Journal of the University of Ruhuna
Volume 13 No 2, January 2025. Pp 93-100
DOI: https://doi.org/10.4038/jur.v13i2.8130
ISSN: 2659-2053

EDITORIAL ARTICLE

Sea Urchins: Sri Lanka's Untapped Blue Economic Resource?

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Abstract: Sea urchins are keystone organisms in shallow marine ecosystems, exerting profound influence on coral reefs, kelp forests, and seagrass meadows through their roles as grazers, bioeroders, and habitat engineers. Beyond their ecological significance, they hold substantial economic value as a luxury seafood item (roe), a source of bioactive pharmaceutical compounds, and a potential driver of sustainable aquaculture. Sri Lankan waters are home to 39 sea urchin species, with *Stomopneustes variolaris* and *Tripneustes gratilla* identified as the most abundant and widely distributed in shallow coastal waters. Despite this rich biodiversity and global market demand, Sri Lanka currently lacks a developed sea urchin fishery or aquaculture industry. This editorial explores the dual ecological and economic importance of sea urchins, provides a detailed evaluation of Sri Lanka's native species as viable resources, discusses global best practices and innovations in aquaculture, and charts a sustainable development pathway. By integrating scientific research, policy innovation, and community engagement, Sri Lanka can position sea urchin aquaculture as a cornerstone of its emerging blue economy, ensuring ecological resilience while generating economic prosperity.

Keywords: *Aquaculture, Blue Economy, Ecosystem Engineer, Pharmaceutical, Roe, Sea urchin, Stomopneustes variolaris, Sri Lanka, Tripneustes gratilla.*

Introduction

Sea urchins (Class Echinoidea, Phylum Echinodermata) are more than just spiny denizens of the seabed; they are pivotal architects of marine ecosystems and a valuable commodity in global markets. Characterized by their spherical bodies with pentamerous symmetrical and a unique feeding apparatus known as Aristotle's lantern, these echinoids inhabit a range of benthic environments from intertidal zones to deep-sea floors. Their ecological function as intense grazers allows them to control algal biomass, thereby influencing the competitive dynamics between algae and corals.

This grazing pressure can prevent algal overgrowth on corals, promoting reef health and resilience (Carpenter, 1990, Hughes, 1994, Lawrence, 2020).

Conversely, in the absence of natural predators or under conditions of nutrient enrichment, sea urchin populations can explode, leading to the creation of "urchin barrens" areas stripped of macroalgae and characterized by low biodiversity (Ling, 2008).

Simultaneously, sea urchins have catalyzed a multi-billion-dollar global industry centered on their gonads, known as roe or *uni*. Prized as a delicacy in Japanese, Mediterranean, and Chilean cuisines, sea urchin roe commands high prices in international markets. Further, their tests (shells) and spines are sources of novel bioactive compounds, such as Echinochrome A, which has demonstrated cardioprotective and ophthalmological therapeutic properties (Mishchenko *et al.*, 2003). This duality—ecological keystone and economic resource—places sea urchins at a critical

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juncture for nations seeking to develop their maritime economies sustainably.

For Sri Lanka, an island nation endowed with 1,340 km of coastline and rich marine biodiversity, the potential of its sea urchin resources remains largely untapped. While the country has engaged in small-scale fisheries for other echinoderms like sea cucumbers, sea urchins have been overlooked. This editorial argues that a strategic, science-led approach to sea urchin aquaculture, rather than wild harvest, represents a significant opportunity. By developing this sector, Sri Lanka can diversify its blue economy, create new livelihood streams for coastal communities, contribute to global food security, and establish itself as a leader in sustainable mariculture in the South Asian region. The following sections will delve into the global context, assess Sri Lanka's native species, and outline an actionable framework for sustainable development.

Global Ecological Significance: From Keystone Grazers to Ecosystem Engineers

Keystone Herbivores and Phase Shift Dynamics

Sea urchins are often described as keystone species due to their disproportionate impact on community structure relative to their abundance. In both temperate and tropical systems, they are primary herbivores capable of mediating phase shifts, dramatic changes in ecosystem state. The most cited example is the catastrophic mass mortality of the long-spined sea urchin *Diadema antillarum* in the Caribbean in the early 1980s due to an unidentified pathogen (Lessios *et al.*, 1984). This event removed the reef's primary grazer, leading to rampant algal growth that smothered corals, suppressed coral recruitment, and fundamentally altered reef ecosystem function for decades (Hughes, 1994, Idjadi *et al.*, 2010). Recovery of *Diadema* populations remains slow and patchy, underscoring the long-term consequences of losing such a critical ecological player.

In temperate kelp forest ecosystems, sea urchins play a similarly decisive role. In the North Atlantic, the green sea urchin (*Strongylocentrotus droebachiensis*) can transition lush, biodiverse kelp forests into extensive, barren grounds dominated by crustose coralline algae (Scheibling, 1986, Filbee-Dexter and Scheibling, 2014). This shift not only reduces habitat complexity but also impacts commercially important species like lobster and fish that depend on the kelp forest for shelter and food. The dynamics of these systems are often regulated by a trophic cascade, where the removal of urchin predators (e.g., sea otters, lobsters) leads to urchin population outbreaks and subsequent kelp deforestation (Estes and Palmisano, 1974, Steneck *et al.*, 2002).

New Case Study: The Tasmanian Example*:* On the eastern coast of Tasmania, the range expansion of the diadematoid urchin *Centrostephanus rodgersii*, likely facilitated by climate change and the strengthening of the East Australian Current, has created extensive and persistent barrens (Ling, 2008, Ling *et al.*, 2009). These barrens represent an alternative stable state that is resistant to reversal, even if urchin densities decline, due to the alteration of the underlying substrate. This highlights the potential for sea urchins to drive long-term, possibly irreversible, ecological changes, emphasizing the need for careful management.

Bioerosion and Carbonate Budgets: The Unseen Architects

Beyond grazing, sea urchins are significant bioeroders. Using Aristotle's lantern, they scrape and ingest calcium carbonate from reefs and rocks. This process serves two key functions: it produces vast quantities of carbonate sediment, which contributes to beach formation and lagoon infill, and it directly influences the reef's structural complexity and carbonate budget, the balance between calcium carbonate accretion (by corals and coralline algae) and removal (by erosion) (Perry *et al.*, 2013).

In some ecosystems, the bioerosive impact of sea urchins can be staggering. Studies on Kenyan reefs have shown that the rate of bioerosion by *Echinometra mathaei* can equal the rate of carbonate production by the entire reef community (Carreiro-Silva and McClanahan, 2001). On the Pacific coast of Panama, the urchin *Eucidaris thouarsii* was found to be responsible for over 80% of total reef bioerosion (Glynn and Manzello, 2015). This erosion is not purely destructive; it creates microhabitats and spaces for new coral settlement. However, in an era of climate change, where ocean acidification weakens coral skeletons and reduces accretion rates, excessive bioerosion can tip the carbonate budget into negative territory, leading to net reef loss and reduced structural integrity (Alvarado *et al.*, 2012). Understanding the role of Sri Lankan Sea urchin species in local carbonate budgets is, therefore, a critical research priority.

Habitat Provision and Biodiversity Enhancement

Sea urchins are also ecosystem engineers that create habitats. The intricate spaces between their long spines provide refuge for a diverse array of commensal organisms, including juvenile fish, brittle stars, polychaete worms, and shrimps (Patton *et al.*, 1985, Gherardi, 1991). This "urchin hotel" effect can significantly increase local biodiversity. For example, the pencil urchin *Eucidaris tribuloides* in the Caribbean hosts a specialized commensal crab, *Dissodactylus primitivus*, which lives exclusively among its spines (Lowry and Pearse, 1973). Furthermore, the grazing activity of urchins maintains open patches on the reef substrate, which are crucial for the settlement of coral larvae and other sessile invertebrates, promoting higher overall species richness (Sammarco, 1982).

Nutrient Cycling and Benthic-Pelagic Coupling

Sea urchins contribute to nutrient cycling through the production of particulate inorganic matter (faeces) and the mobilization of nutrients locked in algal biomass. Their grazing converts macroalgal tissue into fine particulates, making nutrients more readily available to filter feeders and decomposers in the benthic food web (Mamelona and Pelletier, 2005). This process enhances benthic-pelagic coupling—the transfer of energy and nutrients between the seafloor and the water column. In seagrass meadows, sea urchin grazing can help recycle nutrients, potentially increasing the productivity of the system (Heck and Valentine, 2006).

Global Market, Aquaculture Innovations, and Sustainability

The Lucrative Global Roe Market

The primary driver of the sea urchin fishery is the demand for high-quality roe, particularly in Japan (where it is called *uni*), but also in France (*oursin*), Chile (*erizo*), and South Korea. Japan alone consumes over 90% of the world's premium roe, importing from over 20 countries (Stefánsson *et al.*, 2017). Roe quality is assessed based on colour (bright yellow to orange is preferred), firmness, sweetness, and briny aroma. This quality is highly variable, influenced by species, season, diet, and environmental conditions (James (McBride *et al.*, 2004, James, 2007). The global catch peaked in the mid-1990s at over 120,000 tons but has since declined due to overfishing and stringent regulations, creating a supply gap that aquaculture is poised to fill (Alvarado *et al.*, 2012).

Advances in Sea Urchin Aquaculture:

A Three-Pillar Approach

To meet demand sustainably, significant research has been directed towards aquaculture, focusing on three main pillars:

(a). Broodstock Management and Hatchery Technology: Successful aquaculture begins with reliable seed production. Research has optimized conditions for spawning induction (using potassium chloride injections or temperature shock), larval rearing (using microalgae like *Chaetoceros* and *Rhodomonas*), and settlement (using chemical inducers like γ-aminobutyric acid or specific bacterial films) (Pearce and Scheibling, 1994, Dworjanyn *et al.*, 2007). Closed-lifecycle breeding has been achieved for several commercial species, reducing pressure on wild stocks.

(b). Gonad Enhancement and Nutritional Science: The most critical aspect of commercial production is maximizing roe yield and quality. Sea urchin gonads are essentially nutrient storage organs; their size and composition are directly dictated by diet. Research has moved from reliance on wild-harvested macroalgae (e.g., *Laminaria*, *Ulva*) to the development of formulated, pelleted feeds. These feeds are designed to provide optimal protein (25-35%), lipid (5-10%), and carbohydrate levels, and are often supplemented with pigments like astaxanthin to enhance roe colour (McBride *et al.*, 2004). Studies on *Paracentrotus lividus* have shown that diets rich in β-carotene and polyunsaturated fatty acids (PUFAs) significantly improve gonad index (gonad weight as a percentage of total body weight) and sensory scores (Shpigel *et al.*, 2005).

(c). Grow-Out Systems and Integrated Aquaculture: Sea urchins can be grown in various systems: land-based tanks, nearshore cages, or sea ranches. A promising sustainable model is Integrated Multi-Trophic Aquaculture (IMTA). In IMTA, sea urchins are co-cultured with finfish (e.g., salmon) or shellfish. The urchins consume organic waste particulates and biofouling algae from the system, converting waste into a valuable product while improving water quality and system sustainability (Barrington *et al.*, 2009). Norway has been a pioneer in developing IMTA systems featuring the green sea urchin (*S. droebachiensis*) alongside Atlantic salmon (James *et al.*, 2015).

The Pharmaceutical Frontier: Beyond Roe

The economic potential of sea urchins extends beyond the dinner plate. Their tests and spines contain a unique class of polyhydroxylated naphthoquinone pigments known as spinochromes, the most studied being Echinochrome A (ECH). ECH is a potent antioxidant with demonstrated efficacy in treating ischemic heart disease and certain ocular conditions like corneal ulcers and cataracts. In Russia, the drug *Histochrome®* (based on ECH) is approved for clinical use (Mishchenko *et al.*, 2003). Research is exploring its anti-inflammatory, antimicrobial, and even anti-cancer properties. Developing methods to extract these compounds from aquaculture by-products (tests and spines left after roe extraction) could create a circular economy, adding significant value and reducing waste.

Sustainability, Certification, and Traceability

As consumer awareness grows, certification has become a market differentiator. The Marine Stewardship Council (MSC) has certified several wild sea urchin fisheries (e.g., in Maine, USA, and the Falkland Islands) for sustainable management. For aquaculture, standards are emerging from bodies like the Aquaculture Stewardship Council (ASC). Traceability, from hatchery to plate, is increasingly demanded by high-end retailers and restaurants to ensure product authenticity, quality, and ethical production. Sri Lanka's future industry would benefit immensely from adopting these international best practices from the outset.

Sri Lanka's Sea Urchin Resource: A Detailed Species Assessment and Potential

Species Inventory and Dominant Players

As per Arachchige *et al.*, (2019) Sri Lanka's coastal waters host 39 sea urchin species, reflecting the high biodiversity of the Indo-Pacific region. The two most ecologically dominant and economically promising species are:

(a). *Stomopneustes variolaris* (The Black Sea Urchin): This species is a robust, large urchin (test diameter up to 11 cm) with thick, sharp spines. It is a prominent feature of intertidal and shallow subtidal rocky reefs along the southern and western coasts. Recent unpublished survey data indicate population expansions in areas like Beruwala, Ahangama, and Nilwella, sometimes leading to the formation of localized barrens—a sign of its strong grazing impact. Ecologically, it is a key herbivore and bioeroder, playing a role similar to *Diadema* in other reefs.

- **Nutritional Profile:** Gonads of *S. variolaris* are nutritionally dense. Proximate analysis reveals protein content ranging from 11.47–18.81% and a favourable fatty acid profile rich in polyunsaturated fatty acids (PUFAs) like EPA and DHA (Jinadasa *et al.*, 2016). They are also rich in carotenoids (notably β-carotene at 9.4 mg/100g), vitamin C (20 mg/100g), and essential trace elements (Fe, Zn, Cu).

- **Pharmaceutical Potential:** This species is a treasure trove of bioactive compounds. Researchers have isolated two novel fourteen-membered macrocyclic pyrone derivatives named stomopnolides A and B. Stomopnolide A exhibits significant antioxidant and anti-inflammatory activities *in vitro* (Francis and Chakraborty, 2021). Earlier work showed that protein extracts can inhibit haemoglobin glycation (relevant for diabetes management) and possess antibiotic properties (Bharathi and Prabha, 2000). Methanol extracts of the gonads show selective antibacterial activity against pathogens like *Staphylococcus aureus* and *Escherichia coli* (Thennakoon, 2025).

(b) *Tripneustes gratilla* (The Collector Urchin or Masking Urchin): This shorter-spined, often debris-covered urchin is common in sandy areas and seagrass beds. It is already a target species for small-scale fisheries and aquaculture trials in Southeast Asia (e.g., the Philippines, Vietnam) and is used as a biocontrol agent for invasive algae in Hawaii.

- **Market Readiness:** Its gonads are known for their sweet, delicate flavour, making it a commercially viable species. Research in other countries has extensively focused on improving their gonad quality through diet ((Onomu *et al.*, 2020, Brink-Hull *et al.*, 2022).

- **Bioactivity:** Like *S. variolaris*, methanol extracts of *T. gratilla* gonads have demonstrated antibacterial properties against common pathogens, adding to their value (Thennakoon, 2025).

Other Species of Ecological and Potential Economic Interest

- ***Diadema setosum* (The Long-Spined Sea Urchin):** Ecologically crucial for controlling algae on coral reefs. While its gonads are small and less commercially prized, it could be important for reef restoration projects or as a source for pharmaceutical exploration.
- ***Echinometra mathaei* (The Rock-Boring Urchin):** A widespread and abundant bioeroder. Its role in sediment production is significant, and its potential for local, small-scale use or as a model for bioerosion studies warrants investigation.

- ***Salmacis sphaeroides* & *Temnopleurus toreumaticus*:** Smaller, common species whose ecological roles and biochemical properties are completely unstudied in a Sri Lankan context.

Constraints and Challenges for a Wild Fishery

The ecological data present a clear constraint: initiating a wild sea urchin fishery in Sri Lanka is **not ecologically viable or recommended**. The population densities of *S. variolaris* and *T. gratilla*, while locally abundant, are not comparable to the dense aggregations of harvested species in colder waters (e.g., *Strongylocentrotus* spp.). More importantly, both species are keystone species in their respective habitats (intertidal reefs and seagrass meadows). Their removal would likely trigger adverse ecological consequences, including algal overgrowth on reefs and destabilization of sediment dynamics. Therefore, the only sustainable pathway is through aquaculture.

A Strategic Framework for Sustainable Sea Urchin Aquaculture in Sri Lanka

Given the constraints and opportunities, Sri Lanka should adopt a phased, science-based, and policy-supported approach.

Phase 1: Foundational Research and Technology Development (Years 1-3)

Objective: Master the life cycle of native species and develop viable hatchery protocols.

- **Action 1.1:** Establish dedicated broodstock holding and conditioning facilities at national research institutes. Conduct detailed studies on reproductive cycles, fecundity, and optimal spawning triggers under local conditions.
- **Action 1.2:** Develop and optimize larval rearing protocols. Test different microalgal diets, water flow regimes, and tank designs. Crucially, identify effective, locally sourced settlement inducers.
- **Action 1.3:** Initiate gonad enhancement research. Screen locally available and sustainable feed ingredients—such as cultivated seaweed (*Ulva*, *Gracilaria*), agricultural by-products, and formulated feed bases—to develop a diet that maximizes gonad index, colour, and flavour for both *S. variolaris* and *T. gratilla*.
- **Action 1.4:** Conduct thorough biochemical profiling of both species to fully catalogue their pharmaceutical potential, guiding future value-added product development.

Phase 2: Pilot-Scale Aquaculture and Systems Integration (Years 4-6)

Objective: Transition from research to small-scale commercial pilot projects.

- **Action 2.1:** Establish pilot-scale land-based hatcheries and nursery systems to produce juvenile "seed" for grow-out.
- **Action 2.2:** Test different grow-out models:
  - **Land-based tanks/raceways:** High control, suitable for high-value, intensive production.
  - **Nearshore cages or pens:** Lower infrastructure cost, utilizes natural seawater.
  - **Sea Ranching:** Releasing hatchery-reared juveniles into managed coastal areas for later harvest. This requires strong governance to prevent poaching and manage ecological impacts.

Phase 3: Commercialization, Value Addition, and Market Development (Years 7-10)

Objective: Establish a competitive, certified, and sustainable industry.

Action 3.1: Develop a national branding and marketing strategy ("Sustainable Sri Lankan Uni") targeting premium markets in Japan, the EU, and the Middle East. Pursue international sustainability certifications (e.g., ASC) from the start.

Action 3.2: Foster the development of Small and Medium Enterprises (SMEs) and community-based aquaculture cooperatives, particularly in coastal districts like Galle, Matara, and Kalutara, ensuring equitable benefit sharing.

Action 3.3: Establish processing facilities for value addition: fresh roe packaging, frozen products, and extraction of bioactive compounds from tests/spines. Partner with pharmaceutical and nutraceutical companies.

Action 3.4: Integrate sea urchin aquaculture into national tourism offerings (e.g., "farm-to-table" culinary experiences, educational tours), enhancing the overall visitor experience.

Policy, Capacity Building, and Cross-Cutting Support

Policy Integration: The government must explicitly include sea urchin aquaculture in its **National Aquaculture Development Strategy** and **Blue Economy Policy Framework**. Clear and streamlined regulations for licensing, environmental monitoring, and export are essential.

Research & Development Funding: Allocate dedicated funding through national science foundations and encourage public-private research partnerships.

Capacity Building: Develop diploma and vocational training programs in sea urchin husbandry, hatchery management, and seafood processing at technical colleges and fisheries training institutes.

Monitoring and Adaptive Management: Implement a robust science-based monitoring program to assess the environmental impact of aquaculture operations and adapt management practices accordingly. This is non-negotiable for maintaining ecological balance.

Conclusion: Charting a Course for a Blue Future

Sea urchins present Sri Lanka with a paradigm-shifting opportunity. They are not merely another fishery resource but represent a convergence of ecological stewardship, advanced biotechnology, and sustainable economic development. The path forward is clear: **forgo ecologically risky wild harvest and wholeheartedly embrace aquaculture.**

The journey will demand significant investment in research, patient capital, and collaborative governance. It requires marine biologists to unlock the secrets of local species, aquaculturists to refine rearing techniques, entrepreneurs to build market linkages, and policymakers to create an enabling environment. The potential rewards, however, are substantial: a new, high-value export commodity, pharmaceutical innovations derived from marine natural products, job creation in coastal communities, and the bolstering of Sri Lanka's reputation as a responsible steward of its ocean resources.

By taking a strategic, patient, and ecologically grounded approach, Sri Lanka can transform its abundant sea urchin biodiversity from an unexploited natural asset into a pillar of a resilient and prosperous blue economy. The time to invest in science, develop technology, and train the next generation of blue farmers is now. The spiny, unassuming sea urchin could well be one of the keys to unlocking a sustainable maritime future for the nation.

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