



## Mollusk Species Associated with the Scleractinian Coral *Alveopora japonica* Eguchi, 1968 Forming a Coral Carpet in Northwestern Jeju Island

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**Abstract** : The high latitude scleractinian coral *Alveopora japonica* Eguchi, 1965 occurs in high density in the shallow rocky subtidal in Jeju Island, forming coral carpets. Despite its ecological role providing a unique habitat for other benthic organisms, the benthic fauna associated with the *A. japonica* coral carpet is poorly known. To identify fauna associated with the coral carpet, we explored three sites dominated by *A. japonica* and one control site on northwestern Jeju Island in May 2013. Using SCUBA, we collected *A. japonica* and the epibenthic mega-fauna associated with the colonies in 1×1 m<sup>2</sup> and identified them to the species level. At a depth of 10 to 15 m, *A. japonica* colonies heavily covered the seafloor, forming a layer called a coral carpet, with a density of 94 (Keumneung-ri), 133 (Biyangdo), and 155 (Gwidok-ri) colonies/m<sup>2</sup>. Thirty-four molluscan species were identified from the four sites, including 20 bivalves and 14 gastropods. The coral carpets were enriched with sessile bivalves compared to the control site, as we identified twenty bivalve and eight gastropod species from the coral carpets. Most bivalve species associated with the coral carpets had tropical-subtropical affinities, while gastropods were mainly subtropical and subtropical-low boreal species. *Leiosolenus lischkei* M. Huber, 2010, in the family Mytilidae and *Barbatia stearnsi* (Pilsbry, 1895), in the family Arcidae, were the two most abundant bivalve species in the coral carpet, *L. lischkei* being a borer, and *B. stearnsi* a nestler. The tropical to subtropical Pacific star shell *Astrarium haematragum* (Menke, 1829) was the most abundant gastropod at the study sites. The bivalves and gastropods associated with the coral carpet were small-sized juveniles or sub-adults, suggesting that the coral carpet provides a micro-habitat for the bivalves and gastropods.

**Key words** : *Alveopora japonica*, coral carpet, molluscan assemblage, micro-habitat, Jeju Island

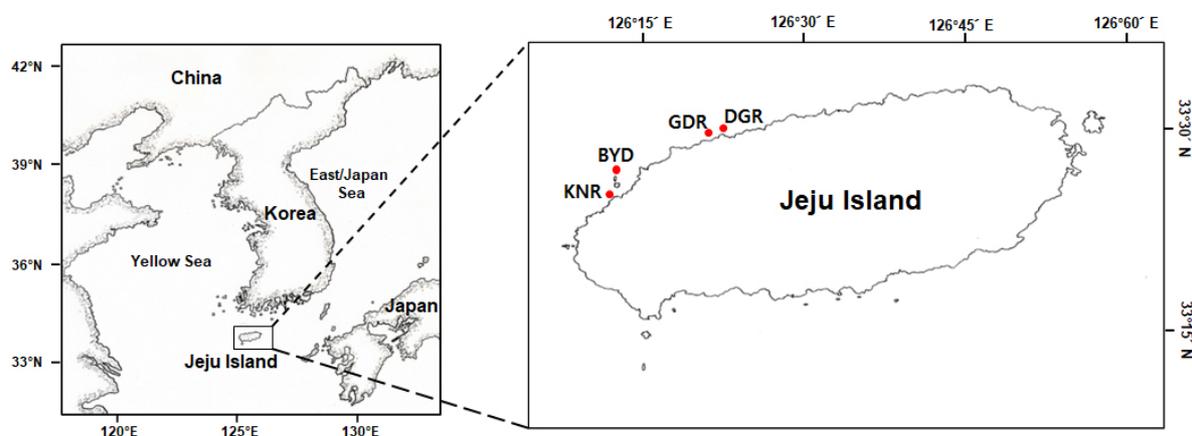
### 1. Introduction

Located approximately 80 km off the south coast of Korea, the shallow subtidal area of Jeju Island is enriched with fauna and flora (Cho et al. 2014; Noseworthy et al. 2016; Kwun et al. 2017). Such a high species diversity in coastal Jeju Island can be attributed to the warm Tsushima current, derived from the Kuroshio current, as numerous fauna have a zoo-geographical affiliation from the subtropical to tropical (Noseworthy et al. 2007; Sugihara

et al. 2014; Lutaenko et al. 2019, 2021). According to Khim et al. (2021), 511 species of marine invertebrate animals have been recorded from Jeju Island, and mollusks constitute approximately 60%. Sugihara et al. (2014) identified seven species of zooxanthellate scleractinian corals on Jeju Island, these corals exclusively occurring there.

The zooxanthellate scleractinian coral *Alveopora japonica* in the family Acroporidae occurs on shallow subtidal hard substrata in southern Taiwan, the Pacific coast of Japan, and Jeju Island, off the south coast of Korea (Veron 2000; Vieira et al. 2016; Kang et al. 2020). The non-reefal *A. japonica* is endemic to the northwestern Pacific as it

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**Fig. 1. Sampling locations in this study. KNR, Keumneung-ri, BYD, Biyangdo Island, GDR, Gwidok-ri, DGR, Donggwi-ri on northwestern Jeju Island**

occurs at a high density in Jeju Island, whereas *A. japonica* is rare in southern Taiwan (Dai and Hong 2009; Denis et al. 2013; Vieira et al. 2016). Unlike other hard corals, *A. japonica* has long elongated polyps characterized by green or brown polyps extended from hemispherical colonies (Vieira et al. 2016; Noseworthy et al. 2016). Recent studies in Jeju Island reported explosive expansion of *A. japonica* (Denis et al. 2013; Vieira et al. 2016), and the coral colonies form a “carpet” due to their high density (Riegl and Piller 2000; Denis et al. 2013; Vieira et al. 2016). Noseworthy et al. (2016) first reported numerous molluscan fauna associated with *A. japonica* colonies on northern Jeju Island, indicating that *A. japonica* coral carpets serve as shelters or nurseries for bivalves and gastropods. However, such faunal affiliation with the coral carpet in Jeju Island is poorly understood, as Noseworthy et al. (2016) surveyed only one site on northern Jeju Island, and non-coral carpet molluscan fauna was not investigated in their study.

In May 2013, we surveyed four shallow subtidal hard bottoms on northern Jeju Island to gain insight into the newly discovered coral carpets and the associated molluscan fauna. This study reports preliminary results obtained from the survey.

## 2. Materials and Methods

For the survey, we selected three shallow subtidal rocky areas located on northern Jeju Island, including Gwidok-ri (GDR), Biyangdo Island (BYD), and Keumneung-ri (KNR) at a depth of 5 to 10 meters where *A. japonica* formed coral

carpets (Vieira et al. 2016; Noseworthy et al. 2016) (Fig. 1). As a control, the Donggwi-ri (DGR) subtidal area was selected, where there is no *A. japonica* coral population. In May 2013, we installed a  $1 \times 1$  m<sup>2</sup> quadrat on the four sampling sites, using SCUBA, and all the coral colonies and associated epibenthic fauna in the quadrats were removed.

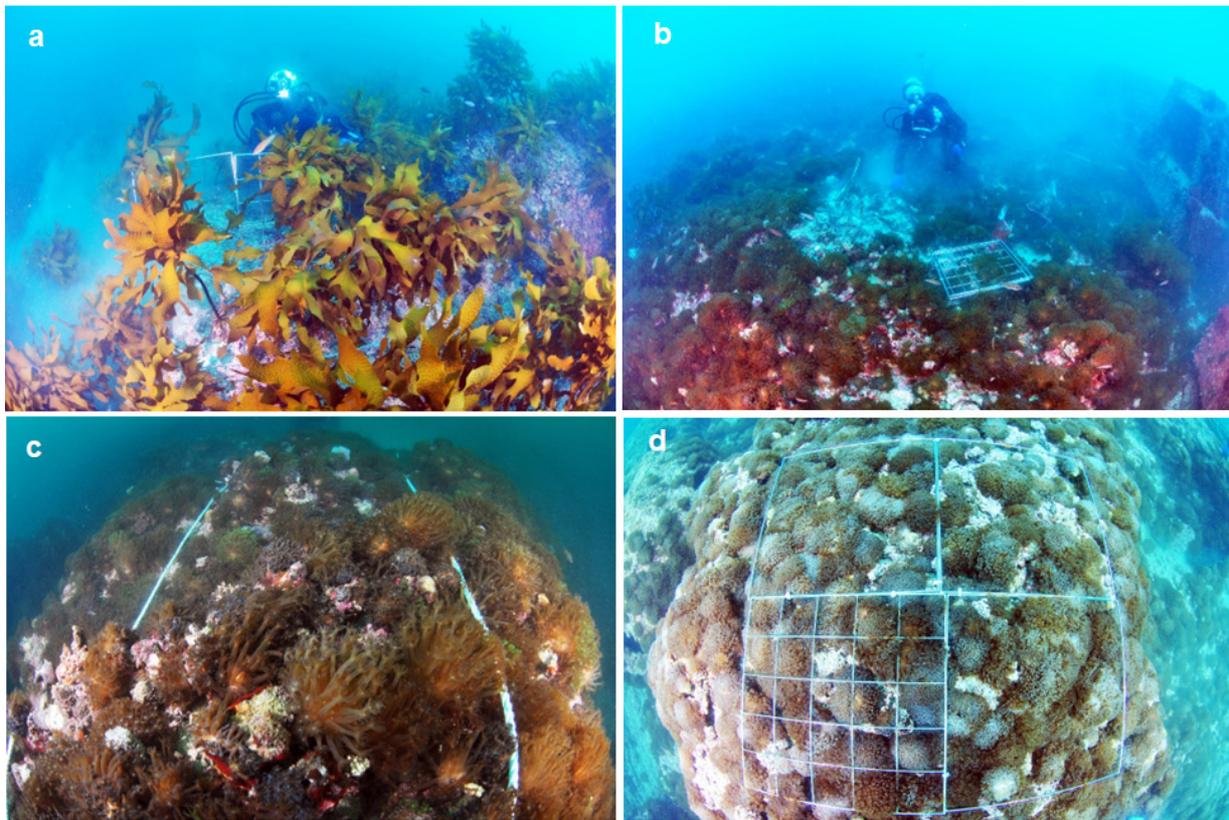
At the laboratory, we counted the number of *A. japonica* colonies in the  $1 \times 1$  m<sup>2</sup> quadrat. Mollusk specimens isolated from the quadrat were identified to the species level (Okutani 2000; Min et al. 2004, Qi 2004; Lutaenko et al. 2019, 2021), and we counted the number.

## 3. Results

The underwater survey revealed that *A. japonica* occurred at a high density forming a layer on the bottom called a coral carpet at GDR, BYD, and KNR (Fig. 2). The densities of *A. japonica* colonies were determined to be 155 (GDI), 133 (BYD), and 94 (KNR) colonies/m<sup>2</sup> respectively.

Numerous molluscan fauna were identified from the quadrats from the four sampling sites. A total of 34 species were identified, 20 bivalve species in 11 families and 14 gastropod species in 9 families, indicating that bivalves outnumbered gastropods (Table 1). The bivalve and gastropod species identified from the coral carpets were distributed from intertidal to shallow subtidal areas and occur in tropical to sub-tropical coastal zones.

The bivalve species richness was much higher in the coral carpet (20 spp.) compared to the control site without the coral carpet (3 spp.). In contrast, the coral carpet habitats showed a low gastropod species number (2 spp. from



**Fig. 2.** Images showing the underwater sampling sites. **a**, DGR selected as a control site with no *A. japonica* coral carpet, showing brown algae *Ecklonia cava* forest covering the bottom. **b**, High density of *A. japonica* colonies covering the bottom at GDR site, demonstrating an example of *A. japonica* coral carpet. **c**, *A. japonica* coral carpet exhibiting a high density of *A. japonica* at KNR. **d**, BYD site, *A. japonica* coral carpet covered with a 1×1 m<sup>2</sup> quadrat

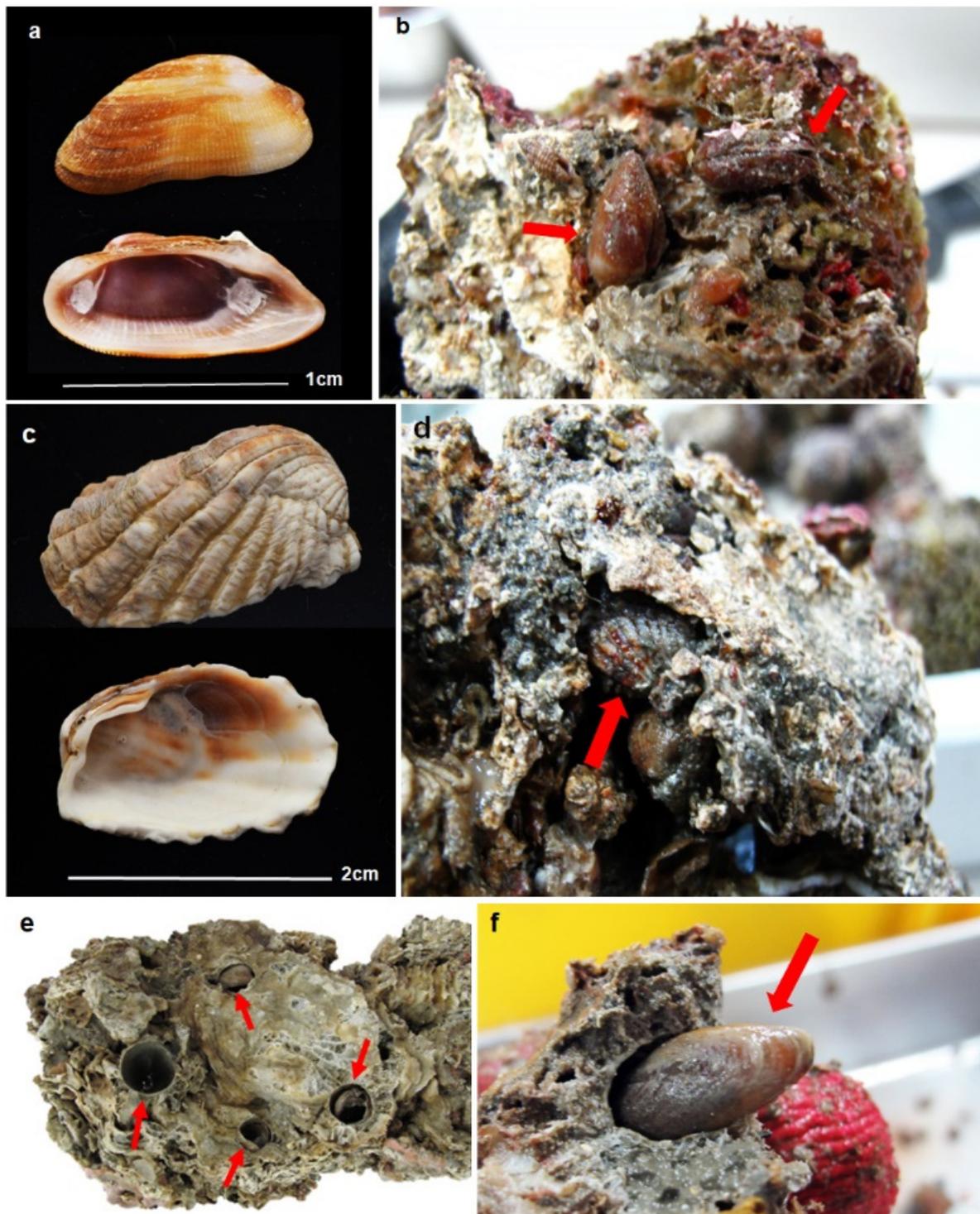
KNR and five spp. from GDR) compared to the control site (9 spp.). *Leiosolemus lischkei*, in the family Mytilidae, *Barbatia steamsi* in the family Arcidae, and *Cardita leana* in the family Carditidae (Fig. 3) were the three most abundant bivalves occurring in the *A. japonica* coral carpet on northern Jeju Island (Table 1). Among the 14 species of gastropods identified in this study, *Astraliium haematragum* in the family Turbinidae and *Engina* cf. *menkeana* in the family Buccinidae were the two most common gastropods occurring in the coral carpet in terms of density (Fig. 4).

#### 4. Discussion

The high density of *A. japonica* colonies covering the shallow subtidal hard bottoms on northern Jeju Island has been reported for the past decade (Denis et al. 2013, 2015; Vieira et al. 2016; Noseworthy et al. 2016; Kim et al. 2022). Vieira et al. (2016) first determined *A. japonica*

colony density in two subtidal sites on Jeju Island. At a depth of 10 m at GDR and Shinheungri on southern Jeju Island, *A. japonica* colonies reached 88 and 155 per m<sup>2</sup>, respectively, which are comparable to the densities determined in this study. According to Vieira et al. (2016), most of the *A. japonica* colonies are small hemispheric with a radius (i.e., height) ranging from 2.0 to 2.5 cm. The *A. japonica* colonies covered the bottom, forming a veneer-like layer called a coral carpet (Riegl and Piller 2000; Zuschin and Piller 1997). In northern Safaga Bay in the Red Sea, some reef-building corals encrust the bottom, forming coral carpets associated with numerous molluscan species, particularly bivalves, boring and cementing on the coral colonies (Zuschin and Piller 1997; Riegl and Piller 1997). In this study, we also observed numerous species of bivalves and gastropods associated with the *A. japonica* colonies boring (*L. curta*) or attaching to (*B. steamsi*) the basal part of the colonies (Fig. 4).

In a coastal hard-bottom benthic community, small



**Fig. 3.** Mollusc bivalves and their association with *A. japonica* identified in this study. a, b, *Barbatia steamsi* nestling in the basal part of *A. japonica* colonies. c, d, *Cardita leana* at the basal area of *A. japonica* colonies. e, f, *Lithophaga curta* boring the base of *A. japonica* colonies

mollusk species or juvenile or sub-adult bivalves and gastropods seek refuge from predators (Stella et al. 2011).

Accordingly, the crevices at the base of the coral colonies and the stinging tentacles of the living polyps of *A.*

Table 1. Molluscan species in *A. japonica* coral carpet surveyed from 4 sampling sites in Jeju Island in May 2013

Class	Family	Species	Zonal-Geographical Grouping	Sampling Site and Density (ind./m <sup>2</sup> )			
				KNR	BYD	GDR	DGR
Bivalvia	Mytilidae	<i>Mytilisepta keenae</i>	subtropical	1		4	1
		<i>Modiolus cf. kurilensis</i>	subtropical-boreal			2	
		<i>Modiolus auriculatus</i>	subtropical-boreal		1		
		<i>Leiosolenus lischkei</i>	subtropical	29	15	10	1
		<i>Leiosolenus malaccanus</i>	tropical-subtropical	2	5		
	Arcidae	<i>Arca avellana</i>	tropical-subtropical	7	16	7	1
		<i>Barbatia stearnsi</i>	tropical-subtropical	16	88	45	
	Pteridae	<i>Pinctada cf. fucata</i>	tropical-subtropical		1		
	Limidae	<i>Ctenoides lischkei</i>	tropical-subtropical	2	8		
	Ostreidae	<i>Ostrea circumpicta</i>	subtropical	1	1		
		<i>Laevichlamys cuneata</i>	tropical-subtropical		1		
	Pectinidae	<i>Scaechla Spondylus squamosus mys lemniscata</i>	tropical-subtropical		1		
		<i>Spondylus squamosus</i>	tropical-subtropical		2		
	Anomiidae	<i>Isomonina umbonata</i>	Subtropical		2		
	Chamidae	<i>Chama cerinohodon</i>	tropical-subtropical	7	2	2	
		<i>Chama limbula</i>	tropical-subtropical	1			
		<i>Cf. Amphichama argentata</i>	Subtropical		1		
	Carditidae	<i>Cardita leana</i>	tropical-subtropical	4	19	23	
	Veneridae	<i>Irus irus</i>	subtropical-low boreal	1			
	Gastropoda	Trochidae	<i>Cantharidus japonicus</i>	subtropical-low boreal			
<i>Cantharidus bisbalteatus</i>			subtropical-low boreal			1	
<i>Clanculus microdon</i>			subtropical				2
Turbinidae		<i>Turbo sazae (=cornutus)</i>	subtropical				1
		<i>Astraliium haematragum</i>	tropical-subtropical		5	15	15
Calyptraeidae		<i>Crepidula gravisponosa</i>	subtropical				1
Vermetidae		<i>Thylacodes adamsii</i>	subtropical			1	
Cypraeidae		<i>Purpuradusta gracilis</i>	tropical-subtropical	1			
Muricidae		<i>Ergalatax contracta</i>	tropical-subtropical			4	2
		<i>Pollia mollis</i>	subtropical	1	2	1	
Buccinidae		<i>Engina cf. menkeana</i>	subtropical-low boreal		3		2
		<i>Pyrene flava</i>	tropical-subtropical				1
Columbellidae		<i>Cf. Mitrella bicincta</i>	tropical-subtropical		1		
	<i>Pusia inermis inermis</i>	subtropical-low boreal				2	

*japonica* would provide refuge and protection from predators. In this study, almost all the bivalves and gastropods associated with *A. japonica* colonies are small species or juvenile and subadult specimens of larger species. Thus, it is likely that the *A. japonica* coral carpets

in Jeju Island are used as a nursery for the juveniles of large gastropods and bivalves, although more investigations are needed to substantiate this hypothesis.

According to Zuschin and Piller (1997), bivalve species associated with the coral carpet in Safaga Bay in the Red

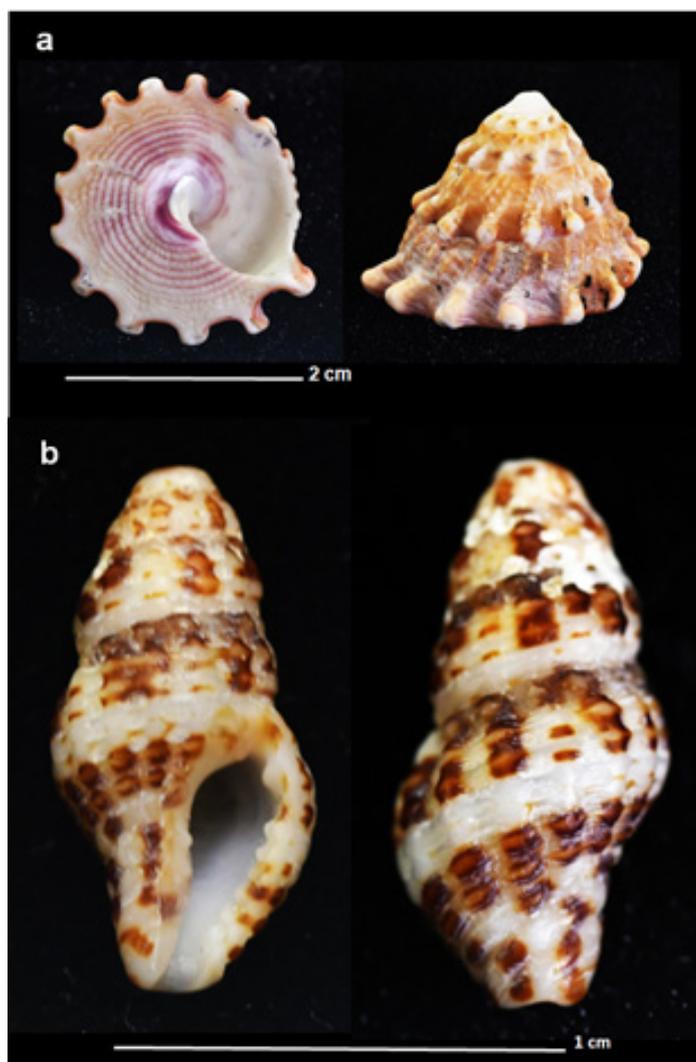


Fig. 4. *A. japonica* coral carpet-associated gastropods in Jeju Island. a, *Astralium haematragum*, b, *Engina* cf. *menkeana*

Sea are suspension feeders. Reed and Mikkelsen (1987) also reported that most bivalve species associated with the ivory scleractinian coral *Oculina verucosa* in coral reefs on the eastern coast of Florida are suspension feeders. The relationship of invertebrates to corals may be facultative or obligate, depending on whether they need their coral hosts for survival. As *L. curta* and *B. steamsi* are often associated with other organisms in the intertidal environment, they are considered to have a facultative association with *A. japonica*. It is believed that the high density of *A. japonica* colonies may trap organic particles, including some planktonic or benthic microalgae and detritus, as they are filtered and utilized by the small suspension-feeding bivalves as observed in this study (Yonge 1955; Carter 1978). The high density of mollusks associated

with *A. japonica* might also point toward the bioerosion of the skeleton of *A. japonica* colonies. According to Vieira et al. (2016), *A. japonica* has a short lifespan varying from 12 to 15 years, suggesting a high turnover capacity of these corals. In the coral carpet habitats in the shallow subtidal on Jeju Island, the dead coral colonies act as substrata for the next generation, facilitated by erosion through associated mollusks and other boring organisms such as coral-boring barnacles (Noseworthy et al. 2016; Kim et al. 2021). Currently, limited studies have investigated ecological associations of benthic fauna with the coral carpets in Jeju Island, which require more surveys and a closer examination of other mollusk assemblages to reveal fresh insights.

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