ECOLOGICAL STUDY OF SOME SANDY BEACHES ALONG THE ISRAELI MEDITERRANEAN COAST, WITH A DESCRIPTION OF THE INTERSTITIAL HARPACTICOIDS (CRUSTACEA, COPEPODA).

by

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Résumé

Etude écologique de quelques plages de sable de la côte méditerranéenne israélienne, avec une description des Harpacticoïdes (Crustacés Copépodes) interstitiels.

Neuf plages de la côte méditerranéenne ont été choisies pour cette étude. L'analyse granulométrique, la mesure de la salinité et du pH de l'eau interstitielle ont été effectuées et des échantillons correspondants ont été prélevés dans le sable où la faune a été trouvée. L'analyse granulométrique a révélé un rapport direct entre la nature et la quantité de la faune et la fraction dominante du sable. Des mesures de température, faites au niveau d'une plage choisie spécialement, ont montré l'existence d'une couche moyenne dans le sable où les variations de température sont faibles. Le taux de salinité et la mesure du pH prouvent l'effet de dilution des eaux continentales.

Dans l'eau interstitielle ont été trouvées huit espèces d'Harpacticides, dont quatre sont nouvelles : *Kliopsyllus minutus* n. sp. ; *Leptastacus operculatus* n. sp. ; *Arenopontia problematica* n. sp. ; *Afrolaphonte pori* n. sp. D'autres groupes ont été signalés et donnent un tableau plus complet des biotopes.

Introduction

Nothing as yet has been published concerning the interstitial fauna of the eastern shores of the Mediterranean Sea. The closest research sites in this field to the west of the Israeli shore line are Italian on the one side and North African on the other. Madagascar is the nearest place to the east where some interstitial work has been done.

This study, which took place during the years 1967 and 1968, was meant to give information (systematic and ecological) on the Harpacticoid Copepods of the Israeli Mediterranean coast line. While the survey was under way, representatives of other interstitial groups were recovered. The Microcerberinae (Isopoda) were dealt with

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separately (Masry, in press) and so was the case with a new species and a new sub-species of Mystacocarida (Masry and Por, in press).

Other interstitial groups were dealt with only as far as to form a general quantitative picture when comparing the different beaches under survey.

Working methods

Two reasons guided the choice of sandy beaches along the Israeli Mediterranean coast line in order to study their interstitial fauna. First, there was the urge to widen our knowledge on as much of the coast line as possible, while, on the other hand, this choice was governed by the need to sample beaches of different sand composition.

The Israeli Mediterranean shore line referred to in this study includes only the coast stretching between the Lebanese border in the north and the Gaza Strip in the south. This coast line extends for 210 km, in a general norh to south direction between latitudes 33°09'N and 41°30'N. It consists mostly of straight and westward facing open beaches, with very few irregularities such as lagoons and estuaries.

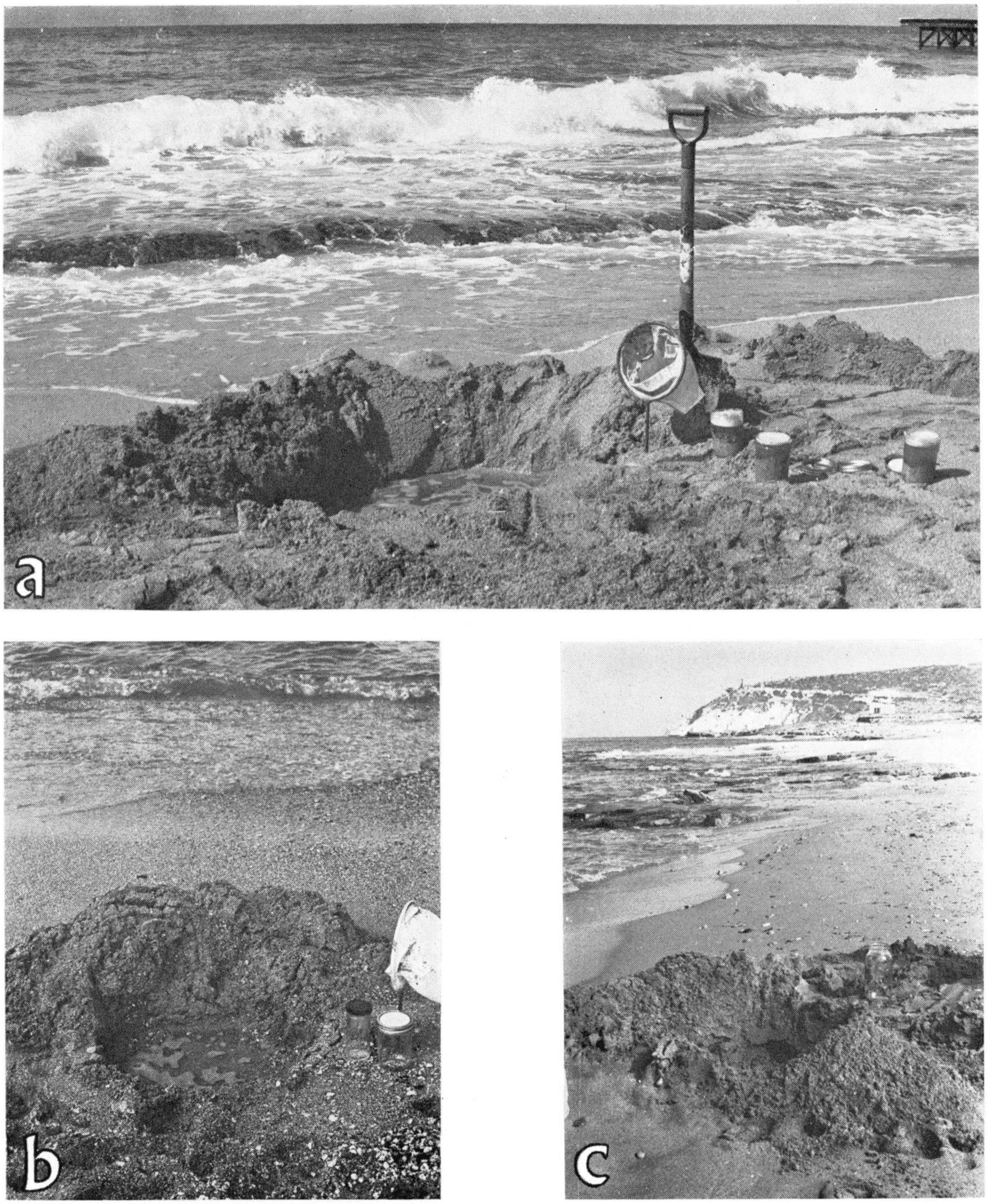
Nine working sites were chosen (Fig. 3), from Nitzanim (1) in the south, to Akhziv (9) in the north. All these beaches faced the open sea (westward) and were unprotected from wave action. Closed and quiet shores, though not many, were avoided as the sand there tended to become anaerobic at a depth of a few centimetres.

Two digging levels were chosen on every beach, for collecting the interstitial fauna. One was situated as close as possible to the water line, while the other was dug at a distance of 5-6 metres inland, towards the top of the seaward slope of the beach (Fig. 1).

When digging at the lower level, very close to the sea, a protective sand barrier was erected to prevent sea water flooding the hole from above (Plate I). Depth of the hole depended on the level of the sub-soil water. This level was reached at a depth of 10-25 cm for holes dug near the water line, or 40-60 cm for holes dug at the higher level. The inflow of interstitial waters brings with it some of the free living interstitial fauna into the hole. For this reason the collecting itself was done from the water that seeped into it.

Two collecting methods were used: the first consisted of dipping a hand net with a mesh size of 50 μ into the water in the hole and sweeping it about while disturbing the bottom. The net is then inverted into a jar containing sea water and the collecting resumed. Several sweeps later, the hole's bottom is redug and the crumbling walls of sand removed to allow renewed working space. This system was generally adopted when specific collecting was desired (i.e. searching for the presence of a certain group) or for preliminary investigation of a new beach.

The second method consisted of dipping a one litre jar into the water in the hole and pouring it through a fine-mesh hand net. This system was preferred when quantitative results were desired. In such cases, the diameter of the hole was kept more or less standard and a constant volume of water was filtered each time. In order to obtain some idea on the relative occurrence of the different species of



DAVID MASRY

PLATE I

a : a hole dug by the water line at Nahariyya to collect interstitial fauna. Collecting equipment are a spade, a hand net with a mesh size of 50 μ and several one liter glass jars. b : a sand barrier is built to protect the hole from wave action. Notice the coarse sand (Nahariyya). c: shown here is the higher of the two digging levels. The beach is that of Akhziv.

Harpacticoida, other Crustacea and groups of interstitial Invertebrates (Fig. 5), holes were dug with a constant diameter of 50 cm and about 30 litres of water were filtered from each hole.

Fauna was preserved on the spot in a final solution of 4 p. 100 neutralized formalin in sea water. Dissecting and mounting were accomplished in a drop of glycerin. Drawings were done with the aid of a camera-lucida and photo-micrography.

The different working procedures dealing with the collecting of ecological data (physical and chemical) on the biotope, will be described later in detail.

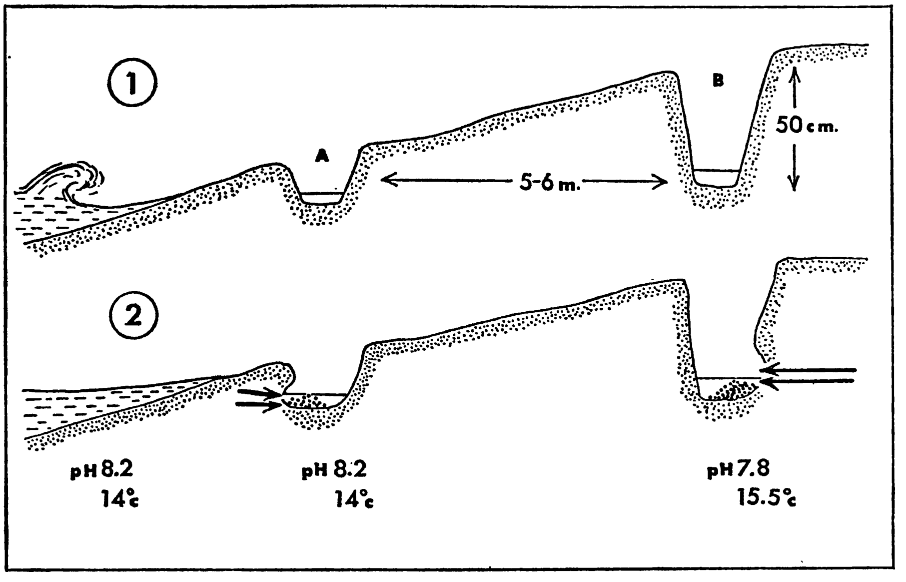


Fig. 1

(1) A schematic cross section in the beach, showing the position of the two digging levels; level A being as close as possible to the water line while level B is situated towards the top of the seaward slope of the beach.

(2) The thick arrows represent the direction of the main subsoil currents at both digging levels. These are detectable by the crumbling of the corresponding sandy walls of the holes.

ECOLOGICAL CONDITIONS

Life in the interstitial is closely related to a combination of extreme ecological conditions. The most important of the physical factors seems to be the grain size of the sand. Distance from the water line (where wave action can cause great disturbances) and the great variations in temperatures occurring at short notice, are some of the other physical factors that shall be dealt with here.

Chemical factors that add to the unstability of this biotope are the changing salinity of the interstitial waters and their oxygen content (Jansson 1966). Here only the salinity will be dealt with in connection with the underground continental water outflow and its diluting effect.

I. Grain size

Sand samples of about 100-150 cm^3 each were taken from every beaches chosen for this study. These were collected for granulometric analysis from the actual digging site, where fauna and salinity data were retrieved.

The sand samples were dried in an oven at 100 °C and then separated into their different grain size groups through six sieves. These were arranged one on top of the other with diminishing mesh size from 4 mm for the topmost sieve to 0.125 mm for the one at the bottom. The whole apparatus was shaken in an electro-mechanical vibrator for 10 minutes. The different components thus separated were weighed out on analytical scales and presented graphically as percentage of the sample's total weight (Fig. 3). The shell and pebble

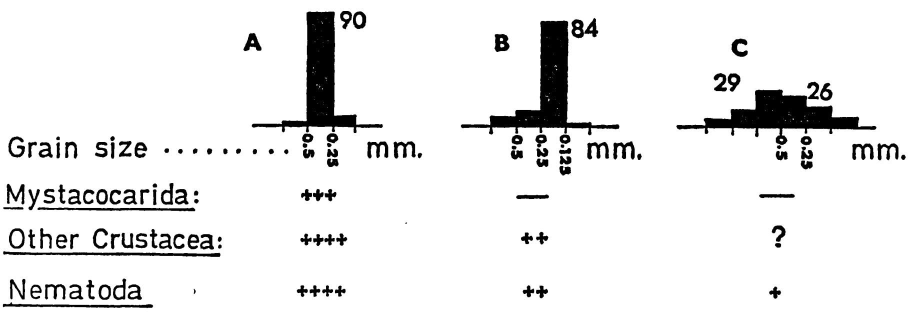


FIG. 2

A comparison between three sandy beaches. Depicted is the correlation between the composition of the sand and the amount of fauna collected. For details see text. *Grain size groups in percentage.*

fractions were neglected in this study, as it seemed that these large-size components do nothing in way of building the intergranular irrigation system.

Results and discussion

A clear correlation was found to exist between the dominant grain size group (together with the quantitative distribution of the different grain size groups in the sample) and the abundance of fauna. Figure 2 depicts this fact where three beaches of completely different granular composition were compared. A more general picture, comparing all faunistic elements from the nine beaches sampled for this study is to be found in Fig. 5. In badly sorted sand—in other words, sand containing a variety of grain sizes with no particular dominance of one grain size group (Fig. 2, C)—the interstitial waterways are clogged with smaller and smaller sand grains. These fill the living space and disturb the circulation of water, food, and oxygen. Beaches having a granulometric profile like that of Akhziv (Fig. 2, A and Fig. 3, 9), with a dominant grain size group of 0.25-0.50 mm were found to be very rich in fauna. The large size and good sorting of the dominant grain size group form large enough interstitial spaces to accommodate a variety of organisms.

The dominance of a smaller size granular fraction (i.e. 0.125-0.25 mm) as found in Akko (Fig. 2, B and Fig. 3, 7), south of Tel Shiqmona (Station 5) and at Palmahim (Station 3), causes the dimi-

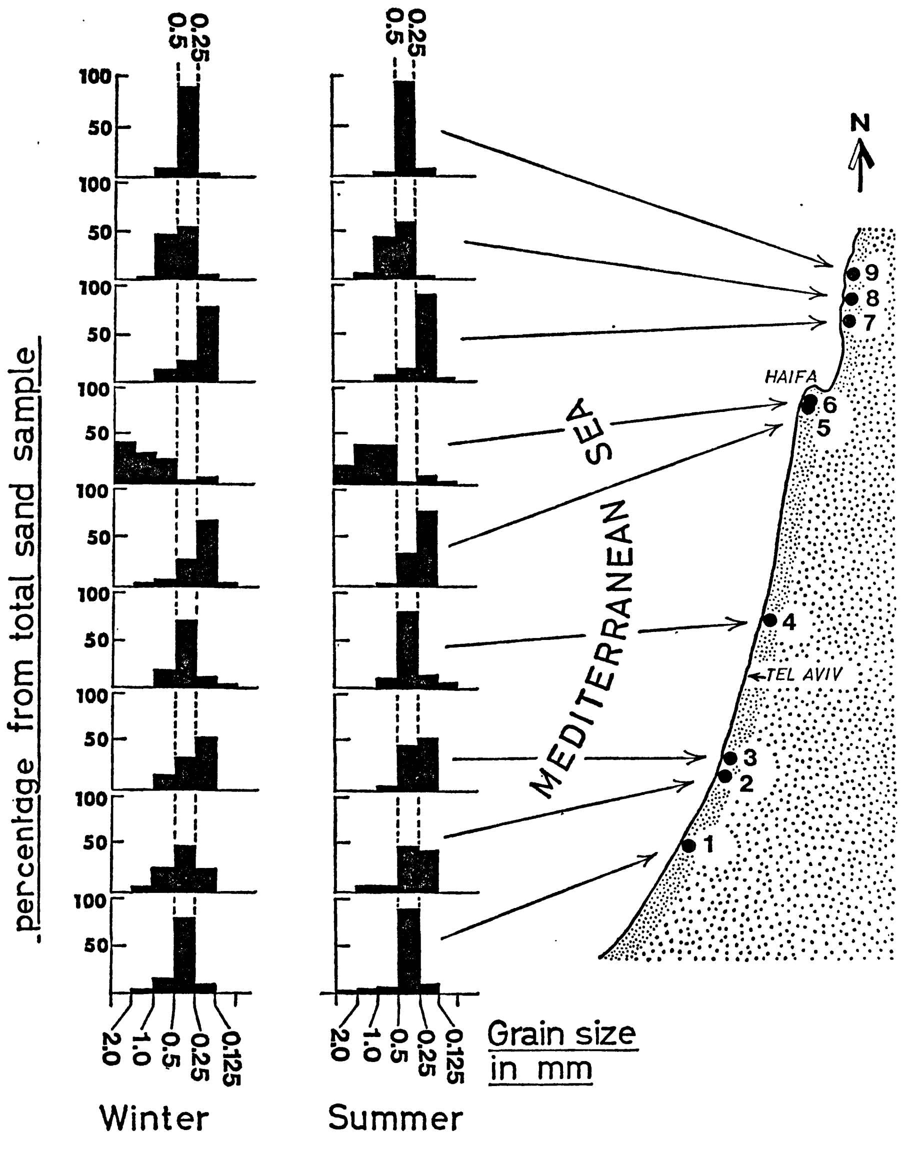


FIG. 3

Sand composition at the nine digging sites chosen along the Mediterranean coast of Israel. Each column in every granulometric histograms gives the weight of a certain grain size group as percentage of the total sample's weight. Side by side are the results of the granulometric analysis in summer and from the same sites in winter, after heavy storms did much damage to the beaches. Stations are: 1-Nitzanim; 2-Tel Yavne; 3-Palmahim; 4-Mikhmoret; 5-South of Tel Shiqmona; 6-North of Tel Shiqmona; 7-Akko; 8-Nahariyya; 9-Akhziv.

nution of interstitial drainage systems to the extent of forcing the absence of several faunistic groups, while others are rather scarce.

Certain orders were found to rely on specific granulometric conditions as one of the main factors determining their existence in the interstitial. The Mystacocarida seem especially dependent upon this factor, demanding well sorted sand where the dominant fraction has a size range equal to or larger than 0.25-0.50 mm. The beach of Akhziv (Station 9) is an excellent answer to this demand, while in Nahariyya (Station 8), where dominant grain size group is of the 0.50-1.00 mm size, Mystacocarida were abundantly found as well (Masry and Por, in print).

Another example of biotope preference, where dominant grain size plays an important role, is the case of the two species of *Arenopontia* found in this survey. As Figure 5 shows, *Arenopontia acantha* Chappuis is abundantly found in Stations 6, 8 and 9, prefering coarse and well sorted sand. *Arenopontia problematica* n.sp., on the other hand, is found in Stations 1 and 5, where sand is well sorted but more to the finer side. It is interesting to note that the latter species is the smaller of the two and that although Stations 5 and 6 are no more than 400 metres away from each other, each species was clearly limited to its specific beach. In beaches where penetration of fine terrestrial sediments (with grain sizes smaller than 0.125 mm) is evident, there is a great reduction in the quality and quantity of the fauna.

Insignificant differences in the granulometric composition of all nine beaches chosen for this study were recorded between winter and summer. The winter samples were taken in January 1968, only several days after strong storms had done much damage all along the coast. This may indicate, in a way, that although we are dealing with a very dynamic biotope, it can survive even heavy storms.

2. Temperature

Temperature measurements were taken from holes dug in a beach of averagely sorted sand north of Palmahim. This beach was chosen for having a sand composition similar to that of many beaches along the Israeli coast line and for the fact that its ability to retain capillary water was good. The latter enabled the measuring of wet-sand temperatures from the actual surface of the sand and downwards, to the level of the sub-soil water.

Thermometers were shoved into the wall of holes dug every hour on the seaward slope of the beach (5-6 m from the water line). One measurement was made right under the sand's surface (0 depth). Going deeper, temperatures were taken every 5 cm till the level of the sub-soil water was reached. This was repeated over a period of two days in February 1968 and during daylight hours only. To conclude each set of measurements, the air temperature (in the shade) and that of the sea surface were noted. The sky was partly cloudy and the sea calm.

The results displayed in Fig. 4 are the average for both days.

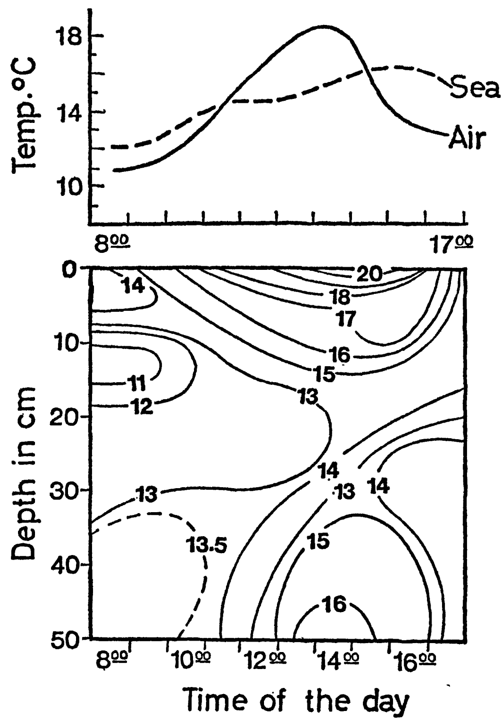


FIG. 4

Temperature changes in the wet sand during daylight hours, an average of two days (January 1968). Hourly measurements were made in freshly dug holes situated 5 metres from the water line. The corresponding air (in the shade) and sea temperatures are given on top.

Results and discussion

The temperatures recorded at different depths in the wet sand vary considerably during the hours of the days. While air temperature clearly affects that of the sand down to 15 cm, the changes in sea water temperature near the shore are followed by similar changes in the wet sand, from a depth of about 30 cm downwards. The above can clearly be seen in Fig. 4 as well as the fact that an intermediate layer existed at a depth of between 15-30 cm. Here sea and air temperatures seem to have little to do, resulting with 1-2° changes over the 11 hours periods considered above.

Data collected from similar observations (although ranging over shorter periods) on colder as well as warmer days, showed that the level where temperature changes are slight always exists but can be found at varying depths.

As all collecting was done in a manner that did not check for horizontal distribution, it is difficult to say much about any vertical migratory patterns that might exist in connection with temperature changes.

3. Salinity and pH

All salinity tests were made on water removed from holes dug in the sand and from which fauna was collected. In each case, a 200 cm^3 water sample was taken in well stoppered bottles. Chloride content of these waters was found by titration with 0.1 N $AgNO_3$ using 5 p. 100 K_2CrO_4 as an indicator. Chlorinity was then calculated to grams of Cl per litre (Cl p. 1000). Results can be seen in table I.

TABLE I

The chlorinity and pH of interstitial waters from holes dug at collecting sites. *For details, see text.*

Station	Chlorinity (gr Cl per litre)			pH		
	Sea water	Hole level A (1)	Hole level B	Sea water	Hole level A	Hole level B
Nitzanim	22.36	22.35	22.32	8.2	8.2	8.2
Tel Yavne	22.38	22.35	22.35	8.2	8.2	8.2
Palmahim	20.60	20.59	20.06	8.1	8.2	8.2
Mikhmoret	23.62	23.61	18.46	8.2	7.9	7.5
south of Tel-Shiqmona	23.05	23.07	21.65	8.2	8.1	7.8
north of Tel-Shiqmona	23.36	23.36	— (2)	8.2	8.2	— (2)
Akko	—	23.15	21.80	8.2	8.2	8.0
Nahariyya	21.60	21.60	20.59	8.1	8.0	7.7
Akhziv	22.08	22.01	21.75	8.2	8.1	8.0

(1) See Fig. 1.
(2) The narrow shoreline allows the digging of holes only at the water line.

Results and discussion

In most beaches, the salinity and pH of the interstitial water decrease when moving away from the water line. In some cases (Station 4), the outflow of continental water can be seen when watching the sandy walls of the hole crumbling (see Fig. 1, (2)). When dealing with wide flat beaches like Stations 1, 2, and 3, very slight differences were recorder in the pH and salinity of water from holes dug near the water line and further up on the beach. Continental outflow in such beaches is slight as they have much low land behind them and there is little dilution of the interstitial water. Mikhmoret (Station 4), on the other hand, has many settlements and much high land behind it. Here there was a difference of 5.15 g Cl/litre in the salinity of water from two holes only 5 metres apart.

FIG. 5

Quantitative and qualitative distribution of interstitial Crustacea and other fauna in the types of sand surveyed. Station numbers correspond to those given in Fig. 3. Digging level A is situated near the water line level B holes were dug 5-6 metres higher up on the beach. One point indicates that only few specimens were collected; two and three points indicate 6-20 specimens per sample; four points indicate that they are found abundantly.

Sand type :	Coarse			Well sorted				Well sorted				Unsorted / with silt					
Dominant grain size (mm)	3.0–0.5	1.0–0.25		0.5–0.25		0.5–0.25		0.25–0.125		0.25–0.125		----		----		----	
Station number :	6	8		9		1		5		7		4		2		3	
Digging level :	A	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Leptomesochra eulitoralis	•••	••	••	••	••		•										
Kliopsyllus minuta n.sp		•	•	••	••			•	••		•						
K. constricta orotavae		••	••			•	•						•				
Psammotopa vulgaris		•	•	•	•	•	•										
Leptastacus operculata n.sp.				•													
Arenopontia acantha	••	••	•••	•••	•••												
Arenopontia problematica n.sp.						•••	••	••	••			•	•		•		•
Afrolaophonte pori n.sp.		••••	••••	•	••	•	••										
Microcerberus remanei israelis n.ssp.	•••	••	••	••	•	•								••	•		
Derocheilocaris tehiyae n.sp.		••	••														
D. remanei achzivi n.ssp.		••	•••	••	•••												
GASTROTRICHA		•	•	•	•	•	•					•					
NEMATODA – *Metepsilonema* sp.	••	••	••	••	••	••••	••	•						•			
NEMATODA – Other	•	•	••	•••	••••	•••	••	••	•	•	•	•	•••	••	••	••	••
POLYCHAETA	•	•								••	•			••	•		
ARCHIANNELIDA	••	•	•	••	••	••	••	•						•	•		
TARDIGRADA	•••					••••	••••			•				•	•		
CYCLOPOIDA	••	•				•	•										
OSTRACODA	•	•		•		•		•									
ACARINA	••	••	••	••	••	••	•										
COLLEMBOLA	•••	•••	•••	••	•	••	•										

Fig. 5

SYSTEMATIC DESCRIPTION

Ameridae Monard, Lang.

Leptomesochra eulitoralis Noodt 1952 (Fig. 6).

Material: many males and females.

Female (Fig. 6).

Length 0.49-0.52 mm. Body cylindrical, elongated and tapering towards end of abdomen. Ten times longer than wide. Dorsal and dorso-lateral surfaces covered by minute chitinous tubercles. Rostrum small and slightly elongated. Antennule eight segmented. Antenna three segmented, the second of which carries a biarticulated endopodite.

P1-4: endopodites P1 and P4 triarticulated while endopodites P2 and P3 are biarticulated. First segment of exopodite P1 1 1/3 times longer than the whole corresponding endopodite. The outer lateral margins in every segment of exopodites P2-P4 bear a row of fine spinulae. Single rows of hair ornate the inner margin of endopodites P2 and P3 and the third segment of endopodite P4. First and second segments of exopodites P2-P4 carry large knob-like subterminal spiny lobes. All basopodites carry a short seta. On P1, it is situated on a small projection. The armature of the swimming legs is as follows:

	P1						P2				
	Exopodite			Endopodite			Exopodite			Endopodite	
(1)	1	2	3	1	2	3	1	2	3	1	2
(2)	0	0	122	1	0	020	0	0	023	1	020
(3)	11:	12:	12:	50:	4:	7:	24:	26:	28:	18:	15:

P3					P4					
Exopodite			Endopodite		Exopodite			Endopodite		
1	2	3	1	2	1	2	3	1	2	3
0	0	023	1	020	0	0	223	1	0	021
25:	27:	29:	15:	14:	25:	23:	29:	12:	10:	8:

(1) segments of swimming legs (2) armature (3) length proportions between leg segments.

P5: expodite rounded, 1 1/3 times longer than wide, carries 5 setae, the terminal one being the longest. Basiendopodite has an outer, laterally situated fine seta and terminates with three setae situated on a step-like formation of the plate's edge.

Furca : rectangular, only slightly longer than wide. The two terminal setae are situated in a shallow depression, formed by the knob-like inner distal corner of the furca and its pointed outer corner. The inner of the two reaches a length equal to half that of the animal and is twice as long as the outer terminal seta. Both terminal setae are delicately jointed along the terminal 2/3 rds of their length. Two fine setae, somewhat longer than the furca, protrude dorsally above the two distal corners of the furca. A third seta, similar in size and shape, is based in the terminal shallow depression of the furca. Two transverse rows of 4-5 spinulae each are found in a median position

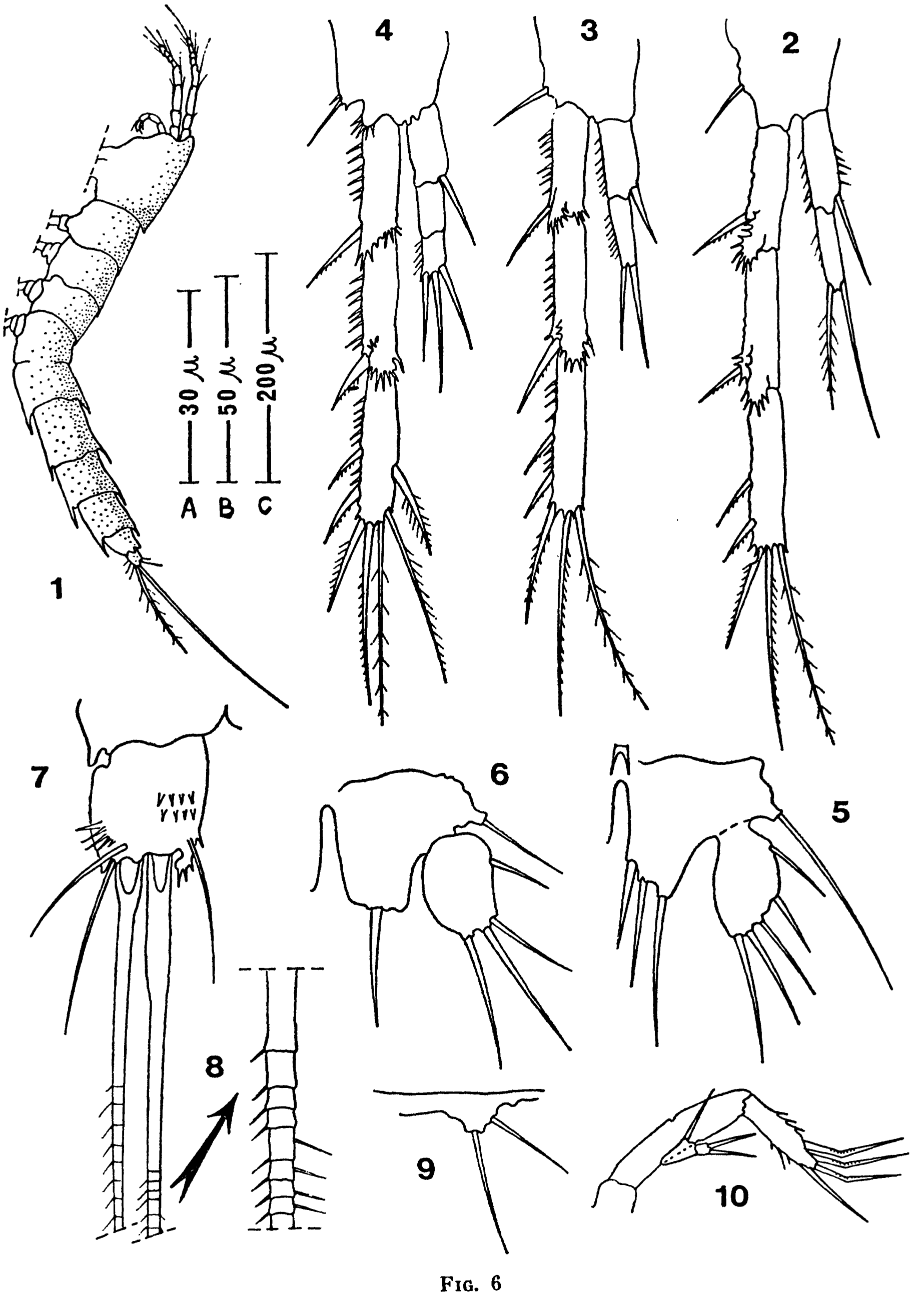


FIG. 6
Leptomesochra eulitoralis Noodt

Female 1, lateral view (scale C); 2, P2 (B); 3, P3 (B); 4, P4 (B); 5, P5 (A); 7, furca (B); 8, segmentation of terminal seta of furca; 10, antenna (B).
Male. 6, P5 (A); 9, P6 (A).

on the furca while 5-6 longer spinulae form a tiny semi-circle at its outer distal corner.

Male (Fig. 6:6,9).

Length: 0.44-0.46 mm. Similar in shape to female, but smaller. The basiendopodite of P5 has only one terminal seta. Exopodite P5 is more rounded than in female and carries three long terminal setae and one shorter lateral one. P6 is made of a narrow plate carrying 2 fine setae on a slight projection.

Occurrence:

Sandy beaches composed of well-sorted coarse sand having a dominant grain size group of 0.25-0.5 mm or larger. Abundantly found in the beaches of Tel Shiqmona (Station 6), Nahariyya (8) and Akhziv (9) and in smaller quantities at Nitzanim (1).

Discussion:

The general structure is similar to that described by Noodt (1952) but several differences in some microstructures catch the eye. Among these, the most evident are the segmentation of the two terminal setae of the furca, the minute tubercles in the body's cuticle and the spiny sub-terminal lobes on the segments of expodites P2-P4.

Paramesochridae Lang

Kliopsyllus minutus n. sp. (Fig. 7).

Material: many specimens, most of them females.

Female (Fig. 7:11-19).

Length 0.240-0.260 mm. Body cylindrical, longer 5 times than wide. Dorsal edges of abdominal segments bear a tight band of fine hair. Genital segment clearly defined by its length. Rostrum absent. Antennule eight segmented the fifth of which carries an elongated aesthete. The three segmented endopodites of the antenna carries a small unisegmented exopodite sub-terminally situated on the first segment.

P1-P4: endopodite P1 bi-articulated while those of P2-4 are made of one segment only. Endopodite P1 is smaller or equal in length to the corresponding exopodite. The inner margins of exo- and endopodites P2-4 are lined with very fine hair. The same is true for the outer margin of the first segment of expodites P2-4. Basopodites P2-4 have a short laterally protruding seta. Armature of swimming legs is as follows:

P1				P2				P3				P4			
Exopodite		Endopodite		Exopodite			Endopodite	Exopodite			Endopodite	Exopodite			Endopodite
1	2	1	2	1	2	3	1	1	2	3	1	1	2	3	1
0	121	0	011	0	0	012	010	0	0	012	010	0	0	011	010

P5: large and well defined. Basiendopodite wide and elongated carrying two terminal weakly pennated setae, one spinulose seta situated between them, and one fine lateral seta. Exopodite rounded and armed with three spines, the middle one being the longest. Egg sac typically having a single pair of eggs.

Furca: long and narrow (3 1/2:1), widest at its base and slowly tapering towards its end. A thick brush-like spine projects at right angles from a sub-terminal position. Two long terminal setae, one

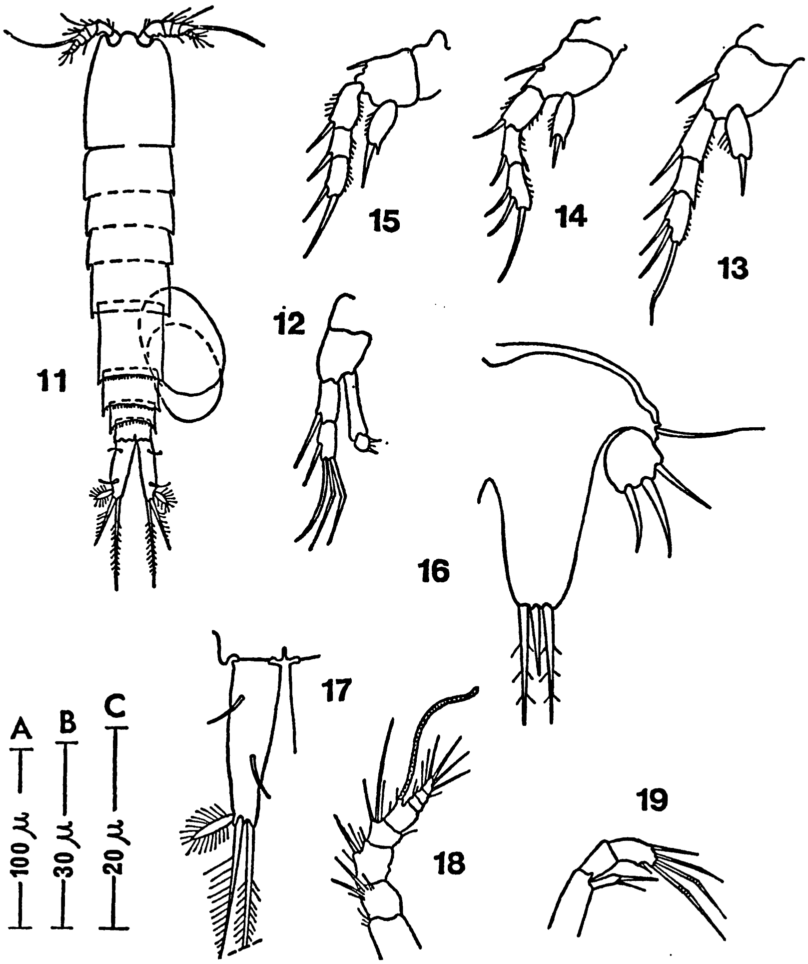


FIG. 7
Kliopsyllus minutus n. sp. *female.*

11, total view, dorsal (scale A); 12, P1 (B); 13, P2 (B); 14, P3 (B); 15, P4 (B); 16, P5 (C); 17, furca (B); 18, antennule (B); 19, antenna (B).

just shorter than the length of the furca the other 1 1/2 times longer, and two short dorsal spines conclude the furca's armature.

Male

Length 0.238-0.250 mm. Similar in shape to the female. Further description not possible because of smallness of size and lack of sufficient specimens.

Occurrence:

Abundantly found south of Shiqmona (Station 5) and Akhziv (9) while the beaches of Nahariyya (8) and Akko (7) yielded considerably fewer specimens. *K. minutus* shows a tendency towards well sorted sand but can tolerate finer dominant grain size groups (i.e. 0.125-0.25 mm, as found in Stations 5 and 7).

Discussion:

Kliopsyllus minutus differs from the other known species of the genus by the combination of the following three morphological structures: elongated furca, P1 with endopodite having large first segment and minute second one and three terminal setae on the basiendopodite of P5.

Kliopsyllus constricta orotavae (Noodt) (Fig. 8).

Material: many males and females.

Female (Fig. 8:20-27)

Length 0.270-0.290 mm. Body cylindrical and tapering towards the abdominal end. About 4 1/4 times longer than wide. Segment edges smooth. Rostrum small, elongated and rounded at its end. Antenna eight segmented, the second of which is broadest and longest. The third segment of the antennule carries a large pinhead seta and the fifth, an elongated aesthete. Endopodites of antenna triarticulated, carrying on its first segment an unisegmented exopodite. Antenna's exopodite has 3 short apical setae.

P1-4: endopodite P1 biarticulated while those of P2-4 are one-segmented. Exopodite P1 biarticulated and equal in size or slightly smaller than the first segment of the corresponding endopodite. Exopodites P2-4 bear fine hair. Armature of the swimming legs same as in *K. minutus*.

P5: basiendopodite well developed, elongated and terminates with two short spines. Exopodite P5 small, roundish, bears hair on its inner margin and three terminal spinulose setae. Eggs (2-4) arranged in a row in a single egg sac.

Furca: rectangular, 1 1/3 times longer than wide, with inner distal corner projecting into a point carrying two spinulae. The armature of the furca consists of a subterminal laterally pointing brush-like spine, two long terminal setae and a short dorsally situated seta.

Male (Fig. 8:28-30).

Length 0.260-0.280 mm. Similar to female in shape and size. Seven segmented antennule with an aesthete on the fifth segment. Sixth segment of antennule very enlarged. P5 is less developed than in female. Basiendopodite much shorter carrying only a weakly pennated lateral seta. Exopodite P5 heart-shaped, armed like in female only that two of the three setae are weakly pennated. P6 connected through a narrow chitinous band and bearing two thick spines and one weakly pennated lateral seta.

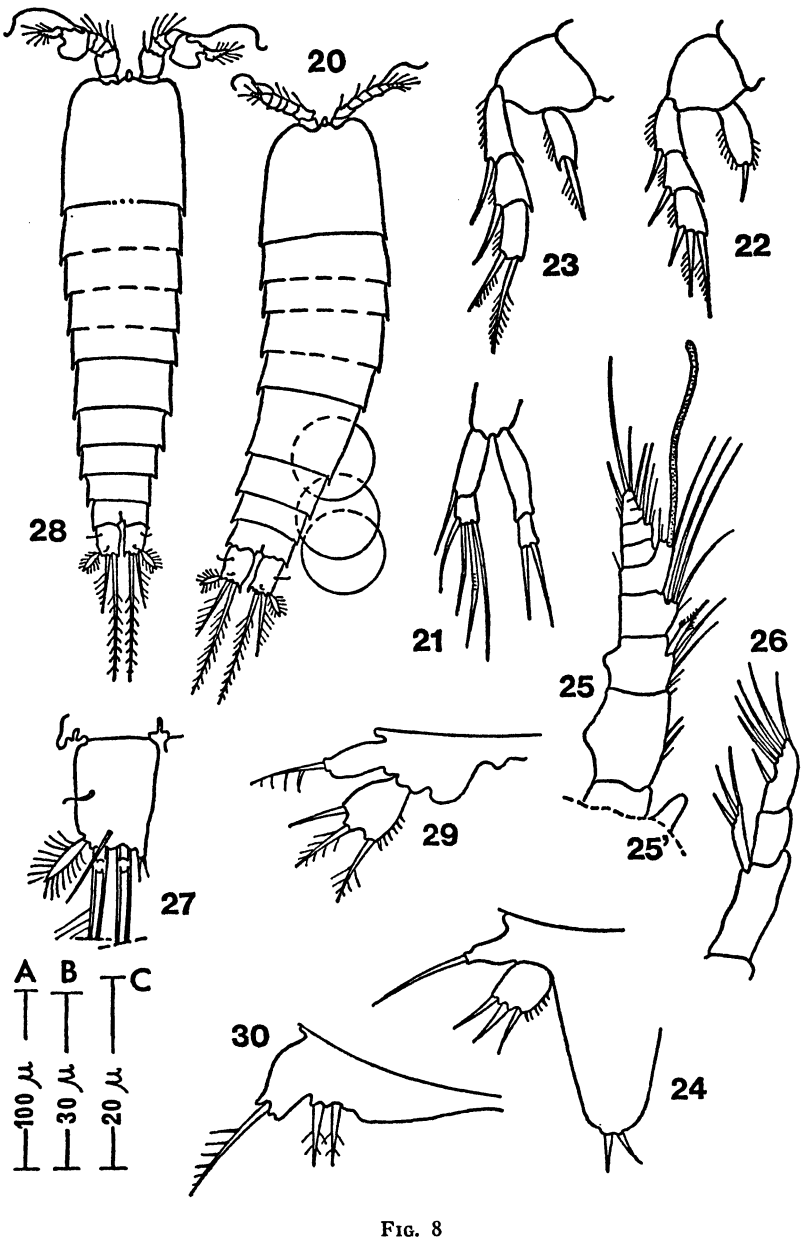


FIG. 8

Kliopsyllus constricta orotavae (Noodt)

Female (20-27). 20, total view, dorsal (scale A); 21, P1 (B); 22, P2 (B); 23, P4 (B); 24, P5 (C); 25, antennule (B); 25', rostrum (B); 26, antenna (B); 27, furca (B). *Male* (28-30). 28, total view, dorsal (A); 29, P5 (C); 30, P6(C).

Occurrence:

Found abundantly in the coarse sand of Nahariyya (Station 8), in same samples that yielded many specimens of *Kliopsyllus minutus* n. sp. Also found at Nitzanim (1) and Mikhmoret (4), but in smaller quantities.

Discussion:

This species is similar in size, shape and armature to *K. constricta orotavae* as described by Noodt (1958). The species described here has finely pennated subterminal and apical setae on exopodites P2-4, while Noodt describes them as having extremely long hair. Slightly different is the ways the setae on the antenna's expodite are arranged and the fact that the short brush like spine on the furca is more thickly covered with hair in the species described here.

Cylindropsyllidae Sars, Lang.

Psammotopa vulgaris Pennak 1942 (Fig. 9).

Material: five females and many males.

Female (Fig. 9: 32-40).

Length 0.40-0.47 mm. Body cylindrical and elongated, slightly tapering towards abdominal end. Rostrum long, cone-like, rounded at its end, bending downwards like a hook. Antennule eight segmented with sensorial setae on segments 3, 4, and 8. A two-jointed antenna carries an unisegmented exopodite that ends with two short setae.

P1-4: endopodite P1 biarticulated. All other endo- and exopodites triarticulated, all with serrated terminal margins on first and second segments. Armature and length proportions between the different segments of the swimming legs are as follows:

P1					P2					
Exopodite		Endopodite			Exopodite			Endopodite		
1	2	1	2	3	1	2	3	1	2	3
0	111	0	0	011	0	0	112	0	0	111
32:	26:	13:	13:	14:	16:	13:	14:	12:	12:	13:

P3						P4					
Exopodite			Endopodite			Exopodite			Endopodite		
1	2	3	1	2	3	1	2	3	1	2	3
0	0	112	0	0	112	0	0	112	0	0	112
16:	14:	14:	13:	12:	13:	15:	14:	17:	14:	12:	15:

P5-6: basiendopodite well defined, bearing two well pennated short setae and one fine lateral seta. Exopodite P5 rectangular, bearing five setae, the middle one being the longest, with only the two inner ones pennated. Sixth leg made of small rectangular plate carrying three short setae.

Furca: rectangular, 1 1/2 times longer than wide and slightly tapering towards its end. Inner margin bearing hair. The terminal surface is base to three setae. The innermost is shorter than the furca itself, the median about six times longer and the outer, three

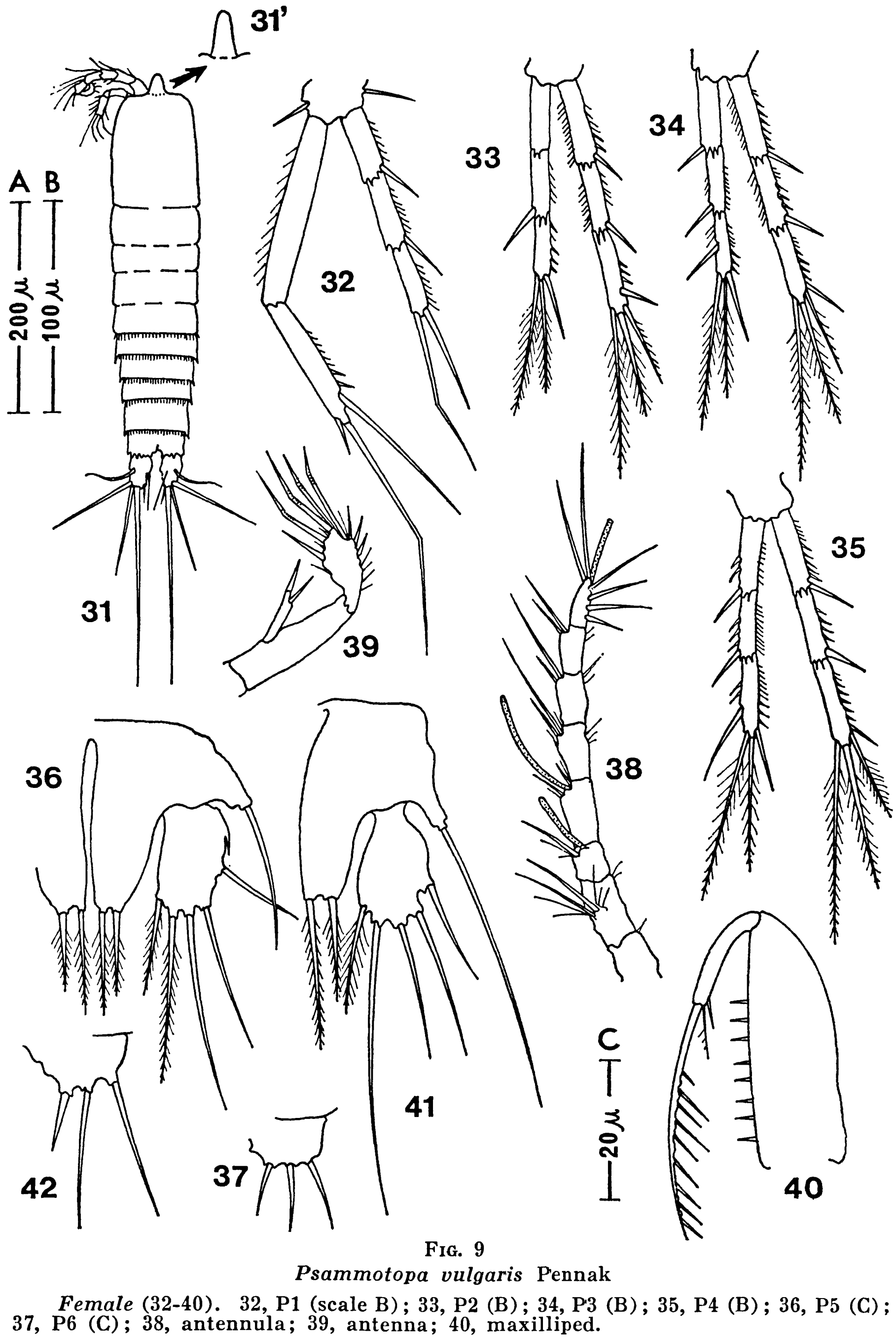


FIG. 9
Psammotopa vulgaris Pennak

Female (32-40). 32, P1 (scale B); 33, P2 (B); 34, P3 (B); 35, P4 (B); 36, P5 (C); 37, P6 (C); 38, antennula; 39, antenna; 40, maxilliped.

Male (31, 41-42). 31, total view, dorsal (A); 31', rostrum; 41, P5 (C); 42, P6 (C).

times as long. Typical is the long spine-like seta emerging two-thirds the way from the furca's base in a lateral position.

Male (Fig. 9:41-42).

Length: 0.37-0.42 mm. Similar to female, only slightly shorter. Antennule seven jointed, carrying sensorial setae on segments 3, 4, and 7. Fourth segment of antennule much longer than that of the female. P5 similar in size to that of female, but the exopodite is much narrower at its base. Lateral seta of basiendopodite P5 is very long and so is the second inner seta of the exopodite which is not pennated as in the female. P6 has two long and one short setae.

Occurrence:

Clean sand, well sorted, and having a dominant grain size group of 0.25-0.50 mm. Abundant at Akhziv (9), Nahariyya (8) and Nitzanim (1).

Discussion:

Females were very scarce and were not found at Nitzanim. Average length of mature species found here is smaller than what Pennak (1942) gives (0.435 mm, as compared with 0.475 for Pennak's females; in males, 0.385 mm as compared with 0.455 mm). Another difference between the specimens described here and those of Pennak is that the setae on exopodite P5 are much longer in the former.

Leptastacus operculatus n. sp. (Fig. 10, 11).

Material: one female; one male.

Female (Fig. 10).

Length 0.418 mm. Body cylindrical, slightly tapering towards end of abdomen. Abdominal segments all bearing a tight band of fine hair along their posterior margin. Rostrum elongated, cane like, rounded at its end and only slightly shorter than the first antennular segment. Antennule seven segments, the second being the longest and the fourth bearing a long aesthete. Antenna and maxilliped typical of the genus.

P1-4: endopodites 1-4 biarticulated. Endopodite P1 about 1 1/4 times longer than the corresponding exopodite. Endopodites 2-4 slightly longer than the first two segments of the corresponding exopodites. Terminal edges of the segments of swimming legs 2-4 serrated into a multiple spine-like finish. The armature of the swimming legs is as follows:

	P 1					P 2					P 3					P 4				
	Exopodite			Endopodite		Exopodite			Endopodite		Exopodite			Endopodite		Exopodite			Endopodite	
	1	2	3	1	2	1	2	3	1	2	1	2	3	1	2	1	2	3	1	2
L. operculatus:	0	0	111	0	011	0	0	021	0	010	0	0	121	0	020	0	1	121	0	*011*
L. constrictus Lang:	0	0	111	0	011	0	0	021	0	010	0	0	121	0	020	0	1	121	0	010

P5: fused into one triangular plate bearing an apical seta on its point. Two more setae, one situated a bit lower of the terminal point and a second lateral one as well as a short lateral spine-like process conclude the armature of P5.

Furca: long and tapering, 2 1/2 times longer than wide. The furca ends with two thick apical points and carries three dorsal setae slightly longer than its own length. A long dorsal sub-terminal seta

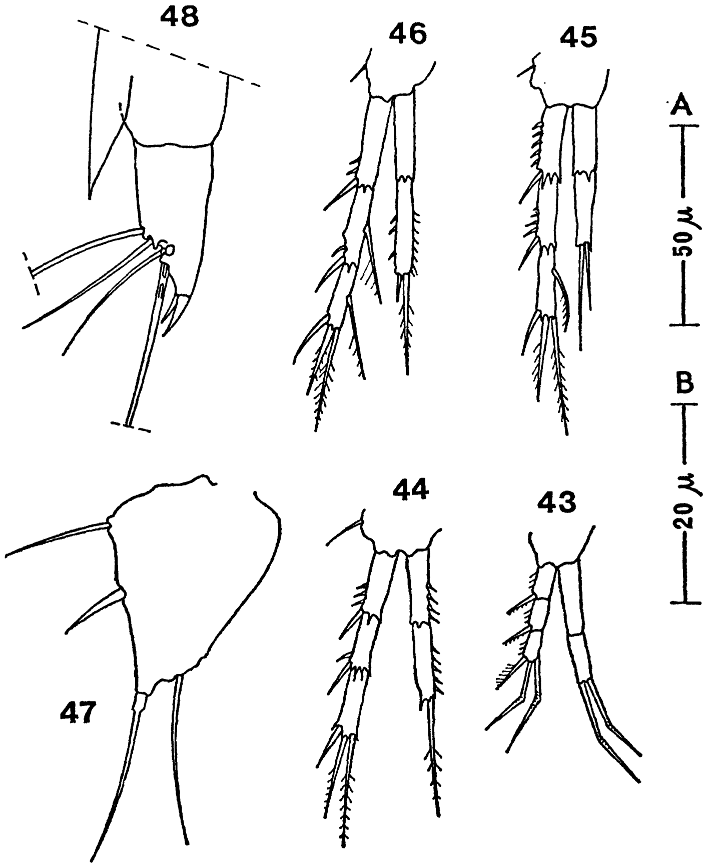


FIG. 10
Leptastacus operculatus n. sp., female (43-48).

43, P1 (scale A); 44, P2 (A); 45, P3 (A); 46, P4 (A); 47, P5 (B); 48, furca and operculum, lateral view (A).

(4 1/2 times longer than the furca), a small spine situated at its base and a short, fine dorsal seta conclude the armature of the furca.

The operculum is very prominent, reaches backwards between the furcal branches and ends with a point covering half their length.

Male (Fig. 11).

Length 0.412 mm. Shape and size resembling female. Operculum larger than in female and reaching back past the halfway line of the furcal branches. Furca with two long dorsal sub-terminal setae, the shorter only twice the length of the furca.

The terminal setae on endopodite P3 much shorter than their equivalent in the female. The lateral spine on the first segment of exopodite P4 of the right leg is 2 1/2 times longer than its equivalent

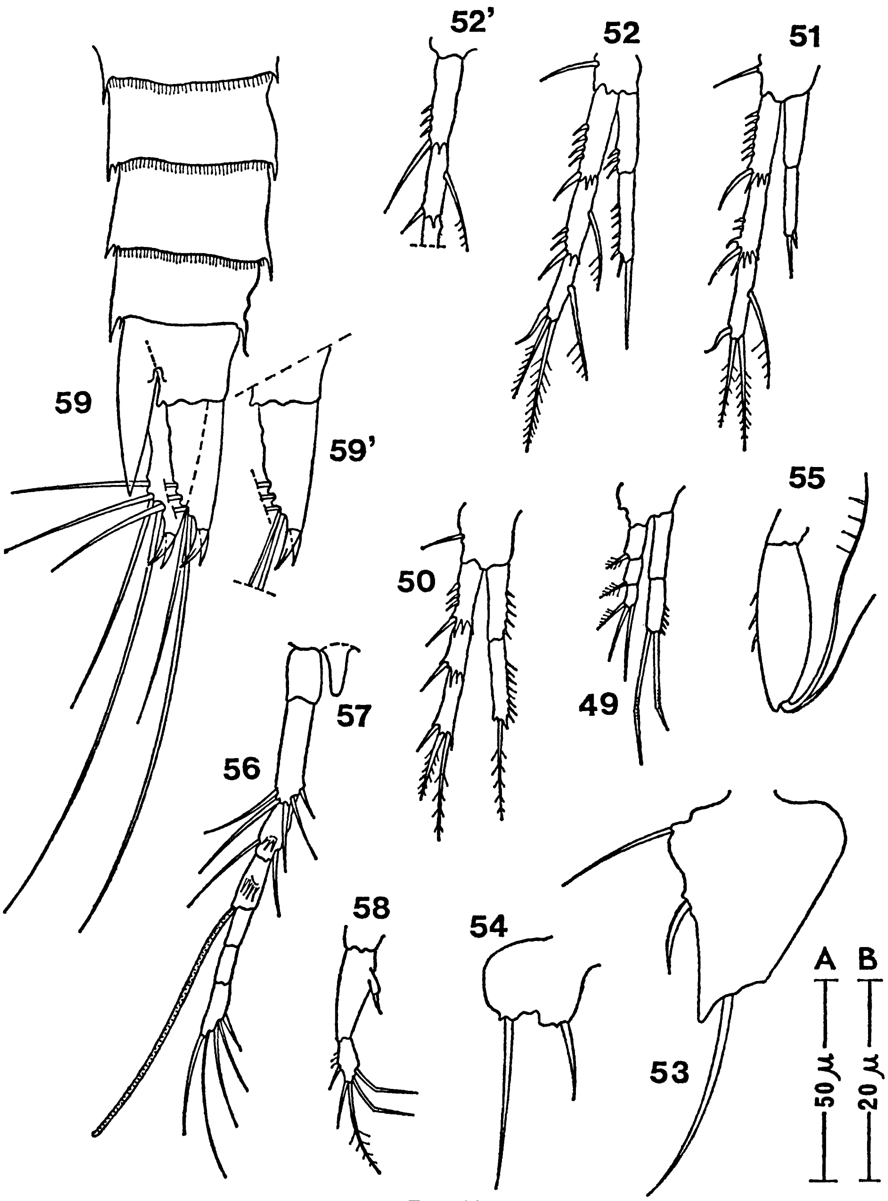


FIG. 11

Leptastacus operculatus n. sp., male (49-59).

49, P1 (scale A); 50, P2 (A); 51, P3 (A); 52, P4 (A); 52', right exopodite P4 (A); 53, P5 (B); 54, P6 (B); 55, maxilliped (A); 56, antennule (A); 57, rostrum (A); 58, antenna (A); 58 and 59', posterior segments of abdomen, operculum and furca, lateral view (A).

on the other leg. P5 is made of one triangularly shaped plate, but lacks a terminal seta on its pointed tip. P6 squarish, bearing one short and one long setae separated by a shallow depression.

Occurrence:

Both male and female were found in a sample taken in summer at Akhziv (Station 9).

Discussion:

The description of *Leptastacus constrictus* Lang (1964) resembles our species in many ways: armature of swimming legs (except for endopodite P4) and shape of P5. While in the male of *L. operculatus,* P5 ends with a rounded point, that of *L. constrictus* has a small apical seta. Antennule similar to that of *L. constrictus* but narrower and longer. Rostrum elongated in both cases, but lacking sensorial setae in our species. *L. constrictus* has a small rounded operculum and the armature of its furcal branches is completely different. *L. operculatus* is rather longer (0.420 mm) as compared with *L. constrictus* (0.350 mm).

Leptastacus rostratus Nicholls (1940) has a long operculum, but it is forked at its end. Size and many other morphological characteristics which differ from *L. operculatus* are called for forming the new species.

Arenopontia problematica n. sp. (Fig. 12).

Material: many specimens, 95 p. 100 of which were females.

Female (Fig. 12:60-69).

Length 0.290-0.320 mm. Body cylindrical, elongated, longer 5 times than wide. Posterior edges of all body segments are smooth. The rostrum is a small rounded-at-the-points triangular plate. Antennule five segmented, the first is nearly equal in length to all the others put together and the fifth bears a long apical aetheste. The two segmented antenna carries no exopodite.

P1-P4: endopodites P1-4 bi-articulated while the corresponding exopodites are tri-articulated. The first segment of endopodite P1 is 1 2/3 times longer than the whole of exopodite P1. Endopodites P2-4 are equal to or slightly longer than the first segments of the corresponding exopodites. Basopodites P2-4 carry a long and weakly pennated seta. The distal margins of the first and second segments of exopodites P2-4 are boldly serrated, and their outer lateral margins carry rows of strong spines. Each of the segments 1 and 2 of exopodites P2-4 bears an outer lateral weakly pennated seta, in a subterminal position.

P1		P2		P3		P4	
Exopodite	Endopodite	Exopodite	Endopodite	Exopodite	Endopodite	Exopodite	Endopodite
1 2 3	1 2	1 2 3	1 2	1 2 3	1 2	1 2 3	1 2
0 0 211	0 011	0 0 111	0 111	0 0 111	0 011	0 0 112	0 011

P5: squarish in shape, bearing a deep incision 1/3 of the way along its posterior margin. Three short spines and one smooth seta form the armature of P5.

Furca: rectangular, slightly tapering and 1 1/5 times longer than wide. A long apical seta and a large terminal spine are most promi-

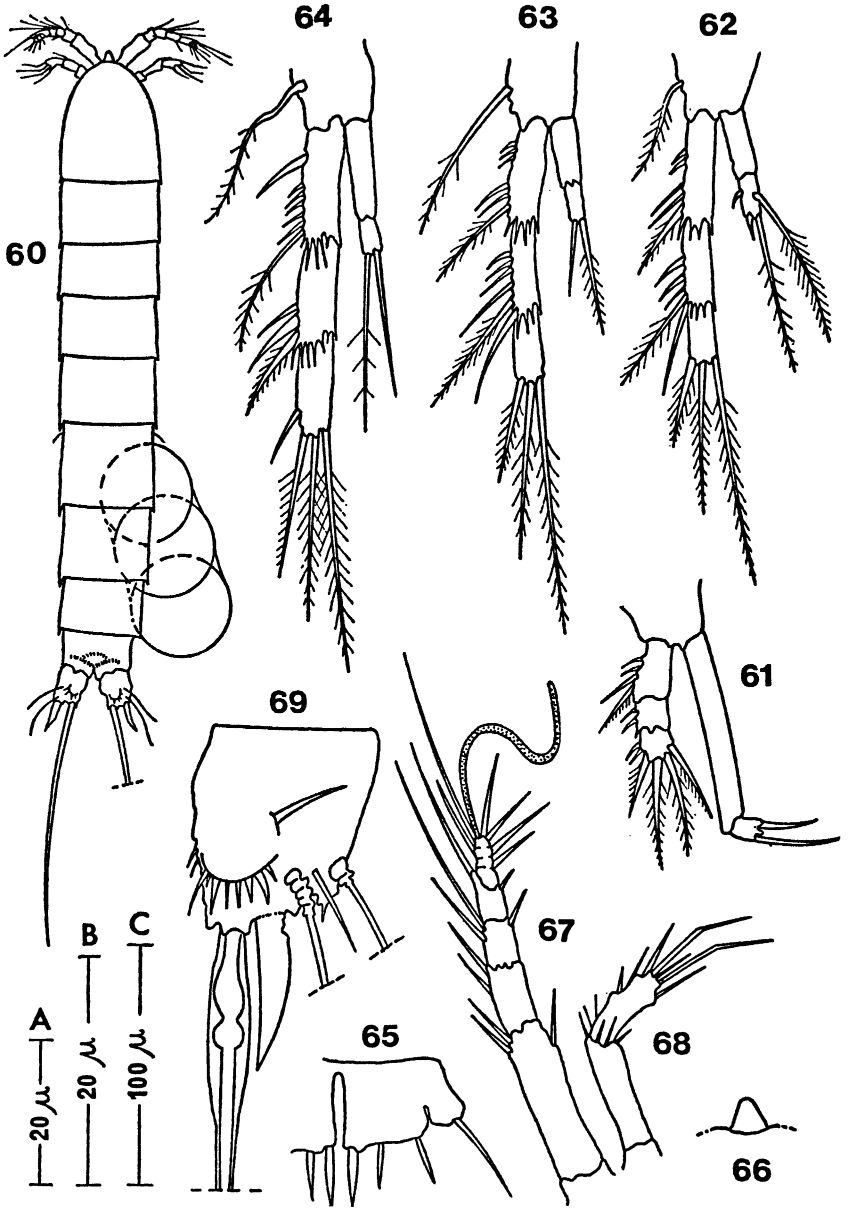


FIG. 12
Arenopontia problematica n.sp., female (60-69).

60, total view, dorsal (scale C); 61, P1 (A); 62, P2 (A); 63, P3 (A); 64, P4 (A); 65, P5 (A); 66, rostrum (A); 67, antennule (A); 68, antenna (A); 69, furca, dorsal (B).

nant characteristics. Two fine setae rise from knob like bases at the outer distal corner of the furcal plate. The furca also carries two short dorsal setae and about a dozen spinulae forming a little semicircle near the inner margin.

Male.

Similar to female but smaller (length: 0.272-0.295 mm). P6 is a minute plate bearing three spines.

Occurrence:

Interstitial sand, well sorted with dominant grain size group of 0.5-0.25 mm or smaller. Abundant in the following beaches: Nitzanim (Station 1), south of Tel-Shiqmona (5), Mikhmoret (4) and in smaller quantities at Palmahim (3) and Tel Yavne (2).

Discussion:

Many similar characteristics are found between *Arenopontia problematica* n. sp. and *A. subterranea* Kunz. While the latter carries a small exopodite on the antenna, it is absent in *A. problematica.* P1 is similar in both cases regarding exo-endopodite proportions, but the terminal setae on the exopodites differ in structure. *A. problematica* has two long terminal setae on endopodite P3 as compared with only one in *A. subterranea.* The armature of the furca and the shape of P5 differ slightly and so does the average length, *A. problematica* being the smaller of the two (0.305 mm and 0.380 mm respectively).

Arenopontia acantha Chappuis 1953 (Fig. 13).

Material: many males and females.

Female (Fig. 13:70-74, 75-79).

Length 0.380-0.420 mm. Body cylindrical, tapering and about 5-6 times longer than wide. The posterior margins of the two last abdominal segments deeply dented by 3-4 rounded depressions. The operculum is small, squarish smooth and enclosed on both sides by pointed projections of the last abdominal segment. Under these pointed projections, the posterior margin of the last abdominal segment partly covers the furcal plates. Rostrum is small and rounded. Antennule six segmented, the second being the longest and the last carrying an elongated apical aetheste. Antenna tri-articulated bearing a small one segmented exopodite.

P1-4: endopodites P1-4 bi-articulated. Endopodite P1 slightly longer than exopodite P1, while endopodites P2-4 slightly shorter or equal in size to the first segment of the corresponding exopodites. Basopodites P1-2 carrying a lateral seta each. Basopodites P3-4 bearing a long and weakly pennated lateral seta. The armature of the swimming legs is as follows:

P 1		P 2		P 3		P 4	
Exopodite	Endopodite	Exopodite	Endopodite	Exopodite	Endopodite	Exopodite	Endopodite
1 2 3	1 2	1 2 3	1 2	1 2 3	1 2	1 2 3	1 2
0 0 022	0 011	0 0 021	0 111	0 0 021	0 011	0 0 021	0 011

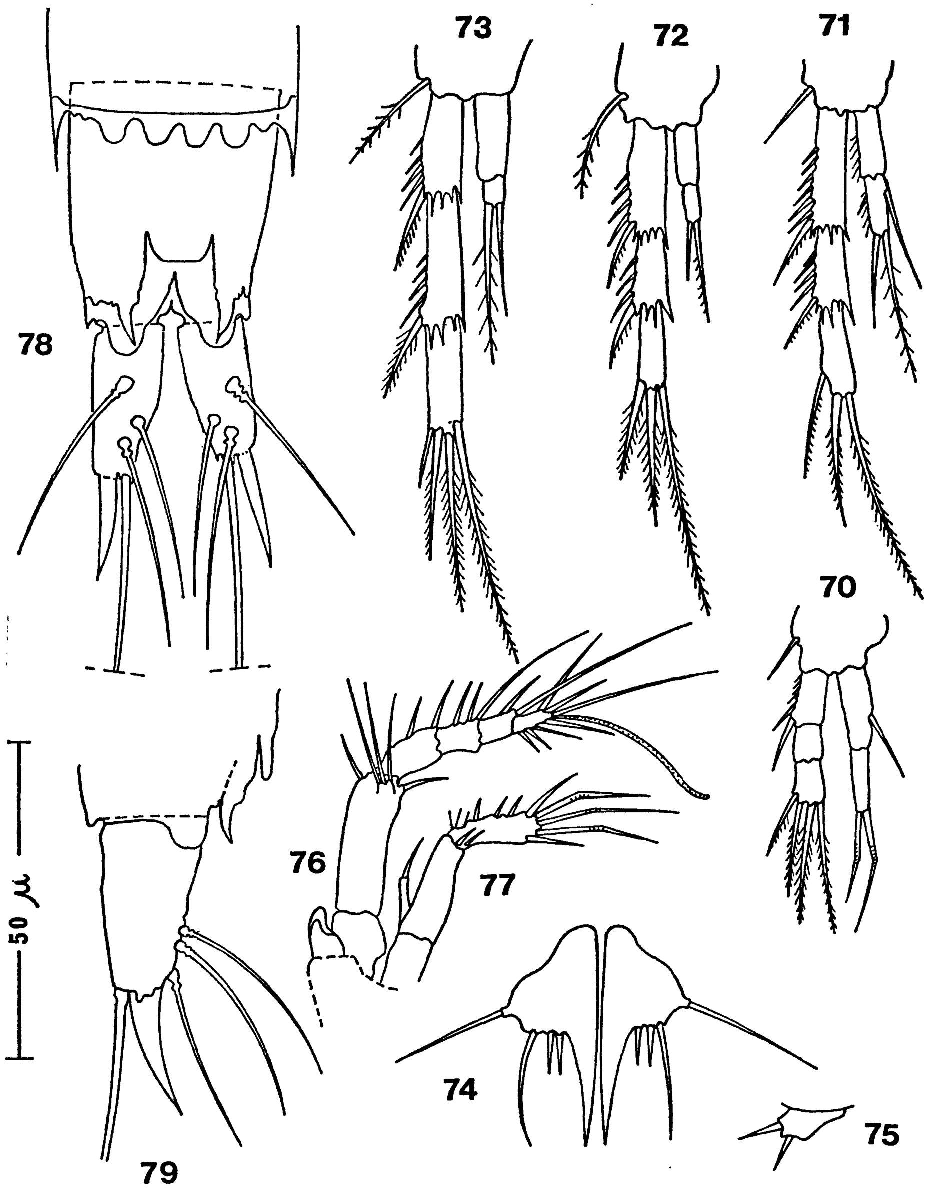


FIG. 13
Arenopontia acantha Chappuis

Female (70-74, 76-79). 70, P1; 71, P2; 72, P3; 73, P4; 74, P5; 76, rostrum and antennule; 77, antenna; 78, posterior segments of abdomen and furcal plates, dorsal view; 79 furca, lateral view.
Male. 75, P6.

P5: a small triangular plate, its inner corner projecting backwards in a long point. Two short spines and one long seta are based along the posterior edge of the plate with one more fine seta emerging from a lateral position.

Furca: rectangular, 2 1/2-3 times longer than wide, slightly tapering and ending with a long curved dagger like process. One long terminal seta and three fine setae with bulb like bases conclude the furca's armature.

Male.

Similar in morphological details to the female but shorter (length 0.365-0.390 mm). P6 made of a very small plate bearing two minute setae.

Occurrence:

Clean sand, well sorted and having a dominant grain size group equal or larger than 0.25-0.50 mm. Abundantly found in Nahariyya (station 8) and Akhziv (9).

Discussion:

Apart for the fact that the specimens I found in the above sites were smaller than *Arenopontia acantha* described by Chappuis (1953) and some minor microstructures which were added above, it is quite reasonable to assume that both species are identical.

Laophontidae T. Scott.

Afrolaophonte pori n. sp. (Fig. 14-15).

Material: many males and females.

Female (Fig. 14).

Length 0.290-0.330 mm. Body cylindrical, slightly tapering 4 1/2-5 times longer than wide. The posterior margins of the abdominal segments bear a band of fine hair. Operculum rounded and rimmed with fine hair. Rostrum triangular in shape with two deep depressions that give it a winged appearance. Antennule six segmented. Inner latero-distal corner of antennule's first segment elongated into a point. The second segment bears a short and thick spine on its outer margin and six setae, three of which have bulb like bases. The fourth segment bears a long aetheste. The sixth segment carries five setae with bulb like bases. Antenna bi-articulated with a small one segmented exopodite that bears four setae.

P 1: coxa bearing spinulae along the outer lateral edge. Basopodite with several longer spines, a bi-articulated endopodite and a small one segmented exopodite. Endopodite's first segment 6 times longer than wide and bear of any armature. The second segment is

3 1/2 times smaller than the first and terminates with a thick seta and a minute spine.

P 2: endopodite absent. Exopodite one segmented bearing two spine-like setae. Basopodite with one lateral seta.

P 3: exopodite tri-articulated. Endopodite bi-articulated bearing two terminal setae. Basopodite with one lateral seta situated on an elongated projection of the basopodite.

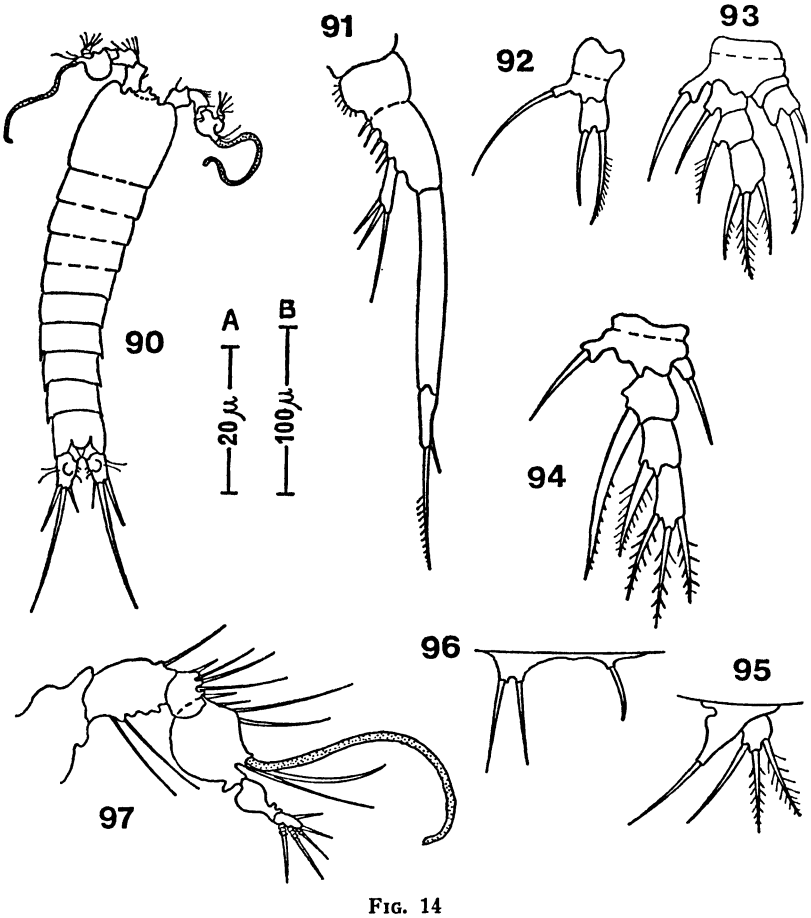


FIG. 14
Afroloaphonte pori n. sp., female (80-99).

80, total view, dorsal (scale B); 81, P1 (A); 82, P2 (A); 83, P3 (A); 84, P4 (A); 85, P5 (A); 86, rostrum; 87, antennule (A); 88, antenna (A); 89, furca (A).

P 4: exopodite tri-articulated, similar in armature to exopodite P 3 but much larger (see below). Endopodite one segmented with two long terminal setae. Basopodite carries a pennated seta on an elongated projection.

P 5: very large and well developed. Basiendopodite carrying two claw-like spines on its inner lateral margin, two pennated setae and one fine seta in an outer lateral position. Exopodite rounded twice longer than wide, carrying four pennated setae and a row of spinulae along its inner margin.

For details on length proportions between the different segments of the swimming legs, see below.

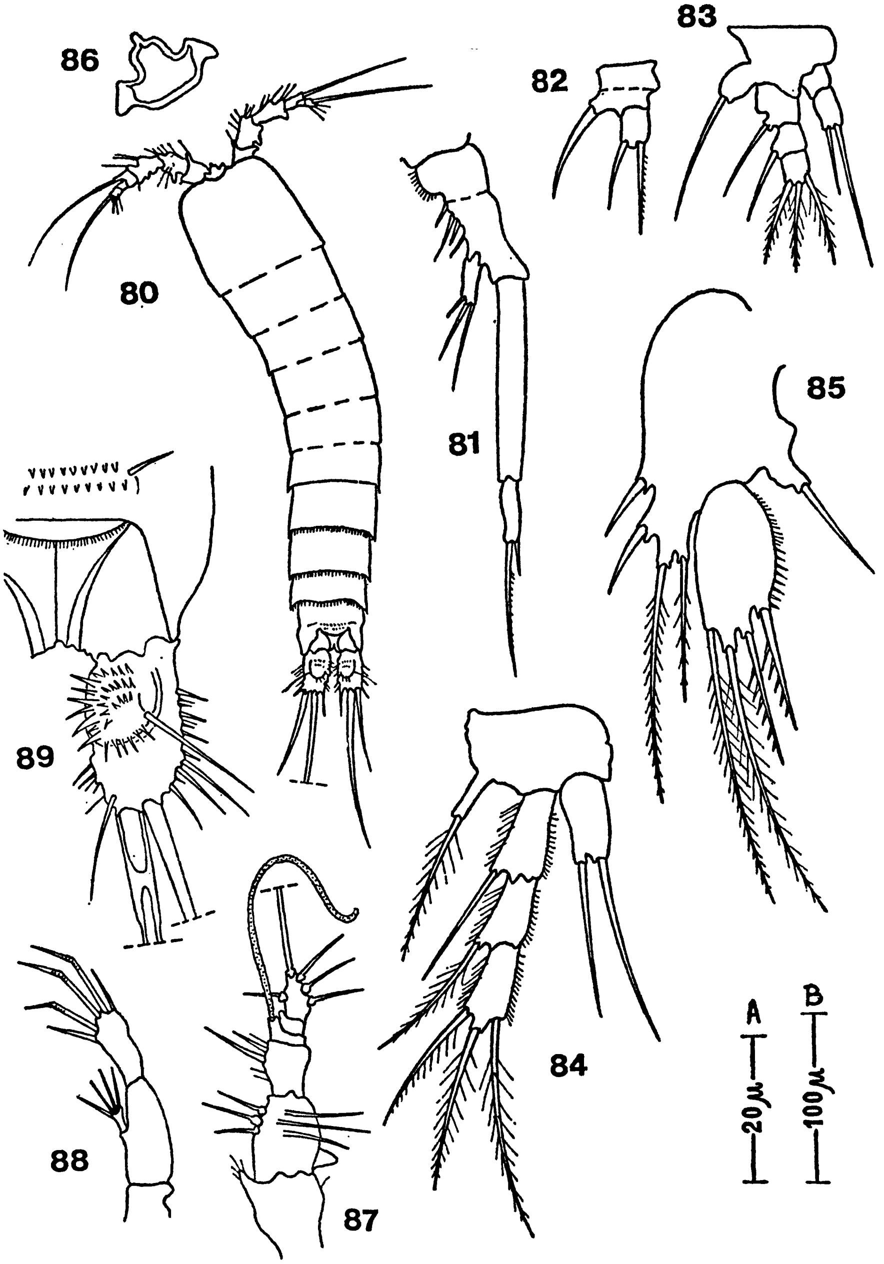


FIG. 15
Afroloaphonte pori n. sp. male (90-97).

90, total view, dorsal (scale B); 91, P1 (A); 92, P2 (A); 93, P3 (A); 94, P4 (A); 95, P5 (A); 96, P6 (A); 97, antennule (A).

	P 1			P 2		P 3					P 4			
	Exopodite	Endopodite		Exopodite	Endopodite	Exopodite			Endopodite		Exopodite			Endopodite
	1	1	2	1	—	1	2	3	1	2	1	2	3	1
Female :	10:	37:	11:	7:	—	7:	6:	6:	5:	7:	17:	14:	17:	16
Male :	9:	35:	10:	6:	—	5:	7:	9:	2:	5:	10:	9:	10:	3

Furca: rectangular, 1 3/4 times longer than wide. A rounded and spiny elevation the size of half the furca, rises along its dorsal surface. Two large terminal setae, two fine setae dorsally situated and a row of spines along the inner and outer lateral surfaces make up the furca's armature.

Male (Fig. 15).

Similar in shape but shorter than the female (length 0.250-0.300 mm). Antennule six segmented, the fourth being very broad and rounded. Aetheste on fourth segment and minute terminal segment carrying five short spines, four of them with bulb-like base.

P 1: similar in size, build and ornamentation to that of female.

P 2: same as female.

P 3: exopodite same as female. Bi-articulated endopodite with two terminal spines. The inner spine very strong and curved like a dagger and 2-2 1/2 times longer than the endopodite. Outer spine small.

P 4: three segmented exopodite and one segmented endopodite, but different in size and proportions as compared with P 4 of female. Segments 1 and 2 of the exopodite bear large dagger-like spines that reach beyond the last segment. Third segment with three pennated spines. Endopodite minute with a fine terminal seta.

P 5: basiendopodite small and triangular bearing one terminal seta. Exopodite pear-shaped bearing two pennated and one smooth setae.

P 6: made of one band shaped plate carrying two setae on an inner elevation and a third one on the outer corner of the plate.

Occurrence:

Very abundant in coarse sands with a dominant grain size group, equal or larger than 0.25-0.50 mm. *Afrolaophonte pori* is the dominant species at all digging levels in Nahariyya (station 8), and is found also in Nitzanim (1) and Akhziv (9).

Discussion:

Our species is closely related to the described species of *Afrolaophonte breviceps* (Chappuis 1954), *A. monodi* (Chappuis 1960) and *A. renandi* (Chappuis et Delamare-Deboutteville 1956). P1, P2 and P4 are similar in shape, although first segment of exopodite P2 (in *A. renandi*) or P4 (in *A. breviceps*) are united with the basopodite. P3 differs from that of our species but P5 (male and female) is similar in shape.

It, therefore, seems quite appropriate to assume that *Afrolaophonte pori* is a new species.

Summary

Nine beaches along the Israeli Mediterranean coast line were chosen for this study. Granulometric analysis of the sand and the salinity and pH of the interstitial waters were studied, and corresponding samples were taken from every one of the digging sites where fauna was collected. Granulometric analysis revealed a direct correlation between the type and amount of fauna and the sand's dominant grain size group. Temperature measurements (taken in the sand of one beach chosen for the purpose) showed the existence of an intermediate layer in the sand where temperature changes were small. The salinity and pH were recorded to reveal the dilutive effect of the outflowing continental water.

Collecting from the interstitial waters yielded eight different species of Harpacticoids, of them four new to science: *Kliopsyllus minutus* n. sp., *Leptastacus operculatus* n. sp., *Arenopontia problematica* n. sp., and *Afrolaophonte pori* n. sp. Other faunistic groups were quantitatively recorded in order to form a more complete picture of the sandy biotopes being dealt with.

Zusammenfassung

Im Rahmen der vorliegenden Arbeit wurden neun Strandareale der Mittelmeerküste Israels untersucht. Überall wo die Lückenfauna gesammelt wurde, wurden Sandproben entnommen, granulometrisch analysiert und pH und Salzgehalt des Lückenwassers bestimmt. Die Ergebnisse der granulometrischen Analysen wiesen auf eine direkte Korrelation zwischen vorherrschender Korngrösse und Art und Menge der Lückenbewohner hin. — Eines der Strandareale wurde zu Temperaturmessungen ausgewählt. Es konnte eine Sand-Mittelschicht festgestellt werden, in der die Temperaturschwankungen gering waren. Mit Hilfe der Salzgehalt- und pH-Daten konnte eine Verdünnung durch vom Festland kommendes Wasser nachgewiesen werden.

Die aufgesammelte Lückenfauna umfasste 8 Harpacticoiden-Arten, von denen 4 neu sind : *Kliopsyllus minutus* n. sp., *Leptastacus operculatus* n. sp., *Arenopontia problematica* n. sp. und *Afrolaphonte pori* n. sp. Weitere Tiergruppen wurden quantitativ ausgewertet ; hierdurch ergab sich ein besser abgerundetes Bild der untersuchten Sandbiotope.

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