

Burrows of *Callianassa bowvieri* NOBILI 1904 from Safaga (Egypt, Red Sea) with some Remarks on the Biology of the Species.

With 5 Text-Figures, 1 Table, and 2 Plates.

PETER C. DWORSCHAK & PETER PERVESLER.

Abstract.

[DWORSCHAK, P. C. & PERVESLER, P. (1988): Burrows of *Callianassa bowvieri* NOBILI 1904 from Safaga (Egypt, Red Sea) with some remarks on the biology of the species. — *Senckenbergiana marit.*, 20 (1/2): 1-17, 5 figs., 1 tab., 2 pls.; Frankfurt a. M.]

Burrows of the thalassinidean shrimp *Callianassa bowvieri* were investigated by *in situ* resin casting in a mangrove stand near Safaga, Red Sea.

The following burrow sections can be recognized: a J leading from the funnel-shaped opening downwards to 1-4 chambers connected by tunnels; a tunnel which becomes constricted distally and then leads upwards as a thin shaft to the second opening at the top of a small mound; an upward spiral; a downward spiral; and occasionally a second upward spiral part branching off one of the deeper chambers. Mean diameter of burrow parts with regular diameter are related to animal size. Total depth, horizontal extension, total length, burrow volume, and burrow surface are size-dependent. Dip and trend angle analyses show a characteristic burrow orientation.

Additional information on biometry, variation in cheliped shape, size frequency distribution, density and fecundity of this species is given. The variation in cheliped shape, the morphology of the burrows, and the influence on the sediment is discussed.

Kurzfassung.

[DWORSCHAK, P. C. & PERVESLER, P. (1988): Die Bauten von *Callianassa bowvieri* NOBILI 1904 aus Safaga (Ägypten, Rotes Meer) mit Anmerkungen zur Biologie der Art. — *Senckenbergiana marit.*, 20 (1/2): 1-17, 5 Abb., 1 Tab., 2 Taf.; Frankfurt a. M.]

Mehrere Bauten des thalassiniden Krebses *Callianassa bowvieri* wurden im untersten Eulitoral einer Mangrove im Roten Meer mit Kunstharz ausgegossen.

Authors' Addresses: Dr. PETER C. DWORSCHAK, Institut für Zoologie, Universität Wien, Althanstrasse 14, A-1090 Wien, Austria. — Dr. PETER PERVESLER, Institut für Paläontologie, Universität Wien, Universitätsstrasse 7, A-1010 Wien, Austria.

Die Ausgüsse lassen folgende Bauabschnitte erkennen: 1. ein zentrales U; bestehend aus a) einem J, das von der trichterförmigen Öffnung in die Tiefe führt; b) ein bis vier Kammern verbunden durch Gänge; c) einem waagrechten Gang, der sich distal verengt und als sehr dünner Schacht an die Oberfläche zur Öffnung an der Spitze eines kleinen Hügels führt; 2. eine vom Zentralabschnitt aufwärts führende Spirale; 3. eine vom Zentralabschnitt abwärts führende Spirale; und 4. manchmal eine zweite, von einer tieferen Kammer abzweigend, aufwärts führende Spirale. Die Bauten weisen eine ausgeprägte Orientierung auf, alle Baudimensionen sind größenabhängig.

Zusätzlich werden Angaben zur Größenverteilung, Biometrie, Variabilität der Chelipeden, sowie Dichte und Fekundität dieser Krebsart angeführt. Im Anschluß werden die Morphologie der Bauten sowie deren Einfluß auf das Sediment diskutiert.

Introduction.

Callianassid shrimps are important infaunal elements of tropical back-reef and lagoonal environments. Their burrowing activity has many effects on the physical and chemical properties of the sediment (summarized in VAUGELAS 1985). This bioturbation may even influence adjacent animal (ALLER & DODGE 1974) and plant communities (SUCHANEK 1983) by lateral particle transport (ROBERTS & SUCHANEK & WISEMAN 1982).

Burrows of callianassid shrimps have been intensively studied since the introduction of an *in situ* resin casting technique by SHINN (1968). Although certain variations do exist, burrows show a characteristic architecture (see DWORSCHAK 1983) which is species-specific (SUCHANEK 1985).

Burrows of two large species of *Callianassa* from the Red Sea have been described recently by VAUGELAS (1984). This paper deals with the biology and the burrows of *Callianassa bowvieri*, which is common in the Red Sea mangal (FISHELSON 1971; PRICE & MEDLEY & McDOWALL & DAWSON-SHEPERD & HOGARTH & ORMOND 1987).

Environmental Setting.

The study area is situated on the western coast of the Red Sea, 20 kilometers south of Port Safaga (Fig. 1). The site itself measures about 1000 by 50 metres and consists of a poorly developed mangrove stand. The only mangrove species is *Avicennia marina*.

The shore is backed by a desert zone. A raised fossil reef flat from a Quaternary reef extends seawards (BRAITHWAITE 1987). This fossil reef flat has been deformed by erosional processes. The outer margin at a distance of approximately 300 meters from the recent shoreline reaches up to the low-water level and forms the base for new coral growth creating a fringing reef enclosing a sandy lagoon. At a distance of 10 to 100 meters from the coast the fossil reef flat, undercut by wave action, is divided into small table-like rocks (Pl. 1 fig. 1). The space between these rocks is filled with fine sand composed of carbonatic and siliciclastic material. Such relatively thin sediments over subfossil or raised coral/rock are typical for the hard-bottomed mangal of the Red Sea (POR 1984).

The sandy supratidal zone is populated by the ghost crab *Ocypode saratan*. The upper intertidal is dominated by the crabs *Uca tetragonon*, *Uca inversa*, *Uca lactea*, *Macrophthalmus depressus*, *Dotilla sulcata*, and *Cyclograpsus* sp. The range of these

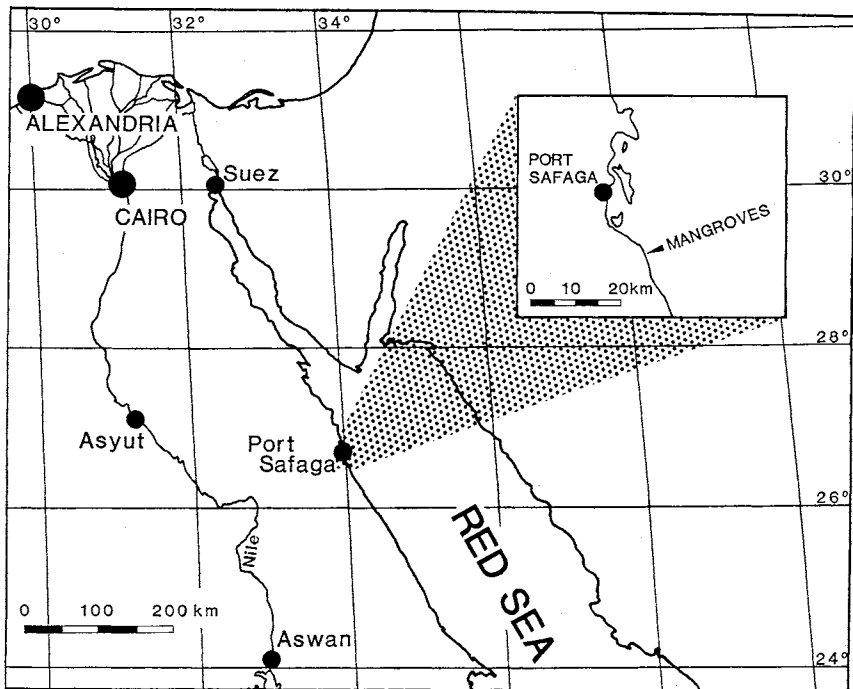


Fig. 1. Map of the northern Red Sea showing location of the mangrove stand (study area where resin casts were made) south of Port Safaga (Egypt).

Abb. 1. Lage der Mangrove im Roten Meer südlich von Port Safaga (Ägypten).

burrowing crabs ends with the appearance of *Avicennia marina* in the lower intertidal zone. This zone consists of muddy fine sand with a median diameter of 115 μm , a subsieve fraction ($< 63 \mu\text{m}$) of 11%, and an organic content of 1.1% (loss on ignition at 450° for 4 h). The sediment surface is characterized by mounds and craters originating in the burrowing activity from the thalassinid shrimp *Callianassa bowvieri* (Pl. 1 figs. 2-3). The burrow density seems to decrease from the sheltered mangrove patches to the open lagoon.

Material and Methods.

Callianassa bowvieri occurs in the Gulf of Aden (Djibouti: NOBILI 1904, 1906) and in the Red Sea (Gulf of Aquaba and Sinai Peninsula: HOLTHUIS 1958), where it is common in sandy sublittoral bottoms (FISHELSON 1971). PRICE & MEDLEY & McDOWALL & DAWSON-SHEPERD & HOGARTH & ORMOND (1987) found this

species to be a typical element of mangroves along the Saudi Arabian coast. The shrimp also occurs in the Indian Ocean (Madagascar: THOMASSIN 1978) and in the Pacific off Japan and Korea (SAKAI 1970).

Animals were captured with a simple "yabby pump" similar to that described by MANNING (1975) and fixed immediately in 4% buffered formaldehyde-seawater. They were measured with sliding calipers (± 0.1 mm), and the drawings made using a stereo-microscope equipped with a camera lucida.

Resin cating was done *in situ* using an epoxy resin (for details of method, see PERVESLER & DWORSCHAK 1985). Orientation of two burrows was measured and evaluated as outlined by HOHENEGGER & PERVESLER (1985). Diameter, depth and length of burrows were measured with sliding calipers.

Results.

The Animals.

Biometry, Size Frequency Distribution.

A total of 37 animals were captured (6 males, 7 females in November 1984; 14 males, 10 females in May 1986). Eight specimens each were deposited in the collections of the Forschungsinstitut Senckenberg (Frankfurt a.M.) and the Naturhistorisches Museum (Wien), respectively. Total length — measured from the tip of the rostrum to the end of the telson — ranges from 12 to 25 mm. Carapace length (CL in mm) is linearly related with total length (TL in mm):

$$\begin{aligned} \text{males:} \quad & \text{CL} = 0.2545 \text{ TL} + 0.322, n = 20, r = 0.9074, p < 0.001 \\ \text{females:} \quad & \text{CL} = 0.2198 \text{ TL} + 0.902, n = 16, r = 0.9361, p < 0.001 \end{aligned}$$

The size frequency distribution of all animals shows one peak at a carapace length between 4 and 5 mm (mean = 4.93 mm; Fig. 2).

A conspicuous sexual dimorphism exists in the size (and shape, see below) of the major cheliped. In both sexes, propodus length (PL in mm) is linearly correlated with total length:

$$\begin{aligned} \text{males:} \quad & \text{PL} = 0.2377 \text{ TL} - 1.0660, n = 15, r = 0.8536, p < 0.001 \\ \text{females:} \quad & \text{PL} = 0.1400 \text{ TL} - 0.0878, n = 12, r = 0.8011, p < 0.002 \end{aligned}$$

This difference between sexes also exists in propodus width (PW in mm):

$$\begin{aligned} \text{males:} \quad & \text{PW} = 0.2663 \text{ TL} - 1.6810, n = 15, r = 0.8766, p < 0.001 \\ \text{females:} \quad & \text{PW} = 0.1434 \text{ TL} - 0.2218, n = 12, r = 0.8234, p < 0.001 \end{aligned}$$

No difference between sexes is present in the length of the propodus of the minor cheliped (males: mean = 1.52 mm, range = 0.8-2.3 mm; females: mean = 1.35 mm, range = 0.8-1.7 mm) and width (males: mean = 1.25, range = 0.7-2.1 mm; females: mean 1.09 mm, range = 0.6-1.5).

The number of animals which have the major cheliped on the left or right side is summarized in Tab. 1.

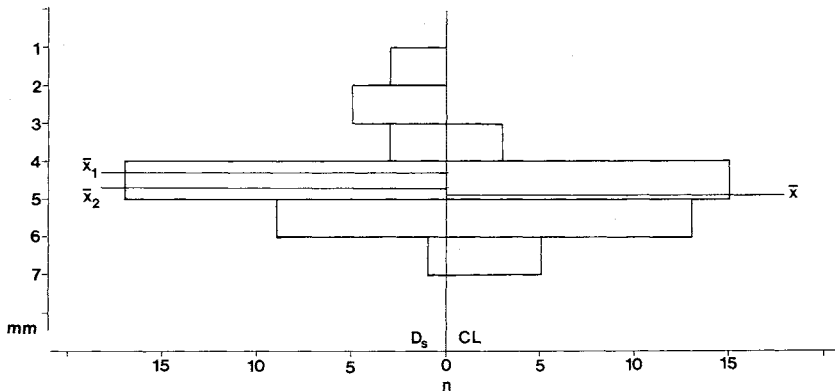


Fig. 2. Size frequency distribution (1 mm size classes) of animals (right, carapace length, $\bar{x} = 4.93$, $n = 37$) and burrows (left side, D_s , mean of all resin casts, $\bar{x}_1 = 4.31$, $n = 45$; and casts with $D_s > 3$ mm, $\bar{x}_2 = 4.73$, $n = 37$). *Callianassa bowvieri*, Safaga, Red Sea.

Abb. 2. Häufigkeitshistogramme (1 mm Größenklassen) der Tiere (rechts, Carapaxlänge, $\bar{x} = 4.93$, $n = 37$) und Bauten (links, D_s , alle Ausgüsse, $\bar{x}_1 = 4.31$, $n = 45$; und Ausgüsse mit $D_s > 3$ mm, $\bar{x}_2 = 4.73$, $n = 37$). *Callianassa bowvieri*, Safaga, Rotes Meer.

Table 1. Position of major cheliped in *Callianassa bowvieri* from Safaga, Egypt, Red Sea.

Tabelle 1. Seitenverhältnis der großen Schere bei *Callianassa bowvieri* aus Safaga, Ägypten, Rotes Meer.

	Left	Right
Males	12	10
Females	12	8
Total	24	18

Cheliped Shape.

A great variation exists in the shape of the propodus of the major cheliped. Nine of the 17 males have the typical incision between the articulation of the dactylus and the fixed finger and agree exactly with the descriptions of NOBILI (1906) and HOLTUIS (1958). The total length of these animals ranges from 15 to 22 mm. Eight males, with TL ranging from 15 to 24 mm, have chelipeds where this incision is not present; the strong denticulation on the lower edge of the dactylus is also missing (Fig. 3). Two of these males (TL 24 and 19 mm) were parasitized by a bopyrid. Only 3 of the 12 females show the typical incision. The cover of the dactylus by setae also differs, its density being independent of the presence of the incision.

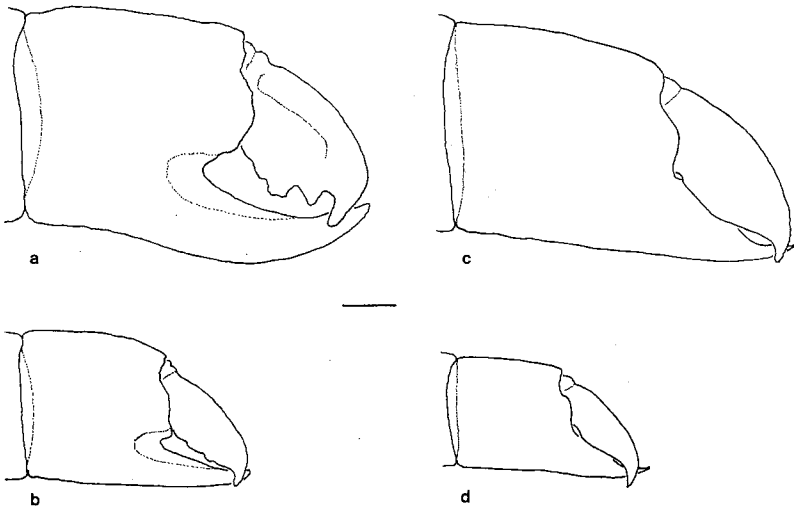


Fig. 3. Propodi of major chelipeds of *Callianassa bowvieri*, inner face; setation not shown. — Left: with typical incision: a. male with TL = 22 mm; b. female with TL = 21 mm. Right: without incision: c. male with TL = 23 mm; d. female with TL = 21 mm. — Scale 1 mm.

Abb. 3. Propodi der großen Chelipeden von *Callianassa bowvieri*, Innenseite. — Links: mit Einbuchtung: a. Männchen mit TL = 21 mm. Rechts: ohne Einbuchtung: c. Männchen mit TL = 23 mm; d. Weibchen mit TL = 21 mm. — Maßstab 1 mm.

Fecundity.

Eight of the 10 females caught in May 1986 were ovigerous. TL of these females ranges from 18 to 25 mm. The eggs were in different stages of development (50% were in an early stage and 50% before hatching). The eggs are of ellipsoid shape ($800 \times 625 \mu\text{m}$); their number ranges from 18 (eyed) to 80 (un-eyed).

Density.

The population density of *C. bowvieri* — as determined by resin casting and assuming one animal per burrow — ranges from 192 to 454 animals m^{-2} .

The Burrows.

Burrow Shape.

The surface of the sediment populated by *C. bowvieri* is characterized by numerous funnels and mounds (Pl. 1 fig. 3). Resin casts show that burrows have at least two openings: one (20 casts) to two (4 casts) in the middle of a funnel and one

to four on top of a mound. The following parts can be distinguished in the resin casts (Pl. 2 figs. 4-6):

1. a central U consisting of a) a J with uniform circular cross section (diameter ranging between 1.8 and 5.7 mm) leading from the funnel (20 to 30 mm in diameter, 20 to 30 mm deep) downwards to a depth between 2.5 and 8.7 cm (T_1) where it turns towards the horizontal; b) one to four bulbous or irregular chambers connected by short tunnels with regular circular cross sections in nearly the same depth as T_1 ; and c) an L-shaped section consisting of a tunnel with circular cross section which is somewhat expanded distally and then becomes constricted, turning upwards and leading as a thin shaft with circular cross section (diameter: 0.9 to 2.5 mm) to the opening on top of a mound.

2. an upward spiral part branching off one of the central chambers. This spiral consists of a series of chambers — some of which may be globular (see Pl. 2 fig. 5) — connected by segments with circular cross section and uniform diameter; it ends 1.7 to 3 cm below the sediment surface or in a funnel-shaped opening (3 casts).

3. a downward spiral part branching off one of the central chambers; this also consists of chambers and connecting segments.

4. a second upward spiral part branching off one of the chambers of the downward spiral; this ends 5 to 17 mm below the sediment surface or in a funnel (one cast).

In addition to the section mentioned in 1c, 5 casts show a second (e.g. Pl. 2 fig. 6) and 3 casts a third L-shaped section branching off one of the deeper chambers and leading to the surface. The total number of chambers varies between 4 and 18.

Burrow Dimensions.

Within the same burrow, the first section (part 1a) below the funnel and the segments between chambers are of very uniform diameter. The average deviation from the mean diameter is 10%. The mean chamber diameter shows a greater variation (average standard deviation = 20% of the mean); mean chamber diameter is 1.77 times that of mean segment diameter. In terms of mean diameter, the thin shaft is 0.44 times thinner than a segment. In four of the resin casts, an animal was entombed. The relation between carapace length and mean segment diameter in these burrows ranges from 1.09 to 1.28:1. A comparison of size frequency distributions of carapace length and mean segment diameters (mean $D_s < 3$ mm excluded) (Fig. 2) results in a $CL:D_s$ relation of 1.04:1. All other burrow dimensions were related to mean segment diameter. The depth (T_1) of the first section (1a) ranges from 2.4 to 8.7 cm and shows no correlation ($n = 36$; $r = 0.2875$; $p > 0.05$) to mean segment diameter. Total depth (T_t , range = 3.1-18.5 cm), horizontal extension (HE, range = 2.6-14 cm), and total length (L_t , range = 5.9-78.2 cm) are linearly correlated to mean segment diameter:

$$T_t = 10.0141 D_s - 5.5948; n = 27; r = 0.6090; p < 0.001$$

$$HE = 1.7280 D_s - 0.7171; n = 27; r = 0.8055; p < 0.001$$

$$L_t = 1.8024 D_s + 1.4973; n = 27; r = 0.5557; p < 0.001$$

The distance between burrow openings of the same burrow ranges from 0.7 to 6.7 cm.

Burrow volume (V) ranges from 0.196 to 19.17 cm³, while burrow surface (O) varies between 3.82 and 135.91 cm². Both are related to D_s :

$$V = 0.041 D_s^{3.26}; r = 0.94; n = 27; p < 0.001$$

$$O = 1.678 D_s^{2.26}; r = 0.86; n = 27; p < 0.001$$

Burrow Wall.

As judged from the resin casts, the walls in the upper parts of the burrow are smooth. The deeper parts have a rougher surface, especially the floors (Pl. 2 figs. 5-6). Here, sediment particles as well as shells, tests of foraminifera, and dactyls of the shrimp's exuviae are attached to the resin. Imprints of fecal pellets (2-3 mm long, 250-350 μ m in diameter) can be seen on the floor of the tunnel leading to the thin shaft and on the floors of the upper chambers. The thin shaft shows a slight annulation.

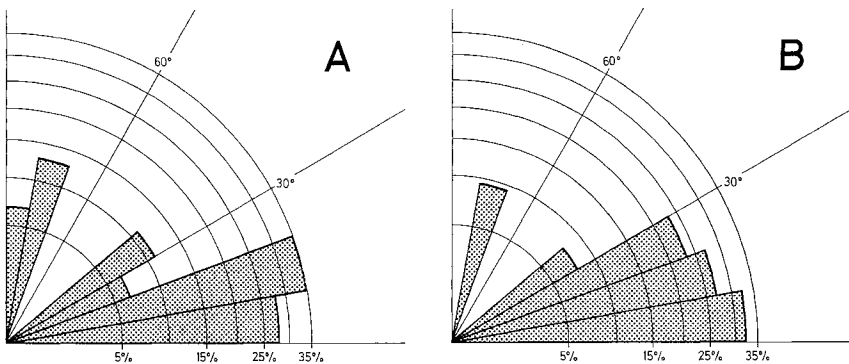
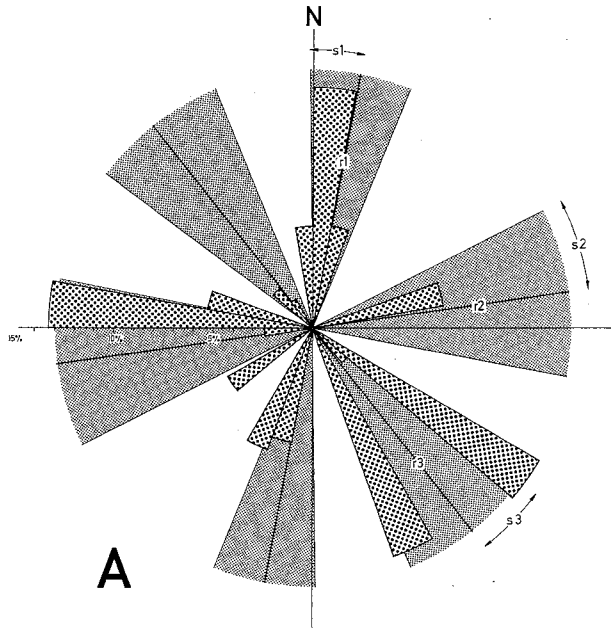
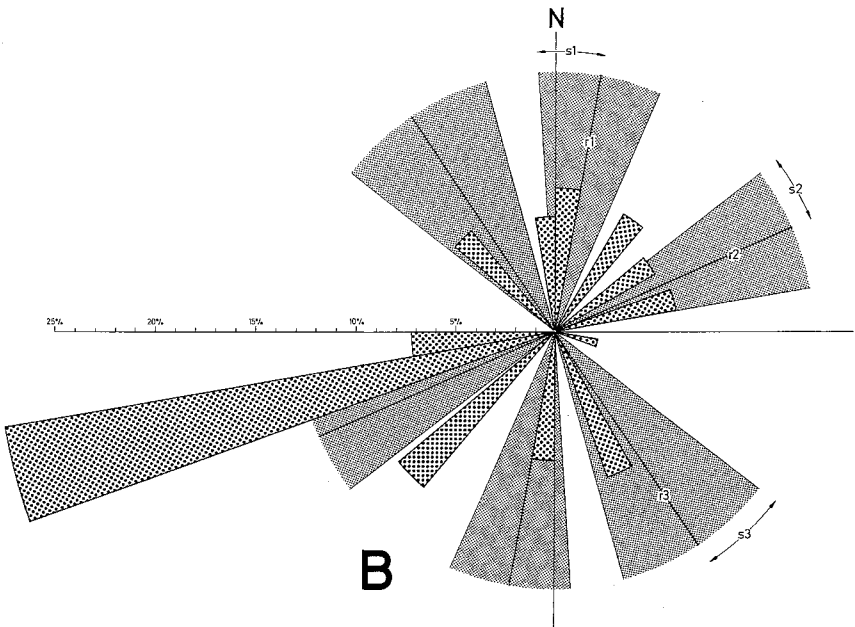


Fig. 4. Angular histogram of dip angles in burrows of *Callianassa bowvieri*. — 100% = total burrow length.

Abb. 4. Häufigkeitsverteilung der in den Bauten von *Callianassa bowvieri* vorkommenden Neigungswinkel. — 100% = Gesamtlänge des jeweiligen Baus.

Fig. 5. Circular histogram of trend angles in burrows of *Callianassa bowvieri*. — r_1, r_2, r_3 mean vectors; s_1, s_2, s_3 standard deviations. Dotted areas indicate empirical data, screened areas angular deviations ($r \pm s$).

Abb. 5. Kreishistogramm der Richtungswinkel, die an den Bauten A und B gemessen wurden. — r_1, r_2, r_3 mittlere Vektoren; s_1, s_2, s_3 Standardabweichungen.

**A****B**

Burrow Orientation.

Data on the orientation of two burrow-casts (Pl. 2 fig. 1, A and B) are presented in this paper. In burrow A as well in burrow B, very steep and very flat burrow sections can be distinguished. In both, flat burrow sections (dip angles between 0 and 30°) dominate in length (Fig. 4). Trend angle analysis show the existence of three main vectors in both systems; these vectors enclose angles of nearly 60° (Fig. 5). The mean vectors of these two burrows are congruent.

Discussion.

Two or more types of major chelipeds have been described for *Callianassa petalura*, *C. japonica* (SAKAI 1969), *C. biformis* (BIFFAR 1971) and *C. arenosa* (POORE 1975). In all of the above-mentioned species, however, only males showed this variation, the second type always being similar to the female's major cheliped. In *C. bowvieri* both sexes have two types of major chelipeds. The relative abundance of chelipeds with the typical incision in males and those without this incision in females indicate the former as the male type, the latter as the female type. The occurrence of female-type chelipeds in two males parasitized by bopyrids suggests an influence of this infestation, but does not explain variations in uninfested males and females.

The burrows of *Callianassa* sp. 1 described by BRAITHWAITE & TALBOT (1972: 276; Fig. 3; Pl. 2 figs. 1-3) from intertidal ripple sands in the Seychelles have a striking similarity with those of *C. bowvieri* presented here. They also show two openings — “one in a conical depression, one terminating in a conical mound” — “a series of sub-spherical rooms joined by gently sloping tunnels” which change “direction through 60° of arc at each room” forming “a triangular spiral”, a “main shaft” opening in a funnel or ending blindly, and a thin “exhalent tube”. It is therefore most probable that *Callianassa* sp. 1 is identical with *C. bowvieri*.

A characteristic feature of *C. bowvieri* burrows — the L-shaped section — occurs in different form in several upogebiid and callianassid burrows. This constriction, often termed “apertural neck”, may be straight (e. g., in *U. affinis*, FREY & HOWARD 1975; *U. wuhsienweni*, FREY & HOWARD & HONG 1987), oblique (e. g., in *C. tyrrhena* DWORSCHAK, unpubl. data), or either straight or L-shaped (e. g., in *C. major*: RODRIGUES 1966; FREY & HOWARD & PRYOR 1978). In all cases this constricted passage is smaller than the animal's diameter. In *C. bowvieri* it is as wide as the minor cheliped's propodus, although the length of the neck exceeds that of the cheliped. In *C. tyrrhena*, constriction of the entrance by action of the minor cheliped has been observed (DWORSCHAK unpubl. data). In *C. bowvieri* this passage is probably constructed in the same way; considering its length this is only possible from the surface down. This indicates that the thin shaft is relatively permanent and kept open by ventilation currents. FREY & HOWARD & PRYOR (1978) mention that the apertural neck may act as one-way, valve-like device preventing extraneous material from entering the burrow.

The presence of a funnel-like opening, a mound at the second opening, and spirals with chambers at different sediment depths suggest a primarily deposit

feeding behaviour for this species. At the same time, the presence of a relatively permanent U (see above) and an animal: burrow fit as good as in suspension feeding upogebiids (DWORSCHAK 1983) may indicate an additional suspension feeding component in *C. bowvieri* or may be related to ventilation.

As in *Jaxea nocturna* from the Adriatic (PERVESLER & DWORSCHAK 1985) and in several fossil burrow systems (HOHENEGGER & PERVESLER 1985), *C. bowvieri* burrows show a characteristic orientation. In *Jaxea nocturna*, burrows from two different sites had a different orientation (PERVESLER unpubl. data), whereas the two *C. bowvieri* burrows from the same casting site had the same orientation. A detailed comparison of orientation patterns of decapod burrows is in preparation.

As the dynamics of *C. bowvieri* burrows are not known, no information on reworking rates of this species are available. From data on density and burrow dimension, however, it can be calculated that the total burrow volume at maximum density (454 m^{-2}) is $3221 \text{ cm}^3 \text{ m}^{-2}$. This is 16% of the total sediment volume of the upper 20 cm, the maximum depth penetration of *C. bowvieri* burrows being 18.5 cm. The surface of all these burrows would be $2.6 \text{ m}^2 \text{ m}^{-2}$. This represents an increase in the sediment-water interface by a factor of 2.6 due to the burrows of *C. bowvieri*.

Acknowledgements.

This study was supported by the projects P 5059, P 5877 and P 5915 of the "Fonds zur Förderung der wissenschaftlichen Forschung in Österreich". Special thanks to Drs. J. HOHENEGGER, J. OTT, H. SOLIMAN, M. STACHOWITSCH, O. ZUNDRITSCH, and Mr. A. MANSOUR.

References.

- ALLER, R. C. & DODGE, R. E. (1974): Animal-sediment relations in a tropical lagoon, Discovery Bay, Jamaica. — *J. Mar. Res.*, **32** (2): 209-232; New Haven, Conn.
- BIFFAR, T. A. (1971): New species of *Callianassa* (Decapoda, Thalassinidea) from the Western Atlantic. — *Crustaceana*, **21** (3): 225-236, 3 figs.; Leiden.
- BRAITHWAITE, C. J. R. (1987): Geology and Paleogeography of the Red Sea Region. — In: EDWARDS, A. J. & HEAD, S. M. [Eds.]: *Key Environments. Red Sea*: 22-44; Oxford, New York, Beijing, Frankfurt, Sao Paulo, Sydney, Tokyo, Toronto (Pergamon Press).
- BRAITHWAITE, C. J. R. & TALBOT, M. R. (1972): Crustacean burrows in the Seychelles, Indian Ocean. — *Paleogeogr. Paleoclimatol. Paleoecol.*, **11**: 265-285; Amsterdam.
- DWORSCHAK, P. C. (1983): The biology of *Upogebia pusilla* (PETAGNA) (Decapoda, Thalassinidea). I. The burrows. — *Pubbl. Stat. zool. Napoli: Mar. Ecol.*, **4** (1): 19-43; Berlin, Hamburg.
- FISHELSON, L. (1971): Ecology and distribution of the benthic fauna in the shallow waters of the Red Sea. — *Mar. Biol.*, **10** (2): 113-133, 11 figs.; Berlin, Heidelberg, New York.

- FREY, R. W. & HOWARD, J. D. (1975): Endobenthic adaptations of juvenile thalassinidean shrimp. — *Geol. Soc. Denm., Bull.*, **24**: 283-297; Copenhagen.
- FREY, R. W. & HOWARD, J. D. & HONG, J. S. (1987): Prevalent lebensspuren on a modern macrotidal flat, Inchon, Korea: ethological and environmental significance. — *Palaios*, **2**: 571-593; Tulsa, Okla.
- FREY, J. D. & HOWARD, J. D. & PRYOR, W. A. (1978): *Ophiomorpha*: its morphologic, taxonomic and environmental significance. — *Paleogeogr. Paleoclimatol. Paleoecol.*, **23**: 199-229; Amsterdam.
- HOHENEGGER, J. & PERVESLER, P. (1985): Orientation of crustacean burrows. — *Lethaia*, **18**: 323-339; Oslo.
- HOLTHUIS, L. B. (1958): Crustacea Decapoda from the Northern Red Sea (Gulf of Aquaba and Sinai Peninsula). I. *Macrura*. Contributions to the knowledge of the Red Sea No. 8. — *Bull. Sea Fish Res. Stn., Haifa*, **17**: 1-40, 15 figs; Haifa.
- MANNING, R. B. (1975): Two methods for collecting decapods in shallow water. — *Crustaceana*, **29** (3): 317-319; Leiden.
- NOBILI, G. (1904): Diagnoses préliminaires de vingt-huit espèces nouvelles de Stomatopodes et Décapodes Macroures de la Mer Rouge. — *Bull. Mus. Hist. Nat., Paris*, **10** (5): 230-238; Paris.
- — — (1906): Faune carcinologique de la Mer Rouge: Décapodes et Stomatopodes. — *Ann. Sci. Nat., Zool.*, (9) **4** (1-3): 1-347, 11 pls., 12 figs.; Paris.
- PERVESLER, P. & DWORSCHAK, P. C. (1985): Burrows of *Jaxea nocturna* NARDO in the Gulf of Trieste. — *Senckenbergiana marit.*, **17** (1/3): 33-53, 3 figs., 4 tabs., 4 pls.; Frankfurt a. M.
- POORE, G. C. B. (1975): Systematics and distribution of *Callianassa* (Crustacea, Decapoda, *Macrura*) from Port Phillip Bay, Australia, with description of two new species. — *Pac. Sci.*, **29** (2): 197-209, 8 figs.; Honolulu, Hawaii.
- POR, F. D. (1984): The ecosystem of the mangal: general considerations. — In: POR, F. D. & DOR, I. [Eds.]: *The hydrobiology of the mangal*: 1-14; The Hague (W. Junk Publishers).
- PRICE, A. R. G. & MEDLEY, P. A. H. & McDOWALL, R. J. & DAWSON-SHEPERD, A. R. & HOGARTH, P. J. & ORMOND, R. F. G. (1987): Aspects of mangal ecology along the Red Sea coast of Saudi Arabia. — *J. Nat. Hist.*, **21** (2): 449-464; London.
- ROBERTS, H. H. & SUCHANEK, T. H. & WISEMAN, W. J. (1981): Lagoon sediment transport: The significant effect of *Callianassa* bioturbation. — In: GOMEZ, E. D. & BIRKELAND, C. E. & BUDDEMEIER, R. W. & JOHANNES, R. E. & MARSH, J. A. JR. & TSUDA, R. T. [Eds.]: *The reef and man. Proceedings of the fourth international coral reef Symposium*, **1**: 459-466; Quezon City, Philippines.
- RODRIGUES, S. DE A. (1966): Estudos sobre *Callianassa*. Sistemática, biológica e anatomia. Ph. D. thesis, Univ. Sao Paulo, iii + 168 pp.; Sao Paulo, Brasilia.
- SAKAI, K. (1969): Revision of Japanese callianassids based on the variation of larger cheliped in *C. petalura* STIMPSON and *C. japonica* ORTMANN (Decapoda, Anomura). — *Publ. Seto Mar. Biol. Lab.*, **17** (4): 209-252; Sirahama, Japan.
- — — (1970): A small collection of thalassinids from the waters around Tsushima islands, Japan, including a new species of *Callianassa* (Crustacea, Anomura). — *Publ. Seto Mar. Biol. Lab.*, **18** (1): 37-47, 4 figs.; Sirahama, Japan.
- SUCHANEK, T. H. (1983): Control of seagrass communities and sediment distribution by *Callianassa* (Crustacea, Thalassinidea) bioturbation. — *J. Mar. Res.*, **41** (2): 281-298; New Haven, Connecticut.

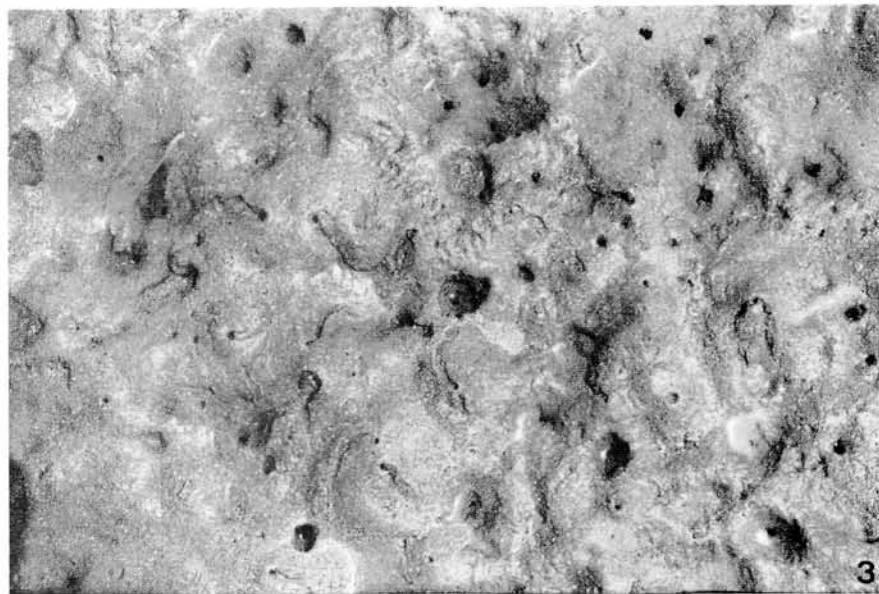
- — — (1985): Thalassinid shrimp burrows: ecological significance of species-specific architecture. — Proc. Vth Intl. Coral Reef Congr., Papeete, Tahiti, 1985, 5: 205-210; Moorea, French Polynesia (Antenne Museum – Ephe).
- THOMASSIN, B. A. (1978): Les peuplements des sédiments coralliens de la région de Tuléar (S. W. de Madagascar). Leur insertion dans le contexte côtier indo-pacifique. — Ph. D. thesis, Univ. Aix-Marseille II, 494 pp. + annexes; Marseille.
- VAUGELAS, J. V. DE (1984): Preliminary observations on two types of callianassid (Crustacea, Thalassinidea) burrows. Gulf of Aqaba (Red Sea). — In: SAAD, M. A. H. [Ed.]: Proceedings of the Symposium on Coral Reef Environments of the Red Sea, Jeddah, Jan., 1984: 520-539; Jeddah (King Abdulaziz University Press).
- — — (1985): Sediment reworking by callianassid mudshrimp in tropical lagoons: a review with perspectives. — Proc. Vth Intl. Coral Reef Congr., Papeete, Tahiti, 1985, 6: 617-622; Moorea, French Polynesia (Antenne Museum – Ephe).

Plate 1.

- Fig. 1. View of study site S of Port Safaga, Egypt. — In the foreground table-like rocks of the fossil reef plate.
- Fig. 2. Sediment surface during low tide showing mounds and funnels of *Callianassa bowvieri* burrows.
- Fig. 3. Close-up of emerged sediment surface showing mounds (sometimes with rill marks) and funnels of *Callianassa bowvieri* burrows.

Tafel 1.

- Fig. 1. Das Untersuchungsgebiet südlich Port Safaga, Ägypten. — Im Vordergrund fossile Riffplatten.
- Fig. 2. Trockenliegende Sedimentoberfläche im unteren Eulitoral mit Hügeln und Trichtern von *Callianassa bowvieri*.
- Fig. 3. Nahaufnahme der trockenliegenden Sedimentoberfläche mit Hügeln (teilweise mit Rieselmarken) und Trichtern.



102 103 104 105 106 107 108 109 111 112 113 114 115 116 117 118 119 121 122 123 124 125 126 127 128 129 131 132 133 134 135 136 137 138 139 141 142 143 144 145 146 147 148

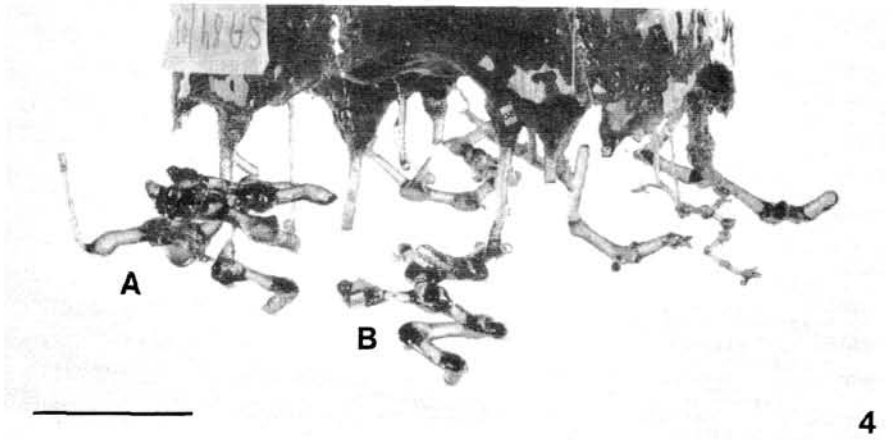
P. C. DWORSCHAK & P. PERVESLER:
Burrows of *Callianassa bowvieri* NOBILI 1904 from Safaga (Egypt, Red Sea)
with some Remarks on the Biology of the Species.

Plate 2.

- Fig. 4. Resin cast 1 (November 1984) in side view with 4 complete and 4 incomplete burrows of *Callianassa bowvieri*. — Burrows A and B were used for orientation measurements. — Scale 5 cm.
- Fig. 5. Resin cast 1C (October 1986) in side view showing central U between funnel- and mound-shaped opening, downward spiral and upward spiral with globular chambers. — Scale 1 cm.
- Fig. 6. Resin cast M4, burrow b (October 1986) in side view showing central U, upward spiral, downward spiral with second L-shaped section, and second upward spiral. Scale 1 cm.

Tafel 2.

- Fig. 4. Ausguß 1 (November 1984) in Seitenansicht mit 4 vollständigen und 4 unvollständigen Bauten von *Callianassa bowvieri*. — Bauten A und B wurden hinsichtlich ihrer Orientierung ausgewertet. — Maßstab 5 cm.
- Fig. 5. Ausguß 1C (Oktober 1986) in Seitenansicht. — Maßstab 1 cm.
- Fig. 6. Ausguß M4, Bau b in Seitenansicht. — Maßstab 1 cm.



4



5



6

P. C. DWORSCHAK & P. PERVESLER:
Burrows of *Callianassa bouvieri* NOBILI 1904 from Safaga (Egypt, Red Sea)
with some Remarks on the Biology of the Species.