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Ecological Status of Fluted Giant Clam of Andrew Bay in Rakhine Coastal Region, Western Myanmar

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Abstract
The fluted giant clam, *Tridacna squamosa* plays a significant role in reef ecosystems, contributing to biodiversity and habitat structure in Andrew Bay of the Rakhine Coastal Region, Western Myanmar. This current research synthesizes its ecological status, highlighting key factors affecting its populations, including environmental changes, overfishing, and habitat degradation. This study indicates that while some populations remain stable, others are declining due to climate change impacts, such as ocean acidification and increasing sea temperatures, which affect their physiological functions and reproductive output. The fluted giant clam's dependence on symbiotic relationships with zooxanthellae is crucial for its health and growth, making it vulnerable to shifts in marine conditions. Conservation efforts are essential to protect this species through habitat restoration and sustainable management practices. Collaborative research between scientists and local communities is encouraged to enhance understanding and protection of the fluted giant clam and its habitat. The findings underscore the need for integrated conservation strategies to ensure the sustainability of this ecologically important species.

Key words
Andrew Bay, Conservation assessment, Ecological status, Fluted Giant Clam, Rakhine Coastal Region, Western Myanmar

1. Introduction

Giant clams, belonging to the family Tridacnidae, are the largest living bivalve mollusks in the world. They are found in warm, shallow waters of the coral reefs in the Indo-Pacific region. There are several species of giant clams, with *Tridacna gigas*, also known as the Southern Giant Clam, being the largest.

The fluted giant clam (*Tridacna squamosa*) primarily inhabits shallow coral reefs and seagrass beds in warm, tropical waters. Its preferred environment typically includes:

- Depth: It can be found at depths of 1 to 25 meters (approximately 3 to 82 feet), usually in areas where sunlight can penetrate to support the growth of symbiotic algae (zooxanthellae) that live within the clam's tissues.
- Substrates: The clams prefer firm substrates, such as sandy or rocky bottom surfaces, which stabilize their large, heavy shells.
- Temperature: As a benthic species, they thrive in warmer waters, typically between 24°C and 30°C (75°F and 86°F).

These clams play a vital role in the health of coral ecosystems, contributing to both biodiversity and the structural integrity of reefs. The health and stability of giant clam populations are closely tied to their habitats. Conservation efforts aimed at protecting coral reefs, restoring seagrass beds, and mitigating human impacts are crucial for ensuring the longevity of these species.

Giant clams in Myanmar face significant environmental challenges primarily due to widespread overfishing and the deterioration of coral reef ecosystems. These issues have led to a decline in clam populations, which are integral to maintaining the health of coral reefs and providing nutritional and economic benefits for coastal communities.

Efforts to protect giant clams in Myanmar include habitat conservation initiatives focused on the Rakhine Coastal Region, which is crucial for marine biodiversity. These initiatives aim to preserve the delicate ecosystems that support giant clams and other aquatic species. Furthermore, there may be ongoing education and awareness campaigns to engage local communities in sustainable practices that protect these clams and their habitats, as the coastal area is vital for the livelihoods of coastal inhabitants. This study aims to determine the ecological status of fluted giant clams in the Rakhine Coastal Region of Western Myanmar.

2. Materials and Methods

The ecological status of fluted giant clams was conducted in Andrew Bay (Lat. 15° 10' N and 17° 30' N and Long. 96° 46' E and 98° 15' E), Rakhine Coastal Region, Western Myanmar from 2012 to 2024 (Fig. 1). Field surveys were made for clam population mapping and their habitat distribution along the bay. The population density, size distribution, habitat usage, potential threats, feeding behavior, and species interacting with them as predators, prey, or epibionts were analyzed through quadrat sampling and underwater visual surveys. The symbiotic relationships between giant clams and algae were examined, as this partnership is crucial for their growth and health. Laboratory analyses included assessments of genetic diversity, reproductive success, and environmental stressors affecting these clams. Key aspects to study.

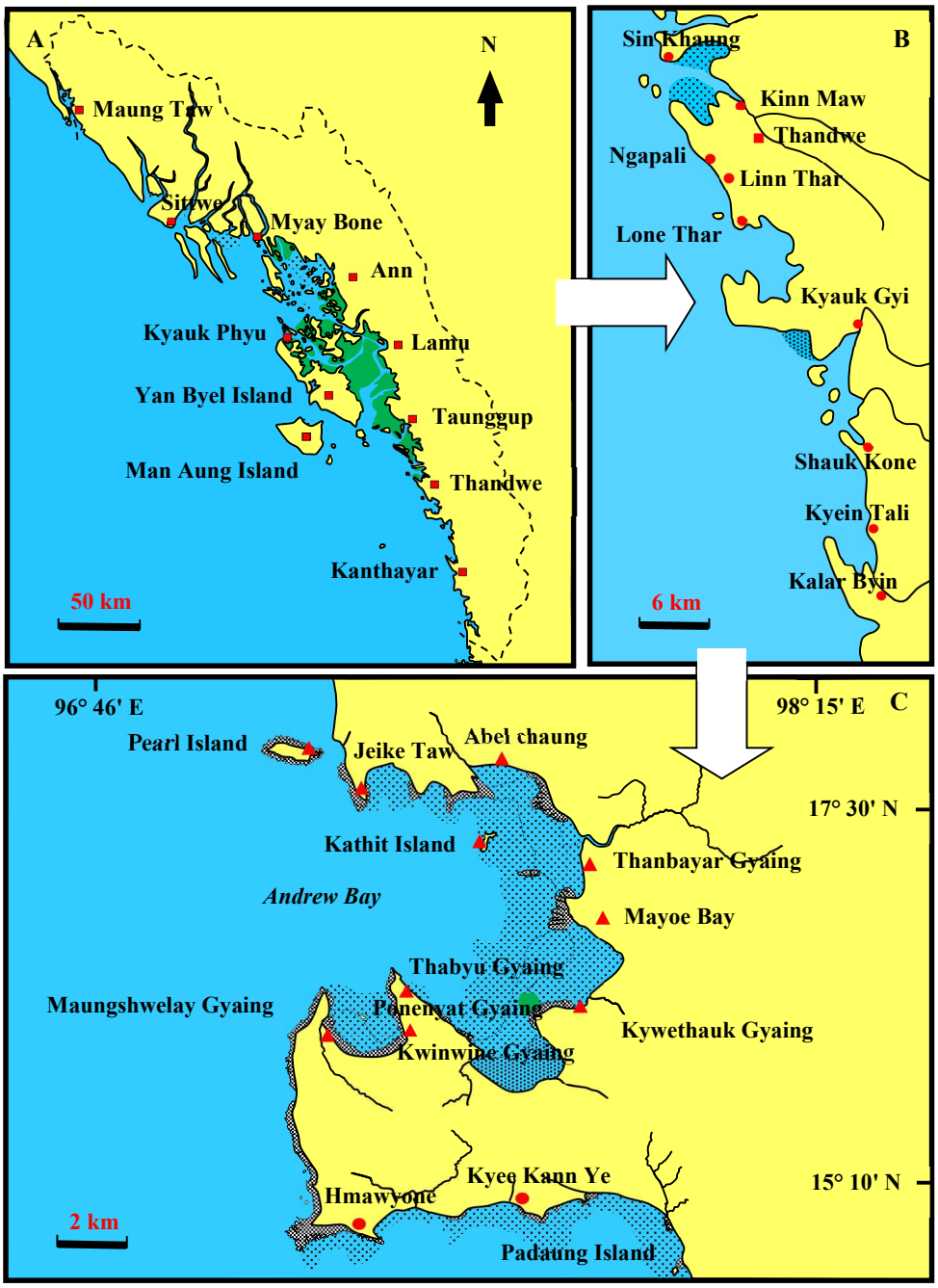

Fig.1. Giant clams survey area; A) Rakhine Coastal Region, B) Andrew Bay and adjacent coastal water and C) Sampling sites in Andrew Bay)

Table 1 Classification of giant clam species recorded in Myanmar

Scheme	Taxa
Phylum	Mollusca (Cuvier, 1795)
Class	Pelecypoda (= Bivalvia) (Linnaeus, 1758)
Order	Cardiida Férussac, 1822
Family	Cardiidae (Lamarck, 1809) (= Tridacnidae (Lamarck, 1819)) (Giant clams)
Genus	*Hippopus* (Lamarck, 1799)
Species	***H. hippopus* (Linnaeus, 1758) Horse hoof clam**
Synonyms	*Chama asinus* (Barbut, 1788); *C. hippopus* (Linnaeus, 1758); *Hippopus brassica* (Bosc, 1801); *H. equinus* (Mörch, 1853); *H. maculatus* (Lamarck, 1801); *Tridachnes ungula* (Röding, 1798).
Genus	*Tridacna* (Bruguière, 1797)
Species	***T. crocea* (Lamarck, 1819) Crocus giant clam**
Synonyms	*Tridacna* (*Chametrachea*) *crocea* (Lamarck, 1819); *T. cumingii* (Reeve, 1862); *T. ferruginea* (Reeve, 1862).
Species	***T. gigas* (Linnaeus, 1758) Southern Giant clam**
Synonyms	*Chama gigantea* (Perry, 1811); *C. gigas* (Linnaeus, 1758); *Dinodacna cookiana* (Iredale, 1937); *Tridacna (Tridacna) gigas* (Linnaeus, 1758).
Species	***T. maxima* (Röding, 1798) Elongate giant clam**
Synonyms	*Tridachnes maxima* (Röding, 1798); *Tridacna (Chametrachea) maxima* (Röding, 1798); *T. acuticostata* (Sowerby III, 1912); *T. compressa* (Reeve, 1862); *T. detruncata* (Bianconi, 1869); *T. elongata* (Lamarck, 1819); *T. fossor* (Hedley, 1921); *T. imbricata* (Röding, 1798); *T. lanceolata* (Sowerby II, 1884); *T. maxima var. fossor* (Hedley, 1921); *T. mutica* (Lamarck, 1819); *T. reevei* (Hidalgo, 1903); *T. rudis* (Reeve, 1862).
Species	***T. squamosa* (Lamarck, 1819) Fluted giant clam**
Synonyms	*T. (Chametrachea) squamosa* (Lamarck, 1819); *T. lamarcki* (Hidalgo, 1903).

2.1. Population Demographics

Abundance: Conduct surveys to count the number of clams in each area, using transects or quadrats to ensure representative sampling.

Size Distribution: Measure the shell length of individuals to assess recruitment rates, growth patterns, and potential overfishing pressure.

Sex Ratio: If possible, determine the sex of individuals to understand reproductive dynamics.

2.2. Habitat Usage

Depth Distribution: Record the depth at which clams are found to understand their preferred habitat conditions.

Substrate preference: Identify the types of coral and reef structures where clams are found the most.

Light Availability: Analyze the light conditions in different areas to assess the impact on their symbiotic algae (zooxanthellae).

2.3 Feeding Ecology

Zooxanthellae Analysis: Examine the density and health of zooxanthellae within the clam's tissue to understand their photosynthetic capacity.

Filter Feeding Activity: Assess the rate at which clams filter water to understand their role in nutrient cycling.

2.4. Interactions with Other Organisms

Predator-prey Relationships: Identify the predators that feed on clams and assess the predation pressure.

Epibionts: Study the organisms that settle on the clam shells and their potential ecological implications.

Commensalism: Investigate any symbiotic relationships with other marine species that benefit from living near clams.

2.5. Environmental Factors

Water Quality: Monitor parameters like temperature, salinity, dissolved oxygen, and nutrient levels to assess their impact on clam health.

Sedimentation: Analyze the amount of sediment deposition and its potential effects on clam feeding and survival.

2.6. Sampling Methods

Underwater Visual Surveys: Scuba diving or snorkeling to observe and count clams in their natural habitat.

Quadrat Sampling: Placing a quadrat frame on the reef to count clams within a defined area.

Tissue Analysis: Collecting clam tissue samples to analyze zooxanthellae density and composition.

Mark-Recapture Studies: Tagging clams to study movement patterns and survival rates.

2.7. Important Considerations

Conservation Status: Be aware of legal regulations regarding the collection and handling of giant clams, as many species are protected.

Ethical Practices: Minimize disruption to the ecosystem during sampling and data collection.

Long-term Monitoring: Establish long-term monitoring sites to track changes in clam populations over time.

3. Results and Discussion

3.1. Identification Status

In Myanmar, five giant clam species are primarily found in the coral reefs and shallow waters along the coast (Table 1), particularly in the following areas:

Myeik Archipelago (Mergui): This group of islands in the Andaman Sea has suitable habitats for giant clams, including healthy coral reefs.

Rakhine State: Coastal waters in Rakhine, particularly around Andrew Bay and other parts of the coastline, are known to host giant clam populations.

Dawei Region (Tavoy): The waters around this area are also conducive to the growth of giant clam species.

These regions typically offer the warm, shallow waters and stable substrate that giant clams require for optimal growth and health. Conservation efforts are important in these areas due to threats from overfishing and habitat degradation.

3.2. Importance of Giant Clams in Marine Ecology

Ecological Role: Giant clams play a crucial role in their ecosystems. They provide habitat and food for various marine organisms and contribute to the biodiversity of coral reef systems.

Symbiotic Relationships: Giant clams have a symbiotic relationship with algae called zooxanthellae, which live in their tissues. The clams benefit from the algae's photosynthesis, while the algae receive nutrients from the clams. This relationship helps to support the energy flow in reef environments.

Water Filtration: As filter feeders, giant clams help improve water quality in their habitats by filtering plankton and other particles from the water, which can assist in maintaining the health of coral reefs.

Cultural and Economic Value: In many regions, giant clams are valued for their meat and shells, which are often used in traditional dishes or as ornamental items. Sustainable harvesting can provide economic benefits to local communities.

Indicator Species: Giant clams can be indicators of reef ecosystem health. Their presence and population health can provide insights into environmental conditions and the impacts of global changes, such as climate change and ocean acidification.

Biodiversity Conservation: Protecting giant clams contributes to broader conservation efforts within marine environments, supporting the balance and resilience of ocean ecosystems.

In summary, giant clams are vital for ecological balance, coral reef systems' health, and communities' livelihoods depending on marine resources. Their conservation is imperative to maintaining marine biodiversity.

3.3. What Conservation Efforts are Being Implemented for Giant Clams in Myanmar?

Conservation efforts for giant clams in Myanmar focus on several key strategies to protect and restore their populations and habitats (Table 2). These include:

Marine Protected Areas (MPAs): Establishing MPAs helps safeguard critical habitats for giant clams and other marine species. These areas limit destructive activities like overfishing and coastal development.

Community Engagement and Education: Local communities are educated about the importance of giant clams to marine ecosystems and their livelihoods. Involving local fishers in conservation efforts promotes sustainable practices.

Restocking Programs: Efforts are underway to breed and restock giant clams in degraded areas. Hatcheries and nurseries may be established to support this initiative.

Research and Monitoring: Ongoing research helps to assess the status of giant clam populations and their habitats, informing conservation strategies and management practices.

Legislation and Policy Development: Strengthening and enforcing laws to protect giant clams and their habitats is crucial. This includes regulating fishing practices and promoting sustainable seafood initiatives.

Partnerships with NGOs and International Organizations: Collaborations with non-governmental organizations and international bodies enhance capacity-building and resource mobilization for effective conservation.

These efforts aim to ensure the survival of giant clams in Myanmar's fragile marine ecosystems while supporting the livelihoods of coastal communities that depend on these resources.

3.4. What are the Main Threats to Tridacna Squamosa?

The main threats to *T. squamosa* include:

Overfishing: This species has been heavily harvested for food and the aquarium trade, leading to population declines in some areas.

Habitat Loss: Destruction of coral reefs due to coastal development, pollution, and climate change impacts affects the natural habitat essential for their survival.

Climate Change: Rising sea temperatures and ocean acidification impact the health of coral reefs, which directly affects giant clams that rely on these ecosystems.

Pollution: Runoff from agricultural and urban areas can introduce harmful substances into the ocean, affecting the health of *T. squamosa* and its habitat.

Invasive Species: The introduction of non-native species can disrupt the local ecosystem, affecting competition and symbiotic relationships vital for giant clams.

Conservation efforts are important to mitigate these threats and ensure the survival of *T. squamosa* populations.

3.5. Tridacna squamosa (Lamarck, 1819)

3.5.1. IUCN status

The IUCN status of *T. squamosa* is classified as "Lower Risk: conservation dependent" (LR/cd). This assessment was last updated on August 1, 1996 (IUCN, 1996).

3.5.2. Diagnostic characters

Shell moderately large (attaining 50 cm in length), moderately compressed (in juveniles) to strongly inflated (in

mature specimens), and nearly equilateral in shape, semicircular in outline (Fig. 2). Umbones about mid-length of shell or slightly anterior. Posteroventral margin of valves with a medium-sized byssal orifice, bordered by 6 to 8 small, non-interlocking crenulations. The dorsal free margin of the shell is regularly rounded and undulated. The posteroventral slope is relatively broad and flat, with crowded radial sculpture that results in crenulations on the margin posterior to the byssal opening. The outer surface of each valve with 5 or 6 broad, rib-like radial folds bearing large and erect, distant, blade-like concentric scales which are delicate and easily broken. A secondary sculpture of many low radial riblets, crossed by concentric growth lines, gives a finely latticed pattern mainly noticeable in the wide interstices of ribs. Inhalant (posterior) siphonal opening with fringing tentacles (Poutiers, 1998).

3.5.3. Colour

The shell's exterior is highly variable, greyish white, often with different hues of orange, yellow, or pink to mauve, and with blade-like scales commonly of different shades or colours. Interior porcelaneous white is occasionally tinged with orange. Dorsally exposed mantle area of living specimens mottled in various mixes of green, blue, brown, orange, and yellow.

3.5.4. Size

Maximum shell length 50 cm, commonly 35 cm.

3.5.5. Habitat, Biology and Fisheries

T. squamosa, commonly known as the scaly clam, fluted, or squamous giant clam, primarily inhabits shallow coral reefs and sandy areas in warm, tropical marine environments. Attached by a byssus to the surface of coral reefs, usually in moderately protected localities such as reef moats. It is often found at depths ranging from 1 to 40 meters. These clams thrive in areas with good water quality and moderate water movement, often seeking out locations where they can benefit from sunlight for their symbiotic relationship with algae (zooxanthellae) that live in their tissues. This relationship allows them to derive energy through photosynthesis. Collected for food and the shell trade. A major threat to the *T. squamosa* is over-exploitation by humans.

3.6 How Does Tridacna Squamosa Reproduce?

Tridacna squamosa, commonly known as the fluted giant clam, reproduces through external fertilization. Here's how the process generally works:

Spawning: During the breeding season, typically coinciding with warmer water temperatures, mature clams will release both eggs and sperm into the water column. This often occurs shortly after sunset.

Fertilization: The eggs and sperm mix in the water, resulting in fertilization. This process is dependent on the synchronous spawning of multiple clams to increase the chances of successful fertilization.

Larval Development: The fertilized eggs develop into free-swimming larvae (called trochophore larvae), which eventually become veligers. This planktonic stage can last for several weeks.

Settlement: After the larval stage, the young clams settle on the substrate (usually coral reefs) and begin to attach themselves. They will start to develop their characteristic shells and adopt a more benthic lifestyle.

Growth: Once settled, *T. squamosa* will continue to grow, with some individuals reaching significant sizes over several years.

This reproductive strategy, while effective, is influenced by environmental factors such as water temperature and lunar cycles, which help synchronize spawning events among individuals.

Distribution: Widespread in the Indo-West Pacific, from East Africa, including Madagascar, and the Red Sea, but not the Persian Gulf, to eastern Melanesia; north to southern Japan, and south to Queensland and New Caledonia (Poutiers, 1998).

3.7. How can local communities support giant clam conservation?

Local communities can support giant clam conservation through several key actions:

Sustainable Fishing Practices: Adopting and promoting sustainable fishing techniques can help reduce overfishing and allow giant clam populations to recover. This includes avoiding destructive fishing methods that damage habitats.

Habitat Protection: Engaging in the protection of coastal and marine environments where giant clams inhabit is crucial. Communities can participate in local efforts to maintain water quality and reduce pollution.

Education and Awareness: Local education programs can raise awareness about the importance of giant clams and the ecological roles they play. Community workshops can help inform residents about the benefits of conservation.

Eco-tourism Initiatives: Developing eco-tourism focused on marine biodiversity can provide economic incentives for communities to protect giant clams and their habitats, creating jobs while fostering conservation efforts.

Involvement in Conservation Programs: Communities can collaborate with NGOs and government initiatives focused on giant clam restoration, such as participating in coral reef rehabilitation or giant clam breeding programs.

Monitoring and Reporting: Training local volunteers to monitor giant clam populations and report illegal activities (like poaching) can help protect these species effectively.

Community-based Management: Establishing community-managed marine areas can empower locals to have a direct stake in the health of their marine resources, promoting long-term sustainability.

By implementing these actions, local communities can play a significant role in the conservation and recovery of giant clam populations in Myanmar and other regions.

3.8. What are Giant Clam Shells Used for?

Giant clam shells are used for various purposes, including:

Decorative Items: These shells are prized for their size and beauty and are commonly used as home decor, garden ornaments, or as part of art installations.

Souvenirs and Collectibles: They are often sold as souvenirs in coastal areas, appealing to tourists.

Jewelry and Accessories: Shells can be polished and crafted into jewelry, such as pendants and earrings, or used in other accessories.

Crafts: Artists and crafters use pieces of giant clam shells in various projects, including mosaics and sculptures.

Natural Habitat: In their original environment, they provide habitat and support marine life, contributing to the overall health of coral reefs.

Cultural Significance: In some cultures, giant clam shells hold symbolic value and may be used in traditional ceremonies.

3.9. Species Status in Andrew Bay, Rakhine Coastal Region, Western Myanmar

There has been research on the giant clam's family Cardiidae (= Tridacnidae) in Myanmar, though the scope and depth vary by region and the specific species of interest.

Species in Myanmar Waters: Giant clams are known from the broader Indo-Pacific region, and Myanmar's coastal waters (including the Bay of Bengal side and near the Andaman Sea) have habitat suitable for several *Tridacna* species. Common species in the region often include *T. derasa*, *T. maxima*, *T. squamosa*, and *T. crocea*, among others. Local distributions can be patchy and influenced by depth, turbidity, and reef structure.

Conservation and Status Assessments: Some studies focus on the conservation status of giant clams in Southeast Asia, including Myanmar, due to overharvesting, habitat loss, and climate impacts. These assessments may be part of national biodiversity inventories or regional programs.

Marine Biodiversity Surveys: Baseline surveys of coral reef and rocky-reef habitats in Myanmar sometimes record molluscan diversity, including giant clams. Such work is often conducted under university-led projects, government research bodies, or collaborations with international conservation organizations.

Ex Situ and Restoration Efforts: In nearby regions, there are programs for ex situ propagation and restoration of giant clams. While Myanmar-specific programs may be limited, regional initiatives sometimes include Myanmar or cross-border reef systems, which could influence or inspire local conservation actions.

Research gaps: Compared to neighboring countries like Thailand, Malaysia, and Indonesia, Myanmar has fewer published, widely accessible studies on giant clams. There may be local or grey literature, including theses, field reports, or NGO project documents, that address species presence, population structure, and threats in Myanmar waters.

Table 2. Assessment of Fluted Giant Clam *Tridacna squamosa* in Andrew Bay (2012-2024)

Status	Study sites													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Population demographics														
Abundance	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Density (ind/m^2)	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Size (cm)	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sex ratio (Male: Female)	•							•						
Habitat usage														
Depth distribution (m)	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Substrate preference	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Light availability (lux)	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Feeding ecology														
Zooxanthellae analysis	•			•				•	•	•				
Filter feeding activity	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Interactions with other organisms														
Predator-prey relationships	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Epibionts	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Commensalism	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Environmental factors														
Water quality	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sedimentation	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Sampling methods														
Underwater visual surveys	•			•			•	•	•	•		•	•	•
Quadrat sampling	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Tissue analysis								•						
Mark-recapture studies	•			•				•				•		
Important considerations														
Conservation status	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Ethical practices		•	•		•	•	•	•	•	•	•	•	•	•
Long-term monitoring	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Symbols: • = monitored & assessed, 1 = Pearl I., 2 = Jeik Taw, 3 = Abel Chaung, 4 = Kathit I., 5 = Thanbayar Gyaing, 6 = Mayoe Bay, 7 = Thabyu Gyaing, 8 = Ponenyat Gyaing, 9 = Kwinwine Gyaing, 10 = Kywethauk Gyaing, 11 = Maungshwelay Gyaing, 12 = Hmawyone, 13 = Kyee Kann Ye, 14 = Padaung I.

4. Conclusion

The status of the Fluted Giant Clam *Tridacna squamosa* in Andrew Bay is not extensively documented, but the giant clams are recognized for their ecological importance in coral reef ecosystems in study areas. They are significant for both biodiversity and as a source of nutrition and income for coastal communities. Research has shown live specimens were collected along the bay area, indicating their presence in intertidal and shallow subtidal zones. However, threats to their populations, such as habitat destruction and overharvesting, may affect their status in Andrew Bay. The status of giant clams can vary regionally, and the trade and mariculture of these clams are rapidly evolving, which could affect local populations. Ongoing research and monitoring are important to understand and protect these species better.

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