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Records of sea star (Echinodermata, Asteroidea) diversity in a disturbed tropical seagrass meadow

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Abstract

Records of sea star (Echinodermata, Asteroidea) diversity in a disturbed tropical seagrass meadow. This study aims to record the sea star distribution in seagrass meadows within Sungai Pulai estuary (Johor, Malaysia) that is under pressure from coastal modification activities. The sampling sites were Merambong Shoal, Tanjung Adang Shoal, Tanjung Bin and Sungai Duku. From January 2016 to March 2018, we surveyed the areas to provide an inventory of sea star species sighted during the lowest tides. A total of seven species were observed, with Merambong Shoal having the highest number of species (seven species) while Sungai Duku and Tanjung Bin had the lowest (one species). We report the first sighting of *Astropecten vappa* in the area. Combined with past studies, there are now a total of eight sea star species in this area. As baseline records, our findings for the sea star community are applicable to the management of the seagrass habitat and help to create awareness of sea star diversity in the area.

Data published in Mendeley and Zenodo (Doi: 10.17632/dzjdnnbykv.1)

Key words: Species checklist, Diversity, Malaysia, Sungai Pulai estuary

Resumen

Registros de diversidad de estrellas de mar (Echinodermata, Asteroidea) en un una pradera marina tropical alterada. El objetivo de este estudio es registrar la distribución de estrellas de mar en las praderas marinas del estuario Sungai Pulai (Johor, Malasia), donde están sometidas a presión ambiental debido a la modificación de las actividades en la costa. Los puntos de muestreo fueron Merambong Shoal, Tanjung Adang Shoal, Tanjung Bin y Sungai Duku. Desde enero de 2016 hasta marzo de 2018 observamos las áreas de estudio para realizar un inventario de las especies de estrellas de mar presentes durante la marea baja. Observamos un total de siete especies, siendo Merambong Shoal el área con el mayor número de especies (siete especies), mientras que Sungai Duku y Tanjung Bin presentaron el número más bajo (una especie). Registramos la primera observación de *Astropecten vappa* en esta área, que sumada a los hallazgos de estudios anteriores supone un total de ocho especies. Nuestros hallazgos referentes a la comunidad estrellas de mar podrían ser aplicables como valores de referencia para la gestión de las praderas marinas como hábitat, así como para sensibilizar acerca de la diversidad de estrellas de mar en esta área.

Datos publicados en Mendeley y Zenodo (Doi: 10.17632/dzjdnnbykv.1)

Palabras clave: Lista de especies, Diversidad, Malasia, Estuario Sungai Pulai

Resum

Registres de diverstat d'estrelles de mar (Echinodermata, Asteroidea) en un una praderia marina tropical alterada. L'objectiu d'aquest estudi és registrar la distribució d'estrelles de mar a les praderies marines de l'estuari Sungai Pulai (Johor, Malàisia), on estan sotmeses a pressió ambiental a causa de la modificació de les activitats a la costa. Els punts de mostreig van ser Merambong Shoal, Tanjung Adang Shoal, Tanjung Bin i Sungai Duku. Des del gener de 2016 fins al març de 2018 vam observar les àrees d'estudi per fer un inventari de les espècies d'estrelles de mar presents durant la marea baixa. Hi vam observar un total de set espècies. L'àrea de Merambong Shoal és la que va presentar un nombre més gran d'espècies, set, mentre que Sungai Duku i Tanjung Bin van presentar el nombre més baix, una cadascun. Vam registrar la primera observació d'*Astropecten vappa* en aquesta àrea, que sumada a les troballes d'estudis anteriors suposa un total de vuit espècies. Les nostres troballes referents a la comunitat d'estrelles de mar podrien ser aplicables com a valors de referència per a la gestió de les praderies marines com a hàbitat i també per sensibilitzar sobre la diversitat d'estrelles de mar en aquesta àrea.

Dades publicades a Mendeley i Zenodo (Doi: 10.17632/dzjdnnbykv.1)

Paraules clau: Llista d'espècies, Diversitat, Malàisia, Estuari Sungai Pulai

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Introduction

Seagrass meadows are important coastal ecosystems due to the ecosystem services that they provide (e.g. Barbier et al., 2011). These meadows not only offer a sanctuary and nursery for various kinds of marine organisms, but also house diverse kinds of organisms that include macroalgae, echinoderms, gastropods, and fish (Boström et al., 2006). Due to their proximity to human habitation, seagrass meadows are prone to disturbances caused by coastal development (Cullen–Unsworth et al., 2014), which invariably affect the community structure of organisms that live and associate with others within the seagrass area. These organisms include sea stars that depend on the seagrass habitat for their continued survival, for instance, as a nursery for outgrowing juveniles (Scheibling and Metaxas, 2010) as well as for food sources (Scheibling, 1982; Bos et al., 2008). Their importance in marine habitats includes roles such as apex predators (Lawrence, 2013) and as keystone species (Paine, 1995). However, in the Indo–Pacific region, there is a lack of sustained research on the ecological relevance of sea stars in coastal habitats. The focus on certain species groups relates directly to economic interests, and because most sea stars are not usually harvested for human consumption, they are therefore not considered economically significant despite their important roles in the marine ecosystems (Bos et al., 2008). Furthermore, limited funding sources and interests in this field results in the limited development of scientific progress in sea star research in this region (Bos et al., 2008).

In Malaysia, few studies have been carried on sea stars and those that do exist have mainly been related to biodiversity or check–list type research; e.g. Choo et al. (2009), Kamarruddin et al. (2011), Pinn et al. (2014), Zulfigar et al. (2008). Only Choo et al. (2009) and Pinn et al. (2014) specifically looked at sea stars in seagrass meadows of Malaysia. According to Lane et al. (2000), the research gaps in the echinoderms inventory of the South China Sea include studies from Malaysia as there is a lack of sampling on this group of organisms in the extensive Sunda shelf. The lack of records on sea star occurences in Malaysian seagrass meadows, especially those sites implicated by severe human disturbances (e.g. Ministry of Natural Resources and Environment, 2016), makes it difficult to understand the community dynamics of sea star species in the habitat. The fact that these sites are threatened by disturbances makes it even more important to develop diversity records. This study therefore aims to record the sea stars species present in the seagrass meadows of Sungai Pulai estuary so as to provide reference data on the contemporary status of the sea star diversity in habitats under pressure from coastal modification activities.

Material and methods

The seagrass meadows from the Sungai Pulai estuary area were surveyed from January 2016 to March 2018 to ascertain the species of sea stars residing in vegetated parts of the meadows. The meadows consist of seagrass growths in the Merambong Shoal, Tanjung Adang Shoal, Tanjung Bin, and Sungai Duku areas (fig. 1). In the absence of clear matrices to quantitatively ascribe the degree of disturbance to the seagrass meadows in the estuary, we resorted to site descriptions to provide a relative measure of disturbance in the four study sites (table 1). Merambong Shoal, categorised as intermediate disturbance, was one of the largest seagrass meadows in Malaysia (Bujang et al., 2006) before land reclamation activities occurred in recent years. In Tanjung Adang Shoal, seagrasses cover decreased due to impact from the development of the Tanjung Pelepas Port in the early 2000s (Bujang and Zakaria, 2003) but at present it is in the midst of recovering its vegetation cover. This site is therefore categorised as less disturbed/recovering. The Tanjung Bin meadow, categorised as most disturbed, is located on the riverbank opposite the port complex and is within the closest vicinity to the port complex and vessel traffic. Vegetated patches off Sungai Duku are at upstream parts of the estuarine area, and furthest away from human activities at the time of the surveys; here, seagrasses can be found on the edges of the riverbank. This site is categorised as the least disturbed.

Observations and records of sea stars were performed by the wandering transect method used by Pinn et al. (2014). We carried out surveys during periods of the lowest tide levels when the seagrass meadows were exposed from submersion. Multiple visits to the seagrass sites were performed over the study period, when the meadows were surveyed in a zigzag manner to survey as much of the meadow as possible. Due to the difference in number of site surveys, some sites were under sampled and therefore the numbers of species found were not quantitatively analysed beyond recording the number of individuals sighted. Details for all sampling efforts are included in table 2. During these surveys, five meters to the left and right and perpendicular to the trekked route were searched thoroughly for any presence of sea stars, including looking under the seagrass canopy in areas of dense vegetation. All sea stars species found were then recorded and photographed, with no specimens removed from the meadows due to the relatively low numbers of individuals sighted. Species identification of the sea stars is based on morphology following the characteristics described by Clark and Rowe (1971).

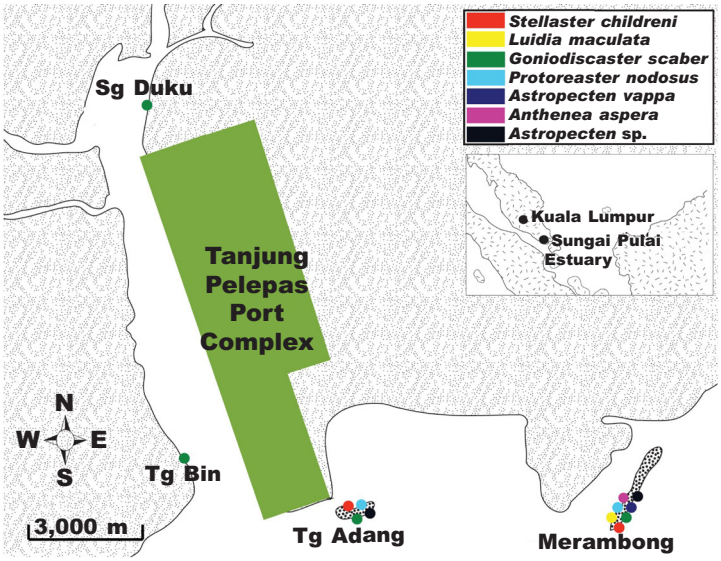


Fig. 1. Map of Sungai Pulai estuarine area and distribution of sea stars species according to the sampling sites.
Fig. 1. Mapa del área del estuario Sungai Pulai y distribución de las especies de estrellas de mar en los puntos de muestreo.

Results

Six species from four families were found in the seagrass meadows of Sungai Pulai estuary (see Mendely datatet). The species were *Stellaster childreni* Gray, 1840 (fig. 2) from the family Goniasteridae, *Luidia maculata* Müller and Troschel, 1842 (fig. 3) from the family Luidiidae, *Goniodiscaster scaber* (Moebius, 1859) (fig. 4), *Protoreaster nodosus* (Linnaeus, 1758) (fig. 5) and *Anthenea aspera* Döderlein, 1915 (fig. 6), all from the family Oreasteridae, and *Astropecten vappa* Müller and Troschel, 1843 (fig. 7) from the family *Astropectinidae*. One individual sighted also belongs to the genus *Astropecten* from the family *Astropectinidae*. However, the taxonomic identification for this individual cannot be done further as its presence was recorded through photographic evidence only. No samples were collected to physically examine this individual, although the species closely resembles *Astropecten indicus* Döderlein, 1888 and further research is needed to confirm the individual taxonomically (fig. 8).

Based on the distribution of species found in all four study sites of the Sungai Pulai estuarine area (fig. 1), the highest number of species of sea stars found was in the western side of Merambong Shoal, where six species were found, with an additional species (three individuals) identified to genus level. The most commonly sighted sea stars here were *Protoreaster nodosus* and *Goniodiscaster scaber* while the least commonly sighted sea stars, *Anthenea aspera*, *Luidia maculata* and *Stellaster childreni,* were sighted only once. In Tanjung Adang Shoal, only five out of seven species were sighted. The most commonly found species here were also *Protoreaster nodosus* and *Goniodiscaster scaber* while the least commonly species was *Stellaster childreni*. One sighting recorded sea stars that could be identified only up to the genus level, *Astropecten* sp. For both Tanjung Bin and Sungai Duku, only *Goniodiscaster scaber* was sighted. The number of individuals found here was

Table 1. Coordinates (C) and relative disturbance levels (RDL) for each sampling site.
Tabla 1. Coordenadas (C) y niveles de alteración relativos (RDL) de cada punto de muestreo.

Sites	C	RDL	Criterion
Tanjung Bin	1.341666 103.542054	Most disturbed	Located near the Tanjung Pelepas port complex and exposed to daily shipping traffic
Merambong Shoal	1.330722 103.598454	Moderately disturbed	Reclamation activity is ongoing during the study period
Tanjung Adang Shoal	1.330728 103.566353	Less disturbed/ recovering	Located relatively near to the port complex, but relatively far from vessel traffic
Sungai Duku	1.387083 103.539472	Least disturbed	Located higher upstream along Sungai (River) Pulai with minimal signs of human disturbances during surveys

also lower than that found in Merambong and Tanjung Adang shoals.

In this study we also compiled past checklists of sea stars in the sampling sites and nearby areas, and then compared these to review the sea stars records found in this study (table 3). These past records include those from Tan and Yeo (2003), Choo et al. (2009) and Pinn et al. (2014), all studies performed in seagrass areas.

Discussion

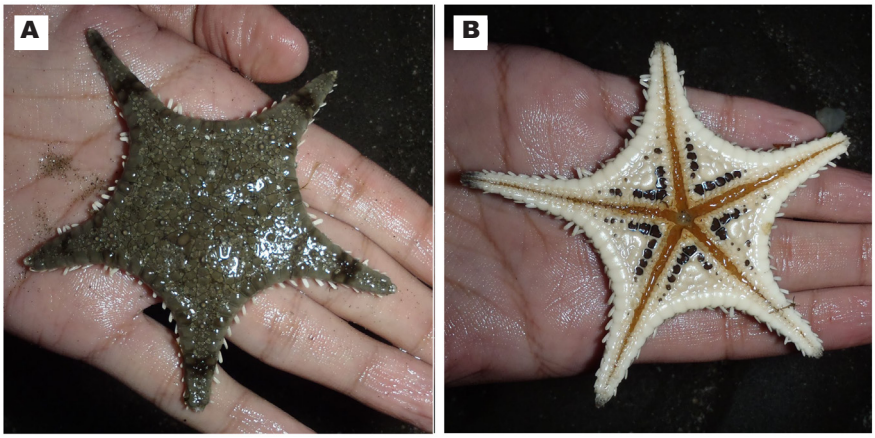
The present study continues work by Pinn et al. (2014), who reported the sea star species found in the seagrass meadows area in 2013. At that time, coastal reclamation of the coastlines was still in its early stages and Merambong Shoal had not yet been modified by the reclamation activity. Pinn et al. (2014) recorded five species of sea stars, with three being new records for Malaysian waters. In the present study, four of the six species sighted had been sighted in Merambong Shoal (Pinn et al., 2014), adding two new sightings for this area, though these species were sighted in Malaysian waters before; *Astropecten vappa* Müller and Troschel, 1843 (fig. 7) from the family Astropectinidae had been sighted in Penang waters in a study carried out by Berry (1984) while the occurrences of *Anthenea aspera* Döderlein, 1915 (fig. 6) from the family Oreasteridae, had been recorded in Sungai Pulai estuary by Choo et al. (2009).

The composition of sea stars species in the area was similar to that observed in the study of Pinn et al. (2014), with the exception of *Archaster typicus* that was not sighted in the present survey. This may indicate that although the disturbances have been ongoing in recent years, the ecological balance of the area in terms of sea star community composition may still be relatively intact. Although the research done by Pinn et al. (2014) can

Table 2. Details of sampling performed at four sites: Date, sampling date; Site, sampling site; SD, sampling duration (min.); NP, number of persons involved (individuals); Species, species sighted; NSp, number os specimens sighted (individuals); Nr, not recorded.
Tabla 2. Detalles del muestreo en cada uno de los cuatro puntos del estudio: Site, área de muestreo; SD, duración del muestreo (min.); NP, número de personas involucradas (individual); Species, especies avistadas; NSp, número de ejemplares avistados (Individual); Nr, sin datos.

Date	Site	SD	NP	Species	NSp
23 I 16	Merambong Shoal	135	3	*Anthenea aspera*	2
				Astropecten sp.	3
				Astropecten vappa	1
				Goniodiscaster scaber	7
				Protoreaster nodosus	9
				Stellaster childreni	5
09 V 16	Tanjung Adang Shoal	120	4	*Goniodiscaster scaber*	Nr
10 V 16	Tanjung Bin	60	4	*Goniodiscaster scaber*	Nr
	Sungai Duku	60	4	*Goniodiscaster scaber*	Nr
11 V 16	Merambong Shoal	135	4	*Protoreaster nodosus*	Nr
19 VIII 16	Merambong Shoal	90	3	*Goniodiscaster scaber*	3
				Protoreaster nodosus	21
				Unidentified	1
19 IX 16	Merambong Shoal	120	2	*Protoreaster nodosus*	5
				Astropecten vappa	1
15 X 16	Tanjung Adang Shoal	135	1	*Astropecten* sp.	Nr
				Protoreaster nodosus	Nr
12 II 17	Tanjung Adang Shoal	75	2	*Goniodiscaster scaber*	3
				Protoreaster nodosus	3
28 IV 17	Sungai Duku	60	4	*Goniodiscaster scaber*	2
	Tanjung Bin	30	4	None	
29 IV 17	Merambong Shoal	120	4	*Astropecten vappa*	1
				Goniodiscaster scaber	9
				Luidia maculata	1
				Protoreaster nodosus	80
02 III 18	Tanjung Adang Shoal	120	3	*Astropecten vappa*	Nr
				Goniodiscaster scaber	Nr
				Protoreaster nodosus	Nr
				Stellaster childreni	Nr

2



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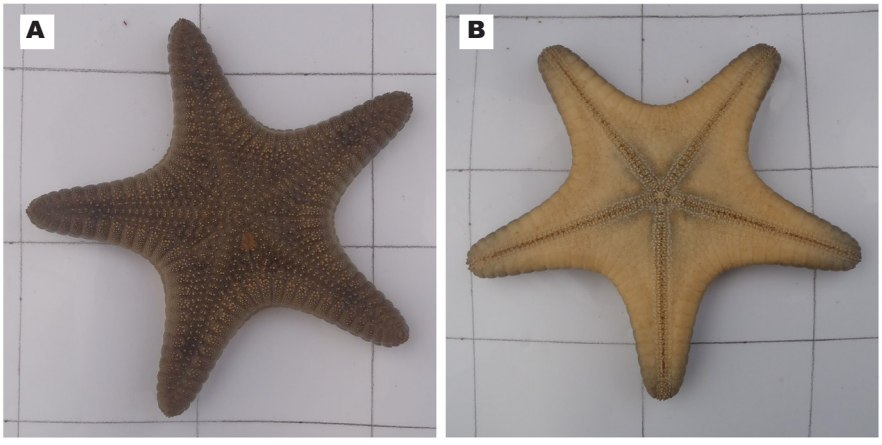
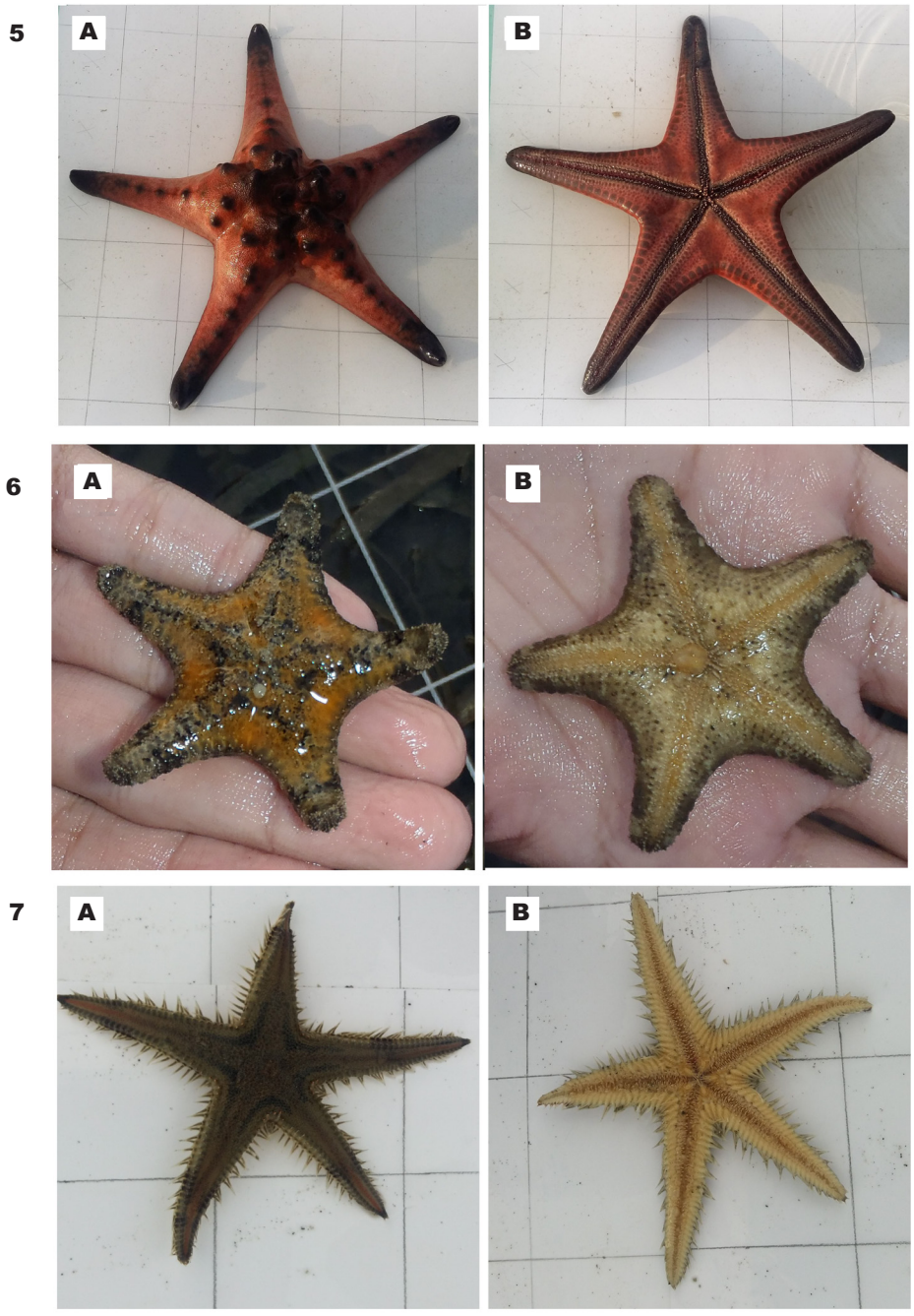


Figs. 2–4. Sea stars sighted in Sungai Pulai Estuary: 2, *Stellaster childreni*; 3, *Luidia maculata;* 4, *Goniodiscaster scaber (A*, aboral view; B, oral view).
Figs. 2–4. Estrellas de mar observadas en el estuario Sungai Pulai: 2, Stellaster childreni*; 3,* Luidia maculata*; 4,* Goniodiscaster scaber *(A, cara aboral; B, cara oral).*



Figs. 5–7. Sea stars sighted in Sungai Pulai Estuary: 5, *Protoreaster nodosus;* 6, *Anthenea aspera;* 7, *Astropecten vappa (*A, aboral view; B, oral view).
Figs. 5–7. Estrellas de mar observadas en el estuario Sungai Pulai: 5, Protoreaster nodosus*; 6,* Anthenea aspera*; 7,* Astropecten vappa *(A, cara aboral; B, cara oral).*

Fig. 8. *Astropecten* sp. found in Tanjung Adang Shoal.
Fig. 8. Astropecten *sp. recolectada en Tanjung Adang Shoal.*

be deemed as pre–disturbance data, their report only covered Merambong Shoal. Also, an important point to note is that in Tanjung Adang shoal, disturbance has been going on since the nearby port complex was started in the early 2000s, with no pre–disturbance data available in regards to the sea stars. Changes in the community structure of organisms in a particular habitat have a strong influence on the ecosystem, considering the role of the sea stars as predators in the meadows. At present, the reason for the absence of *A. typicus* in our surveys is unclear. Some sea stars are known to use seagrass as a transition habitat in the juvenile period. This is clearly exhibited by *A. typicus* (Bos et al., 2011), where the juveniles migrate from mangrove to sandy and seagrass areas before proceeding to the shore. However, it is plausible that this species may be more sensitive towards disturbance in relation to the reduction in the size of the seagrass meadow, but further studies are needed to confirm whether this species can be sighted upon reduction in disturbance activities.

In addition to confirming species found in past studies, we also sighted one sea star species (*Astropecten vappa*; fig. 7) as a new record for the Sungai Pulai estuarine seagrass meadows. *Astropecten* are distributed worldwide in both intertidal and subtidal areas. Their habitat ranges from sand to mud and, gravel, and some species, such as *Astropecten irregularis,* migrates to deeper parts of the ocean during the winter months (Freeman et al., 2001). Sightings of *Astropecten* have also been reported in seagrass meadows, especially those that live in sand patches (Arakaki and Kusen, 2000).

The species composition recorded in the Sungai Pulai estuarine area is also comparable to the sea star species in the seagrass meadows of Tanjung Chek Jawa (Singapore) on the eastern side of the Straits of Johor (Tan and Yeo, 2003). These authors recorded at least eight species, with five coinciding with the present study (i.e. *Archaster typicus, Astropecten* sp., *Goniodiscaster scaber, Protoreaster nodosus* and *Anthenea aspera*). Tanjung Chek jawa is classified as one of the largest intertidal seagrass meadow in Singapore, with increasing conservation efforts focused there. The sea star diversity in that particular area would simulate situations of low anthropogenic disturbances. Although there are very few seagrass meadows that can be considered pristine in the surrounding localities, the Tanjung Chek Jawa may potentially be an example of a meadow closest to pre–disturbance conditions.

Our findings contribute to understanding the general biodiversity in Malaysia, and particularly the seagrasses of Sungai Pulai estuary that haverecently been highlighted as among the recommended and prioritised meadows for conservation efforts in Southeast Asia (Tan et al., 2018). On gaining insights into the ecological status of the Sungai Pulai estuarine

Table 3. Lists of records of sea stars (including this study): 1, Tan and Chao, 2003; 2, Choo et al., 2009; 3, Pinn et al. 2004; 4, this study; * new species sighted in the sampling area.
Tabla 3. Registros de estrellas de mar (incluido este estudio). (Para las abreviaturas, véase arriba).

Species	1	2	3	4
Archasteridae				
Archaster typicus Müller and Troschel, 1840	X	X	X	
Asterinidae				
Aquilonastra coronata (von Martens, 1866)	X			
Nepanthia sp.	X			
Astropectinidae				
Astropecten sp.	X			X*
Astropecten vappa Müller and Troschel, 1843				X*
Stellaster childreni Gray, 1840			X	X
Luidiidae				
Luidia maculata Müller et Troschel, 1840			X	X
Oreasteridae				
Anthenea aspera Döderlein, 1915	X	X		X
Goniodiscaster scaber (Moebius, 1859)	X	X	X	X
Gymnanthenea laevis H. L. Clark, 1938	X			
Protoreaster nodosus (Linnaeus, 1758)	X	X	X	X

seagrass meadows under threat from anthropogenic activities, our findings complement findings from other studies (e.g. Bujang et al., 2016, Rozaimi et al., 2017, Ponnampalam et al., 2015) that delved into the contemporary status of ecosystem health and functioning of the area.

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