BIODIVERSITAS
Volume 25, Number 5, May 2024
Pages: 1965-1974

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d250513

Intertidal echinoderm identification keys for a reef-walking-tour at Mandalika, Lombok Island, Indonesia

IMAM BACHTIAR[1,♥], ENI SUYANTRI[1], TRI AYU LESTARI[1], MUHAMMAD IRSYAD A. GHAFARI[2]

[1]Department of Biology Education, Faculty of Teacher Training and Education, Universitas Mataram. Jl. Majapahit No. 62, Gomong, Selaparang, Mataram 83115, West Nusa Tenggara, Indonesia. Tel.: +62-370-633007, Fax.: +62-370-636041, ♥email: imambachtiar@unram.ac.id

[2]Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu. 21030 Kuala Nerus, Terengganu, Malaysia

Manuscript received: 6 March 2024. Revision accepted: 7 May 2024.

Abstract. *Bachtiar I, Suyantri E, Lestari TA, Ghafari MIA. 2024. Intertidal echinoderm identification keys for a reef-walking-tour at Mandalika, Lombok Island, Indonesia. Biodiversitas 25: 1965-1974.* The coastal biodiversity of Lombok Island has not been utilized holistically for tourist destinations. The Special Economic Zone (SEZ) of Mandalika, Central Lombok District, West Nusa Tenggara Province, Indonesia was established on the island's southern coast, designed to be an ecoresort with thousands of super-premium rooms. New tourist attractions are therefore required to fulfill the increasing demands. The present study aims to provide a pre-requisite science to develop a new tourist attraction related to marine biodiversity in intertidal areas. An intertidal reef walking tour will be initiated to add existing ecotourism options on the island. Culturally, the intertidal area is used for reef gleaning and seaweed farming. The gleaning tradition has the potential to be integrated into the reef walking tour as the cultural menu of ecotourism. The present study offers identification keys for echinoderm fauna inhabiting the intertidal area of the Mandalika SEZ. The identification keys are new and designed specifically for tourist users with broad discipline backgrounds. Twenty-four echinoderm fauna can be identified using the new tourism-designed keys. The echinoderm keys may apply to intertidal areas of many islands in the Indonesian Archipelago and the Western Pacific.

Keywords: Biodiversity, coastal, ecotourism, zoology

Abbreviations: SEZ: Special Economic Zone; DP: Dental Papillae; GR: Granula; IB: Inter Brachial; OP: Oral Papillae; RS: Radial Shield; SC: Scale; SP: Spine

INTRODUCTION

Lombok Island is one of the most popular coastal tourist destinations in Indonesia. The island's tourism has flourished since the 1990s, mostly in northern areas (Bachtiar 2000). In 2016, the Indonesian government established a tourism mega project, the Special Economic Zone (SEZ) of Mandalika. Tourism development in the Mandalika SEZ is designed to contain 10,000 super-premium room ecoresorts (Pauzi and Purwoko 2022). Highly reputable moto-sport racing has been developed in the Mandalika to complement the existing surfing and diving tours, paragliding, and a cultural festival of *Bau Nyale* (harvesting polychaete-worm epitokes). The *Bau Nyale* festival is one of the province's biggest annual cultural tourism attractions (Bachtiar and Bachtiar 2019). Hosting a high number of super-premium tourists, the Mandalika SEZ needs more variety of tourist attractions. Lombok Island is rich in nature-based resources with high biodiversity, so ecotourism is potentially developed in terrestrial and marine areas. Among the existing tourist attractions on Lombok Island, nearly none of them may be classified as ecotourism.

Ecotourism has been overseen as obligatory for all nature-based tourism for the last 25 years (Weaver and Lawton 2007). Community awareness of responsible tourism has been increasing rapidly, but its implementation in developing countries is still challenging (Das and Chatterjee 2015; Stronza et al. 2019; Irani et al. 2022), including Indonesia. Ecotourism must meet three conditions, these are conserving nature, educating people, and bringing economic impacts on local people. Nearly all nature-based tourism in Lombok has been linked with conservation efforts and positive economic impacts on local people. These nature-based tourist attractions do not properly educate tourists to understand the visited nature. The likely explanation for the lack of education component in the ecotourism of Lombok is that most or nearly all tourist guides have an insufficient science background, the ecotourisms were not well planned, or the required scientific information was unavailable.

Ecotourism has the potential to be developed on Lombok Island. The island has natural beauty, a unique landscape, high biodiversity, and social capital to carry out ecotourism (Sukuryadi et al. 2020; Syamsi and Lee 2021). The intertidal area of Mandalika SEZ offers highly diverse animals to be introduced to tourists with special interests. Coral reefs of the intertidal (reef flats) are known as the habitat of nyale worms (Bachtiar and Odani 2021), polychaete worms belonging to the family Eunicidae. Echinoderm fauna is also prominently seen during low tides in the same intertidal area (Bachtiar et al. 2020). Many (20-30) local people traditionally harvest sea urchins and mollusk for subsistence consumption at low tides

(Febrianti et al. 2023). Both intertidal fauna diversity and reef-gleaning culture may be developed into a tourist attraction in the context of ecotourism. At present, intertidal gleaning is perceived to contradict ecotourism (McKenzie et al. 2021; Derrick et al. 2023) since it causes overexploitation of macrobenthic intertidal fauna, such as sea urchins, clams, and oysters. In Mandalika SEZ, the southern coast of Lombok Island, the reef-gleaning tradition (Sasak, *Madak*) is potentially integrated as an additional cultural menu in a reef walking tour during low tides.

Walking tours have been developed in urban areas (Gordon 2014; Guano 2015; Nilsson and Zillinger 2020) and remotely unique villages (Ghorbani et al. 2022; Mao and Lingjun 2022). Therefore, a reef walking tour at the intertidal area is potentially developed as ecotourism in the Mandalika SEZ. During the low tides, the tourist guide may introduce the names of animals they found on the reef flat and explain how to identify them. This unique reef walking tour may be hardly found elsewhere in the southeast Asian countries. Identifying the names of intertidal fauna is very complicated as there are many technical terms that only specialists or biologists are familiar with. The existing available identification keys for echinoderms (Echinodermata) and mollusk (Mollusca) fauna are not suitable for tourists but for scientific purposes. Therefore, new identification keys specifically designed for tourism are needed to set up a unique reef walking tour in the Mandalika SEZ. Existing echinoderm keys are merely for zoologists, which are likely incompatible with tourists, for example, Cunha et al. (2021), Gondim et al. (2018), and Granja–Fernández et al. (2014). Furthermore, the keys are not designed for intertidal echinoderms of the Indonesian Archipelago.

The present study aims to fill the gap by providing echinoderm identification keys for tourism purposes. Many technical terms used in the scientific paper have been removed or replaced with more familiar words. Tourists are from a variety of backgrounds but some of them like to experience something challenging. The specifically designed identification key of echinoderms may serve as the right level for non-science background tourists to identify the scientific name of the echinoderms. The echinoderms are marine fauna that are predominant in the intertidal of the Mandalika SEZ. They have a disk-like body form and five or more radial arms. The unique body form may raise curiosity for eco-minded tourists. Furthermore, identifying echinoderms would be a life experience. It will also be an unforgettable experience as there is no harm in tourists holding most echinoderms in their hands, except for some sea urchins. At present, there is no similar or relevant studies on this issue.

MATERIALS AND METHODS

Study area

This study was conducted at intertidal areas of three beaches, i.e., Kuta, Seger, and Serinting Beaches (Figure 1). The three beaches comprised more than 50% of the intertidal area of the Special Economic Zone (SEZ) of Mandalika, Central Lombok District, West Nusa Tenggara Province, Indonesia.

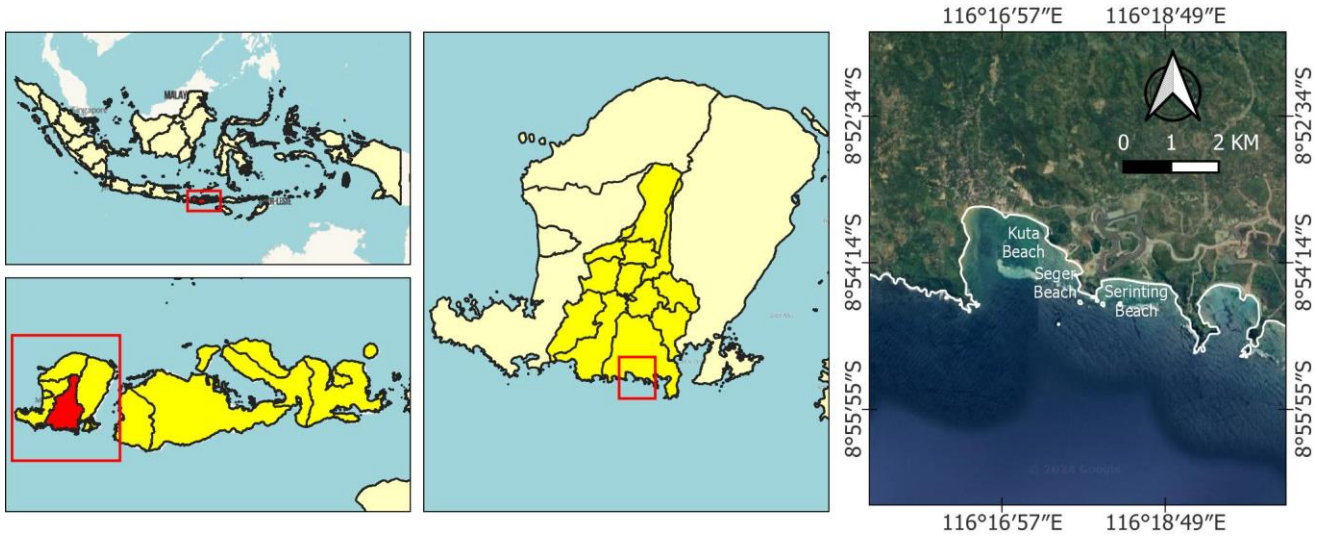

Figure 1. Location of study in Special Economic Zone (SEZ) of Mandalika, Central Lombok District, West Nusa Tenggara Province, Indonesia

The beaches are also the most visited area by traditional gleaners. Currently, Kuta Beach is just on the seaward side of the Raja Hotel, while Seger Beach is on the seaward side of the Novotel. The Serinting Beach has no accommodation yet; it is about 100 m from the motor racing circuit (10th turn). A preliminary study revealed that at Mandalika Beach, between Seger and Serinting Beaches, the intertidal reef flat has 10.25±10.08% coral cover, mainly massive corals (unpublished data). Intertidal of the Kuta Beach is mostly seagrass beds (>80%) with coral reefs (<20%) on the seafront. Seger Beach's seagrass bed is about 20% of the intertidal area. Coral colonies are patchily distributed among sandy, low-bottomed reefs. The intertidal of Serinting Beach has the widest area, mostly covered by foraminifera sands (>75%). About <5% is seagrass bed. Coral colonies (<20% cover) may be found patchily on a sandy bottom and at the seafront. During low tides, the reefs are exposed to the air, creating closed and semi-closed tide pools. The reefs are mostly covered by micro- and macro-algae. Several local people and some tourists walk on the reefs during the low tides.

In Mandalika SEZ, the local community traditionally uses the intertidal coral reefs for reef gleaning; people walk on the reef and collect sea urchins, bivalves, gastropods, and other edible fauna for subsistence needs. The coral abundance is very low (~10%) in the intertidal. As the low coral populations occur on the southern coast of Lombok Island which directly faces the Indian Ocean, it is apparently due to high waves from the Indian Ocean. Coral populations are patchily distributed, with large foraminifera sands occupying low elevations among the coral colonies and small bommies. The intertidal reefs are mostly formed from foraminifera sediments (personal observation).

Samples containing 114 specimens of echinoderms were collected haphazardly in the four walking cruises (Table 1) during the lowest tide of March and were repeated during the lowest tide of July 2023. Four researchers walked along the walking track and collected various echinoderm specimens. All the specimens were fixated for 48 hours in a formalin solution of 4% in seawater (weight). The fixated specimens were then preserved in a 70% alcohol solution. Scientific identification was carried out using published identification keys, i.e., Alitto et al. (2018), Boissin et al. (2016), Clark and Rowe (1971), Cunha et al. (2021), Goharimanesh et al. (2021), Gondim et al. (2013), Granja-Fernández et al. (2014), Nasser et al. (2019), and Pomory (2007).

Table 1. Position of walking cruise trails

Location	Walking cruise trails
Kuta	-8.89558, 116.28324; -8.89893, 116.28356; -8.90289, 116.28787; -8.89985, 116.29068
Seger	-8.90427, 116.29457; -8.90719, 116.29309; -8.91012, 116.29602; -8.90575, 116.29680
Serinting 1	-8.90705, 116.30245; -8.91183, 116.30243; -8.91201, 116.30437; -8.90704, 116.30503
Serinting 2	-8.90750, 116.30938; -8.91222, 116.30853; -8.91322, 116.31177; -8.90816, 116.31254

After identifying the scientific names of collected specimens, new identification keys were developed based on observable characteristics. The observable characteristics are non-microscopic, and tourists can recognize them on-site. This identification key is designed to be friendly for tourists with various discipline backgrounds. The present identification key is new, as all existing scientific identification keys use many technical or biological terms incompatible with ordinary tourists. The new keys were tried out for students' field trips on the Invertebrate Zoology Course consisted of 20 groups. Each group comprised 4-5 students. When submitting the report, they were directly asked about its practical uses and the reason for their opinions.

RESULTS AND DISCUSSION

There were all five classes of Echinodermata found at the intertidal areas of Mandalika SEZ (Table 2), i.e., Asteroidea, Ophiuroidea, Echinoidea, Holothuroidea, and Crinoidea (Brusca et al. 2016). The five classes may be distinguished by their unique characteristics. Asteroidea (sea stars) have a stellate-form body with rigid, non-articulated arms, while Ophiuroidea (brittle stars) have a disk-like body with flexible articulated arms. The number of arms is usually five, but it could be six or more. Echinoidea (sea urchins) have a globose body form covered by movable spines without arms (Brusca et al. 2016). Its fleshy and sausage-shaped body is identify Holothuroidea. Crinoidea has a cup-like body with feathers-like arms. The fauna of Ophiuroidea was the most prominent and diverse, with 10 species (Table 2).

Moreover, several unfamiliar terms may cause some confusion for beginners. Although these identification keys have been designed intentionally for tourists (beginners), some technical, biological terms cannot be avoided. A list of technical terms is presented in Table 3 and Figure 2 to ease the use of the identification key. Appearances of oral and aboral disks in Figure 3 also lessen difficulties in identifying ophiuroids (brittle stars).

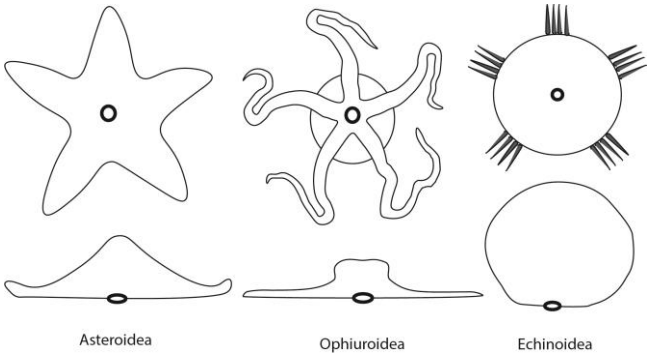

Figure 2. Body plan comparison of Asteroidea (sea stars), Ophiuroidea (brittle stars), and Echinoidea (sea urchins) from both oral view (above) and lateral or side views (below). Circle or semi-circle show mouth position

Table 2. List of Echinoderms found at intertidal areas of Mandalika SEZ, Central Lombok, West Nusa Tenggara, Indonesia

Class	Genus-species
Asteroidea (sea stars)	1. *Protoreaster nodosus*
	2. *Culcita novaeguineae*
	3. *Linckia laevigata*
	4. *Linckia multifora*
	5. *Echinaster luzonicus*
	6. *Aquilonastra* sp.
Echinoidea (sea urchins)	1. *Diadema setosum*
	2. *Echinothrix calamaris*
	3. *Tripneustes gratilla*
	4. *Echinometra mathaei*
	5. *Echinometra* sp.
Ophiuroidea (brittle stars)	1. *Ophiocoma scolopendrina*
	2. *Ophiocoma erinaceus*
	3. *Ophiocoma* sp.
	4. *Ophiomastix annulosa*
	5. *Ophiomastix elegans*
	6. *Macrophiothrix* sp.
	7. *Ophiarachna incrassata*
	8. *Ophiolepis* sp.
	9. *Ophiocnida scabriuscula*
	10. *Ophioplocus imbricatus*
Holothuroidea (sea cucumbers)	1. *Holothuria sp.*
	2. *Synapta maculata*
Crinoidea	1. *Comanthus* sp.

Three identification keys were developed for the first three classes. Identification keys for Holothuroidea and Crinoidea were not developed because the two classes contained only three and one species, respectively, so the keys were unnecessary. The identification key starts from the key #1a. For example, to identify an unknown seastar. If the sea stars characters fit the description of having 5 or 6 arms, then go to #2a as indicated at the end line of the description; the same procedures are applied to the next keys.

Table 3. List of technical terms used in the identification keys

Term	Meaning
Aboral	The opposite side of the oral, upper side
Dental	Connected or related to the teeth
Dorsal	Related to the back of an animal
Granule	Small grain-like form
Inter-brachial	Space between two arms
Lateral	Related to the side of an animal
Madreporite	A perforated plate at the aboral side of sea stars
Oral	Connected or related to the mouth, downside
Papillae	Projection from an animal organ or tissue
Pentaradial	Five axes spreading out from a central point
Radial shield	Pairs of distinguished plates at the aboral disk close to the arm base of ophiuroids
Ventral	Related to under the body of an animal

On the other hand, if the seastar does not fit with description #1a, then go to description #1b. The seastar is likely a new record if it neither fits #1b. This means that the sea star is not yet listed in this paper.

Identification key for sea stars (Asteroidea)

Its solid arms may easily recognize sea stars, although *Culcita novaeguineae* lacks arms. The arms can hardly be bent, and they only move using tube feet on the underside of the arms. They have 5 or 6 arms, which give them a radial symmetrical body. The pentaradial symmetrical body is disrupted in *Echinaster luzonicus*. The sea star *E. luzonicus* is special for its fleshy body. Some sea stars may have blunt spines, while others have more granulated skin. Madreporites among the granules or blunt spines may be found on the aboral side. All sea stars in Mandalika SEZ are harmless and may be touched or held by a naked hand. The identification key for sea stars is as follows.

1	a.	Body star-like with 5 or 6 arms	2
	b.	Body globose without arms	*Culcita novaeguineae*
2	a.	Body with 5 arms	3
	b.	Body with 6 arms	6
3	a.	Aboral has spineless skin covered with granules or scales	4
	b.	Aboral side is covered with large rounded spines, and the spines' tips are dark.	*Protoreaster nodosus*
4	a.	Long arms, medium size body (≥3 cm wide from central disk to longest arm tip)	5
	b.	Short arms, small size body (<3 cm wide)	*Aquilonastra* sp.
5	a.	Arm dorsally with bluish monochrome coloration, about the same arm lengths	*Linckia laevigata*
	b.	Arm dorsally with light color and dark patches, arm lengths vary	*Linckia multifora*
6	a.	All arms have different sizes, and skin contains dull spines	*Echinaster luzonicus*
	b.	Some arms have different lengths, granulated spineless skin	*Linckia multifora*

Note: Some anomalies in the number of arms may be found among sea stars. For example, *Protoreaster nodosus* and *Echinaster luzonicus* may have one less or more arm than their typical arm number

Identification key for brittle stars (Ophiuroidea)

Brittle stars may be the most attractive members of intertidal echinoderms. They live under rocks or coral rubbles, crevices on reefs, and seagrass bed too. They have articulated arms so that they use their arms for walking or creeping. The arms consist of many segments and contain blunted spines. All brittle stars are not dangerous, and tourists may hold them by hand for further observation. Several brittle stars lost their arms from predation, and many show regenerating arms. Identifying brittle stars is more challenging than sea stars and sea urchins as the distinguishable features are minute in size. For example, the type of aboral disk skin or teeth may not be distinguishable without a magnifying glass. The following key is to identify brittle stars at Mandalika SEZ.

1	a.	Aboral disk covered by granules (Figure 3.A & B) or short spines (Figure 3.C)	2
	b.	Aboral disk is scaly (Figure 3.D) or covered with soft skin	4
2	a.	Oral disk and ventral arms are light color or cream	3
	b.	Oral disk and ventral arm are all black, and oral and dental papillae are present.	*Ophiocoma erinaceus*
3	a.	Arm length ≤7 times disk diameter	7
	b.	Arm length >7 times disk diameter	6
4	a.	Aboral disk covered with scales (Figure 3.D)	5
	b.	Aboral disk is covered with smooth dark skin, and the oral disk has a light color.	*Ophiomastix elegans*
5	a.	Scale sizes vary, and smaller scales regularly surround large scale (Figure 3.D)	*Ophiolepis* sp.
	b.	Scale sizes are very similar, and smaller scales irregularly surround larger scales.	*Ophioplocus imbricatus*
6	a.	Disk covered with small spines (Figure 3.C), some arm dorsal spines enlarged form club-like shape	*Ophiomastix annulosa*
	b.	Disk covered with granules (Figure 3.A & B), radial shield (Figure 3.B & D) obvious, no oral papillae.	*Macrophiothrix* sp.
7	a.	Disk granules are obvious and pretty rough, and oral and dental papillae are tidy (Figure 3.E)	8
	b.	Disk granules are very smooth and undistinguished, irregular in size of oral and dental papillae (Figure 3.F)	9
8	a.	Inter-brachial oral disk granulated	*Ophiocoma scolopendrina*
	b.	Inter-brachial oral disk (Figure 3.E & F) naked, without granules	*Ophiocoma* spp.
9	a.	Dorsal arm spine length is shorter than the ventral one, light in color with dark or brown bands.	*Ophiarachna incrassata*
	b.	Dorsal arm spine length is about the same as the ventral spines, light color without bands.	*Ophiocnida scabriuscula*

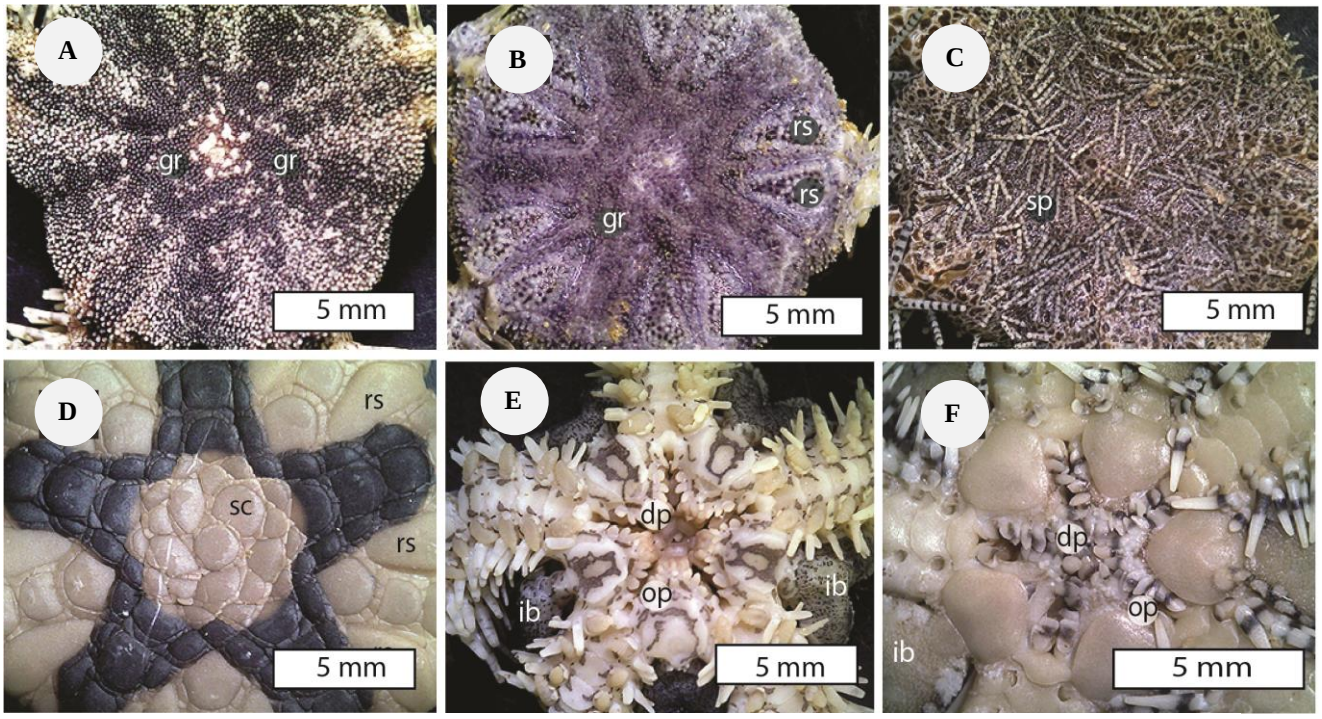

Figure 3. The aboral (A-D) and oral (E-F) disks of ophiuroids from Mandalika SEZ, Central Lombok, West Nusa Tenggara, Indonesia: A. *Ophiocoma*; B.*Macrophiothrix*; C. *Ophiomastix*; D. *Ophiolepis;* E. *Ophiocoma;* F. *Ophiarachna*; dp: dental papillae, gr: granula, ib: inter brachial, op: oral papillae, rs: radial shield, sc: scale, sp: spine

Identification key for sea urchins (Echinoidea)

The absence of arms and the presence of conspicuous spines covering their globose bodies are the most recognizable characteristics of sea urchins. The spines usually form rows from the top (aboral) down to the bottom (oral) of the body. The rows of spines divide the sea urchin body into a pentaradial symmetrical form. Some sea urchins are considered dangerous; their spines can penetrate the skin when handled or touched, and the broken spines in human skin take several days to disappear naturally. Tourists should never touch sea urchins *Diadema* and *Echinothrix*. The following is a key for sea urchin identification.

1	a.	Disk with short spines, spine length ≤3 times disk diameter	2
	b.	Disk with long spines, spine length >3 times disk diameter, white or orange line encircles the anus opening	*Diadema setosum*
2	a.	Spine sizes are relatively homogenous laterally	3
	b.	Spine sizes vary laterally	4
3	a.	Lateral spine length >0.5 times disk diameter	*Echinothrix calamaris*
	b.	Lateral spine length ≤0.5 times disk diameter	*Tripneustes gratilla*
4	a.	The mouth opening is not obviously seen, covered with long oral spines	*Echinometra mathaei*
	b.	Mouth opening is easily recognized, surrounded by short oral spines	*Echinometra* sp.

The three identification keys have not yet been implemented for Mandalika tourists. The keys, however, have been tried out for pre-service Biology teachers during an Invertebrate Zoology field trip at Mandalika. Most students (>80%) feel convenience using the identification keys, as the echinoderms show very distinguished characteristics. Members of the sea stars (Figure 4) and sea urchins (Figure 5) are the most distinguishable. The sizes of these two animal groups are about 3-30 cm. Students' difficulties mostly happened in the key for brittle stars (Figure 6). The identification key for the brittle stars relies on their disk properties. The sizes of the disks are about 1-3 cm and identifying the brittle stars' disk properties requires a magnifying glass. The student field trip was for academic purposes for which identification accuracy is highly expected. On the other hand, such an expectation may not necessarily apply to tourism.

Sea cucumbers (holothurians) and lilies (crinoids) may be identified without identification keys. The existing fauna of the two groups is not diverse in Mandalika SEZ. There were only four taxa, including one of sea lilies (*Comanthus* sp.) (Figure 7). Many holothurians have high economic values that reef gleaners may harvest as soon as they are spotted. Black sea cucumber *Holothuria* sp. has a cucumber-like body and 20 branched tentacles surrounding its mouth. The size is about 20 cm, although it may grow to 60 cm. Sticky snake sea cucumber *Synapta maculata* has a long, slender (snake-like) body with delicate, sticky skin; there are 15 feathery tentacles surrounding its mouth. The sea lilies *Comanthus* sp. may be distinguished by cirri possession, unbranched, jointed curved organs attaching the animal to the rocky bottom, and feathery arms.

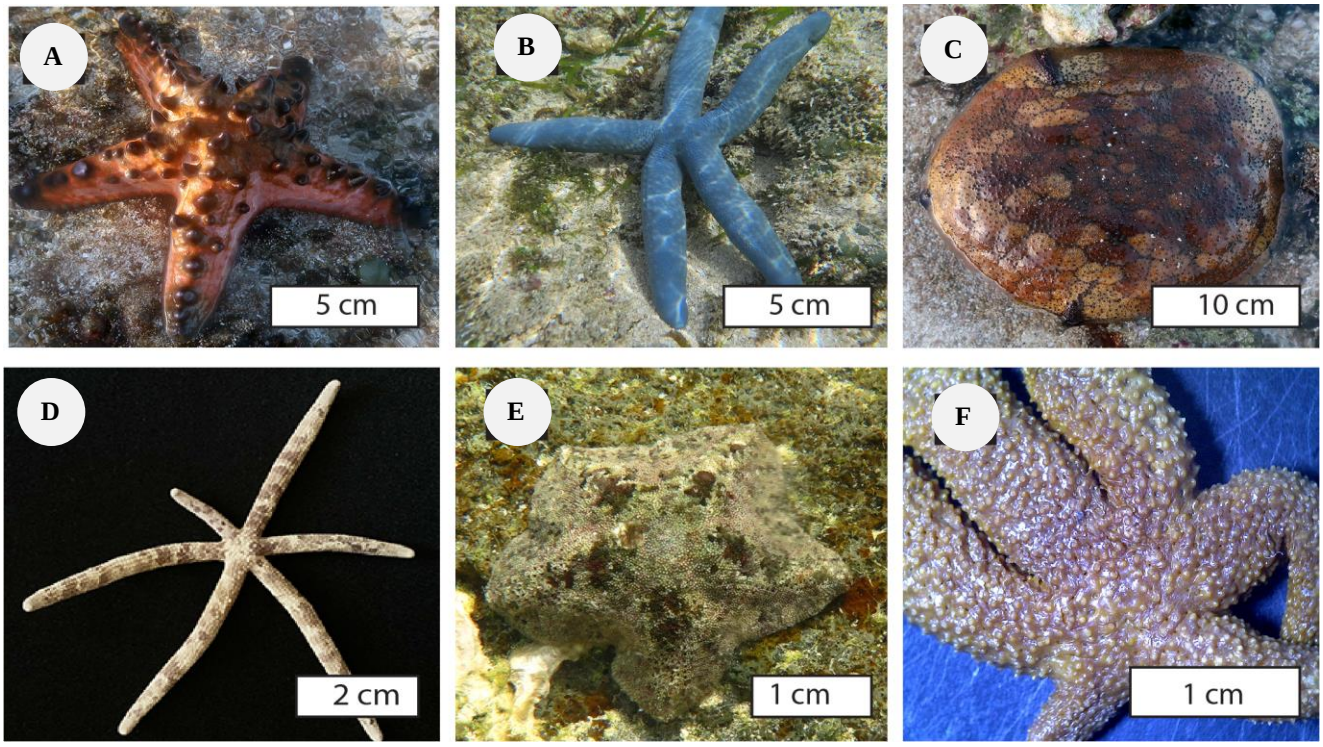

Figure 4. Sea stars may be found during a reef walking tour in Mandalika SEZ, Central Lombok, West Nusa Tenggara, Indonesia. All sizes are not on the same scale. From top left: A. *Protoreaster nodosus*; B. *Linckia laevigata*; C. *Culcita novaeguineae*; D. *Linckia multifora*; E. *Aquilonastra* sp.; F. *Echinaster luzonicus*

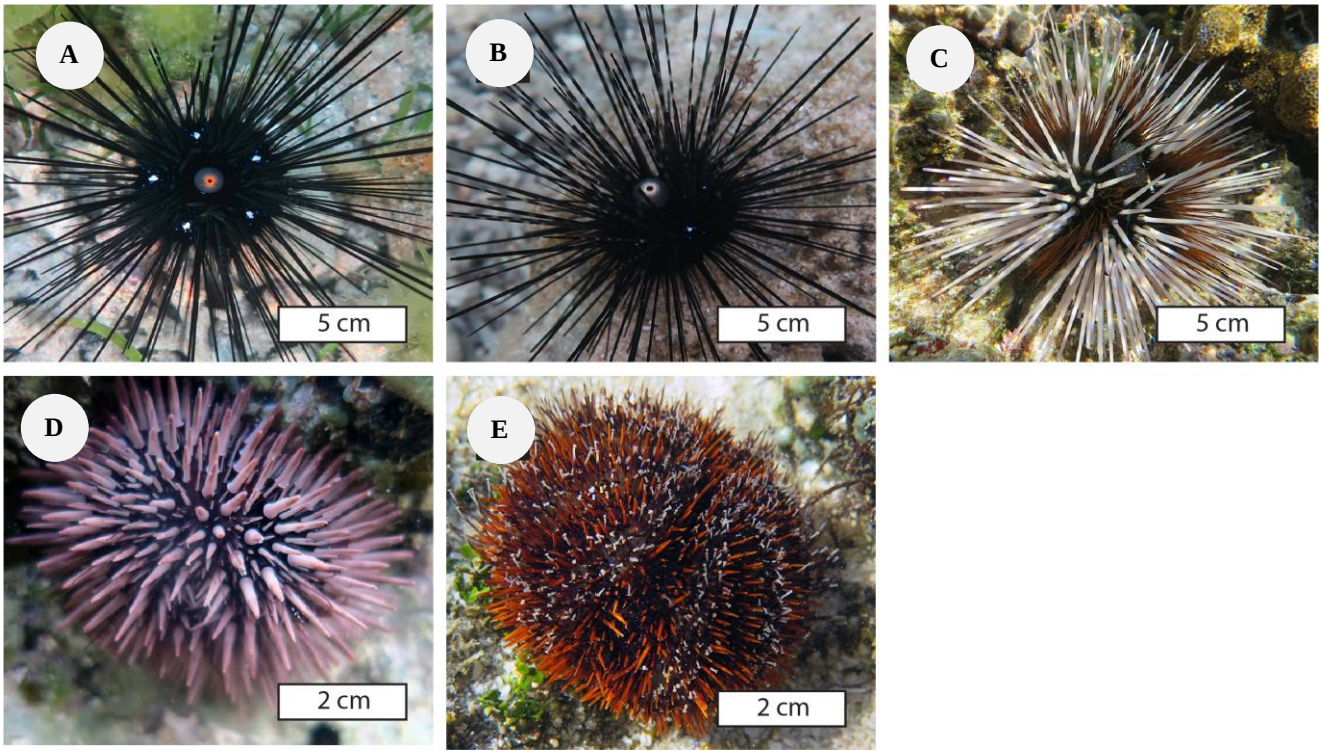

Figure 5. Sea urchins that inhabit the intertidal reefs of Mandalika SEZ, Central Lombok, West Nusa Tenggara, Indonesia. All sizes are not on the same scale. From top left: A. *Diadema setosum*; B. *Diadema setosum*; C. *Echinothrix calamaris*; D. *Echinometra mathaei*; E. *Tripneustes gratilla*

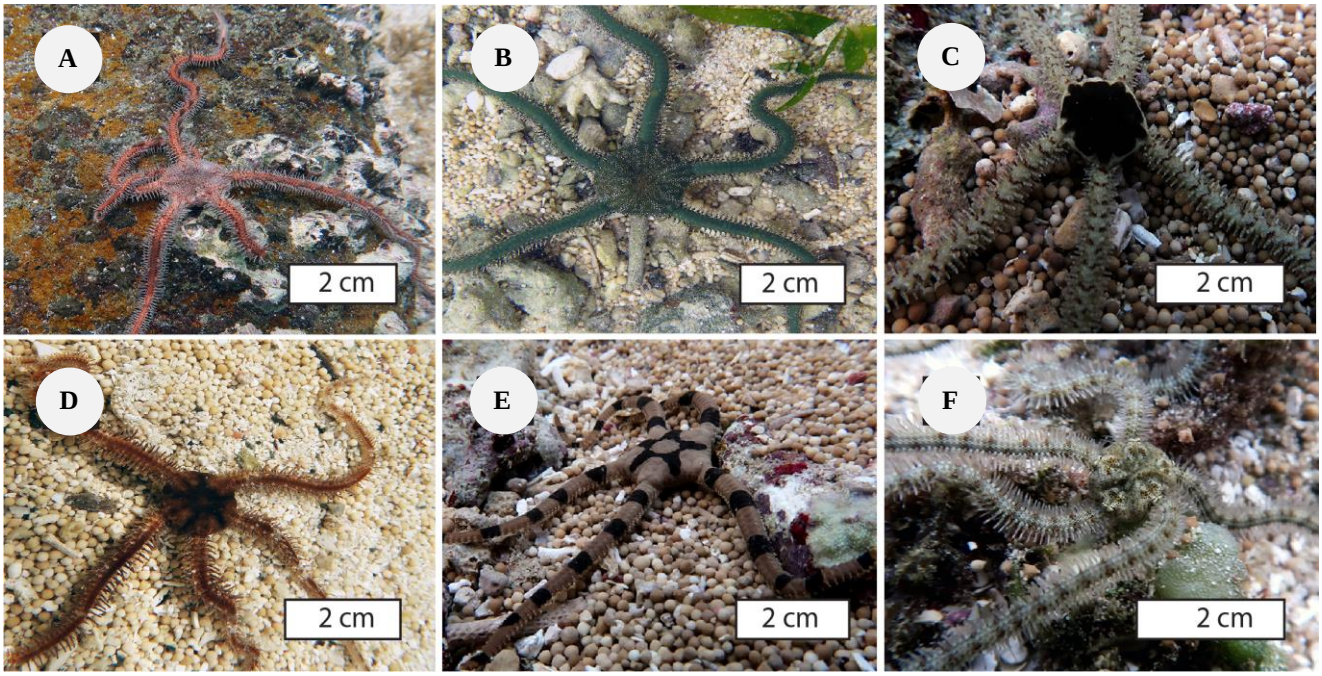

Figure 6. Brittle stars may be encountered during a reef walking tour in Mandalika SEZ, Central Lombok, West Nusa Tenggara, Indonesia. All disk sizes are about 10 to 20 mm. From top left: A. *Ophiomastix annulosa*; B. *Ophiarachna incrassata*; C. *Ophiomastix elegans*; D. *Ophiocoma scolopendrina*; E. *Ophiolepis* sp.; F. *Macrophiothrix* sp.

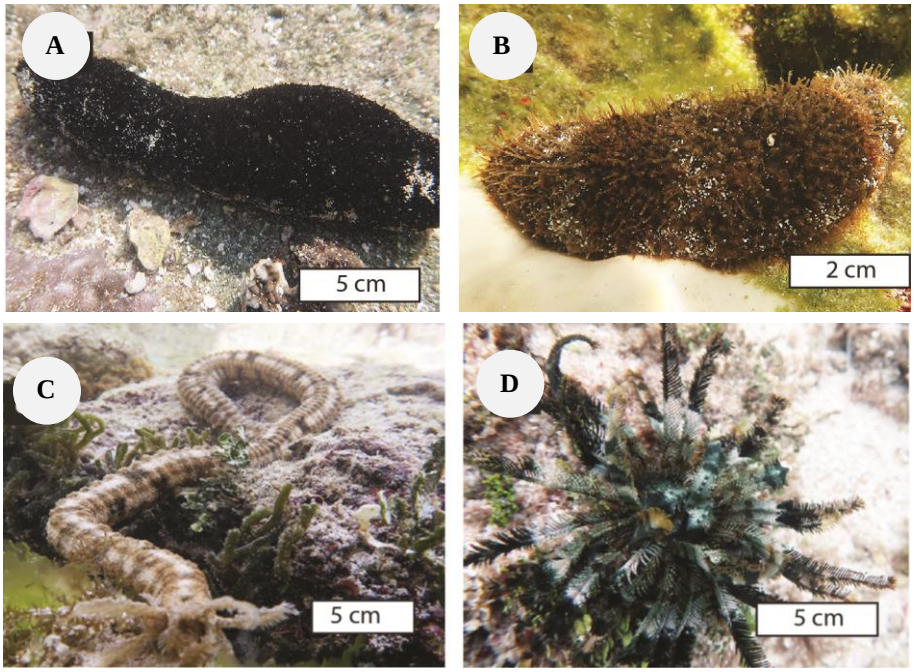

Figure 7. Sea cucumbers and feather stars may be found during the reef walking tour in Mandalika SEZ, Central Lombok, West Nusa Tenggara, Indonesia. A. *Holothuria* sp.; B. *Actinopyga* sp.; C. *Synapta maculata*; D. *Comanthus* sp.

Discussion

Identifying echinoderms down to species is an academic task of a biologist or zoologist. Converting academic tasks into tourist attractions has not been much developed. Bird watching may be the only very successful in the conversion. Bird-watching tourism has been rapidly developing in Europe, and they have projects to establish e-Bird (Sullivan et al. 2009). In the bird watching tourism, tourists walk along a track that is suitable for finding targeted birds. A similar tourism development may also be applied to reef walking tours. Tourists walk along a safe reef track suitable for finding targeted intertidal echinoderms. Many brittle stars become active when tidal water is about to rise. They move their arms as water floods back the reefs. Sea urchins and sea stars often demonstrate their movement ability using tube feet in tide pools. These natural attractions may raise tourist curiosity and motivation to know more about the animals' names and their roles in the ecosystem. The present identification keys will help them to satisfy some of tourist curiosity. Tourism that exposes non-professional tourists to carry out scientific tasks has also been introduced successfully in SCUBA diving. Reef Check has been popular among divers to enjoy holidays and collect coral reef data in Australia (Done et al. 2017; Schläppy et al. 2017).

A reef walking tour in Mandalika SEZ is a potential ecotourism attraction. Deng et al. (2002) listed five dominant elements of nature-based tourism in Australia, i.e., resources, accessibility, facilities, local community, and peripheral attractions. Resources to be promoted as attractions are abundant in Mandalika SEZ: echinoderms, mollusks, crustaceans, and foraminiferans. Accessibility to Mandalika SEZ is also very convenient, about an hour from the capital city of Mataram and about 30 minutes from the island's international airport. Tourism facilities are very good. There are options for accommodations from non-star to five-star hotels within 10 minutes by car from Mandalika SEZ. The presence of reef gleaners on reef walking tours is a cultural attraction bonus for tourists participating in the reef walking tour. Snorkeling at tidal pools may be a peripheral attraction in the tour. Since the snorkeling tour is at only 1 m depth, this peripheral attraction is compatible with non-swimmers.

The development of reef walking tours will bring economic benefits for local people. In Mandalika SEZ, local community involvement in the super-premium tourism facilities is difficult due to their low capacity to work in super-premium hotels. The reef walking tour will diversify tourist attractions in the Mandalika SEZ and increase local community involvement in megaproject tourism. In the Kerandangan National Park, western Lombok, bird-watching tourists are willing to pay between USD 15-36 for soft and adventure trails, respectively (Suana et al. 2020). Similar rates may be applicable for the reef walking tour. Additional fees may be added for specific guiding services and snorkeling gear.

The only issue in developing reef walking is the availability of qualified tourist guides. Tourist attractions must provide new experiences in relaxing or entertaining environments. Knowing the scientific names of coral reef animals is a new experience for many tourists. Using the identification key may also be a new experience for many of them. Therefore, if we added some relaxing and entertaining guidance, we have a new tourist attraction. Implementing the reef walking tour as a relaxing experience is challenging. This challenge largely depends on the tourist guides. Despite having good hospitality, the guides must be creative to develop an experiential learning

atmosphere. They must also be sensitive to tourist refutation signs when guiding the tour; then they move on to other plans. Learning about the ecology of the coral reefs and reef-associated traditional culture while walking on the reefs are the other plans that may be presented to the tourists in Mandalika SEZ.

In the walking tour, tourist attractions need to be diversified, not only about knowing the names of intertidal animals (zoology) but also story-telling about the animal's role in the ecosystem. The guides, therefore, must have a sufficient science background in intertidal ecology that can provide a rational explanation of the ecology of the introduced animals. As the reef walking tour is carried out at the habitat of nyale worms (Bachtiar and Bachtiar 2019; Bachtiar and Odani 2021), story-telling about the *Bau Nyale* tradition and the biological science of nyale worms may also increase the tourist experience and satisfaction during the tour. During low tides, the only time window for reef walking tours, several local people regularly carry out reef gleaning (Febrianti et al. 2023). Story-telling about the reef-gleaning culture is also important to be granted during the tour. This integrated scientific and cultural walking tour will be a substantial bonus for the tourists. Besides, this also avoids opposition that may come from the existing traditional reef gleaners (Derrick et al. 2023; McKenzie et al. 2021). Tourists do not only learn about zoology but also the coastal culture of Lombok people. The attraction in the reef walking tour should also be developed for other intertidal animals. The key to identifying echinoderms is the only beginning in the present study. Echinoderms are the most abundant and interesting animals to introduce in the Mandalika SEZ. Many other animal groups are to be introduced and packaged as tourist attractions. For example, sea snails and sea slugs (Gastropoda, Mollusca), oysters and clams (Bivalvia, Mollusca), and foraminifera (Sarcodina, Protozoa) are also attractive. Since the walking tours require special tourist guides knowledgeable in zoology and ecology, they should preferably be recruited from biological sciences graduates with tourist guiding certificates.

In Australia, reef walking has been abandoned since the last century (Pocock 2021) to protect declining coral reefs from human disturbances. The reef walking on Mandalika differs in several ways from the Great Barrier Reefs, and the declining coral cover may be avoided. The intertidal reefs of Mandalika are only partially covered by corals (Nurhaliza et al. 2019), so breaking coral colonies during reef walking can be easily hindered when the main coral reefs are not in the intertidal. Naturally, the coral reefs of Mandalika are formed by sediments of single-celled foraminifera animals. The existing living corals are mostly massive-form corals (Nurhaliza et al. 2019) resistant to breakage. Therefore, the sustainability of the reef walking tour should still be assessed regularly, and the carrying capacity should be determined as early as possible.

The sustainability of the reef walking tour is similar to the bird-watching tour. Both are conducted in two sensitive ecosystems: coral reefs and forests. Furthermore, both tourist attractions rely on the presence of animals in their natural habitats. The two nature-based tourism, however, also have different impacts. In bird watching, tourists never harm the birds; they take pictures and identify the names of the birds. In the reef walking tour, tourists may harm targeted animals by collecting them, for example, shellfish (marine bivalves and snails). Furthermore, tourists may also step on other intertidal animals during the tracking, unintentionally killing them. Sustainable tours should, therefore, be planned more seriously for reef-walking than bird-watching tours. Besides, intertidal animals' recolonization may occur rapidly as marine animals produce much more offspring than terrestrial ones. The standard protocols of ecotourism, “take nothing but pictures and leave nothing but footsteps”, should be applied as much as possible, while touching living intertidal animals must be minimized.

Touching living marine animals may not only inadvertently disturb their physiological processes and natural behavior, but also may be harmful for tourists. For example, lifting a sea urchin out of water cause it to loose water and vital nutrients that affecting its overall fitness. Some intertidal animals also have protective structures and behavior to overcome their predators. Sea urchins *Diadema* sp. and *Echinothrix* sp., and seastar *Acanthaster planci* have sharp spines that frequently cause painful stings to reef visitors. Corals and sea anemones have stinging cells that may instigate irritation and discomfort to visitors. Before walking to the reefs, participants should therefore be informed beforehand not touching any animals without consent from the tour guide.

The reef walking tour should adopt existing citizen science projects. Potential tourists may be offered several options of tour packages. One of the tour packages should be becoming a citizen scientist; the interested tourists will contribute data on reef animal diversity and abundance in the Mandalika SEZ. In the long term, such data may show environmental changes in the intertidal reefs. Similar citizen science has been developed in e-Bird (Sullivan et al. 2009) and Reef-Check (Done et al. 2017). The data will benefit both local governments and the management body of the Mandalika SEZ.

Future studies should address the practical and efficacy of using echinoderm keys to entertain tourists with academic challenges in zoology. Studying their responses to using identification keys as an ecotourism attraction is also very important. Positive responses can be strengthened in future development, while negative ones should be avoided. Tourist segmentation will be useful to understand further which segment is compatible with such an academic-like tourist attraction.

In conclusion, the biodiversity of the intertidal Echinoderm may be developed as a tourist attraction in the Mandalika SEZ. The providence of identification key for echinoderms is the first step to developing a reef walking tour. The walking tour development is supported by abundant resources, convenient accessibility, complete supporting facilities, warm local people, and snorkeling attraction additionals. The walking tour potentially develops to include other animal groups and local traditional culture. The suggested reef walking tour is an ecotourism in which tourists will learn about the zoology

and ecology of coral reef animals and their conservation strategies. Local guides are preferable due to their higher knowledge of the attractions so that the walking tour will benefit locals economically. When the walking tour produces economic benefits, conservation efforts will be more easily conducted to sustain the economy of the walking tour. Therefore, the walking tour will complete the existing tourist attractions in Mandalika SEZ.

ACKNOWLEDGEMENTS

The study was funded by DIPA Universitas Mataram, Indonesia, contract number 1955/UN18.L1/PP/2023. The field trip would have been impossible without assistance from volunteering students: Faza Firjatullah Al-Khulaifi, Muhamad Andrian, Marwa Azzahra, and Ni Wayan Anggun Diah Utami. We want to thank Dr. Frédéric Ducarme (Muséum National d'Histoire Naturelle, Paris) for verifying the species identification.

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