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# Complementary investigation and taxonomic identification of starfishes, (Echinodermata: Asteroidea) from the Northern Persian Gulf, Iran

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## Abstract

Sea Stars are one of the most incredible creatures in the coastal and open waters. In this study, 11 species of starfishes have been identified which belonging to six genera and five families in northern islands of Persian Gulf during May 2017 to September 2018. Among the species, *Astropecten hemprichi* (Müller & Troschel, 1842), *Astropecten indicus* (Döderlein, 1888), *Astropecten polyacanthus polyacanthus* (Muller and Troschel, 1842), *Astropecten polyacanthus phragmorous* (Muller and Troschel, 1842), *Luidia hardwicki* (Gray, 1840), *Aquilonastra iranica* (Mortensen, 1940), *Linckia multifora* (Lamarck, 1816), *Culcita novaeguineae* (Muller & Troschel, 1842) and *Pentaceraster mammillatus* (Audouin, 1826) have been reported in the past. The species of *Aquilonastra watersi* (O'Loughlin and Rowe, 2006) and *Linckia laevigata* (Linnaeus, 1758) are new records in the Persian Gulf.

**Key words:** Sea stars, morphology, Iran, systematic, Echinodermata

## INTRODUCTION

Asteroidea (starfish or sea stars) is one of the most diverse classes of phylum Echinodermata comprising about 1900 extant species (Mah and Blake, 2012). So far 21 species of starfishes are recorded for the Persian Gulf. The first report of Echinodermata in the Persian Gulf was performed by Mortensen in 1940. In this work 10 species of starfishes were identified from Iranian waters of the Gulf. Then Clark and Row (1971) in their paper with title of monograph of Shallow-water Indo-West Pacific Echinoderms described 13 species of starfishes from Persian Gulf. Price (1983) was reported 14 species from the Saudi coasts in the Persian Gulf in 1981 and 1983. Price and Rezai (1996) recorded the species of *Acanthaster planci* from Larak and Tonb-e-Kouchak Islands. Pourvali (2015) recorded six species of starfishes from Hormuz Island (Table 1).

Since studies on the morphological identification of starfish from Iranian waters of the Persian Gulf are very limited, our knowledge of the identification of this fauna in this region still remains unsatisfactory from a systematic and an ecological point of view. The aim of the present work is to expand our knowledge of the morphological characteristics of the species of Asteroidea from northern Persian Gulf and complements the molecular analysis performed by Adeli *et al.* (2020).



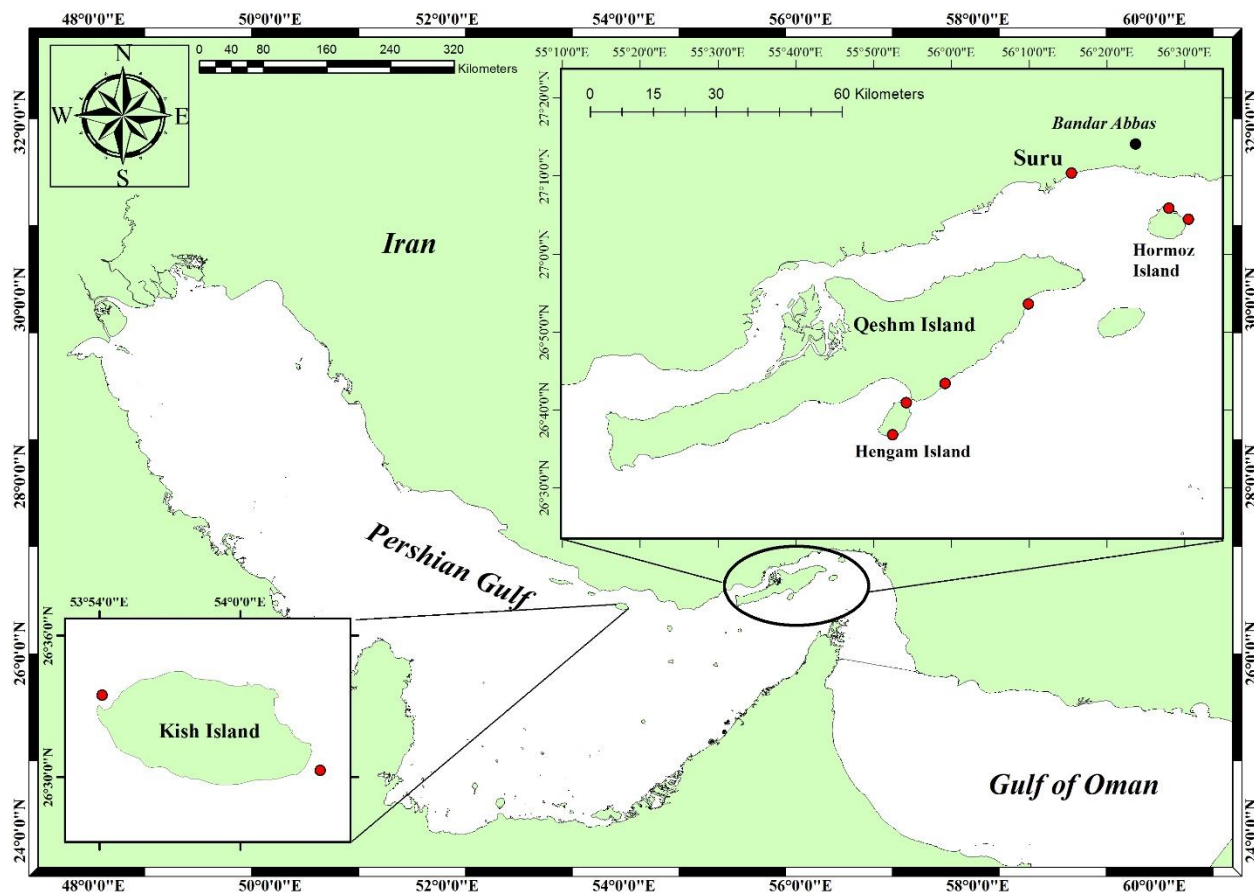


FIGURE 1. The locations of the sampling stations.

## MATERIAL AND METHODS

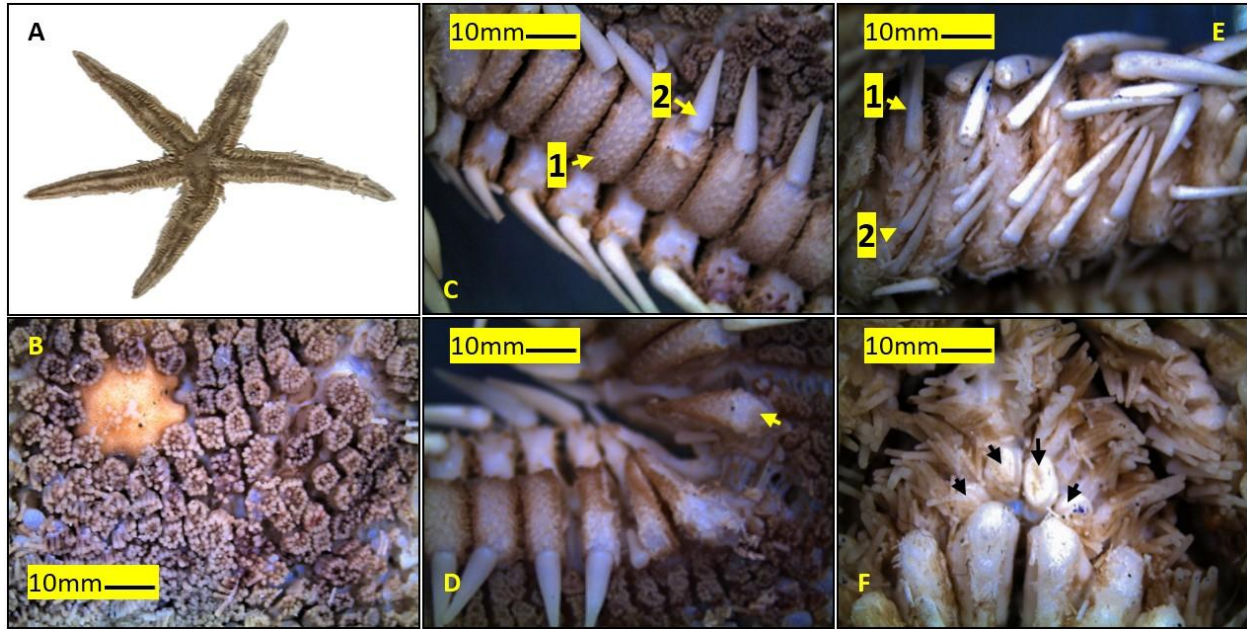
52 specimens of starfishes were collected between May 2017 and September 2018 at nine locations from the northern islands (Qeshm, Kish, Hengam and Hormuz) and Suru beach in the tidal zones by scuba diving (Fig. 1). The samples were transferred to the laboratory and the significant morphological characteristics were photographed using a stereomicroscope (Leica Ez-40). The identification of species was performed following Clark and Row (1971).

## RESULTS

Total of 11 species of starfishes was identified belonging to six genera, five families and two orders including *Astropecten hemprichi* (Müller & Troschel, 1842), *Astropecten indicus* (Döderlein, 1888), *Astropecten polyacanthus polyacanthus* (Muller and Troschel, 1842), *Astropecten polyacanthus phragmorous* (Muller and Troschel, 1842), *Luidia hardwicki* (Gray, 1840), *Aquilonastra iranica* (Mortensen, 1940), *Aquilonastra watersi* (O'Loughlin and Rowe, 2006), *Linckia laevigata* (Linnaeus, 1758), *Linckia multifora* (Lamarck, 1816), *Culcita novaeguineae* (Muller & Troschel, 1842) and *Pentaceraster mammillatus* (Audouin, 1826) (Table 2).

### Taxonomic account

**Class Asteroidea de Blainville, 1830**  
**Order Paxillosida Perrier, 1884**  
**Family Astopectinidae Gray 1840**  
**Genus *Astropecten* Gray 1840**



**FIGURE 2.** *Astropecten hemprichi*. A, Abactinal surface. B, Madreporite. C, 1) Supero marginal plates. 2) Supero marginal spine. D, Absence of spine in two first Supero marginal plates. E, 1) Infero marginal spines. 2) Ventral spines on Infero marginal plates. F, Actinal plates.

***Astropecten hemprichi* (Müller & Troschel, 1842) (Fig. 2)**

Synonym: *Astropecten bonnieri* Koehler, 1905.

**Remarks:** five rays;  $R/r = 83/13$ . *Astropecten hemprichi* have long arms with 40 supero marginal plates. Disk paxillae bear numerous spinelet around the conspicuous madreporite. Supero marginal plates fringe with adradial (inner part) spines. These plates cover with dense squammules. This specimen has marginal spines on all of the outer edges of infero marginal plates with two rows ventral spines. Four actinal plates on interradius part of actinal surface. Ambulacral groove border with two rows of spines. Adambulacral spines were larger than the furrow spines and middle furrow spines were longer than remaining spines. This species identified by two distinctive features. The first is the lack of supero marginal spines on first two plates. The next is brown stripes along interradius on abactinal surface.

**Material examined:** one specimen was collected from 10 m depth in sandy subtidal at Suru beach ( $27^{\circ}07'N$ ,  $56^{\circ}15'E$ ).

**General distributions:** West, North and East of Indian Ocean, East Africa and Madagascar, Red Sea (Clark & Rowe, 1971); Southeast Coast of India (Chamundeeswari *et al.*, 2013); Persian Gulf (Price, 1981).

***Astropecten indicus* (Döderlein, 1888) (Fig. 3)**

Synonyms: *Astropecten pleiacanthus* Bedford, 1900.

**Remarks:** five rays;  $R/r = 40/12$  mm. Paxillae arrange regularly on abactinal surface of arms. Three to four actinal plates are at interradiar area. The width of supero marginal plates is more than the length, when viewed from above. The supero marginal spines conspicuously arise on inner margin of the proximal supero marginal plates, ( $R = 40$ mm). Smaller specimens have a series of short spines on middle part of the supero marginal plates after the first ones. Ambulacral groove border with two rows of spines. Subambulacral spines are larger than the furrow spines and middle furrow spines are larger than other ones.

**TABLE 1.** Summary of identified asteroids in the Persian Gulf.

Species	Mortensen (1940)	Clark & Row (1971)	Price (1983)	Price & Rezai (1996)	Pourvali (2015)
<i>Luidia hardwicki</i>		•	•		•
<i>Luidia maculata</i>		•	•		
<i>Luidia prionota</i>		•			
<i>Astropecten hemprichi</i>			•		
<i>Astropecten indicus</i>	•	•	•		
<i>Astropecten monacanthus</i>			•		•
<i>Astropecten phragmorous</i>	•	•	•		•
<i>Astropecten polyacanthus</i>	•	•	•		•
<i>Astropecten pugnax</i>		•	•		
<i>Anthenea rudis</i>		•			
<i>Stellaster equestris</i>	•	•			
<i>Pentaceraster mammillatus</i>	•	•	•		
<i>Leiaster leachi</i>					
<i>Linckia guildingi</i>		•			
<i>Linckia multifora</i>	•	•	•		
<i>Asteropsis carinifera</i>			•		
<i>Asterina cephea</i> var. <i>iranica</i> *	•				
<i>Asterina burtoni</i>		•	•		
<i>Aquilonastra samyni</i>					•
<i>Aquilonastra iranica</i>					•
<i>Acanthaster planci</i>				•	
<i>Euretaster cribrosus</i>			•		

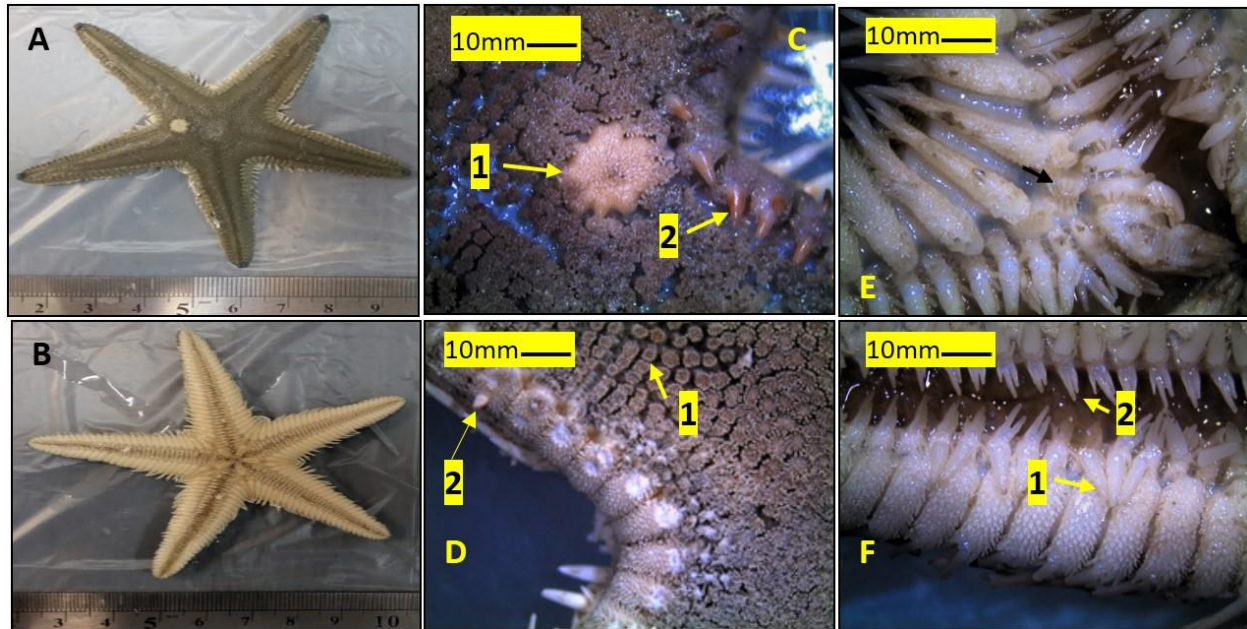
\*: is raised to species status (*Aquilonastra iranica*) by O'Loughlin and Waters in 2004.

**TABLE 2.** Identified asteroids in this study.

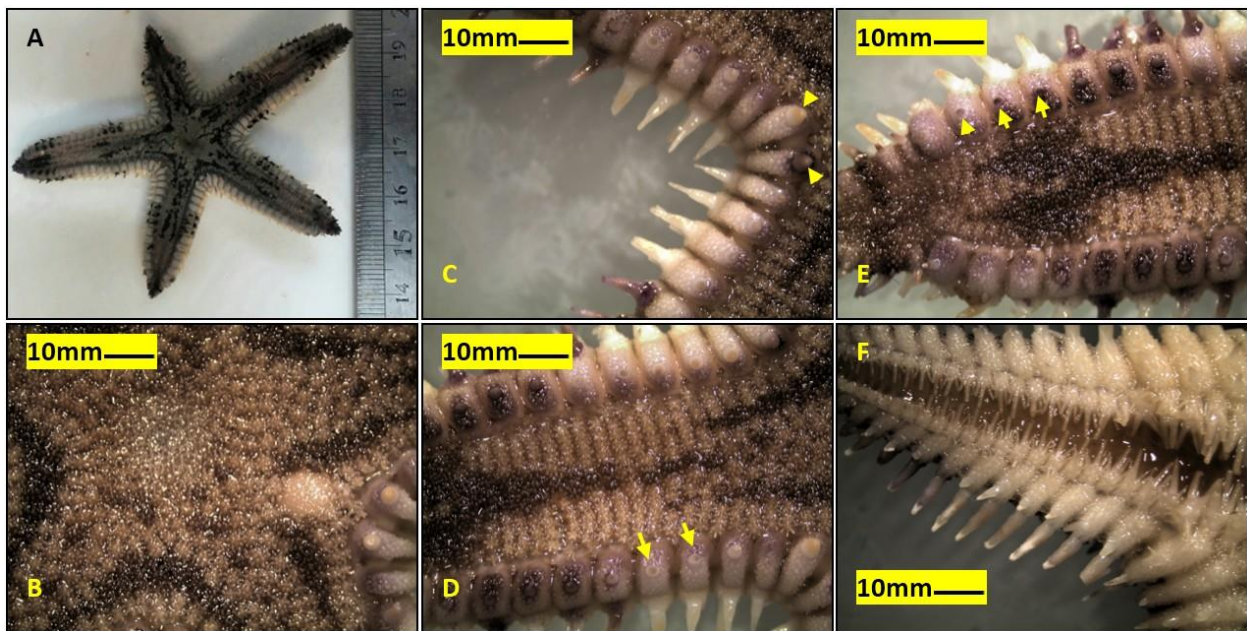
Species	n	Type of bed	Location
<i>Astropecten hemprichi</i>	1	Sandy	Subtidal/Suru beach
<i>Astropecten indicus</i>	4	Sandy	Subtidal/Hormus Island
<i>Astropecten polyacanthus phragmorous</i>	3	Muddy	Intertidal/Hormus Island
<i>Astropecten polyacanthus polyacanthus</i>	4	Muddy	Intertidal/Hormus Island
<i>Astropecten</i> sp.	1	Muddy	Intertidal/Hormus Island
<i>Luidia hardwicki</i>	7	Sandy	Subtidal/Suru beach Hormus Island
<i>Aquilonastra iranica</i>	2	Rocky	Subtidal/Qeshm Island
<i>Aquilonastra watersi</i>	10	Rocky	Subtidal/Qeshm Island
<i>Linckia laevigata</i>	5	Coral reef	Intertidal/Qeshm Island
<i>Linckia multifora</i>	2	Coral reef	Subtidal/Kish Island
<i>Linckia</i> sp.	10	Coral reef	Subtidal/Hengam Island
<i>Culcita novaeguineae</i>	1	Coral reef	Subtidal/Kish Island
<i>Pentaceraster mammillatus</i>	2	Coral reef	Subtidal/Hengam Island

**Material examined:** four specimens were collected from 10 m depth in sandy subtidal at Hormuz Island (27°05'N, 56°03'E).

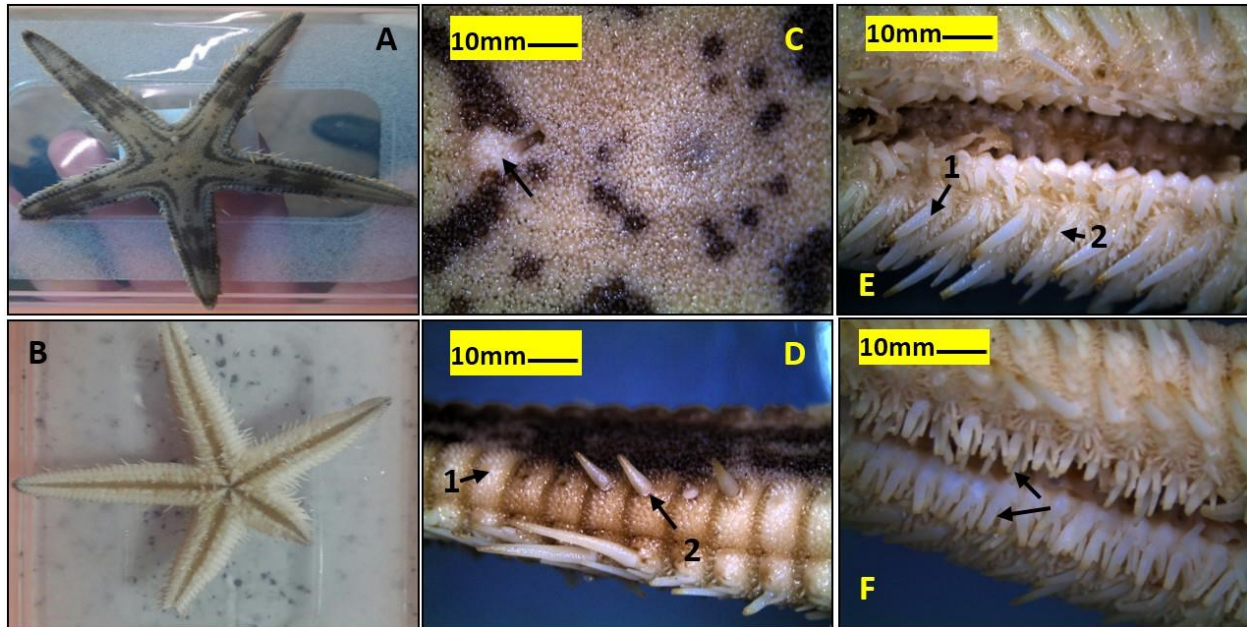
**General distributions:** Arabian coast, West India and Pakistan, North and East of Indian Ocean (Clark & Rowe, 1971); Southeast Coast of India (Prabhu and Bragadeeswaran, 2012; Chamundeeswari *et al.*, 2013); Persian Gulf (Mortensen, 1940; Clark & Rowe, 1971; Price, 1981).



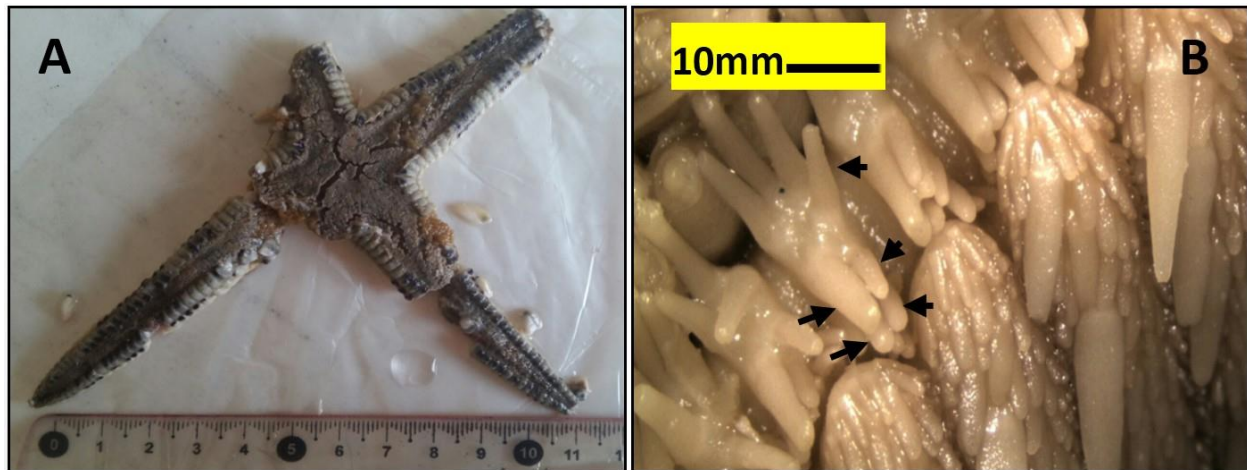
**FIGURE 3.** *Astropecten indicus*. A, Abactinal surface. B, Actinal surface. C, 1) Madreporites. 2) Supero marginal spines in the interradial part (R=40). D, 1) Regular paxillae. 2) Supero marginal spines on middle part of arm (R<40). E, Actinal plates. F, 1) Subambulacral spines. 2) Furrow spines.



**FIGURE 4.** *Astropecten polyacanthus phragmorous*. A, Abactinal surface. B, Madreporites. C, Consecutive supero marginal spine on proximal part. D, Consecutive supero marginal spine on middle part of arm. D, Consecutive supero marginal spine on end of arm. F, Infero marginal plates and Furrow spines.



**FIGURE 5.** *Astropecten polyacanthus polyacanthus*. A, Abactinal surface. B, Actinal surface. C, Madreporites. D, 1) Supero marginal plates. 2) Supero marginal spines (some pages do not have spines). E, 1) Infero marginal spines. 2) Spinelets. F, 1) Adambulacral spines in two series.



**FIGURE 6.** *Astropecten* sp. A, Abactinal surface. B, Adambulacral spines in more than two series.

***Astropecten polyacanthus phragmorous* (Fisher, 1913) (Fig. 4)**

**Remarks:** five rays; R/r=55/12 mm. Paxillae have one single central spinelet (adradial paxillae) or granule (carinal rows and disk paxillae) surrounded by six to eight peripheral ones. Madreporite sometimes conceal by the paxillae. The width of supero marginal plates is less than their length, when viewed from above. Most of the supero marginal plates cover by granules and bear conspicuous spines on upper edge. The supero marginal spines have one row consecutive supero marginal spine without any gap. Infero marginal plates have a series of large spines on margin and two rows of shorter spines on ventral part. The color of live specimens is light brown with dark spot.

**Material examined:** three specimens were collected from muddy intertidal at Hormuz Island (27°05'N, 56°27'E).

**General distributions:** Philippine Islands (Clark & Rowe, 1971); Persian Gulf (Mortensen, 1940; Clark & Rowe, 1971; Price, 1981; Pourvali, 2015).

***Astropecten polyacanthus polyacanthus* (Muller and Troschel, 1842) (Fig. 5)**

**Synonyms:** *Astropecten chinensis* Grube, 1866; *Astropecten edwardsi* Verrill, 1867; *Astropecten ensifer* Grube, 1866; *Astropecten hystrix* Müller & Troschel, 1842; *Astropecten samoensis* Perrier, 1869.

**Remarks:** five rays; R/r=51/11 mm. The difference in *Astropecten polyacanthus polyacanthus* and *A. polyacanthus phragmorous* is presence or absence of spines on supero marginal plates. The supero marginal spines are reduced after the ones on proximal supero marginal plates in this specimen. Three acute spines present on each infero marginal plate with slender spinelets around them. Adambulacral plates have two series of spines with same length and width.

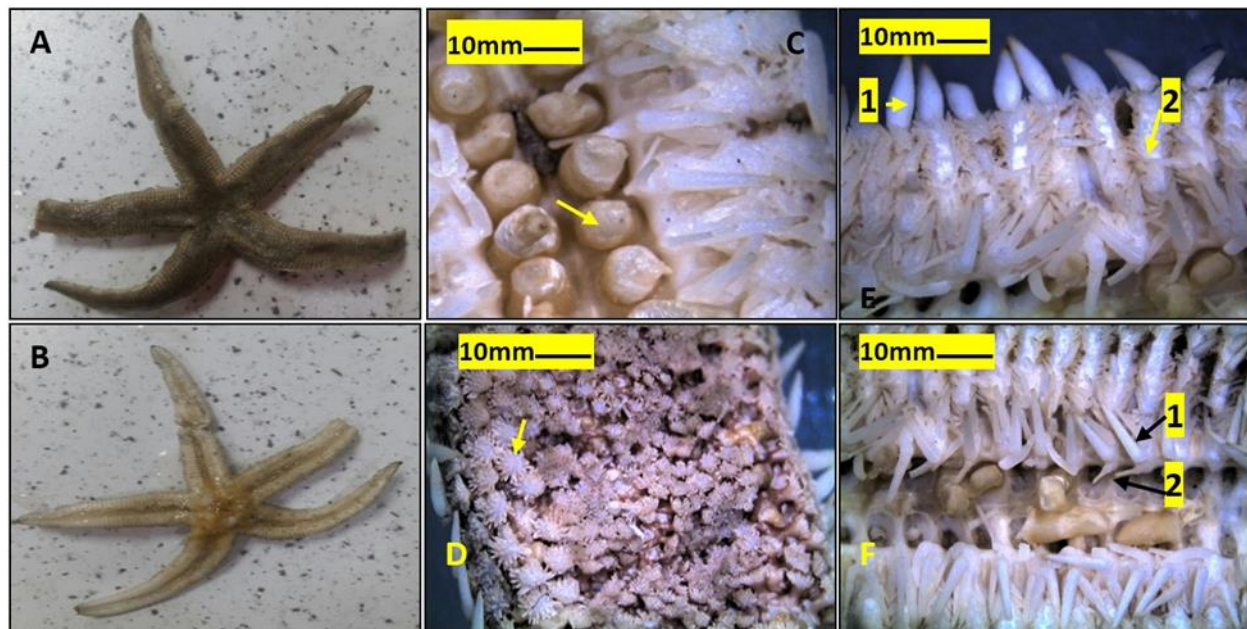
**Material examined:** four specimens were collected from muddy intertidal at Hormuz Island (27°05'N, 56°27'E).

**General distributions:** West, North and East of Indian Ocean, Mascarene Islands, East Africa & Madagascar, Red Sea, Arabian Coast, North Australia, Philippine Islands, China and South Japan, South Pacific Islands and Hawaiian Islands (Clark & Rowe, 1971); Persian Gulf (Mortensen, 1940; Clark & Rowe, 1971; Price, 1981; Pourvali, 2015).

***Astropecten* sp. (Fig. 6)**

**Remarks:** four rays; R/r=80/15 mm. The color form of this specimen is like *Astropecten polyacanthus* but the subambulacral spines are more than two series. This sample in terms of supero marginal spines is similar to *Astropecten polyacanthus polyacanthus* subspecies.

**Material examined:** one specimen was collected from muddy intertidal at Hormuz Island (27°05'N, 56°27'E).



**FIGURE 7.** *Luidia hardwicki*. A, Abactinal surface. B, Actinal surface. C, Podia. D, Lateral paxilla cover supero marginal plates. E, 1) Infero marginal plates. 2) Spinelets on ventral part. F, 1) subambulacral spines. 2) Furrow spines.

**Family Luidiidae Sladen, 1889****Genus *Luidia* Forbes, 1839*****Luidia hardwicki* (Gray, 1840) (Fig. 7)**

Synonyms: *Petalaster hardwicki* Gray, 1840; *Luidia forficifer* Sladen, 1889.

**Remarks:** five rays; R/r= 70/13 mm. Arms are flattened and the color in live specimens on center disk and carinal lines constricted are darker than other areas. Madreporite hidden by paxillae. Large paxillae with 10-15 central granules and 20-25 peripheral granular spinelets are in regular rows on lateral parts and transverse rows. Small ones occur with fewer granules on disk center and carinal lines. Supero marginal plates cover by lateral paxillae. Infero marginal plates have one row of well-defined marginal spine on outer edge and numerous spinelets on ventral part. The Length of lateral infero marginal spines is equal to the length of two consecutive infero marginal plates. Adambulacral plates have three spines; two straight subambulacral spines and curved furrow ones.

**Material examined:** five specimens were collected from 10 m depth in sandy subtidal at Hormuz Island (27°05'N, 56°03'E) and 2 specimens from Suru beach (27°07'N, 56°15'E).

**General distributions:** West, North and East of Indian Ocean, North Australia, China and South Japan (Clark & Rowe, 1971); Singapore (Vanden Spiegel *et al.*, 1998); Anambas (Purwati & Lane, 2004); Persian Gulf (Mortensen and Heding, 1940; Clark & Rowe, 1971; Price, 1981; Pourvali, 2015) and the Gulf of Oman (Fatemi and Fatemi, 2018)

**Order Valvatida Perrier 1884****Family Asterinidea Gray, 1840****Genus *Aquilonastra* O'Loughlin & Waters, 2004*****Aquilonastra iranica* (Mortensen, 1940). (Fig. 8)**

Synonyms: *Asterina cephea* var. *iranica* Mortensen, 1940; *Asterina burtoni* Clark and Rowe, 1971, Price, 1983; *Asterina burtoni burtoni* var. *iranica* Clark, 1993; *Aquilonastra iranica* O'Loughlin and Waters, 2004.

**Remarks:** five rays; R/r= 20/10. The 5 proximal abactinal plates have two populae in the carinal parts. There are not any secondary plates between the abactinal plates. Abactinal plates have short, thick and conical spinelets in small clusters. There are about 12 spinelets in proximal abactinal plates. Actinal plates have about 4-6 thick and conical spinelets on interradial part. Each supermarginal plates with six spinelets located in the edge of abactinal surface. There are about six spinelets on distal interradial plates and 7 oral, 6 suboral and 6 furrow spines on actinal surface. The color of abactinal surface is Grayish with red or brown spots.

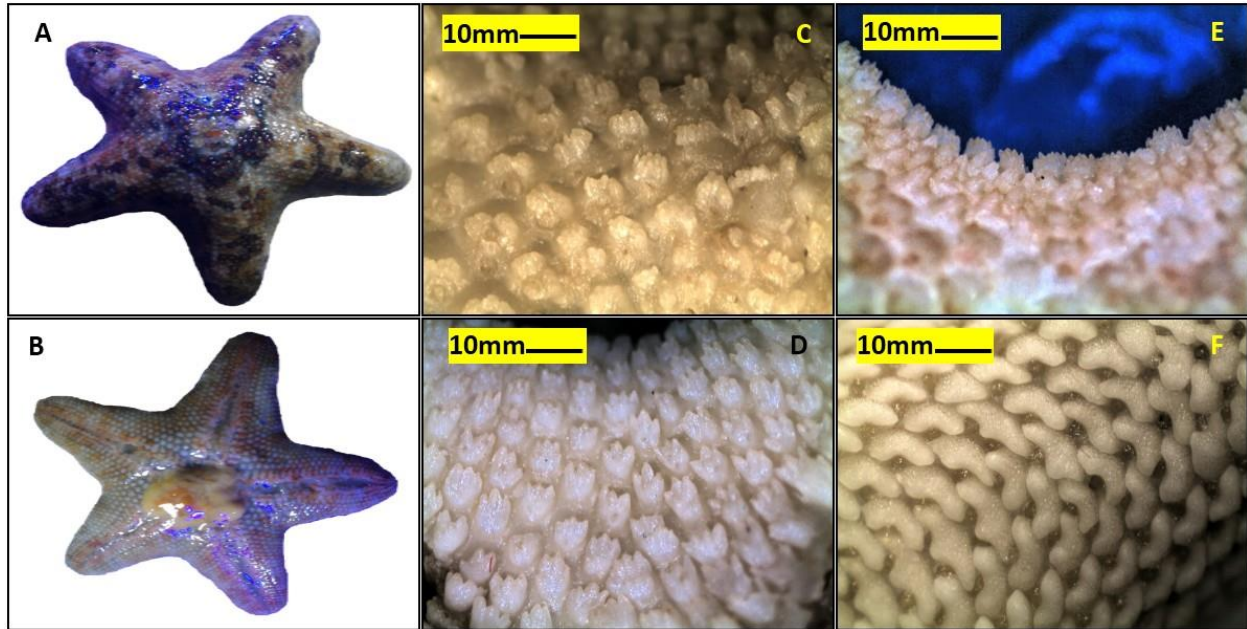
**Material examined:** two specimens were collected from rocky subtidal at Qeshm Island (26°53'N, 56°10'E).

**General distributions:** Iranian Gulf, Arabian Sea, West Pakistan, (O'Loughlin *et al.*, 2004); Persian Gulf (Mortensen, 1940; Pourvali, 2015).

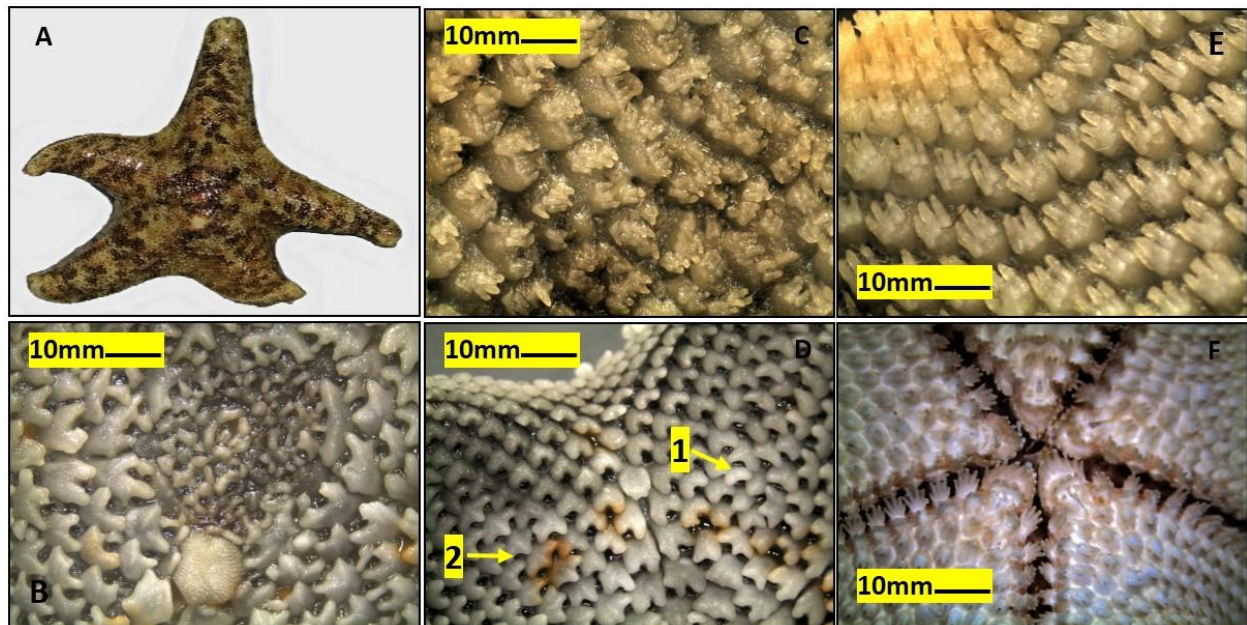
***Aquilonastra watersi* (O'Loughlin and Rowe, 2006) (Fig. 9)**

Synonyms: '*Asterina*' sp. 1. Rowe and Richmond, 2004; '*Asterina*' sp. 2. Rowe and Richmond, 2004; *Asterina cephea*. Loriol, 1885.





**FIGURE 8.** *Aquilonastra iranica*. A, Abactinal surface. B, Actinal surface. C, Abactinal plate spinelets. D, Actinal plate spinelets. E, Superomarginal plates in edge of abactinal surface. F, 2 papulate in a carinal plate and lacking secondary plates.



**FIGURE 9.** *Aquilonastra watersi*. A, Abactinal surface. B, Madreporites. C, Abactinal plate spinelets. D, 1) Secondary plate. 2) 2 papulate in a carinal plate. E, Actinal plate spinelets. F) Oral, suboral, furrow and subambulacral spines.

**Remarks:** five rays;  $R/r= 26/13$ . The arms are conical shaped and circulated at the tip. There is a conspicuous madreporite in the abactinal surface. The 6-7 proximal abactinal plates have two papulae in the carinal parts. There are small secondary plates between the abactinal plates. The proximal abactinal plates are arranged in irregular series. Each Abactinal plate has small, thin and long spinelet in four clusters. There are 15 spinelets in per cluster. There are about 3-5 spinelets on distal interradial plates and

six oral, six suboral, five furrows and five subambulacral spines on actinal surface. These species were in two color patterns: gray with red spots and gray with green spots. *A. watersi* was distinguished by small secondary plates between the abactinal plates and daboule papulate in a carinal plate. This species is reported for the first time from the Persian Gulf.

**Material examined:** 10 specimens were collected from rocky subtidal at Qeshm Island (26°53'N, 56°10'E).

**General distributions:** Arabian Sea, Oman, Red Sea, Egypt, West Indian Ocean, Mauritius, Rodrigues (O'Loughlin *et al.*, 2004).

### **Family Ophidiasteridae Verrill 1870**

#### **Genus *Linckia* Nardo 1834**

#### ***Linckia laevigata* (Linnaeus, 1758) (Fig. 10)**

Synonyms: *Asterias laevigata* Linnaeus, 1758; *Linckia browni* Gray, 1840; *Linckia crassa* Gray, 1840; *Linckia hondurae* Domantay & Roxas, 1938; *Linckia laevigata f. hondurae* Domantay & Roxas, 1938; *Linckia miliaris* Muller & Troschel, 1840; *Linckia rosenbergi* von Martens, 1866; *Linckia suturalis* von Martens, 1866; *Linckia typus* Nardo, 1834; *Ophidiaster clathratus* Grube, 1865; *Ophidiaster crassa* Gray, 1840; *Ophidiaster laevigatus* Linnaeus, 1758; *Ophidiaster miliaris* Müller & Troschel, 1842; *Ophidiaster propinquus* Livingstone, 1932; *Asterias laevigata* Linnaeus, 1758.

**Remarks:** 5-6 ray; R/r= 45/5 mm. These starfishes have small disks with two madreporites. The arms are cylindrical and blunt at the tips. All plates covered by granules on actinal and abactinal surface. Popular areas have 5-15 pores on abactinal surface. The popular pore areas of supereo and infero-marginal plates are larger than surrounding plates. The granules on swollen areas are larger than depression areas. Subambulacral spines or tubercles separated from furrow spines by the granules. The furrow spines are in two sizes with unequal lengths. The color is blue with bluish-green spots. This is the first report of *Linckia laevigata* from the Persian Gulf and Iranian waters.

**Material examined:** five specimens were collected from intertidal area at Qeshm Island (26°41'N, 55°55'E).

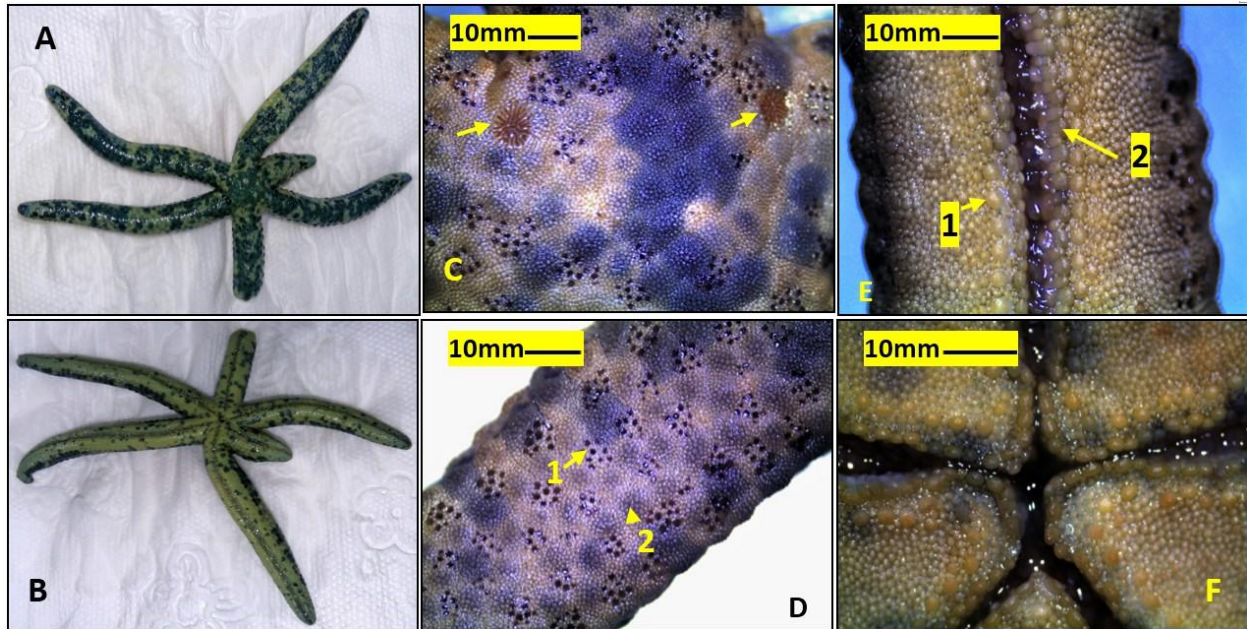
**General distributions:** West, North and East of Indian Ocean, Mascarene Islands, East Africa & Madagascar, North Australia, Philippine Islands, China and South Japan, South Pacific Islands and Hawaiian Islands (Clark & Rowe, 1971).

#### ***Linckia multifora* (Lamarck, 1816) (Fig. 11)**

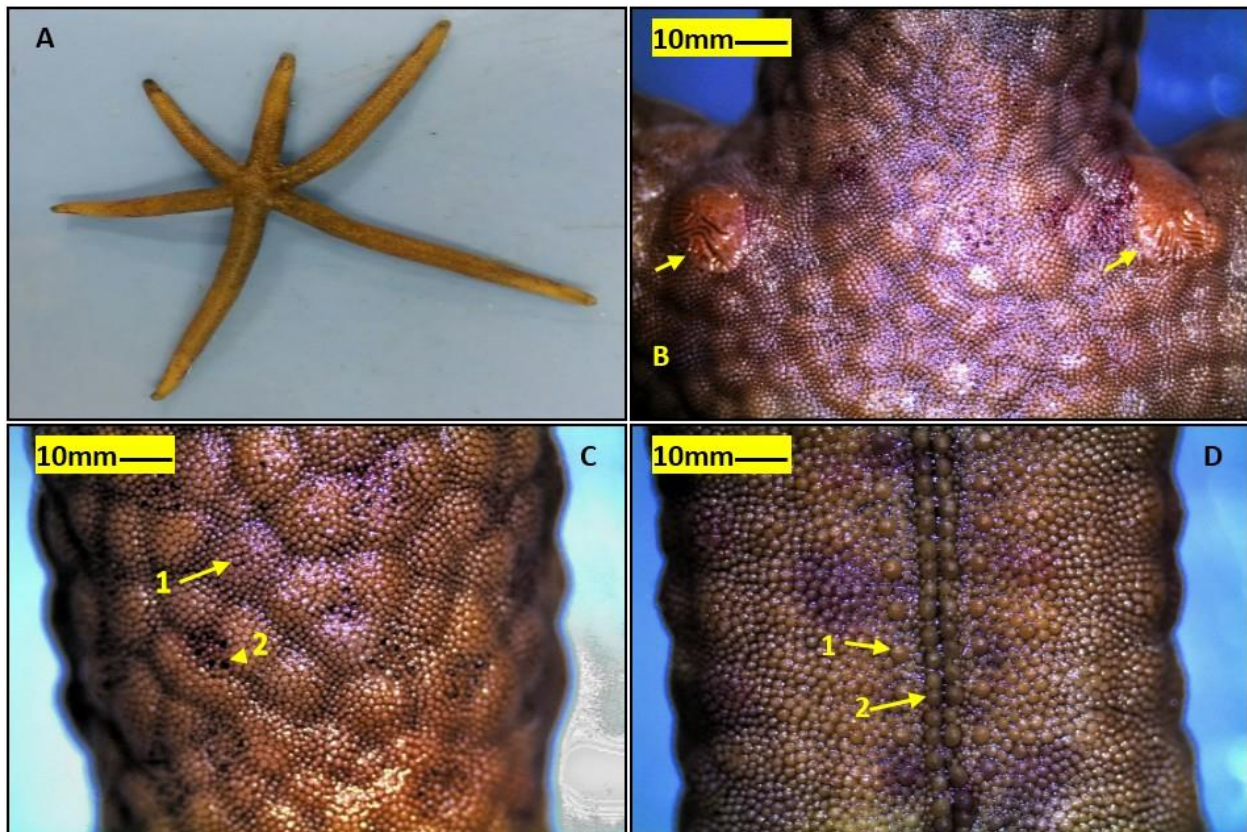
Synonyms: *Asterias multifora* Lamarck, 1816; *Linckia costae* Russo, 1893; *Linckia leachi* Gray, 1840; *Linckia typus* Gray, 1840; *Ophidiaster multiforis* Lamarck, 1816.

**Remarks:** 5-6 rays; R/r= 50/5mm. The arms are more slender and tipped with unequal length in these specimens. The ratio of R in r often exceeded from 10 mm. This specimen has two madreporites and a variegated color of brownish with red spots. The granules, popular pore areas, subambulacral spines and furrow spines are like *Linckia laevigata*.

**Material examined:** two specimens were collected from 4.5 m in coral reefs at Kish Island (26°30'N, 54°03'E).



**FIGURE 10.** *Linckia laevigata*. A, Abactinal surface. B, Actinal surface. C, Madreporites. D, 1) Popular pore areas. 2) Granules. E, 1) Subambulacral spines. 2) Furrow spines. F, Abactinal spines.



**FIGURE 11.** *Linckia multifora*. A, Abactinal surface. B, Madreporites. C, 1) Granules 2) Popular pore areas. D, 1) Subambulacral spines. 2) Furrow spines.

**General distributions:** West, North and East of Indian Ocean, Mascarene Islands, East Africa & Madagascar, Red Sea, Arabian Coast, North Australia, Philippine Islands, China and South Japan, South Pacific Islands and Hawaiian Islands (Clark & Rowe, 1971); Persian Gulf (Mortensen and Heding, 1940; Clark & Rowe, 1971; Price, 1981).

***Linckia* sp. (Fig. 12)**

**Remarks:** five rays; R/r= 47/5 mm. The shape and length of arms are an intermediate form between *Linckia laevigata* and *Linckia multifora*. This specimen has two madreporites. This specimen is similar to other species of *Linckia* in granules, subambulacral and furrow spines. The color is orange with green spots in live sample.

**Material examined:** 10 specimens were collected from coral reefs at Hengam Island (26°40'N, 55°54'E).

**Family Oreasteridae Fisher, 1911**

**Genus *Culcita* Agassiz, 1836**

***Culcita novaeguineae*, (Muller & Troschel, 1842) (Fig. 13)**

Synonyms: *Anthenea spinulosa* Gray, 1847; *Culcita acutispinosa* Bell, 1883; *Culcita grex* Muller & Troschel, 1842; *Culcita pentangularis* Gray, 1847; *Culcita plana* Hartlaub, 1892; *Goniaster multiporum* Hoffman in Rowe, 1974; *Goniaster sebae* Muller & Troschel, 1842; *Goniodiscides sebae* Muller & Troschel, 1842; *Hippasteria philippinensis* Domantay & Roxas 1938; *Hosia spinulosa* Gray, 1847; *Pentagonaster spinulosus* Gray, 1847; *Randasia granulata* Gray, 1847; *Randasia spinulosa* Gray, 1847.

**Remarks:** Outline of the body pentagonal to circular. The body is cushion-like without prominent tubercles. Actinal plates have polygonal granules. The color is light greenish black. It is common in reef flats at low tide.

**Material examined:** one specimen was found at 12m depth in coral reefs at Kish Island (26°34'N, 53°53'E).

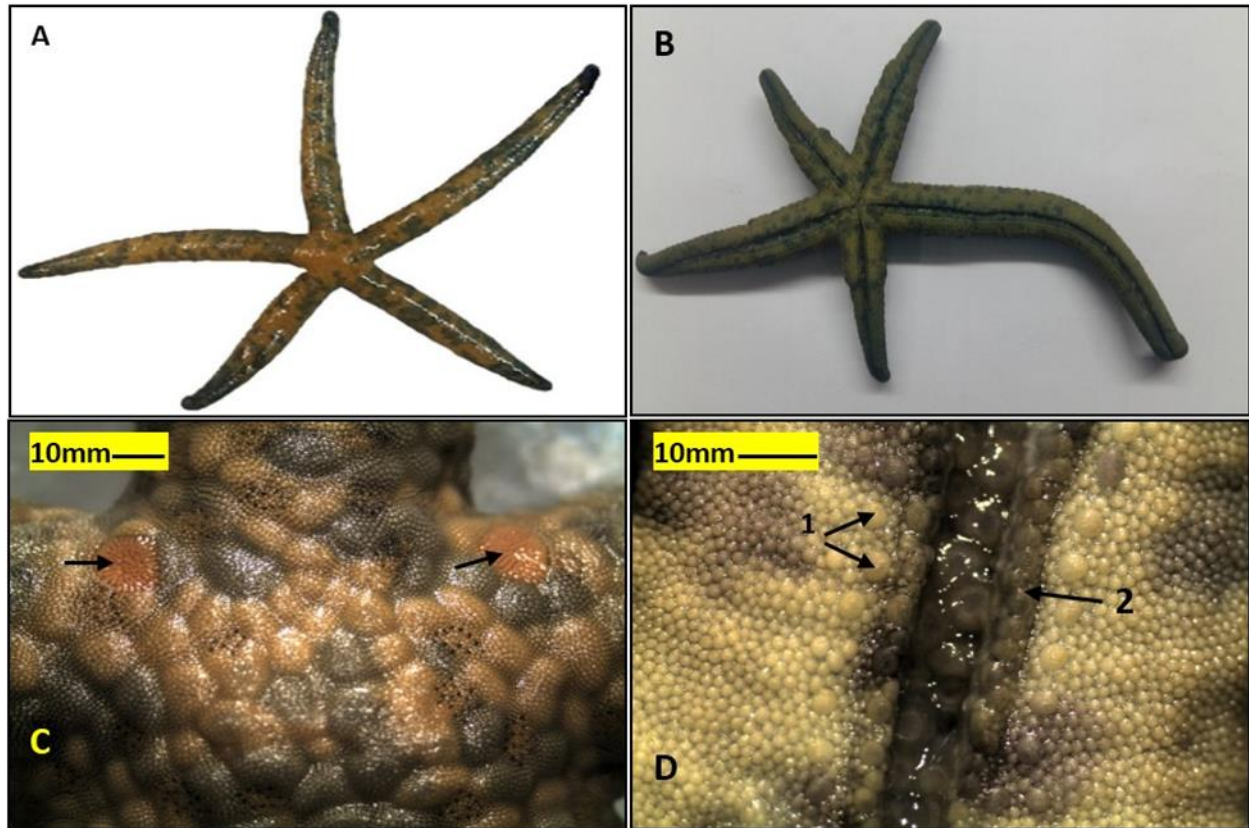
**General distributions:** East Indies, North Australia, Philippine Islands, China and South Japan, South Pacific Islands and Hawaiian Islands (Clark & Rowe, 1971). India (Raghunathan, *et al.*, 2013).

**Genus *Pentaceraster* Döderlein, 1916.**

***Pentaceraster mammillatus* (Audouin, 1826) (Fig. 14)**

Synonyms: *Asterias mammillata* Audouin, 1826; *Oreaster mammillatus* Audouin, 1826; *Oreaster verrucosus* Müller & Troschel, 1842; *Pentaceros mammillatus* Audouin, 1826; *Pentaceros verrucosus* Muller & Troschel, 1842.

**Remarks:** five rays; R/r= 150/60 mm. A large starfish with well-developed arms. The plates form regular series in the abactinal and actinal surfaces. Most spinose specimens have spines constricted at the base with a tubercle at the tip. In specimens with less spine, the lateral spines are smaller than the carinal spines. Actinal surfaces cover with polygonal and rounded granules. The supero- and infero-marginal plates are very similar. The adambulacral plates have eight slender furrow spines that the centers are longer than sides. These plates bear two or three subambulacral spines with unequal lengths. The oral plates have twelve furrow spines, increasing in length towards the mouth, and three or four large subambulacral spines.



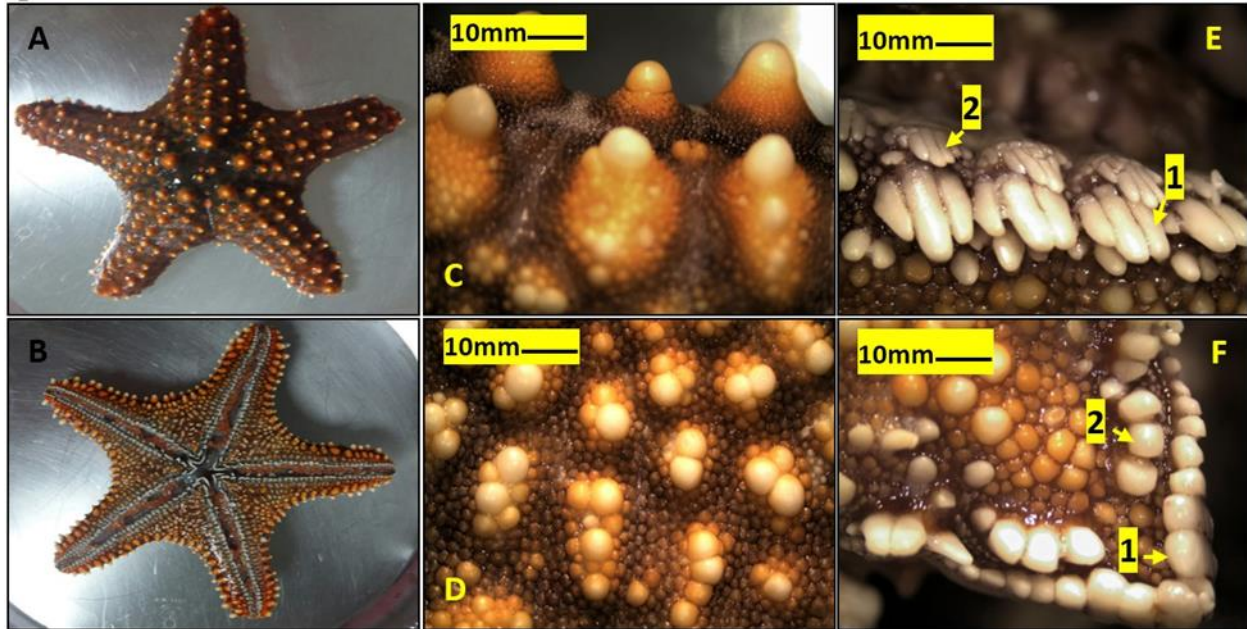
**FIGURE 12.** *Linckia* sp. A, Abactinal surface. B, Actinal surface. C, Madreporites. D, 1) Ambulacral spines. 2) Furrow spines.



**FIGURE 13.** *Culcita novaeguineae* in natural habitat. Actinal plates with polygonal granules.

**Material examined:** two specimens were collected from coral reefs at Hengam Island (26°38'N, 55°54'E).

**General distributions:** East Africa and Madagascar, Red Sea, Arabian coast (Clark & Rowe, 1971); Mozambique (Walenkamp, 1990); Persian Gulf (Mortensen and Heding, 1940; Clark & Rowe, 1971; Price, 1981).



**FIGURE. 14** *Pentaceraster mammillatus*. A, Abactinal surface. B, Actinal surface. C, Supero- and infero-marginal plates. D, Granules in the actinal surface. E, 1) Subambulacral spines. 2) Furrow spines at the adambulacral plates. F, 1) Furrow spines. 2) Subambulacral spines at the oral plates.

#### DISCUSSION

In this survey, 11 species of asteroids were identified which two species of *Linckia laevigata* (Linnaeus, 1758) and *Aquilonastra watersi* (O'Loughlin and Rowe, 2006) are new records in the Persian Gulf.

The genus *Linckia* distinguishes by cylindrical arms, small oral discs, granules and popular pores on aboral surface. Although Clark and Row (1971) suggested color in life is useful for identifying *Linckia* species, but there is considerable diversity in color of some specimens. They suggested *Linckia* species which have colors of blue and green-blue with an  $R/r=5-10/1$  ratio, are named *Laevigata* and the specimens that were red or yellow, with an  $R/r=10/1$  ratio of more than 10, are called *multifora*. Previous studies demonstrated that *L. Laevigata* with color variation is common in the Indo-West Pacific. Williams (2000) displayed the species of *L. Laevigata* and *L. multifora* can be distinguished when alive by color pattern, number of madreporites and the ratio of arm length to breadth. In our study, since all specimens of *Linckia* with different color patterns have 2 madreporites, so determination of species boundary needs more research. Molecular analysis can aim to clarify the specimens like *Linckia* sp (Figure 12) with phenotypic diversity. Since molecular analysis along with morphological studies can aim to clarify the specimens like *Linckia* sp (Figure 12), we found this species is *Linckia Laevigata* in our previous literature (Adeli *et al.*, 2020).

Among the families of Asteroidea, Astropectiniidae has the most genus and species after Goniasteridae (Mah and Blake, 2012). The genus *Astropecten* with 150 species has the most speciose genus and abundant species in shallow waters. Zulliger and Lessios (2010) identified 40 species in the widespread tropical genus *Astropecten* and discovered species complexes and likely cryptic species. In these previous studies in morphological identification of species of *Astropecten* (Gondim, *et al.*, 2014) several taxonomic characters such as paxillae and the superomarginal plates with the number and shape of the superomarginal spines were used to distinguish the species of *Astropecten*. The character of adambulacral spines is similar among these specimens. *Astropecten* sp. (Figure 6) differs from other species of *Astropecten polyacanthus* for the number of subambulacral spines and arm length. We thought it was *Astropecten hemprichi* for having a long arm, but the character of color pattern similar to *Astropecten polyacanthus* rejected this assumption. However, there is high morphological diversity in this genus. This phenotypic variability leads to different subspecies and it is difficult to identify

morphologically. Our molecular results (Adeli et al., 2020) showed this species belongs to *Astropecten polyacanthus*.

### Conclusion

Eleven species were identified in this study including: *Astropecten hemprichi* (Müller & Troschel, 1842), *Astropecten indicus* (Döderlein, 1888), *Astropecten polyacanthus polyacanthus* (Muller and Troschel, 1842), *Astropecten polyacanthus phragmorous* (Muller and Troschel, 1842), *Luidia hardwicki* (Gray, 1840), *Aquilonastra iranica* (Mortensen, 1940), *Aquilonastra watersi* (O'Loughlin and Rowe, 2006), *Linckia laevigata* (Linnaeus, 1758), *Linckia multifora* (Lamarck, 1816), *Culcita novaeguineae* (Muller & Troschel, 1842) and *Pentacaster mammillatus* (Audouin, 1826). Although this study has increased knowledge of the biodiversity of asteroids especially in the northern islands of Persian Gulf, the present records are thought to be incomplete. The absence of species from the other starfish families indicates that more sampling is needed, especially in deeper waters and suggests the possibility of additional starfish taxa being present.

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