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Occurrence and Distribution of *Anoplodactylus arescus* (Phoxichilidiidae: Pantopoda) from the Red Sea Coast, Egypt

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ABSTRACT

Anoplodactylus arescus du Bois-Reymond Marcus, 1959, was first recorded and described from the northern Red Sea. New material was collected from soft bottom substrates spanning Hurghada to Halayeb from 2019 to 2020. The collection sites varied in depth, ranging from intertidal to 35 meters deep. The intertidal sand samples were manually collected during snorkeling, while the deep samples required SCUBA diving for collection. Pycnogonid fauna were isolated, sorted, counted, and then identified to the lowest taxonomic level. The results revealed *Anoplodactylus arescus* as abundant species among the seven study areas selected. Grain size analysis was conducted at each site to evaluate its effect on the pycnogonid distribution. A list of species of pycnogonids reported from the Red Sea was provided based on our collection and approved literature. The results revealed a diverse community of pycnogonids in the Red Sea, with 17 species identified, belonging to nine genera and eight families. The study further indicates that coarse and medium sand, ranging from 125- 500µm, provides a suitable substrate for *Anoplodactylus arescus*. Pycnogonids were found in lower densities out of this grain size range.

INTRODUCTION

The Red Sea is an elongated, semi-enclosed, warm body of water nearly 2,000 kilometers in length with a maximum width of 335km, a surface area of about 485,620km2, and a volume of almost 250,000km^3 **(Neumann, 1967; Head, 1987)**. It is an inlet to the Indian Ocean between the African and Asian continents, running nearly in a straight line from N.N.W. to S.S.E., between 22º30ºN and 12º 30' N. The Red Sea widens significantly around Ras Banas, spanning approximately 145km, halfway between the northern gulfs and the southern straits **(Neumann, 1967)**. The Red Sea is linked to the Indian Ocean and the Arabian Sea through the Gulf of Aden in the south via the narrow strait of Bab-al-Mandab, which is 30km in length, 310 meters deep, and 25km wide at Perim Island **(Morcos, 1970)**.

The early investigation of the Red Sea started in the mid-eighteenth century during Arabia Felix (1761- 1767), followed by many oceanographic expeditions to explore the Red Sea. The distribution of species along the depth gradient is due to their ability to deal with physical factors (such as sediment composition and hydrodynamics) and biological factors (e.g., food, competition, and predation) **(Carvalho *et al*., 2012)**. Sandy beaches dominated the open shores of tropical and temperate areas **(Davies, 1972)**. They represent the most common shoreline ecosystem globally, hosting diverse biological communities that provide various ecosystem services and functions. Small organisms dominate the biological communities of sandy beaches, which are primarily organized by the environment's physicochemical properties, such as tidal regime, wave energy, slope, salinity, dissolved oxygen, and grain size **(Mclachlan & Brown, 2006)**.

Sea spiders are marine-living animals found down in a depth of 7,000m **(Wolff, 1958, 1970)**. They usually have four pairs of legs, but some species have five or six pairs of legs **(Hedgpeth, 1947; Fry & Hedgpeth, 1969)**. The smallest sea spider leg is 2mm in length. Leg length increases to 70cm as their distribution gets closer to the polar region **(Arango, 2002; Crooker, 2008)**. Sea spiders or pycnogonids are exclusively marine invertebrates of worldwide distribution, which rarely occur in large numbers. They are often cryptic and usually have very little economic significance. Most species are epibenthic ectoparasites of invertebrates, and few are interstitial or bathypelagic. Revisions for major taxa of pycnogonids do not exist, except for **Stock's (1957)** contribution to the Austrodecidae. Much of the existing information on pycnogonids scattered across numerous brief papers and descriptions, especially in the older literature, are often insufficient for reliable determinations. A total of 1392 species of pycnogonids have been discovered globally **(Bamber *et al*., 2024)**. This number is believed to underestimate the true diversity of the pycnogonid species, particularly in less explored regions like the Red Sea.

Concrete data on the Red Sea Pycnogonida originates from the early Percy Sladen Trust Expedition, which extensively surveyed the Red Sea. The results were published by **Carpenter (1910)** and **Stock (1957, 1958)** explorations. Later, five species were collected from different regions of the Red Sea and published by **(Stock, 1970)**. The known recent species are distributed in two suborders and eleven families worldwide. Seven families and one temporary family are found in the Red Sea. They are Colossendeidae Jarzynsky, 1870, Nymphonidae Wilson, 1878, Ammotheidae Dohrn, 1881, Ascorhynchoidea *incertae sedis* (temporary name), Phoxichilidiidae Sars, 1891, Endeididae Norman, 1908, Callipallenidae Hilton, 1942, and Pallenopsidae Fry, 1978 **(Bamber *et al*., 2024)**. Seventeen pycnogonid species were recorded by Carpenter, 1910; Hall, 1912; Calman, 1923, 1927; Stock, 1954, 1957, 1958, de Bois-Reymond Marcus in 1959; Stock, 1968, 1970, 1975. Therefore, the authors presented the distribution and occurrence of *Anoploductylu*s *arescus* du Bois-Reymond Marcus, 1959, across various sites and sediment sampling depths within soft bottom collections in the Red Sea.

MATERIALS AND METHODS

The study area in this examination spanned approximately 670km along the Egyptian Red Sea coastline, extending from Hurghada to Abu Ramad (Halayeb City). The study area for the soft bottom collection consisted of seven locations, which included the classification of intertidal species and sampling of subtidal areas up to a depth of 35 meters. The sampling sites were determined using the global positioning system (GPS).

The following is a brief description of each study area:

First site (Hurghada)

Hurghada is positioned at the proper Red Sea's northern region 27˚ 14′ 28.32″ N and 33˚ 51′ 2.88″ E. The shore profile of this site is considered as medium to sharp slope; its bottom consists of sandy and scattered rocks as a mixture substrate. The slope increased gently until 3m depth at reef edge, and then abruptly increased until 25m. About 80% of the slope was covered with sand, rubbles, and dead corals. This slope increased gently with depth, and the sandy bottom alternated between gravel and mud in specific locations.

Second site (Safaga)

Safaga is located in the northern region of the study area, at coordinates of 26˚46′.30″ N and 33˚ 56′ 42 ″ E. The shore profile is considered as an entire gentle slope shore; its bottom consists of fine to medium sand in addition to some scattered *Halophila stipulacea* seagrass mates. About 90% of the slope was covered in sand up to a depth of 15 meters.

Third site (Quseir)

Quseir is located at 140km southern to Safaga City at 26˚ 33′ 25.92″ N and 34˚ 02′ 16.8″ E. This site is almost similar to Hurghada site. From the coastline out to 30 meters, the region is characterized by small rocks and large gravel, with a maximum depth of 1.5 meters. Beyond the 30-meter mark, the back reef begins, featuring patches of separated branched corals, both live and dead, as well as dispersed patches of brown macro-algae. The depth increases gradually from the coastline to the reef edge, creating a gentle slope. The reef edge abruptly increased in depth to 15m, and this reef wall substrate was covered with massive and branched corals (90% coverage); then the slope sharply increased to 25m and was covered entirely with fine sand and eel garden, and afterward slope increased slightly to 35m and more.

Fourth site (Abu-dabbab)

Abu-dabbab is located at 25˚ 23′ 42″ N and 34˚ 42′ 18″ E; mid-distance between the sampling sites. 50m is the off- shore distance to the reef edge, and the maximum depth observed is 70cm. This region was covered with small rocks and large gravels with scattered branched coral patches. After reef edge, the depth abruptly increased to a huge lagoon with more than 25 meters depth. After the lagoon borders, the depth increases to more than 35 meters.

Fifth site (Lahmy)

Lahmy beach is strongly similar to Safaga site but located at the southern part of Egyptian Red Sea coast at 24˚ 22′ 48″ N and 35˚ 16′ 30″ E. This sandy shore has rocky splash zone covered with scattered macro-algal patches until the 600m off shore line, which contains small rocks and large gravels, and the maximum depth is 50cm. 90% of the slope was covered with sand, and the slope was gently increased up to 15 meters.

Sixth site (Shalateen)

Shalateen site is positioned at 23˚ 28′ 58.08″ N and 35˚ 29′ 32.64″ E, and the back-reef region extended from the shoreline to 150 meters offshore to the reef edge. The substrate is composed of coarse sand, gravels, and calcareous limestone for no more than 150cm depth. Few sponge species, numerous algal patches and dead and live corals were involved in this region. Generally, the region is covered by large coral atolls, coral patches, and a few scattered sandy to mud substrates which cover more than 60% of the bottom.

Seventh site (Halayeb)

Halayeb open site is located at 22° 24' 10.08" N and 36° 25' 42.24" E in the southern part of the Egyptian coastal area of the Red Sea. The offshore area to 50m long is composed of small rocks and large gravels as well as branched coral patches, and this region is about 100cm as a maximum depth. A huge lagoon is present heading the reef edge with more than 300m diameter, and its depth is more than 12m, then the depth increases sharply to more than 35m.

1.1. Samples collection

All material examined during this work was collected from a fisheries research project covering the Egyptian Red Sea coast. Surveys encompassed a range of habitats and depths, from intertidal to 35 meters. Intertidal samples were collected using a 15 x 15cm nylon bag with a mesh size of 0.5mm during snorkeling excursions. In contrast, subtidal samples required SCUBA diving for collection, utilizing the same type of nylon bags **(Attallah *et al*., 2021)**. All samples were sorted and identified to the family level, and then *Anoplodactylus* specimens were selected for further examination and confirmation.

The material was dissected in 70% alcohol and glycerin ca, 1:1, and the parts were mounted on glass microscope slides in dissecting media. They were examined under a LEICA DM LS2 compound microscope and drawn with camera Lucida. After that, amphipod specimens were isolated under the dissecting microscope models OPTIKA-SLX-3 (Italy) and EUROMEX-RZT (Netherlands). Pycnogonid individuals were sorted, counted, and identified to the lowest possible taxon using traditional taxonomic methods and keys used in the studies of **Child (1979)**, **Stock (1994)**, **Child (1998)** and **Bamber (2010)**.

The grain size analysis involved placing the samples in a glass jar and drying them in an oven at 65ºC for 96 hours. The samples were then examined through a series of sieves ranging from less than 0.38 to about 2mm, attached to an automatic shaker. The content of each sieve was weighed, and the percentage was determined using the Went-Worth Grade Classification **(English *et al*., 1997)**. The temperature, pH, salinity, and dissolved oxygen levels in water samples were measured at each sampling site using the multi-parameter device HI 9829 from Hanna Instruments, with three replicates for each measurement.

RESULTS

Pycnogonids species list of the Red Sea explorations

Table (1) shows the recent pycnogonid species list, compiled from previous expeditions, individual research across the entire Red Sea main body and northern gulfs, and the current collection from the western north of the Red Sea (Egyptian coasts). Data in Table (1) reveals the presence of 17 pycnogonid species belonging to 9 genera and distributed across eight families. Those were recorded from the Red Sea as the following; (Family: Phoxichilidiidae): *A. pygmaeus* (Hodge 1864), *A. glandulifer* Stock 1954, *Anoplodactylus arescus* du Bois-Reymond Marcus, 1959, and *A. turbidus* Stock 1975; (Family: Ammotheidae): *Ammothella appendiculata* (Dohrn, 1881) and *A. vanninii* Stock 1982, *Achelia echinata* Hodge, 1864; (Family: Callipallenidae): *Callipallene pectinata* (Calman, 1923); (Family: Ascorhynchoidea *incertae sedis*): *Pigrogromitus timsanus* Calman, 1927; (Family: Nymphonidae): *Nymphon maculatum* Carpenter 1910, and *N. foxi* Calman 1927; (Family: Pallenopsidae): *Pallenopsis crosslandi* Carpenter 1910; (Family: Colossendeidae): *Rhopalorhynchus pedunculatus* Stock 1957, and *Rh. lomani* Stock 1958; (Family: Endeididae): *Endeis biseriata* Stock 1968, *E. meridionalis* (Bohm, 1879), and *E. pauciporosa* Stock 1970.

Data show that the family Phoxichilidiidae was the most diverse family, with four recent species—followed by Ammotheidae and Endeididae, represented by three species each. On the other hand, all the recorded families were represented by one genus, except the family Ammotheidae, which was represented by *Ammothella* and *Achelia* genera. The families Ascorhynchoidae *incertae sedis*, Callipallenidae, and Pallenopsidae were recorded by only one species, meanwhile, the remaining two families were represented by two species each. All the recorded genera are well known from the Red Sea and globally, except for the genus Pigrogromitus of family Ascorhynchoidae incertae sedis, which was not recorded in any other location worldwide and is considered as endemic to Lake Timsah, the Suez Canal. In other words, the Red Sea species have a high level of endemism. Specifically, out of the 17 recorded pycnogonid species, four are endemic to the waters of the Red Sea and the Suez Canal. Each of the recorded species from the Red Sea has one or more preferable substrate(s), so the present as well as the previous recordings of the pycnogonids spotted sea spiders living on the soft substrate, such as *Ammothella appendiculate*, *Rhopalorhynchus lomani*, *Anoplodactylus arescus*, and *Endeis biseriata*; algae; such as *Callipallene pectinata*, and *Endeis pauciporosa*; corals; such as *Ammothella vanninii*, and *Nymphon maculatum*.

Systematic account of the recorded pycnogonid species in the Egyptian Red Sea coastal area

The collected data of the present work of the Red Sea pycnogonids revealed that *Anoplodactylus arescus* du Bois-Reymond Marcus is the most abundant pycnogonid species at the sites of collection from Hurghada to Halayeb. Approximately, 99% of the collected materials were identified as *A. arescus,* where the genus *Anoplodactylus* was characterized by tiny to medium-sized species, partially and well-segmented trunks, body compact or very slender, cephalic segments prolonged forward with distinct neck. The ocular tubercle is usually high. The proboscis is cylindrical or slightly tapering distally (one species pipette is up-curved). Therefore, chelifore scape one-segmented, chalae small, fingers plain or toothed. Palps are lacking. Ovigers are six-segmented, slender, in males only, distal segment setose. Legs are slender or robust and long, with heel and spines, soles with setal lamina, and tiny auxiliary claws are lacking. Cement glands have multiple or single tubes, pores, or slits at mid-femur or more distal.

Table 1. The recorded pycnogonid species list of the Red Sea among the previous expedition and small collections and the present collection data

#	Genus/species	Habitat/depth	Red Sea record	Other Records	References
1	*Ammothella appendiculata* (Dohrn)	Soft substrate (Mud & Sand)	Eilat	South Africa, Gulf of Mexico, North Atlantic Ocean	**(Dohrn, 1881; Stock, 1970; Legakis, 2001; Felder & Camp, 2009)**
	A. vanninii Stock	Pocillopora corals/ Shallow water	Egypt & Israel	Somalia, Tanzania	**(Stock, 1982)**
	Achelia echinata Hodge	Not available	Red Sea	Gulf of Aden, Indian Ocean, Mediterranean, North East Atlantic, and North West Pacific.	**(Hodge, 1864; Bouvier, 1923; Calman, 1938; Stock, 1992)**
2	*Pigrogromitus timsanus* Calman	Not available/ Shallow water	Lake Timsah, Suez Canal	Not available	**(Calman, 1927)**
3	*Callipallene pectinata* (Calman)	Brown Algae, Dead Acropora sp/0 – 66m	Red Sea	Arabian Coast, Andaman Islands, Madagascar	**(Calman, 1923, 1938; Correa, 1948; Stock, 1964, 1968; Arnaud, 1972)**
4	*Rhopalorhynchus pedunculatus* Stock	Littoral/6m	Suez and Eilat Red Sea	Not available	**(Stock, 1957, 1958a, 1958b, 1970)**
	Rh. lomani Stock	Muddy & Sand/ 26 – 86 m	Southern Red Sea, John Murray Exp. Red Sea	East Indian Archipelago, Arabian Coast, Saya de Malha	**(Calman, 1938; Stock, 1958)**
5	*Nymphon maculatum* Carpenter	*Margaritifera vulgaris*, Soft coral, Reef/0.5m	Port Sudan Harbor, Aabak-Dahlak Archipelago	Not available	**(Carpenter, 1910; Stock, 1964)**
	N. foxi Calman	Gravel/40 – 1315m	Suez Canal	Arabian Coast, Gulf of Aden, Australia	**(Calman, 1927, 1938; Stock, 1957, 1968; Muller, 1989)**
6	*Pallenopsis crosslandi* Carpenter	10 fathoms	Port Sudan Wasin Channel, the coast of British East Africa	Not available	**(Carpenter, 1910)**

7	*Anoplodactylus arescus* du Bois-Reymond Marcus	Algae, Sand/0-35m present study	Entire Red Sea, Aqaba, Suez	Madagascar, Tanzania, Philippines, mid-Pacific (Samoa)	**(du Bois-Reymond Marcus, 1959; Stock, 1968; Arnaud, 1973, 1975; Child, 1988; Nakamura and Child, 1988)**
	A. glandulifer Stock	Harbor/ 0 – 5m	Red Sea	Kenya, Singapore, Samoa, Indian Ocean	**(Stock, 1954; Child, 1982, 1988)**
	A. pygmaeus (Hodge)	In different substrates, Drifting weeds, Obelia sp/0-4558m	Entire Red Sea	Azores, Mediterranean sea, Virginia & Florida, Mexico, Caribbean sea	**(Hodge, 1864; Topsent, 1889; Carpenter, 1905; Dogiel, 1913; Giltay, 1928; Schottke, 1932; Lebour, 1945; Hedgpeth, 1948; Stock, 1954, 1958, 1962, 1970a, 1970b; King, 1972; Arnaud, 1973; Krapp, 1973; King, 1974; Arnaud, 1976; Stock, 1981; Krapp, 1983; Arnaud, 1987; Bitar, 1987; Stock, 1990; Child, 1992; Perez-Ruzafa, 1992; Harms, 1993)**
	A. turbidus Stock	Shallow water	Dahlak Archipelago	Madagascar, Eastern (Hasa) Saudi Arabia, Socotra Archipelago, Yemen, Ethiopia, Tanzania	**(Stock, 1964, 1974, 1975)**
8	*Endeis biseriata* Stock	Algae, Stones, Sand flat rubble, Ascidians, Bryozoans, Sponges	Piers of Eilat, gulf of Aqaba	Brazil, the Indian Ocean, Indonesia, the Philippines, Australia and Hawaii	**(Stock, 1968, 1970, 1974, 1979; Child, 1988, 1990; Stock, 1992)**
	E.meridionalis (Bohm, 1879)	Plankton collection	Gulf of Suez	Indian Coast, Madagascar, Singapore and Christmas Islands	**(Calman, 1939 (fig. 15); Gul and Gani, 2012)**
	E. pauciporosa Stock	On Galaxea/ 5m	Harbor pier of Eilat, Al-Ghardaqa (Hurghada) Egypt,	Caribbean Sea of Colombia	**(Stock, 1970)**

#; 1- Family: Ammotheidae Dohrn, 1881, 2- Family: Ascorhynchoidea *incertae sedis*, 3- Family: Callipallenidae Hilton, 1942, 4- Family: Colossendeidae Jarzynsky, 1870, 5- Family: Nymphonidae Wilson, 1878, 6- Family: Pallenopsidae Fry, 1978, 7- Family: Phoxichilidiidae Sars, 1891 and 8- Family: Endeididae Norman, 1908.

Family: Phoxochilidiidae **Sars**
Genus *Anoplodactylus* **Wilson (1878)**
Anoplodactylus arescus **du Bois-Reymond Marcus (1959)** (Fig. 1)

Anoplodactylus arescus du Bois-Reymond Marcus, 1959: 105-107, pl. 1, Stock, 1968: 53 [text]; 1975: 133, figs. 10-12. Arnaud, 1973: 954.

Material examined:
HURGHADA (Merit beach), 5m, fine and coarse sandy substrate, Nov. 2019, 1♀, 15m, coral rubble, and coarse sandy substrate, Nov. 2019, 1♂; 15m, coral rubbles and coarse sandy substrate, Mar. 2020, 1♀, 25m, coral rubble, and coarse sandy substrate, Mar. 2020, 16♀, 13♂, 35m, coarse sandy substrate, Mar. 2020, 1♀; 35m, coarse sandy substrate, Nov., 2019, 3♀, 1♂, (Project # 30198, YR call-STDF). SAFAGA (Main beach), 5m, fine sandy substrate, Nov. 2019, 3♀; 5m, fine sandy substrate, Mar. 2020, 1♂, 15m, fine sand, and muddy substrate, Aug. 2019, 6♀, 12♂; 15m, fine sand, and muddy substrate, Mar. 2020, 1♂, (Project # 30198, YR call-STDF). QUSEIR, 15m, coral rubbles, and coarse sandy substrate, Mar. 2020, 11♀, 7♂, 25m, fine and coarse sandy substrate, Mar. 2020, 18♀, 13♂, (Project # 30198, YR call-STDF). ABO DABBAB, 0.5m, seagrass, and coarse sandy substrate, Aug. 2019, 13♀, 11♂, 25m, coral rubble, fine and coarse sandy substrate, Aug. 2019, 6♀, 1♂; 25m, coral rubble, fine and coarse sandy substrate, Nov. 2019, 2♀, 7♂; 25m, coral rubble, fine and coarse sandy substrate, Mar. 2020, 1♀, 4♂, (Project # 30198, YR call-STDF). LAHMY, 0.5m, fine and coarse sandy substrate, Aug. 2019, 1♀, 5m, fine sandy substrate, Aug. 2019, 1♀; 5m, fine sandy substrate, Nov. 2019, 1♀, 15m, muddy and passable sandy substrate, Aug. 2019, 1♀, 4♂; 15m, muddy and passable sandy substrate, Mar. 2020, 1♀, (Project # 30198, YR call-STDF). SHALATEEN, 0.5m, coarse sandy substrate, Aug. 2019, 2♀, 1♂, 5m, fine and coarse sandy substrate, Mar. 2020, 6♀, 1♂, 15m, fine and coarse sandy substrate, Nov. 2019, 2♂, 35m, fine and coarse sandy substrate, Aug. 2019, 1♀; 35m, fine and coarse sandy substrate, Nov. 2019, 6♀, 10♂, (Project # 30198, YR call-STDF). HALAYEB, 5m, fine and coarse sandy substrate, Nov. 2019, 2♀; 5m, fine and coarse sandy substrate, Mar. 2020, 6♀, 4♂, 15m, fine and coarse sandy substrate, Nov. 2019, 1♀; fine and coarse sandy substrate, Mar. 2020, 1♂, 35m, coarse sandy substrate, Nov. 2019, 1♀, 1♂; 35m, coarse sandy substrate, Mar. 2020, 8♂, (Project # 30198, YR call-STDF).

Remarks

This tiny individual and other materials are typically assigned to Marcus' species. Our materials consist of males and females from the type material of Marcus collection. A few differences were reported between the present study materials and the type of collection. First, this material has a leg of the third pair more setose peripherally on the femur and tibiae, (Fig. 1A, B), while Marcus materials setose upwardly only at the same positions. Second, male individuals in the present work have identical structures of propodus but are more setose than Marcus materials. Third, this male and female have small block-like papillae lateral to the ocular tubercle. Fourth, the male movable part of Chelophore (Fig. 1D), has more long and short setae dorsally, but Marcus material had one seta. None of these differences, on its own, is sufficient to warrant describing this as a new species. Therefore, I will tentatively assign this specimen to *A. arescus*. This species was described for the first time in Egyptian waters Hurghada by du Bois-Reymond Marcus, 1959, Red Sea. Then, it was recorded from the western Indian Ocean area (Madagascar and Tanzania) and the Philippines from the western Pacific. However, the new addition here is that the depth range of *A. arescus* has been extended from intertidal to thirty-five meters, and the recording sites covered the Egyptian coast of the Red Sea from Hurghada to Halayeb (present study).

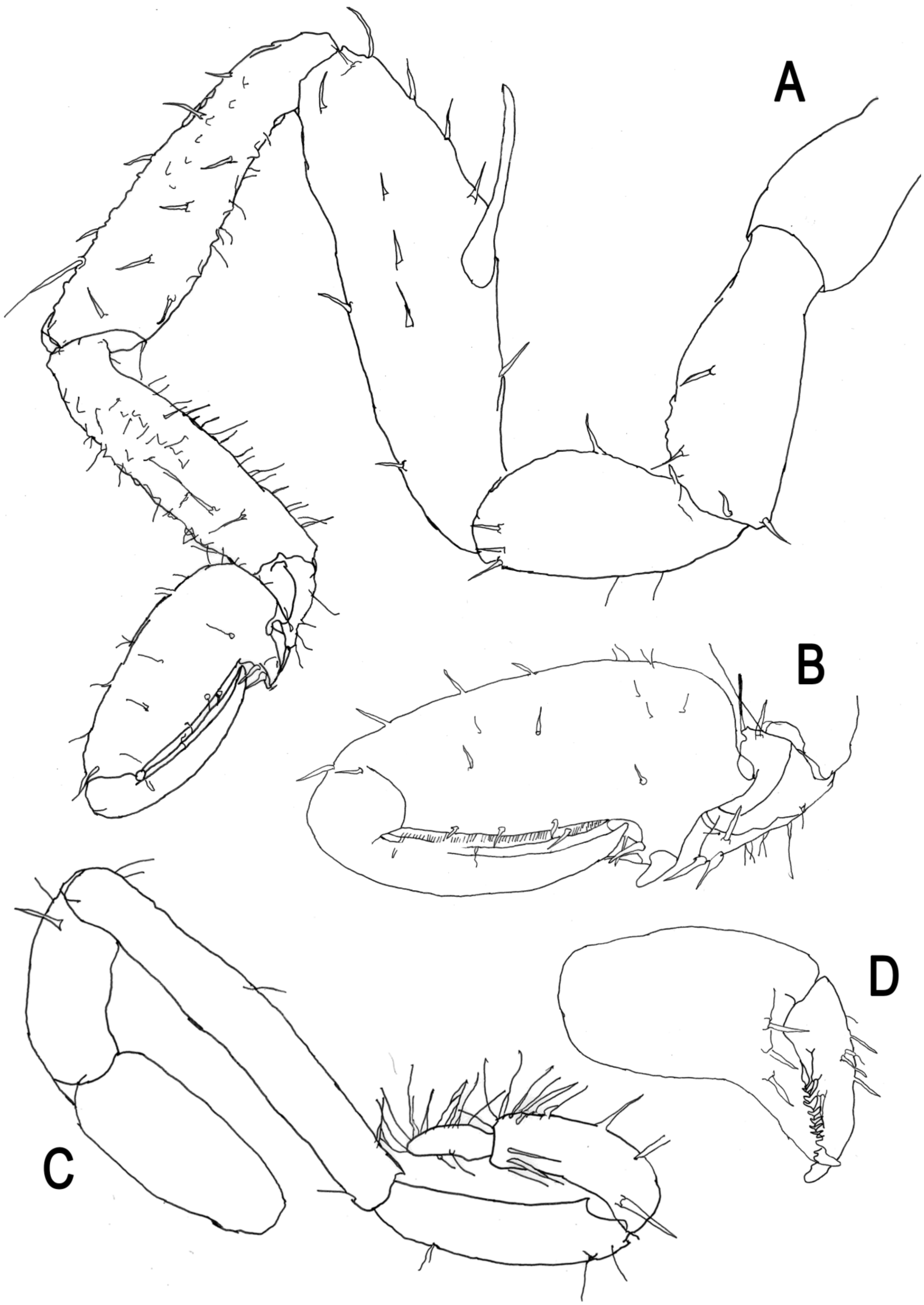

Fig. 1. *Anoplodactylus arescus* du Bois-Reymond Marcus; **A.** Male, leg of the third pair. **B.** Tarsus, propodus & claw. **C.** Male, oviger. **D.** Anterior part of Chelophore

Grain size variation among different collecting sites

Fig. (2) data represent the grain size variation between the collecting depths within the sites. Hurghada site has coarse to medium sand among shallower depths and tends to be fine sand at a depth of 35m. Quseir, Shalateen, and Abo dabbab have the same substrate type covering all collected depths in addition to coarse and gravel percent. On the other hand, Safaga has an ideal fine and very fine sand structure among its three obtained depths. Finally, the remaining site, Halayeb, has a grain size fluctuating between depths, but generally, it is categorized with a medium sand type.

The effect of grain size on the *Anoplodactylus arescus* distribution

Pycnogonids in the present work showed a remarkable correlation between their density and the type of sand at each collection site. Data represented in the Puble chart (Fig. 3) show a high density of *Anoplodactylus arescus* recorded from depth 25m at Hurghada, Quseir, and Abu dabbab, represented by 29, 31, and 21 individuals, respectively, with coarse to medium sand. On the other side, the intertidal zone of Abu dabbab also had many individuals of *Anoplodactylus arescus* during summer. Only 24 individuals live on coarse to medium sand.

Anoplodactylus arescus was recorded from some sites with medium densities as shown in Puble chart in-depth 15m at Safaga and Quseir by 19 and 18 ind., respectively living on medium to fine sand. In comparison, 17 ind. were recorded in Shalateen at 35m depth living on medium sand, and 12 ind.detected at the second depth of Halayeb living on fine sand. The remaining collections have low individual densities (less than 10 ind.) among their sites or depths, mainly scattered over different gain-size substrates (Fig. 3).

Based on the grain size similarity between sandy substrates at each depth (Fig. 4), the analysis results show that all sites were divided into major subclusters. The first subcluster showed that the grain size at depths of Shalateen and Halayeb was the most similar, followed by the parallel cluster with a less similar value between Safaga and Lahmy. The other subcluster included three sites arranged in a single cluster.

On the other hand, another cluster resulted between depths, however, different collecting sites based on the grain size percent. Monophyletic ancestor showed between depths based on their grain size, which showed that 5 and 35m were the most similar. The rest of the depths were less similar in a separate single sub-cluster in each (Fig. 4).

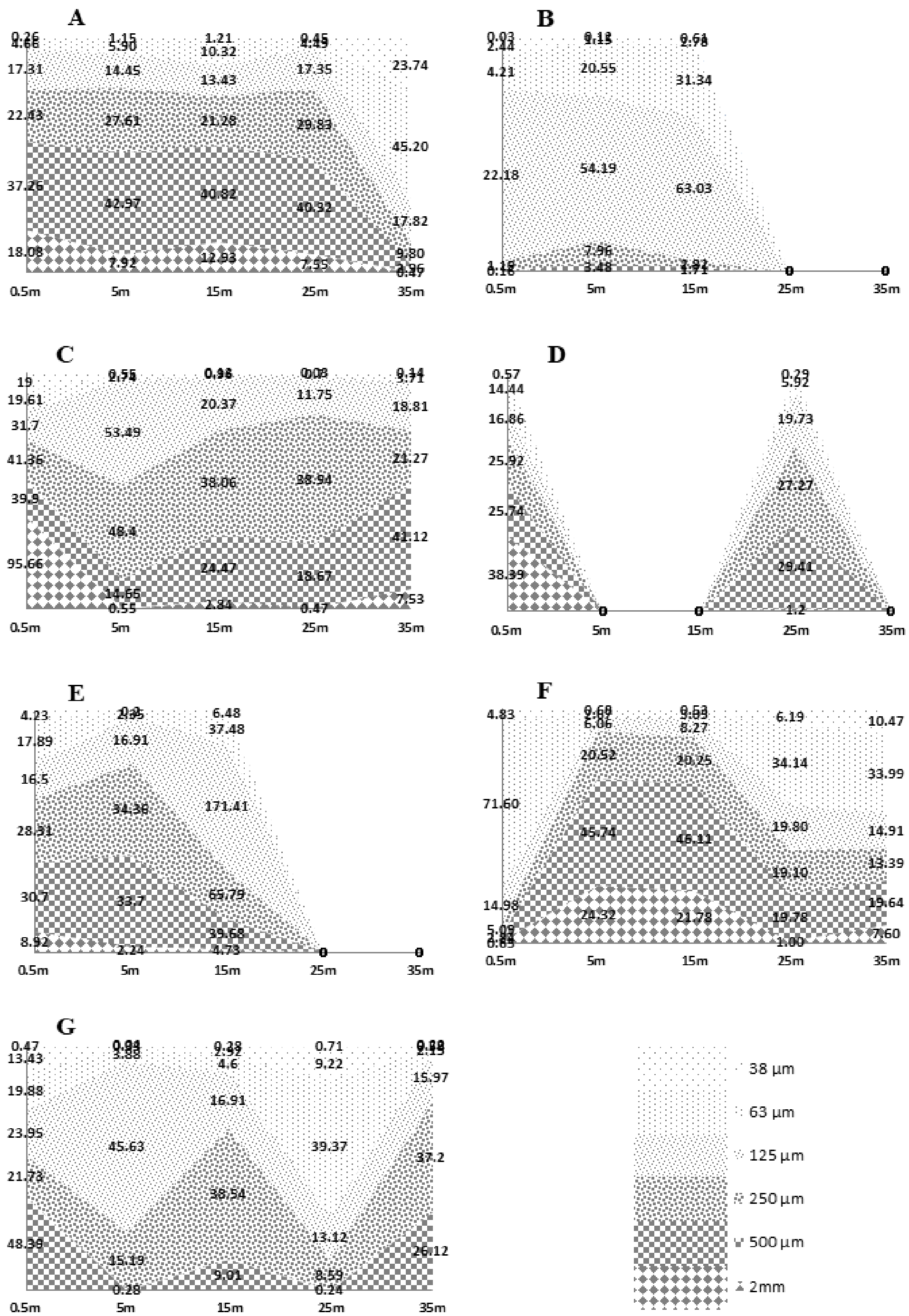

Fig. 2. Grain size percentile via different depths of the collection sites; **A.** Hurghada, **B.** Safaga, **C.** Quseir, **D.** Abo Dabbab, **E.** Lahmy, **F.** Shalateen and **G.** Halayeb

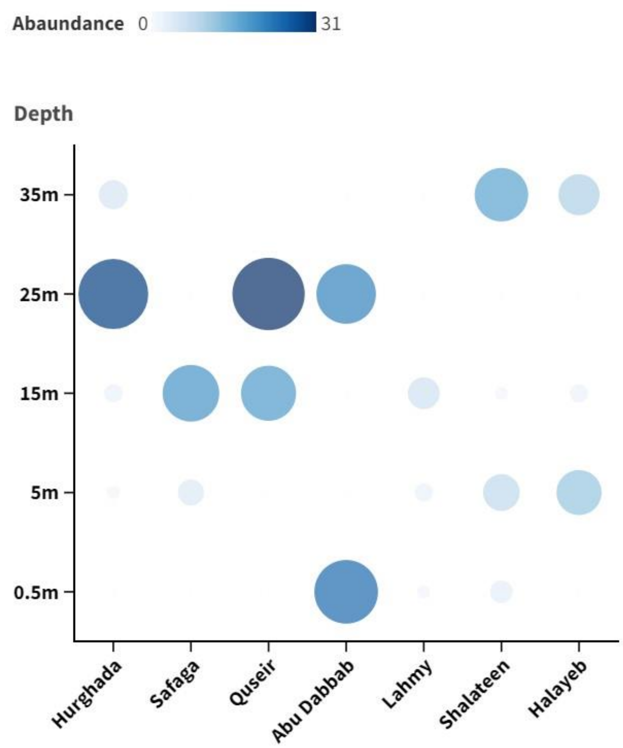

Fig. 3. Puble chart; showed *Anoplodactylus arescus* distribution and density among different collecting sites

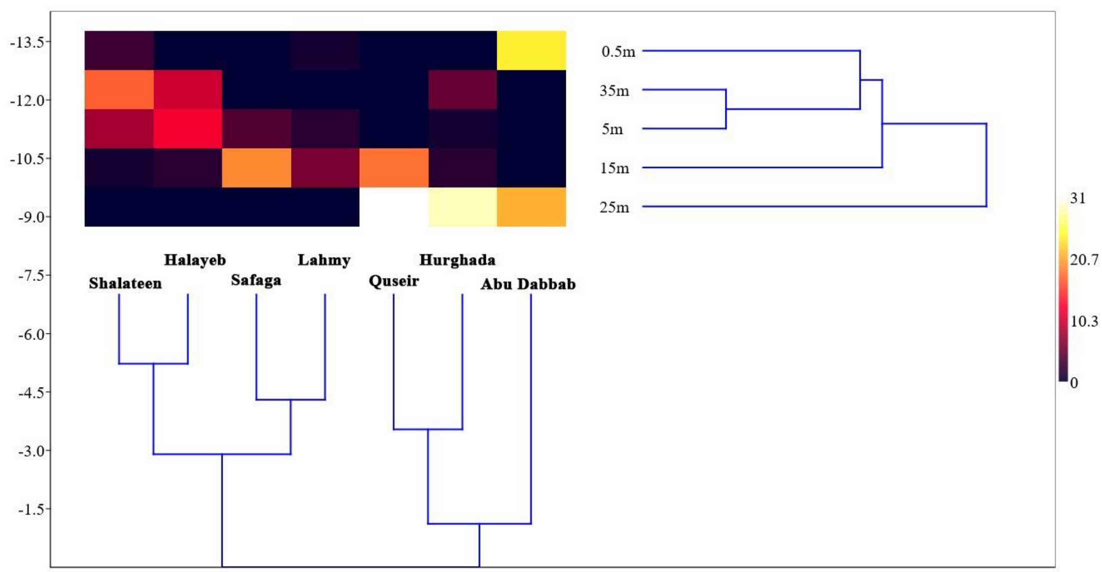

Fig. 4. Similarity cluster between collecting sites based on the density of pycnogonid individuals among depths

DISCUSSION

There are now seventeen species of the marine pycnogonids recorded from the Red Sea. *Anoplodactylus arescus* was redrawn using new materials collected from the type locality, adding a new range of vertical distribution (up to 35m depth) and specific localities (Hurghada—Halayeb) among the Red Sea for this pycnogonid species. *A. arescus* individuals were first described in Hurghada in 1959 by du Bois-Reymond Marcus in French. This was followed by recording the species in other localities distributed from the western Indian Ocean to the mid-Pacific Ocean. It is possible that this species has distribution limits within a restricted thermal barrier lined with tropical, sub-tropical, or temperate waters.

The remaining *Anoploductylus* species recorded from the Red Sea also has a wide distribution range spatially and vertically, from the Atlantic Ocean to the Pacific Ocean **(Stock, 1975)**, while other *Anoploductylus* species were found in cold waters like the North and South Pacific Ocean **(Hodgson, 1914; Nakamura & Child, 1983)**, and the Atlantic Ocean **(Hedgpeth, 1948)**. Analyzing the provenance of these species is challenging due to past misidentifications, historical records relying on limited literature at the time, and the incomplete understanding of specific characteristics **(Bamber & Costa, 2009)**.

Some species were recorded specifically from the Red Sea as new species, including *Pigrogromitus timsanus, Rhopalorhynchus pedunculatus, Nymphon maculatum* and *Pallenopsis crosslandi*. These species are considered as endemic species to their type localities. On the other hand, another species considered as cosmopolitan for example, *Achelia echinata*, a species with a type locality in the United Kingdom, has been recorded in the literature not only throughout the North East Atlantic, Mediterranean, and the Red Sea but also from the Indian Ocean, China, Japan, California and Alaska (North & East Pacific). Similar species in their distribution are considered cosmopolitan species: *Ammothella appendiculata* and *Endeis biseriata*.

Endeis pauciporosa has limited distribution to the Atlantic province (Caribbean Sea and Colombia) and its Eilat Harbor and Hurghada recording. There is a possibiliy that this species was transported with the ballast water according to the active trading through the Suez Canal; finally, according to the available data of the recorded fauna, it seems to have Arabian, East African, and Indian distributions.

In light of the aforementioned data, it is notable that the most diverse genus recorded, *Anoplodactylus*, includes species known to live upon medusae and thus obtain a passive dispersion in the plankton; the comparatively widespread distribution of the *Anoplodactylus* species is commonly attributed to this process **(Bamber, 1998)**.

Thus, as far as we know, most species' proximity and known distributions would favor colonization by species from the East. However, the incidence of species recorded in the Latin Americas in the plankton or floating algae gives a mechanism for transport, which would argue for colonization from the West. In reality, the pycnogonid colonization of the shallow water habitats of the Red Sea may be attributed to both processes. However, the mechanism of immigration from the East remains purely speculative.

The high diversity of ycnogonid species may be linked to the abundant oxygen levels in the Antarctic waters. **Levin and Gage (1998)** demonstrated strong relationships between oxygen levels and macro-benthos diversity in different bathyal regions. Oxygen availability has been suggested to cause the enlarged size range and gigantism seen in the pycnogonids in the Southern Ocean **(Chapelle & Peck, 1999)**. Conversely, the decline and dwarfism were detected in tropical and subtropical macro-invertebrates in the Red Sea province, known for their reduced faunal size **(Barnard, 1965; Zeina & Guerra-Garcia, 2016)**.

Finally, soft-bottom macro-benthic communities in the study area exhibited a clear intertidal to offshore spatial pattern that may reflect the relevant influence of the grain size **(Soto *et al.*, 2017)**. *Anoplodactylus arescus* was positively affected by the presence of coarse sandy substrates, where high densities of *A. arescus* were represented mainly by the high content of the medium sandy substrate. This type of substrate has high percentages of grain sizes between 125 and 500µm. This substrate is attractive or favorable for pycnogonid individuals to live in. Usually, this kind of grain size had been found at a depth range from 15– 35m in most collecting sites. The causes of this correlation between pycnogonid density and the grain size of the substrate may be because this medium size usually resulted from the destruction, fragmentation, and crushing of coral reef polyps by wave action or coral reef fishes. Alternatively, it may be attributed to the variation in food supply from the water column to the seabed, which induces noticeable changes in the chemical properties of the sediments. Regular upwelling conditions and alterations influence these changes in the physical variables of the sediment, ultimately determining habitat heterogeneity. Long-time series studies will elucidate the natural expansion of hypoxic zones to the coastal zones in upwelling systems and enable a better understanding of their influence on benthic biodiversity **(Soto *et al.*, 2017)**.

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