

# First comprehensive taxonomic account of *Salmacis bicolor* L. Agassiz in L. Agassiz & Desor, 1846 (Echinodermata: Echinoidea) from Manbar Island, Makran Coast, Pakistan

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Received 10 October 2025 | Accepted 24 November 2025 | Published 01 December 2025

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## Abstract

The present study provides the first comprehensive morphological and taxonomic account of *Salmacis bicolor* L. Agassiz in L. Agassiz & Desor, 1846 from Pakistan, based on recently collected specimens from the intertidal rocky shore of Manbar Island along the Makran coast, Balochistan. Although earlier reports documented the occurrence of this species in Pakistan, subsequent works either omitted it or offered only photographic records without accompanying morphological descriptions. The examined specimens exhibit diagnostic characteristics consistent with global accounts of the species, including a hemispherical to subconical test; interambulacral plates with zig-zag sutures; crenate but non-perforated tubercles arranged in horizontal series; and cylindrical, finely striated spines, banded in red with yellowish, violet, or green hues, typically with red bases. These observations confirm the presence of *S. bicolor* along the Makran coast and constitute the first verified morphological description of the species from Pakistan. This study not only substantiates earlier fragmentary records but also contributes to the expanding baseline knowledge of echinoid diversity in the northern Arabian Sea, highlighting the need for further investigations that integrate both morphological and molecular approaches.

**key words:** Diversity, Echinoidea, *Salmacis bicolor*, morphology, Makran coast, Pakistan

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## 1. Introduction

Echinoidea (Echinodermata) comprises an entirely marine group that inhabits ocean floors across all depth ranges, from shallow intertidal zones to the deep sea. Sea urchins play a fundamental role in marine ecosystems and are widely used as bioindicators for assessing reef health. Their spatial distribution is largely determined by habitat type, underscoring the central importance of habitat characteristics in shaping their ecological roles (Yiu and Chung 2024). In temperate regions, sea urchins are key benthic grazers that exert strong control over

macroalgal proliferation, thereby maintaining ecosystem balance (Lewis, 1958; Paine and Vadas 1969; Johansson et al. 2010; Kriegisch et al., 2016).

Clark (1925) and, lately, Clark and Rowe (1971), reported six species of sea urchins from Pakistan: *Prionocidaris baculosa* (Lamarck, 1816), *Stomopneustes variolaris* (Lamarck, 1816), *Salmacis bicolor* L. Agassiz in L. Agassiz & Desor, 1846, *Tennopleurus toreumaticus* (Leske, 1778), *Echinometra mathaei* (Blainville, 1825), and *Echinostrephus molaris* (Blainville, 1825). However, most species were described briefly, without exact morphological data. In contrast, later works by Tahera (1992) and Tahera and Kazmi (2005) documented only four species, *Echinometra mathaei*, *Echinostrephus molaris*, *Stomopneustes variolaris*, and *Tennopleurus toreumaticus*. More recently, Gul (2017) recorded *Salmacis bicolor* from Chara Island, Karachi, based solely on underwater photography, but without providing detailed taxonomic information. Consequently, the status of *S. bicolor* in Pakistan remained uncertain.

The lack of prior detailed morphological descriptions from Pakistan contributed to long-standing uncertainty regarding the species' occurrence in the region. The present study, nearly a century after Clark's initial note in 1925 (Clark, 1925), provides the first comprehensive morphological and taxonomic description of *Salmacis bicolor* from Pakistan, based on specimens collected from the intertidal rocky shore of Manbar Island along the Makran coast, Balochistan.

## 2. Materials and methods

A total of four specimens of *Salmacis bicolor* were collected from the intertidal rocky shore of Manbar Island (25°06'06"N 62°05'35"E), Makran coast, Balochistan, Pakistan (Figs 1–2). The island is characterized by rocky ridges, tidal pools, and a diverse benthic community. Sampling was conducted during low tide at -0.07 m (16:03 local time). Specimens were collected manually using a hand net and forceps and placed in labelled plastic containers filled with seawater.

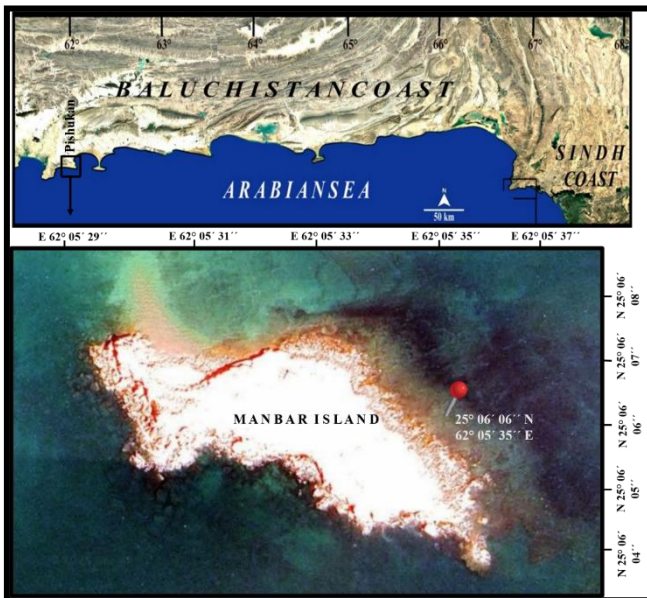


Figure 1. The map of the study area and locality, where specimens of *Salmacis bicolor* L. Agassiz in L. Agassiz & Desor, 1846 were collected.

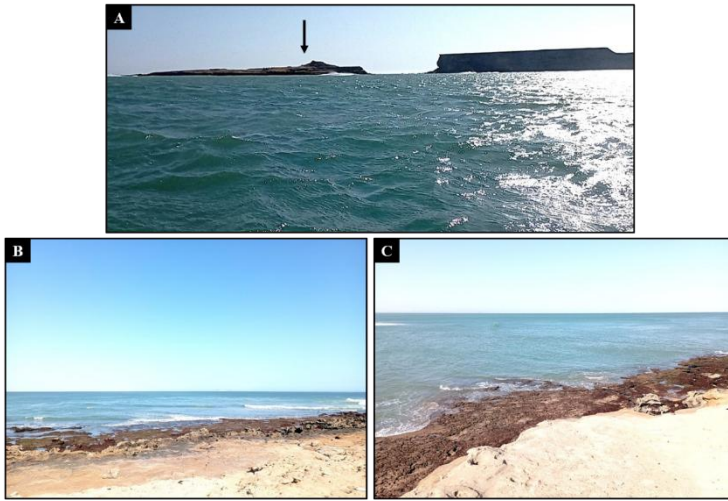


Figure 2. General view of the study area. A. Manbar Island (arrow), B-C. Rocky ledge exposed during low tide.

Of the four specimens, three were preserved for morphological examination and one was dried for skeletal analysis. Specimens were initially fixed in 5% formalin and subsequently transferred to 70% ethanol for long-term storage. Morphological characters were examined under a stereomicroscope (Wild 181300, Switzerland) at 10–50× magnification. Measurements were taken using Vernier callipers (Model MC 11000012; precision 0–150 mm). Specimens were photographed using a digital camera (Model DMC-TZ80). Diagnostic features—including test diameter, test height, spine length, coloration patterns, and the arrangement of tubercles, as well as ambulacral and interambulacral plates, were recorded.

For detailed skeletal examination, dried tests were prepared by removing soft tissues in a dilute sodium hypochlorite (bleach) solution, followed by thorough rinsing and air-drying. Identification was carried out using the taxonomic keys and diagnostic descriptions of Clark and Rowe (1971) and Schultz (2010, 2015). The specimens were catalogued (Cat. no. MRC&RC-UOK-ECHI-112) and deposited in the Repository of the Marine Reference Collection and Resource Centre (MRC&RC), University of Karachi.

### 3. Results

Phylum Echinodermata Klein, 1778

Class Echinoidea Schumacher, 1817

Order Camarodonta Jackson, 1912

Family Temnopleuridae Agassiz, 1872

Genus *Salmacis* L. Agassiz, 1841

***Salmacis bicolor* L. Agassiz in L. Agassiz & Desor, 1846**

(Figures 3, 4)

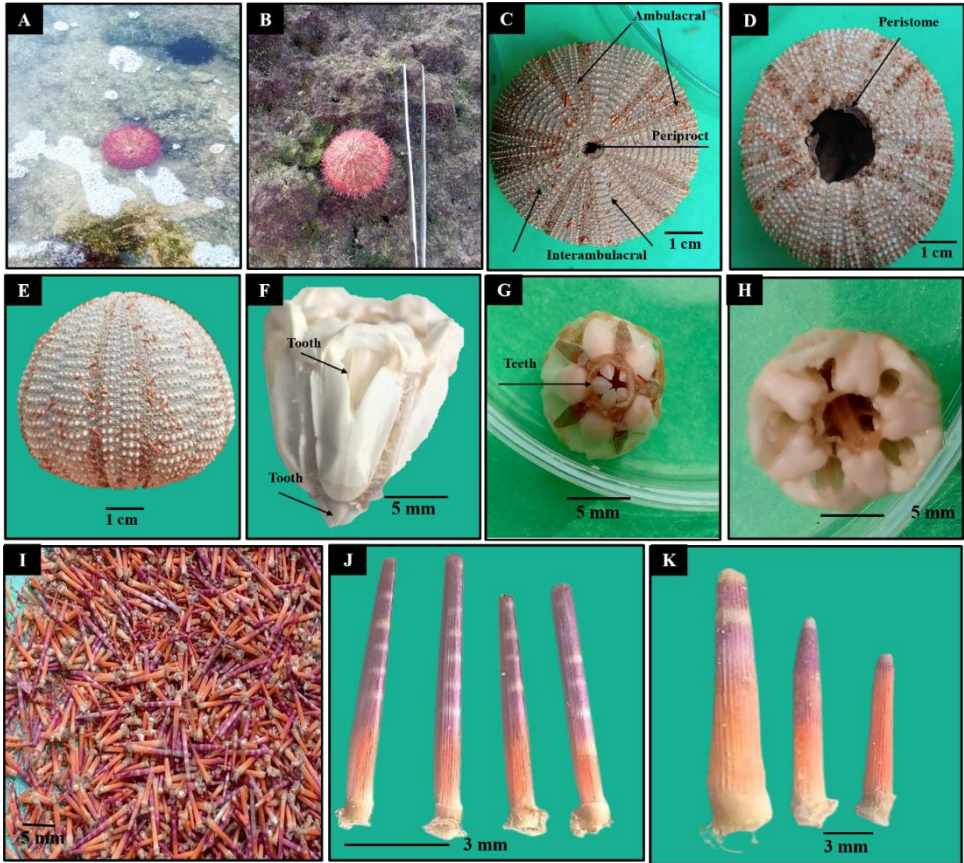


Figure 3. *Salmacis bicolor* L. Agassiz in L. Agassiz & Desor, 1846. A-B. Live specimen in a rock pool and on the algal-covered substrate. C. Aboral view of test showing ambulacral and interambulacral areas, D. Oral view of the test showing the peristome region, E. Lateral view of the test, F. Tooth from Aristotle's lantern, G-H. Dorsal and ventral views of the Aristotle's lantern showing the arrangement of teeth, I. Spines of varying lengths and colors, J. Primary spines with sharp tip displaying banded pattern, K. Secondary spines with spade-like flattened tips.

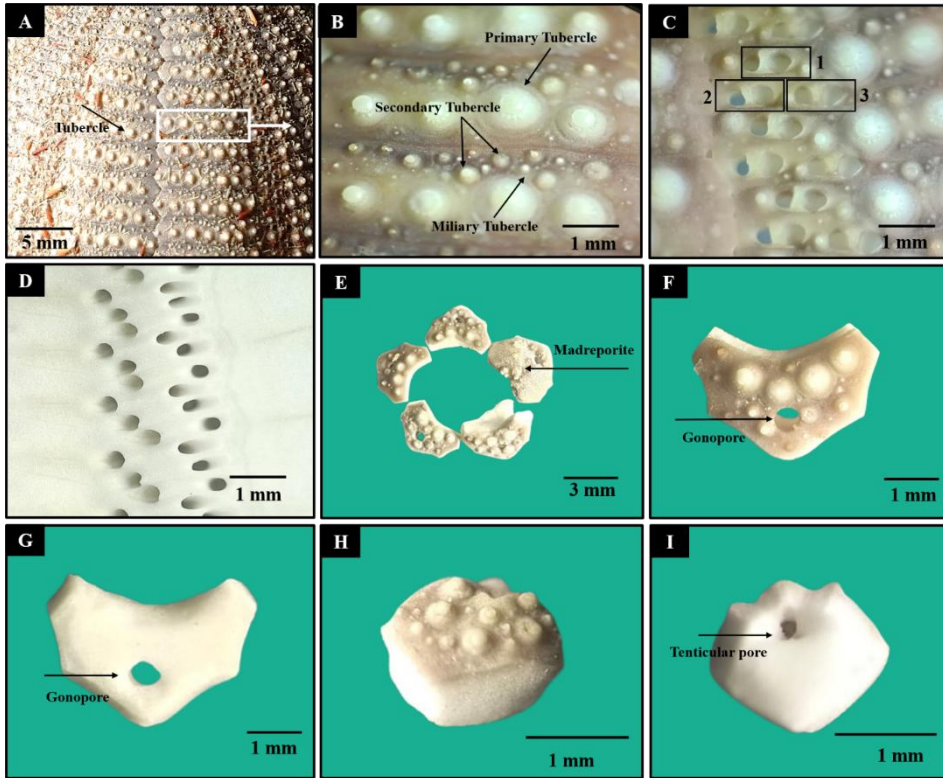


Figure 4. *Salmacis bicolor* L. Agassiz in L. Agassiz & Desor, 1846. A. Tubercles Crenate, B. Close-up view of tubercles showing primary, secondary and military tubercles, C. Ambulacral pore pair arrangements and numbers, D. Ventral view of ambulacral pore pair arrangements, E. Genital plates and the madreporite, F. Dorsal view of genital plate showing gonopore, G. Ventral view of genital plate, H. Dorsal view of ocular plate, I. Ventral view of ocular plate showing tenticular pore

**Materials examined.** Four specimens collected from the intertidal zone at Manbar Island (25°06'06"N 62°05'35"E), Makran coast, during low tide -0.07m (16:03) on 17 October, 2024.

**Morphological Characters.** Test small to medium size with deep pink coloured in live. Test hemispherical with circular and subconical in shape and slightly flattened at the base. Mouth small. Buccal membrane naked. Auricles thin, sharp, touching at their base, and closed at the apex. Four finely granulated anal plates, as well as the genital and ocellar plates. The ambulacrum narrower and not as broad as the interambulacrum. Ambulacral pores arranged in double pairs. The margin of Interambulacral plates formed as a zig-zag line on the interracial suture. Sutures of the plates distinct. Small angular pores. Tubercles Crenate, but not perforated, forming at least ten rows which appear in the form of regular horizontal series on each interambulacral plate. Pore pairs in arcs of 3.

**Test measurements.** Test diameter 4-7 cm; test height 4.5-6.5 cm.

*Spine and colour.* Spines cylindrical and finely striated, reaching a length up to of 10 mm; upper spines sharp, lower spines with spade-like flattened tips. They are slender, densely packed, and distinctly banded in red with yellowish, violet, or green shades, usually with red bases.

*Habitat.* Rockpools, and found attached to rocky substrate.

*Distribution.* Indo-west Pacific. Red Sea, Eastern coast of Africa, Pakistan, Maldives area, Western coast of India, Sri Lanka, Bay of Bengal, Vietnam, Singapore, Hong Kong, Philippines, southern coast of China and southern islands of Japan (Clark & Rowe, 1971; Liao & Clark, 1995; Schultz, 2010; Britayev *et al.*, 2013).

## 4. Discussion

Sea urchins of the family Temnopleuridae constitute an ecologically important component of benthic communities; however, their diversity and distribution in the northern Arabian Sea remain insufficiently documented. The present study provides the first comprehensive morphological and taxonomic description of *Salmacis bicolor* from Pakistan, based on specimens collected from Manbar Island along the Makran coast, Balochistan. This contribution addresses a longstanding gap in the regional echinoid literature, where previous records were incomplete or lacked detailed morphological analyses.

Sea urchin *Salmacis bicolor* L. Agassiz in L. Agassiz & Desor, 1846 was originally described from Bombay (India) in 1846. Since its original description, the species has been widely reported throughout the Indo-Pacific region, including the Red Sea, East Africa, Sri Lanka, Vietnam, southern China, Japan, the Philippines, and Hong Kong (Clark and Rowe, 1971; Liao and Clark, 1995; Schultz, 2010; Britayev *et al.*, 2013). This sea urchin inhabits tropical and subtropical waters, where its grazing activity contributes to the maintenance of ecological balance, and plays a meaningful role in shaping biodiversity patterns and ecological dynamics within its habitats (Lewis, 1958; Paine and Vadas, 1969; Johansson *et al.*, 2010; Kriegisch *et al.*, 2016; Yiu and Chung, 2024).

*Salmacis bicolor* is characterized by its conical test, a periproct encircled by tubercles, and relatively large tubercles that diminish in size toward the apical system (Schultz, 2010). It reaches a maximum test diameter of approximately 100 mm (Schultz, 2010). The specimens examined from Manbar Island conform closely to these diagnostic traits. The test is small to medium in size (4–7 cm in diameter), hemispherical to subconical, and slightly flattened at its base. The species is readily identifiable by its distinctively red-banded spines, often interspersed with yellowish, violet, or green tones and typically with red bases, a distinctive morphological feature highlighted by Clark and Rowe (1971). This striking banding pattern has been consistently reported across its geographic range (Liao and Clark, 1995; Schultz, 2015). Nonetheless, some variation occurs, as Schultz (2015) noted individuals with more subdued coloration in certain populations. The Manbar Island specimens exhibited the characteristic red-banded spines with red bases, confirming their identity and aligning well with previous descriptions. Functionally, the combination of upper, sharply pointed spines and lower, spade-like spines may represent an adaptation to rocky substrates and moderate current regimes, similar to observations made for Hong Kong populations (Liao and Clark 1995).

*Salmacis bicolor* can be reliably distinguished from its closely related Indo-Pacific congeners *S. virgulata* and *S. sphaeroides* by coloration, spine morphology, and test structure. Sea urchin *S. virgulata*, originally described from Sri Lanka as "*Salmacis virgulatus*" by Agassiz and Desor (1846), possesses uniformly purplish, unbanded primary spines with whitish bases, a key diagnostic feature noted by Arachchige *et al.* (2019). In contrast, *S. sphaeroides* exhibits short, thin spines that are densely banded in red, brown, purple, whitish, or green hues, typically with a green base, and displays test shapes ranging from oval to conical (Yiu *et al.*, 2024). *S. bicolor* differs from both species by its deep pink hemispherical test and cylindrical,

finely striated spines, which may reach up to 10 mm in length. The upper spines are sharply pointed, whereas the lower ones are flattened. Its spines are distinctly banded in red with yellowish, violet, or green hues and usually have red bases, a combination not observed in *S. virgulata* or *S. sphaeroides*.

Collectively, these observations confirm the taxonomic identity of *Salmacis bicolor* from the Makran coast of Pakistan and represent the first comprehensive morphological record of this species from the region. These findings validate earlier scattered reports and contribute to the expanding knowledge of echinoid diversity in the northern Arabian Sea. The recognition of *S. bicolor* in Pakistan underscores the importance of continued regional surveys integrating both morphological and molecular approaches to refine species boundaries and elucidate biogeographic patterns of echinoids across the Indo-Pacific.

## Acknowledgements

The authors would like to express their gratitude to the Pakistan Science Foundation (Project No. PSF/CRP/Constrm 636) for providing financial support for the collection of samples, and also would like to acknowledge the Marine Reference collection and Resource Centre, University of Karachi, for providing services for sample collection and laboratory facilities for specimen identification.

## Conflict of interest

The authors declare that they have no competing interests.

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