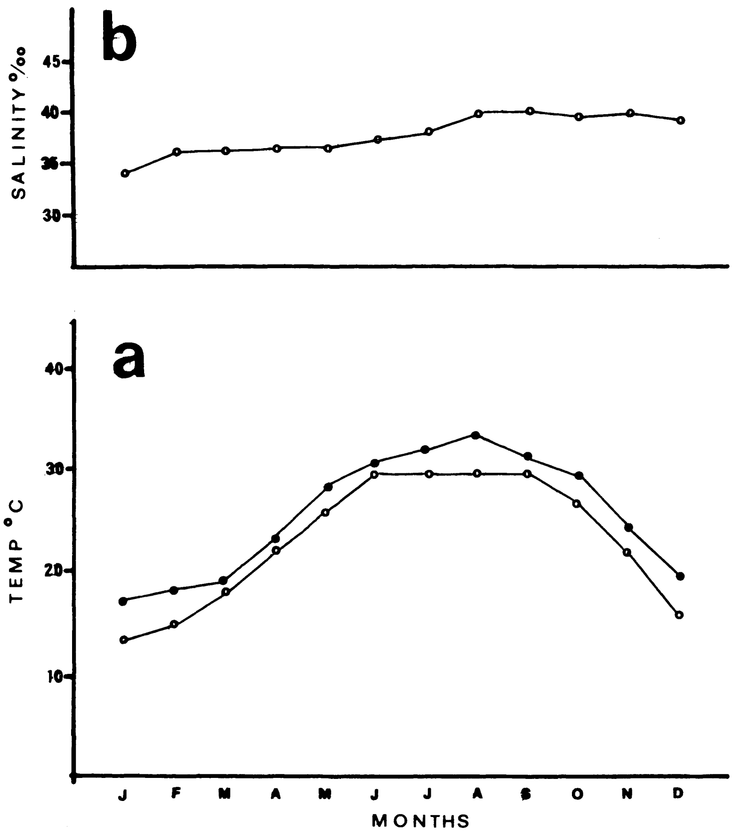

Fig. 5. a, mean monthly sea surface temperature for Kuwait Bay (○) and for Dammam, Saudi Arabia (●) during 1980; b, mean monthly sea surface salinities for Kuwait Bay during 1980. Data supplied by Kuwait Institute for Scientific Research.

The present coastline configuration of Kuwait is recent, reached when sea levels stabilised some 5,000 years ago (Kassler, 1973). Soft sediment shores in Kuwait Bay grade from extensive areas of soft mud flats at the western end, to fine or medium sand beaches at both sides of the entrance (fig. 1, table I). In all areas of mudflats the upper shore is an admixture of silicated estuarine clays and silts originating from the Shatt Al Arab delta and aeolian sands. The beaches facing the Arabian Gulf (fig. 1) are subject to greater wave action and are composed of clean fine to medium sand, the only exception being the creek system at Al Kiran where shelter has again produced areas of mudflats, in this case composed of carbonate sediments. Tides are semi-diurnal and range from 3.5-4.0 m in the north of Kuwait to 1.8 m in the south. There is often a large diurnal inequality giving rise to the terms Mean higher high water (MHHW) and Mean lower low water (MLLW). Lowest tides of the year occur during winter months at a time when low tides in general coincide with daytime, conversely high tides tend to occur during the day in summer. Fig. 6 shows how

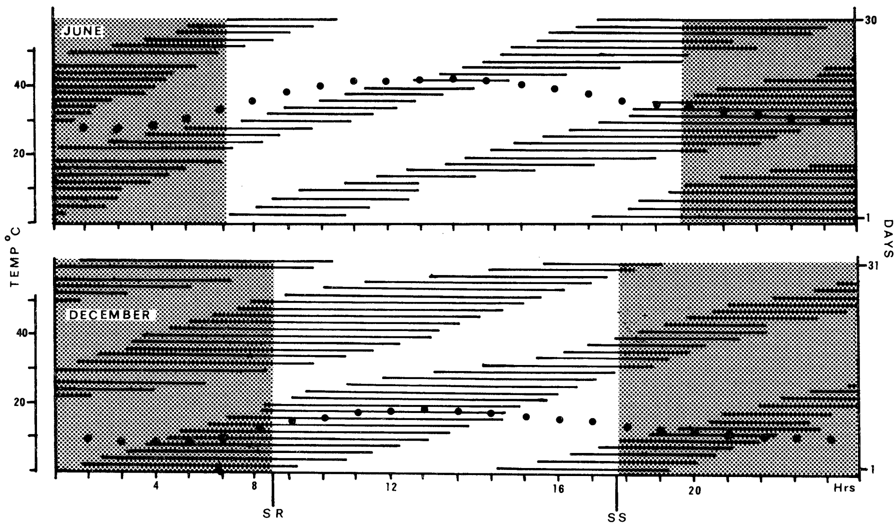

Fig. 6. Daily periods of air exposure of the intertidal zone at 2 m above datum in Kuwait Bay for June and December 1980, together with monthly mean hourly temperatures (–) represents length of exposure on each tide calculated from Admiralty Tide Table 1980-81; (...) monthly mean hourly temperatures calculated from air temperature records 1952-80 (Kuwait Meteorological Office). SR, Sunrise; SS, Sunset.

the tides act to ameliorate the harsh climatic conditions imposed upon intertidal organisms, as longest periods of exposure coincide with highest air temperatures in winter and with lowest temperatures in summer. This situation is restricted to the northern Gulf and tidal regimes further south may offer no protection to intertidal organisms (J. Hunter pers. comm.).

Distribution

Both *Cleistostoma* and *Paracleistostoma* were only found associated with sheltered sand/mudflats in Kuwait (fig. 1), and were absent from the open coast beaches where *Ocypode saratan* (Forsk.) and *Emerita holthuisi* Sankolli dominated. *P. arabicum* has the widest distribution, colonising sandy mudflats at Al Kiran and areas of salt marsh at Doha (fig. 1). *C. dotilliforme* and *C. kuwaitense* appear to be restricted to areas of Kuwait Bay where sediments are finer. Table I shows that *P. arabicum* is found on sediments with a medium particle size (mps) 145-190 μm, clay/silt fraction 9.6-21.6% and percentage organic content ranging from 0.51-2.88. In contrast *C. kuwaitense* is restricted to sediments with a mps of 50-122 μm, 14.4-41.2% clay/silt, and 1.0-4.77% organic content and was not found in the same area as *P. arabicum*. *C. dotilliforme* appears to have a preference for intermediate sediments with mps 50-190 μm, 11.4-52.4% clay/silt and 2.5-5.76% organic content, and overlaps with the other species in some areas (table I).

The burrows of *C. kuwaitense* show a clear pattern of zonation centred on the high shore (table I), at approximately the same level as *Uca lactea annulipes* (H. Milne Edwards). Their distribution overlapped with the lower edge of a zone of Cyanophycea which is invariably present on the surface of the mud between highest annual tide (HAT) and MHHW. All burrows examined descended to the water table which is some 0.6 m below the surface during low tide. The mud surface between the burrows dries to a soft moist consistency and retains the claw prints of crabs for some days. Juvenile *C. kuwaitense* were found either associated with adult burrows or formed a distinct band at the lower edge of the adult population. Both *P. arabicum* and *C. dotilliforme* are found slightly lower on the mudflats (table I), the latter species extending slightly lower onto the wet mud zone which marks the appearance of the water table on the surface at low tide.

Biology

Females of all three species were found to be incubating eggs during March and April, and it seems likely that breeding is seasonal as ovigerous females were not observed after April. Juvenile *C. kuwaitense* were abundant at both Kathmah and Salaibakhat, and formed a distinct size mode with carapace widths of 0.5 to 1.0 cm, indicating the presence of at least two year classes. Whilst the smallest juveniles were concentrated at the lower edge of the adult zone, larger juveniles were often found in small burrows leading off from adult burrows.

Direct observation confirmed that both *C. dotilliforme* and *P. arabicum* are deposit feeders and examination of chelae, mouth parts and proventriculus structure, together with gut contents, indicates that *C. kuwaitense* feeds in a similar manner. Fig. 7 compares the small chelae of the three species and shows that there is a close correlation between the development of the chela and sediment grade associated with each species. The chela of *P. arabicum* is forceps-like and is used to pick up sand grains which form a large proportion of the sediments at Al Kiran and Doha (table I). In contrast the chelae of *C.*

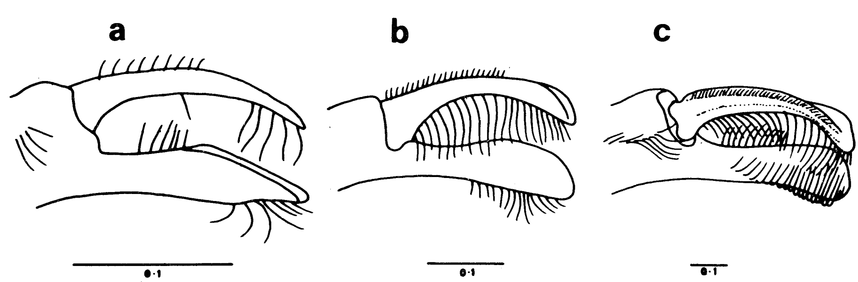

Fig. 7. Chelae of small adults. a, *Paracleistostoma arabicum* sp. n.; b, *Cleistostoma dotilliforme* Alcock; c, *C. kuwaitense* sp. n.

dotilliforme and *C. kuwaitense* are spatulate and bear rows of long fine setae used to spoon up and retain finer particles from the mudflats.

Food sorting in the buccal cavity with the formation of rejected sand pellets is common amongst the deposit feeding ocypodids *Uca*, *Scopimera*, *Ilyoplax* and *Dotilla* (Altevogt, 1955; Crane, 1975; Hartnoll, 1973; Icely & Jones, 1978; Ono, 1965), but was not observed in the present species. Although the merus of the second maxilliped and coxa and merus of the first maxilliped of all three species are heavily setose, specialised spoon tipped setae (Crane, 1941) are absent. In addition the merus of the second maxilliped is not expanded as it is in *Uca* species feeding on sandy sediments (Icely & Jones, 1978). However, the large operculiform third maxilliped which forms a generic character, may be an adaptation to fine particle feeding. The inner surface (fig. 2d) bears rows of setae and the expanded carpus fits against a specially flattened area in the roof of the buccal cavity (fig. 2, b). The concave structure of the maxillipeds thus provides a posterior space lined with setae rows which may be utilised for straining water from food material.

Both *C. dotilliforme* and *P. arabicum* were often observed feeding on the surface of the sand and mudflats as soon as the ebbing tide left their burrows. Feeding continued for 1 to 2 hours after which time they returned into their burrows, reappearing with the approach of the next high tide. *C. kuwaitense* was observed emerging from burrows 30 minutes before the tide reached the burrows during the day. Crabs could often be observed sitting in burrow entrances at other times but feeding activity appears to be restricted to a short period on the ebb and flood tide, although it may continue during high tide.

DISCUSSION

The genera *Cleistostoma* and *Paracleistostoma* have an Indo-west Pacific distribution and thus contain tropical or sub-tropical species. They are usually found associated with mangroves but may also occur on open mudflats.

C. dotilliforme has previously been recorded from Karachi (Alcock, 1900) and the Arabian Gulf (Stephensen, 1945; Basson et al., 1977) where the latter authors report population densities of upto 200 m^{-2} in the halophyte zone (upper intertidal zone) of tidal mudflats. This species has a zonation centred slightly lower on Kuwait shores, perhaps in response to the lower winter temperatures. All three species in Kuwait are remarkably eurythermal and euryhaline, *C. kuwaitense* in particular surviving burrow water salinities of over 100‰ and below 20‰ near sewage effluent channels.

The present survey revealed a total of 17 species of tropical burrowing crabs belonging to the Grapsidae and Ocypodidae distributed across the sand and mudflats of Kuwait. As the rocky shore fauna is impoverished and composed mainly of warm temperate species, it seems likely that it is the burrowing habit which has allowed a rich tropical crab fauna to develop on soft sediment shores. Despite an air temperature range of 0 to 55°C, minimum burrow temperatures recorded during winter were 15°C and maximum summer temperatures 27°C.

Some habitat preference is exhibited by the three *Cleistostoma* and *Paracleistostoma* species, and this appears to be related to deposit feeding adaptations. Similar preferences for muddy habitats have been shown to exist for *P. cristatum* and *C. dilatatum* in Japan by Ono (1965). This author demonstrated that feeding specialisation in relation to habitat preference occurs not only within a genus, but also between genera of ocypodid crabs.

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ZUSAMMENFASSUNG

Zwei neue Arten der Familie Ocypodidae wurden bei der Untersuchung der Fauna des Sand- und Schlickwatts in Kuwait entdeckt: *Paracleistostoma arabicum* und *Cleistostoma kuwaitensis*. *C. dotilliforme* war ebenfalls häufig. Die neuen Arten werden beschrieben, und es werden Angaben zur quantitativen Verteilung aller drei Arten gemacht. Alle Arten leben in Wohnröhren, sie ernähren sich von Sediment und, wie die Untersuchung der Mundwerkzeuge und des Darminhalts zeigt, bevorzugt jede Art bestimmte Sediment-Korngrößen. Daß sich trotz der relativ strengen klimatischen Bedingungen eine reiche tropische Krebsfauna in den Wattengebieten Kuwaits entwickeln konnte, wird auf die Lebensweise in Wohnröhren zurückgeführt.

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