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Diversity of hairy ark cocklealong northern coast of Java, Indonesia and their variation in phenotypical traits

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Abstract

Hairy ark cockleis one of the bivalves of family Arcidae. High similarity on morphology among species of hairy ark cockles leads to difficulty in identification. Hence they are categorized as cryptic species. Due to variability of habitat, hairy ark cockles may develop variation in morphology as a result of adaptation. This study was aimed at assessing diversity of hairy ark cockles from six locations located along the northern coast of Java, Indonesia, i.e. Banten, Subang, Cirebon, Rembang, Gresik and Probolinggo. Eight morphometric characters were examined, including shell length (SL), shell width (SW), shell height (SH), ligament length (LL), umbo height (UH), symmetry of right valves (SRV) and left valves (SLV), and radial ribs (RR). These shell characteristics of 316individuals were measured from those locations. The results showed that there were three species found from the study locations, i.e. *Anadara inaequivalvis*, *A. gubernaculum* and *A. cornea*. Those species showed unique phenotypic traits, such as body shape and size shells, shell color, as well as number of ribs. Morphometric characters and meristic diversity could be brought about variation in environmental factors of location.

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Introduction

Bivalves, in general, consist of 15000 species living in all types of substrate and depth of ocean water, and the remaining is in the freshwater (Pachenik, 2005). Therefore, they accounted for second largest mollusc following gastropods. Based on Ocean Biographic Information System in2005 there are 300 species of bivalves inhabiting world's ocean.

In addition to that, around 180 species of 30 generas lives Indo-Pasific waters. Community of bivalves plays an important role in ecological and biological processes (Poore and Wilson, 1993). Beside that, family Arcidae has economic values, such as *Anadara granosa*, *A. pilula*, *A.antiquata* as food and trading accesories. These species are not only traded locally but also exported overseas.

In terms of morphology, hairy ark cockles of family Arcidae have unique characteristics. In general their shells are covered by brown or black hairs, and have a paired of valves with round shape (Vongpanich, 1996). Dixon *et al.* (1995) reported that adventitious hairs derived from the periostracum as the outer layer of valve.

The hairs have been proposed as a defensive role against predation (Harper and Skelton, 1993) and formed as of self-protection from threat of environmental fluctuations. Adventitious hairs found in several other bivalves, such as Arcoidea, Mytiloidea, and Veneroidea (Watabe, 1988). In Indonesia especially on the north coast of Java, there are six dominant species of hairy ark cockles, i.e. *A. inaequivalvis, A. antiquata, A. pilula, A. antiquata, A. gubernaculum* and *A. cornea* (Ambarwati and Trijoko, 2011).

Given their morphological resemblance, hence, they are difficult to identify. They are grouped into cryptic species. Diversity of bivalve in Indonesia is moderately high.

The biodiversity not only addresses the variety (number) or richness of species, but also concerns in size and shape of shell, habitats and structure of food webs, as well as trophic levels of species (Hendrickx *et al.,* 2007).

High diversity of habitat may lead to morphological diversification of similar organism.

This study was aimed at assessing diversity of morphometric, meristic, and phenotypic characters of hairy ark cockle populations at six locations along northern coast of Java, Indonesia.

Materials and methods

Sampling location

Sample of the hairy ark cockles were collected from six locations along northern coast of Java, Indonesia, i.e. Banten coast, Subang coast, Cirebon coast, Rembang coast, Gresik coast and Probolinggo coast, from March-July 2015. A total of 316 individuals of cockles were collected from the six locations. The position of the locations and map is presented in Table 1 and Fig. 1.

Collected samples were preserved in 10% buffered seawater-formalin. In laboratory, eight morphometric characters were examined, including shell length (SL), shell width (SW), shell height (SH), ligament length (LL), umbo height (UH), symmetry of right (SRV) and left valves (SLV), and radial ribs (RR) (Fig. 2). Shell dimension were measured using digital calipers to the nearest 0.01 mm, except RR which was counted.

Data analysis

Review of literature was conducted to determine the valid name and synonyms for the species. Taxonomic identification were done based on Vongpanich (1996), Huber (2010) and FAO identification Key (Poutiers, 1998).

Following morphological measurements, all morphological ratio data were calculated in which SL is fixed as a reference variable. Dendrogram and grouping was constructed using morphological ratio data to visualize phenotypic tree by means of PAUP.

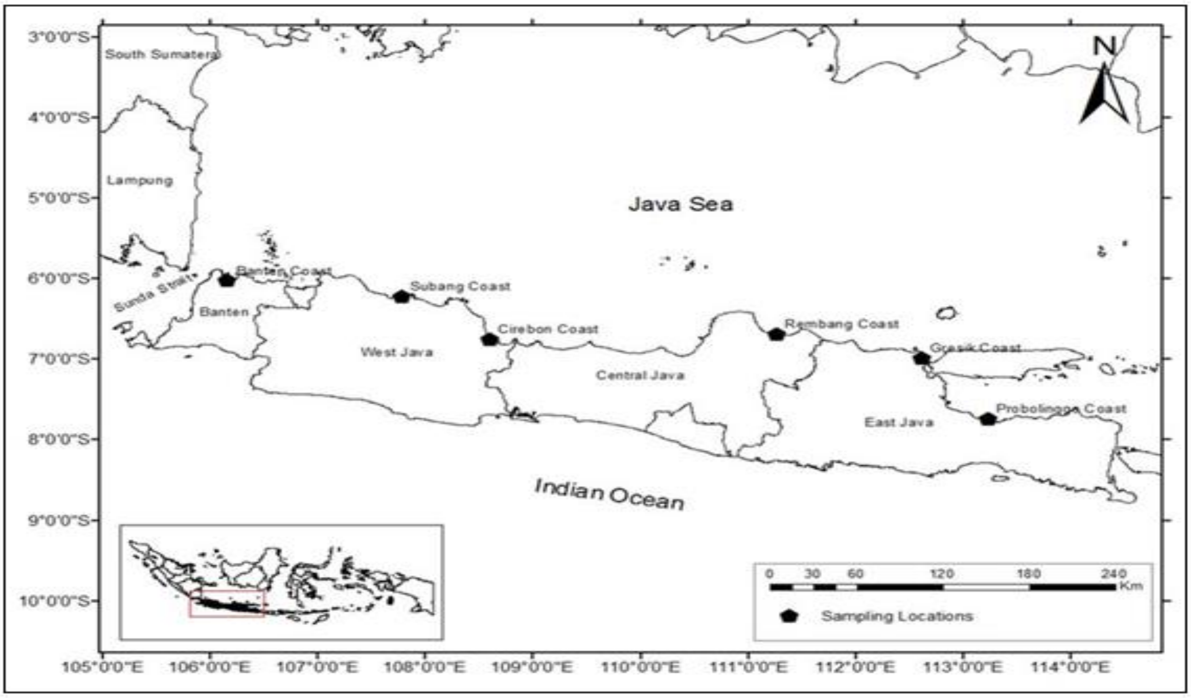

Fig. 1. Sampling locations of the hairy ark cockles along northern coast of Java, Indonesia. (insert: map of Indonesia).

Results

Performances of hairy ark cockles from six study areas are shown in Fig 3. The results of identification showed 3 species from six study areas, namely *A. inaequivalvis, A. gubernaculum,* and *A. cornea*. The species were site-specific. *A. inaequivalvis* were most common species found in Banten, Subang, Cirebon, Rembang, and Gresik. While *A. gubernaculum* and *A. cornea* were specific to Subang and Probolinggo, respectively. The shell of the three species can be seen in Fig 4. Visually those species are look similar and difficult to distinguish.

Table 1. List of sampling location, latitude position and number of collected sample.

Sampling location	Latitude position	Number of collected sample
Banten	6°01'22.08"S, 106°09'37.44"E	92
Subang	6°13'01.92"S, 107°46'49.44"E	49
Cirebon	6°45'00.00"S, 108°35'51.36"E	13
Rembang	6°41'06.72"S, 111°16'07.68"E	25
Gresik	6°58'49.44"S, 106°09'37.44"E	22
Probolinggo	7°01'22.08"S, 106°09'37.44"E	115

The three species of *Anadara* showed some unique characters, i.e. shell shape, number of ribs, and the presence of chevron-like teeth. Based on Albano *et al.* (2009), chevron on ligament is considered as an important character, and they have observed high variation of this pattern in specimen from same locality. In this study, chevron are often present, but number of ribs may influential in identification process, and can be used as a key identification of species. Morphological data is necessary to supporting phenotype each species. Morphometric measurements of hairy ark cockles from six study areas are presented in Table 2. This study revealed that those entire hairy ark cockles were almost resemble.

Table 2. Morphological ratio for separation of cockle species at each study areas. SL is fixed as a reference variable.

Characters	*Anadara inaequivalvis*					*Anadara gubernaculum*	*Anadara cornea*
	Banten	Subang	Cirebon	Rembang	Gresik	Subang	Probolinggo
SW/SL	0.8518±0.0430	0.8687±0.0331	0.8603±0.0461	0.8378±0.0387	0.8209±0.0696	0.7159±0.0286	0.8247±0.0690
SH/SL	0.6623±0.0507	0.6663±0.0385	0.6526±0.0378	0.6533±0.0491	0.7166±0.0625	0.6340±0.0440	0.6777±0.0666
UH/SL	0.0872±0.0362	0.0851±0.0178	0.0836±0.0288	0.0940±0.0171	0.0968±0.0399	0.0741±0.0289	0.1000±0.0378
LL/SL	0.7487±0.0305	0.6737±0.0841	0.6745±0.0856	0.7329±0.0491	0.7421±0.0613	0.6651±0.0514	0.6539±0.0607
SRV/SL	0.3877±0.0222	0.3865±0.0247	0.3680±0.0120	0.3760±0.0328	0.3621±0.0320	0.3577±0.0260	0.3802±0.0435
SLV/SL	0.3575±0.0364	0.3531±0.0219	0.3319±0.0136	0.3316±0.0287	0.3317±0.0310	0.3221±0.0226	0.3487±0.0411

Note: SL: shell length, SW: shell width, SH: shell height, LL: ligament length, UH: umbo height, SRV: symmetry of right valves, SLV: symmetry of left valves.

Table 3. Morphological comparisons between *Anadara inaequivalvis, A. gubernaculum*, and *A. Cornea* collected along the northern coast of Java, Indonesia.

Characters	Cockles Species		
	A. inaequivalvis	*A. gubernaculum*	*A. cornea*
Valves outline	Subquadrate andelongated	Subrectangular and laterally compressed	Subquadrate and elongated
Position of umbo	Umbo closed tomidline, more elevated in the left valve	Umbo situated anteriorly	Umbo closed to midline, more elevated in the left valve
Inequivalvity of shell	Left valve overlaps right valve on the ventral margin	Left valve overlapsright valve on theventral margin	Left valve overlapsright valve on theventral margin
Number of ribs	30-36	22-30	26-30
Interrib space	Wide	Narrow	Wide
Chevrons onligament	Often present	Often present	Often present
External colour	Dull white,sometimes yellowish in the umbo area	Dull white,sometimes brownish in posterior	Bluish greenposteriorly

Therefore, it needs careful identification. It is pre-concluded that hairy ark cockles along northern coast of Java are cryptic species. Among three species, *A. inaequivalvis* was the most cosmopolitan compared to other cockles in this study.

Size of *A. inaequivalvis* of Banten was the largest among other similar species of other locations.

Fig. 5 showed that population formed a morphometrically well separated into two groups, i.e. Probolinggo population and Subang (Ai) population which were identified as different species. Population from Subang (Ag) and Cirebon do not represent distinct groups but show a intra-similiarity in morphological characteristics, as well as population from Banten and Rembang. Centroid grouping may be due to external and internal factors.

Discussion

Bivalves included Arcidae predominantly live in marine environment. In family Arcidaemorphological characters are important indicator in species identification, although the radial ribs are often similar between species. In this study three species were found from six locations with the similarity of all species in adventitious hairs.

The function of hair structure in molluscs could be as protection of shell and mantle margins from other organisms, camuflage, a buoyancy aid for spat during settlement, and mechanism to reduce competition (Bottjer and Carter,1980; Dixon *et al.*,1995). A wide range of variability in morphology was observed. However, the examination of the similarities between *A. inaeqivalvis* and *A. cornea* are rather clear (see Table 3).

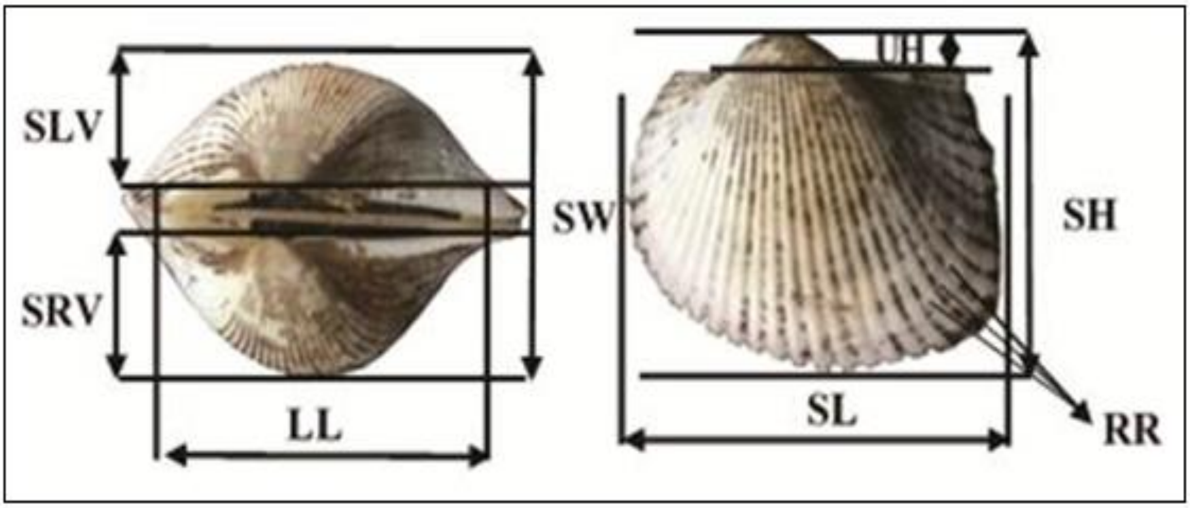

Fig. 2. Measurements of eight morphological characteristics [shell length (SL), shell width (SW), shell height (SH), ligament length (LL), umbonal height (UH), symmetry of right (SRV) and left valves (SLV)]in the hairy ark cockles collected from six locations along northern coast of Java, Indonesia. Radial ribs (RR) was counted.

Fig. 3. Comparison between outer and inner shell among species collected from northern coast of Java, Indonesia. (AB-1) *A. inaequivalvis*, Banten; (AB-2) *A. inaequivalvis*, Subang; (AB-3) *A. inaequivalvis*, Cirebon; (AB-4) *A. inaequivalvis*, Rembang; (AB-5) *A. inaequivalvis*, Gresik; (AB-6) *A. gubernaculum*, Subang; (AB-7) *A. cornea*, Probolinggo. (Scale bar= 10 mm).

A. cornea have a unique character with a bluish green color of the posterior shell, and in this study similiar with new record of *A. cornea* from Minicoy Lagoon Lakshadweep India (Prabhakaran *et al.*,2012). Mollusc shell contain proteins (Souji *et al.*,2014) and carbohydrates that are responsible for unique shell structure morphology and may affect formation of the matrix in outer shell layers (Hedegaard *et al.*, 2005).

Brake *et al.* (2004) reported that variation pigmentation in shell was due to genetic causes an environmental cause. Environmental effects, such as sort of diet could affect shell coloration in the different habitat (Bauchau, 2001).

Character differences might have occured through evolution as consequences of adaptation to habitat (Mariani *et al.*, 2002; Qonita *et al.*,2014).

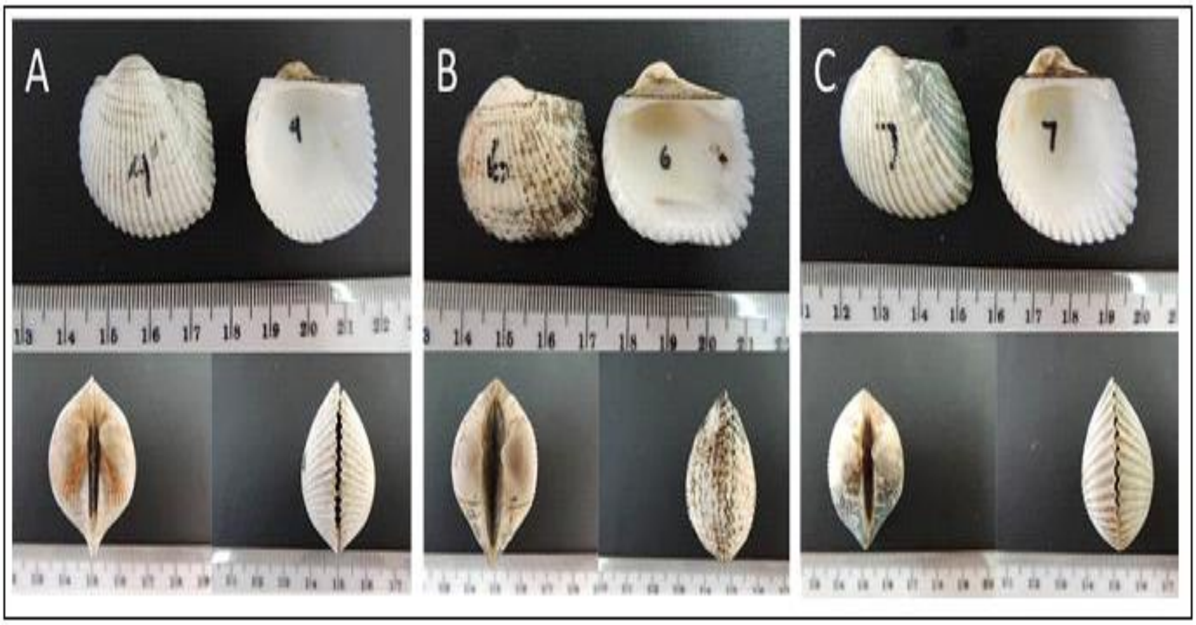

Fig. 4. Shell differences among the three *Anadara* species collected from northern coast of Java: (A) Shell of *A. inaequivalvis*; (B) Shell of *A. gubernaculum*; and (C) Shell of *A. cornea*.

Environmental fluctuation is believed to have large impact on morphology of organism from different ecosystem, especially in high phenotype plasticity sedentary organisms (Imre *et al.,* 2001). Grouping by dendrogram by using morphological character ratio is seen in Fig. 6.

The figure showed that species from Banten, Subang (Ai), Cirebon, Rembang, and Gresik are same species because it has the same characters.

While the species from Probolinggo, *A. cornea* have more similarities with *A. inaequivalvis* from Subang (Ag).Morphometric variation within species mainly may be caused by separation due to geographical barrier (Krakau, 2008).

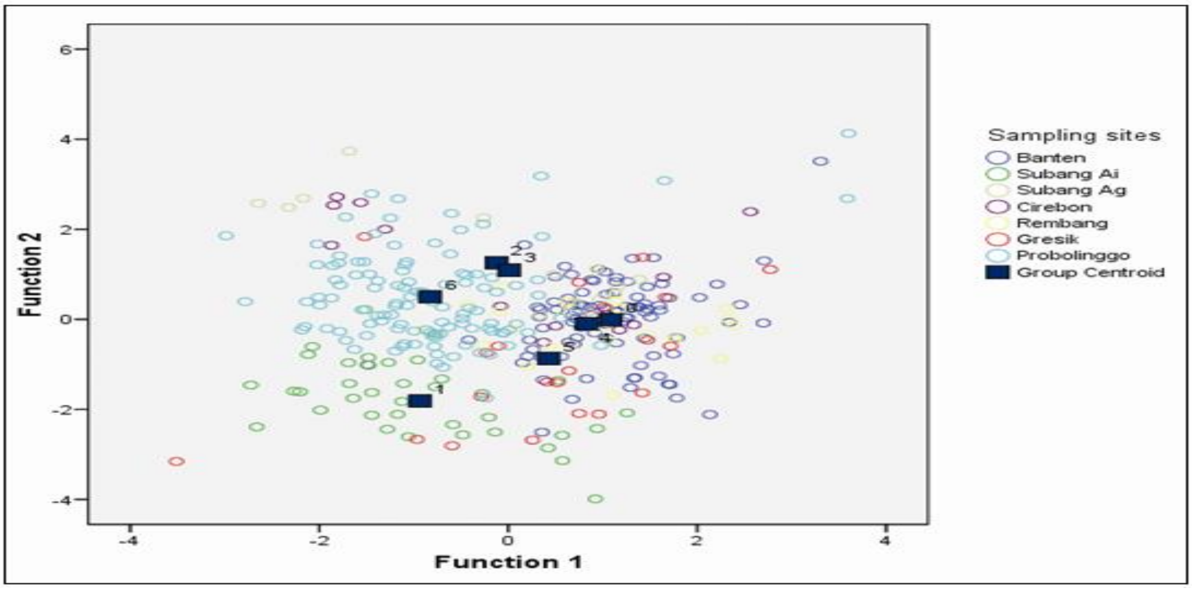

Fig. 5. Separation of morphological characteristics in population of the three species of*Anadara* along northern coast of Java from different six locations.

In marine environment, topography, type of substrate, salinity level, temperature degree (Mariani *et al.,* 2002; Peyer *et al.,* 2010), depth (Peyer *et al.,* 2010), current, tidal level, wave exposure (Kandratavicius and Brazeiro, 2014; Versteegh, 2012; Conde-Padin *et al.,* 2007) and environmental influence can affect the shape and size of mollusk shell (Gaylord and Gaines, 2000; Funk and Reckendorfer, 2008). Differences in habitat conditions that can cause stress factors naturally against the organism.

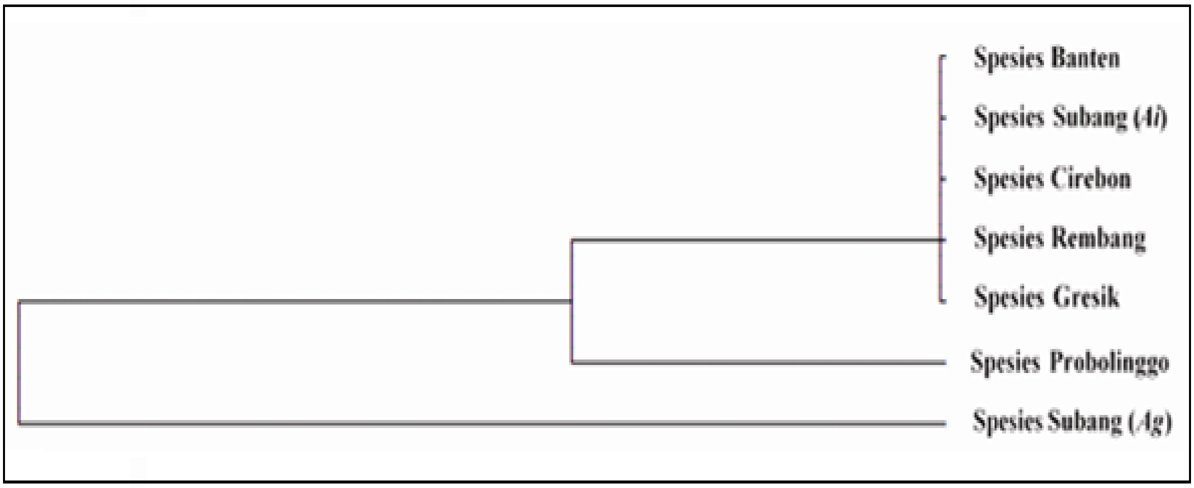

Fig. 6. Dendrogram construction based on morphological characters of three species of *Anadara* showing three clusters of the six locations.

The situation may be forcing species to adapt. Species which stay in bottom of water are supposed to cope the threat with phenotype by adaptation in morphology or other escape strategies (Vermeij, 1995). Adjustment strategies of organisms with the environment facilitated by changes in the biochemical, physiological and genetic adaptation (Pigliucci, 2005) in the long term (Peyer *et al.,*2010; Evans and Hofmann,2012).

Conclusion

Along the northern coast of Java, Indonesia three species of hairy ark cockles were found during the study, i,e. *A. inaequivalvis, A. gubernaculum,* and *A. cornea*. Although looks similar there are differences in morphometric and meristic characteristics among *A. inaequivalvis, A. gubernaculum,* and *A. cornea*, such as shape and size of shell, color of shell, and number of radial ribs. It is believed that the variation in morphology characters of the three species is due to their adaptation to varied habitat. For future work, it is important to use genetic markers for detection of such cryptic species or sibling species at the DNA level.

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