Tegillarca granosa - Blood Cockles

Figure 1: The blood cockle in its natural habitat (Credits: Wild Singapore – Ria Tan) versus where we we think it should be, in our plates (Author’s own collection)

Introduction

Welcome to the secret life of the blood cockle, seen from an animal perspective! This species page aims to help you to understand and know more about the beloved blood cockles that you often see in classic Singaporean dishes like Laksa and Char Kway Teow. Although there will be recipes and food-related information in the Cultural and Culinary section, we would be focusing more on the animal aspects of the Blood Cockle. In some of the sections, there are general information about the animal group of ‘Bivalves’ - includes many other edible shellfish like clams, cockles, scallops and mussels!

What is the blood cockle?
- a form of an animal.
- part of a big and varied group of animals called ‘Bivalves’

Guide to reading this webpage:

- the names Tegillarca granosa, Arca granosa, Anadara granosa, blood cockle and sea hum will be used interchangeably to refer to the same and main species in discussion here.
- since this page is rather lengthy, please navigate through the page using the table of contents on the right-side of the page.

• Introduction
  • Synonyms
  • Etymology
  • What's with the blood? (Viewer's Discretion Advised)
  • Gender
  • Behaviour/ Movement
  • Reproduction
Name

Scientific name: *Tegillarca granosa* (Linnaeus, 1758)

Vernacular English (Common) names: Blood Cockles, Blood Clam, Granular Ark, Mud cockle,'sea hum/sea ham' (colloquial), (common names in other languages)

Synonyms

*Anadara granosa* (Linnaeus, 1758)
*Anadara bisenensis* Schrenck & Reinhart, 1938
*Anadara thackwayi* Iredale, 1927
*Anomalocardia pulchella* Dunker, 1868
*Arca aculeata* Bruguière, 1789
*Arca corbicula* Gmelin, 1791
*Arca corbula* Dillwyn, 1817
*Arca granosa* Linnaeus, 1758
*Arca granosa kamakuraensis* Noda, 1966
*Arca nodulosa* Lightfoot, 1786 (invalid: junior homonym of *Arca nodulosa* O. F. Müller, 1776)
*Arca obessa* Kotaka, 1953
*Tegillarca granosa bessalis* Iredale, 1939

Etymology

- Original Latin translation for chest is reflected in the genus of the original species name, *Arca* (see above in synonyms section)
• English usage of the word ‘ark’ is referred to the a type of boat. This reference might be stemming from the boat-like inner surface of ark shells, as mentioned here.

Biology

What's with the blood? (Viewer's Discretion Advised)

Wow, that's some messy business. So the main question is: Is the red liquid really blood?

The red liquid that is the first thing that you notice when you see or smell the blood cockle. As its name suggests, the red liquid is actually similar to the human blood that we have! The liquid also carries haemoglobin and red blood cells that help it to survive in environments with low oxygen levels\(^1\). In addition, an added edge is that the oxygen-carrying capacity of the red blood cells increase as environmental temperatures increase\(^2\), hence it can better cope with these two stressors at the same time.

Figure 3: Blood Cockles' 'blood' on finger (Author's own collection)

Other interesting sections below: Behaviour/ Movement section, Health and Safety section, Cultural and Culinary Section, How to pick cockles at the supermarket?

Gender

There are rare instances where there are individuals that are hermaphrodites (\(<1.5\%) for the blood cockle\(^3\), but otherwise, they are mostly unisexual - either male or female\(^4\).

Behaviour/ Movement
As compared to many other animals, bivalves are way less active. However, there are instances when bivalves make surprisingly big movements!

One such movement has to do with the use of the bivalve's feet to dig into the ground to seek cover, or even travel by leaping (Video 1)!

**Video 1: Bivalve using foot to move and jump. (Source: YouTube, 10/8/2010, 'I Love Shelling', The Cockle Hop.mov, permission pending)**

Another sort of movement that the blood cockle does is the closing and opening of its shell, in response to changing environmental conditions. When the salinity of the surrounding waters drops below 19 ‰ (parts per thousand), the blood cockle reacts by clamping down and closing its shell. This attempt to protect itself is only effective in the short-term. If low salinity conditions persist for more than three days, it could result in mortality. On the other end of the spectrum, the blood cockle would widely open its shell, when not submerged in water for long periods of time. In such low oxygen conditions, opening its valves has the purpose of increasing extraction of oxygen from atmospheric air [5].

- 3 more interesting sections below: Health and Safety section, Culture and Culinary Section, How to pick cockles at the supermarket?

**Reproduction**

The blood cockle reproduces sexually. When male and female *Tegillarca granosa* reach sexual maturity (usually when male lengths = 20mm, females = 24mm [6]), the gametes (sperm and egg) will just be actively released into the water. The sperm is released in a steady stream, while the egg is released in spurts. Fertilisation occurs in the water and the eggs eventually develop into a free-swimming 'trochophore' [7]. A trochophore is a larvae that lives in the water column, tiny enough (cannot be seen by the naked eye) to be swayed and moved along by the currents.

The blood cockle is a 'dribble spawner' [8] (FAO, 2017), where it spawns a little throughout the whole year, with some peak months that differ every year [9]. In Penang, this period is in July to October [10], while it is July to August in Pattani Bay, Thailand [11].

**Life Cycle**

Following the trochophore stage mentioned under the Reproduction section,

- develop and move on to the veliger (something like infant) stage. The blood cockle is extremely vulnerable during this two stages, and mortality is high then [12]
- undergo metamorphosis and transition into a non-swimming, sessile stage, the spat (like a mini shell)
- finally grows out into an adult

A depiction of the general life cycle of a bivalve, as previously described, is roughly in Figure 4.

![Figure 4: General developmental stages of a bivalve. Adapted from FAO](image)

**Feeding Habits**
Blood cockles are filter feeders, a subset of suspension feeders. This means that it ‘sucks in’ water in the water column, sieves this water to obtain their ‘food’, and then expel out the excess water. Bivalves are able to selectively take in organic matter like phytoplankton that they eat as food, among other inorganic material in the water column. Other such organic matter that serves as food include algae, detritus and nanoozooplankton. Eating bacteria has been shown to biomass increase in bivalves. However, there is also a critical linking organism, nanoozooplanktons, in this relationship. Nanoozooplanktons also feed on bacteria. By eating the bigger nanoozooplanktons, the bivalves can better retain the bacteria that the nanoozooplanktons ingests.

During feeding, the ctenidium, or the gills, act as the filter, as well as the organ creating the flow of water in and out of the bivalve.

**Habitats**

*Tegillarca granosa* is generally found in muddy areas in the intertidal zone.

**Salinity**

Bivalves can be found in areas of different kinds of salinities, from freshwater to hypersaline habitats. Since blood cockles thrive in the intertidal zone, the environment is largely estuarine, with low salinities. The blood cockles are also cultivated in the intertidal with salinities ranging from 10-32 ‰ (parts per thousand). Also, in Malaysia, it has been known to persist in waters that have salinities of about 30 ‰. In the tropics, changes in salinity at a certain area can be more volatile. When there is increased rainfall, the salinity of the water in that area could fall drastically. In turn, this can affect the presence of *Tegillarca granosa* as well as other marine animals that are used to a certain range of salinity.

**Water and substratum conditions**

The *Tegillarca granosa* species prefers to reside in water that has low wave action such as shallow inlets and bays, although some water flow is still desirable. These small movements ensure the constant suspension of organic material in the water, potential food for the blood cockles. Increased turbidity would mean that the blood cockles have more opportunities to ‘catch’ the food in the water, since they are filter feeders. More information about their feeding behaviour can be found in the ‘Biology’ section below. Areas with ‘soft flocculent’ and silty mud seem to also be favoured by *Tegillarca granosa*. However, there have been instances in Phuket, Thailand where the species have been found on sediments that are more sandy in nature.

**Temperature**

In the tropical regions that the blood cockles reside, the blood cockles thrive in areas with temperatures ranging from 25°C to 40°C.

!Important! Health and Safety - So are blood cockles safe to eat?

Yet again, as filter feeders with high filtration rates, and as sessile organisms, blood cockles are more likely to accumulate pollutants.
Blood cockle meat, either chilled or frozen is considered a high-risk seafood in Singapore, as classified by the AVA. The import of chilled cockles are banned totally, while that of frozen cockles have to be accompanied by a health certificate, because of 'food safety reasons'. What might these reasons be? Let's check it out!

In the paper by Mirsadeghi et al. in 2013, Tegillarca granosa has also shown to bioaccumulate polycyclic aromatic hydrocarbons (PAHs). Bioaccumulation is the transfer of chemicals from the environment into the tissue of an aquatic organism (i.e. blood cockles), resulting in an increase in concentration of the chemical in the tissues. In environments with higher amounts of PAHs, Tegillarca granosa that grow there have greater levels of PAHs in their tissue as well. Since PAHs are carcinogenic and toxic, it is important to know the source of the blood cockles that you consume.

Okay, so they might have increased concentrations of this PAH compound. What does this mean for us? Firstly, PAHs are carcinogenic. This means that PAHs have the potential to be cancer-causing. More carcinogenic foods can be found here. Increased exposure of PAHs can increase the likelihood of getting skin, liver, bladder, lung and gastrointestinal cancers. Secondly, PAHs are also endocrine disrupters. In particular, increased exposure can affect the reproductive health of animals and humans. Lastly, it has also been mentioned that consumption is linked to cholera, hepatitis A and dysenteric shellfish poisoning. Apart from PAHs, levels of radioactive isotopes of Polonium that are higher than safe limits have been found in blood cockles. The cockles sampled were near a coal power plant in Malaysia, which could have resulted in the high concentrations.

Blood cockles have also been found to contain the bacteria Vibrio parahaemolyticus that can cause gastroenteritis if eaten raw, or not well-cooked. In fact, in room temperature, infectious doses of Vibrio parahaemolyticus can be cultivated in the cockle in just a few hours.

In Thailand, high popularity of the blood cockles eaten only half-cooked might have led to the high number of cases of people getting diarrhoea.

2 more interesting sections below: Culture and Culinary Section, How to pick cockles at the supermarket?

Distribution

South-East Asia and Northern Australia houses the few densest areas of Blood Cockles in the world. Also widespread in the Indo-Pacific region (Na rasimham, 1988).

The Eastern banks of China also has a substantial area of blood cockles concentration. Being a shellfish that is eaten as food, they are being extensively farmed especially in South-East Asia. Here in Singapore, you would be surprised that the Blood Cockles are also being harvested off the coasts of Eastern Singapore, one prominent company being ‘Ah Hua Kelong’.

Anatomy
You would be surprised to find out not only do blood cockles have a circulatory system and lips, they have feet as well! Aren’t they starting to sound like animals now? Figure 7 below would be used to describe the major parts (labelled a - h) of the blood cockles’ anatomy.

Table 1: Summary of Anatomy sections (a) - (h)

<table>
<thead>
<tr>
<th>Part of animal</th>
<th>Main points/ Function (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Valve</td>
<td>positioning of the animal can be deduced from where relative positions of certain anatomical features are</td>
</tr>
<tr>
<td>Ligament</td>
<td>Control the opening and closing of the shell. This can also help in movement (e.g. to swim or burrow)</td>
</tr>
<tr>
<td>Posterior Adductor Muscles</td>
<td>Muscles that relax to open the shell, and contracts to shut the valves.</td>
</tr>
<tr>
<td>Mantle Edge</td>
<td>The ‘skirting’ encompassing the soft body inside</td>
</tr>
<tr>
<td>Gills</td>
<td>Used to breathe and to filter food that the sea hum ‘sucks’ in</td>
</tr>
<tr>
<td>Labial Palps</td>
<td>‘Lips’</td>
</tr>
<tr>
<td>Muscular Foot</td>
<td>Used to move, e.g. by hopping or digging into the sand/mud</td>
</tr>
<tr>
<td>Dorsal Region</td>
<td>The region where the hinge and ‘teeth’ are present.</td>
</tr>
</tbody>
</table>

**Legend**

(a) Right valve  
(b) Ligament  
(c) Posterior adductor muscle  
(d) Mantle edge  
(e) Gills  
(f) Labial palps  
(g) Muscular foot  
(h) Dorsal region

Figure 7: The basic anatomy of a blood cockle (Filibranch bivalve) with parts labelled (a) - (h) (Illustration drawn by author, Ang Ju Hui)

If you are not able to spend time reading this detailed section on the blood cockles’ anatomy, Table 1 below is a summary of the parts (a) - (h)

**a) Sides of a bivalve**

All bivalves have a right and left shell (or valve), even though it is tough to see a difference between the two shells from the exterior. To align the animal appropriately, you would first need to ascertain the anterior and posterior end of the blood cockle. This is mainly done by examining the content of its body inside the shell. One good way is by identifying the labial palp (part f). The labial palp is actually the ‘lips’ of the animal. LIPS? Yes, the blood cockle, like many other bivalves, have lips surrounding the mouth of the animal. Hence, where the mouth is, is where the anterior end is. After identifying the anterior end, point the anterior end upwards. Then, imagine that the hinge (where the two shells are connected, and where is ligament is) is your spine, and your head would be the anterior end, while the bottom half of your body is the posterior. By using your body as a model, it would be easy to ascertain which shell (or valve) is the left or right one. Figure 8 below shows a demonstration of the correct alignment.
b) Hinge Ligament

This ligament is a proteinaceous material that allows the cockles to control the opening and closing of the shell. The hinge ligament works like a muscle, in co-operation with the adductor muscles (c). To open the valves, the adductor muscles contract, while the ligament relaxes. The reverse is true when the bivalve closes. Figure 9 shows how a shell closes from its form in A to B. In the figure, the ligament consists of the ‘fibrous’ and ‘lamellar’ layers.
In addition, for some groups of bivalves, like the ‘swimmers’ and ‘burrowers’ use their ligaments to move. ‘Swimmers’ open and close their shells quickly to swim, while burrowers also use it to aid it in burrowing into the mud or ground.

\[\text{c) Adductor Muscles}\]

The adductor muscles are muscles that are attached to both sides of the valves, making sea hums difficult to open before you toss the ‘meat’ into your mouth. When forcing the shells open, the adductor muscles usually break in the process. As seen in Figure 9, they are vital in helping the animal control the opening and closing of its shell.

The sea hum has an anterior and posterior adductor muscle, just many other bivalves. The anterior posterior muscle is the one at the anterior of the sea hum, the same side as where the lips (part f) are. However, there are exceptions like the well-known green mussel (Perna viridis), that only has posterior adductor muscles. The positioning and appearance of these muscles can be seen in Figure 10. It appears white-ish, and is the muscle that you feel the resistance from when you are pulling the shells apart. When torn apart, usually there would be a ‘residue’ of the muscle on the inner surface of the shells as seen also in Figure 11.
Figure 10: Torn adductor muscles (Author’s personal collection)

Figure 11: Open blood cockle with adductor muscle scars for both anterior and posterior ones. The white dotted lines are where the adductor muscles should be. (Author’s own collection)
d) Mantle Edge
The mantle edge is the ribbed ‘skirting’ that encompasses the main body inside. The mantle edges line the internal shell on both sides. Figure 12 shows how the mantle edges look like in a raw blood cockle.

![Mantle Edges](image)

**Figure 12**: Mantle edges outlined in white in various positions; a, in the shell, with no detachment. b, in shell with one side detached. c, out of shell, mantle edge at the top is torn (Author’s own collection)

e) Gills (Ctenidium)
Just like fish have gills, as a marine or estuarine organism, bivalves have gills to breathe, although they might be somewhat structurally dissimilar. There are three different structures of gills, classifying bivalves into three groups: Protobranchs, Filibranchs and Eulamellibranchs. The blood cockle is a filibranch bivalve, as are all other species in the family Arcidae\(^\text{[42]}\). It might be rather difficult to identify the ctenidium of the blood cockle without any tools, but Figure 13 shows how the three different structures look differ, if you manage to.
The gills are also the organ that filters out their 'food' from the water column (See section on Feeding Habits).

f) Labial Palps (The 'Lips')
It is rather difficult to distinguish the labial palps of the blood cockle just by looking at the body inside. However, as compared the other parts of their body, they feel significantly more hardy, similar to how cartilage feels like. As mentioned above, the labial palps are an anatomical component of the body that helps us to discern the anterior and posterior end of the blood cockle, as well as most bivalves. Figures 14 and 15 gives us a closer look at how the lips look in reality.
Figure 14: The posterior and anterior end of the blood cockle ascertained by the positioning of the labial palps (circled in white) (Author’s personal collection)

Figure 15: Labial palps (circled in white) laid out, without shell (Author’s personal collection).
In Figure 15, the labial palps can be seen connected to the gastrointestinal tract, part of the digestive system of the blood cockle.

**g) The muscular foot**

Like us, bivalves have ‘feet’ as well! However, its anatomy and physiology is very different from the feet that we have. Their ‘feet’ is entirely made up of muscle, and is very versatile in its uses. For a burrowing bivalve such as the blood cockle\(^1\), one of the main functions of the foot is to dig into enable the the sea hum to dig and burrow into the mud. This could be the case when the bivalve is trying to seek shelter in the sand from the sweltering heat in the intertidal area. The foot is the most noticeable part of the cockle (Figure 16), probably the only part that you initially thought consisted of its ‘body’.

![Frontal view of an opened raw blood cockle. The foot is circled in white](image)

**Figure 16: Frontal view of an opened raw blood cockle. The foot is circled in white (Author’s personal collection)**

**h) Dorsal region**

This part of a bivalve is not really part of its anatomy, but more of a position. For the sea hum, it is an area of the bivalve where the hinge, teeth and ligament is. Table 1 below further clarifies these three parts of the sea hum.

<table>
<thead>
<tr>
<th>Hinge</th>
<th>The point where both valves are ‘stuck’ together.</th>
</tr>
</thead>
</table>

**Table 2: Descriptions and picture of the three components in the dorsal area of the blood cockle.**
Ecological Interactions

**Predators**
- **Snails**: Natica maculosa, Thais carinifer, Bedeva blosvillei
- **Birds**: Skates, Tringa nebularia (greenshank)
- **Fish**: Plotosus anguillaris
- **Starfish**: Asterias amurensis

**Infestations**
The pea crab (*Pinnotheres alcocki, now Arcotheres alcocki*) is a species of crustacean that uses the blood cockle as a host[^44][^45]. Although there seems to be little information of how the pea crab interacts with the blood cockle, studies of similar species seem to show that the female pea crab functions as a parasite[^46]. In other bivalves, the presence of similar crabs in the bivalves show a negative effect as compared to uninfected bivalves. Another example is how *Pinnotheres maculatus* reduces the ability of mussels to breathe, by reducing filtration rates of the gills[^47].
Also, the barnacle Balanus amphitrite can be found encrusted on the shells of aquacultured blood cockles. Being strategically mounted on the posterior side of the bivalve, the side where the blood cockle ‘eats’ from, the barnacle is essentially ‘stealing’ the blood cockles’ food.

**Red Tides & Algal Blooms**

As filter feeders (more information in ‘Feeding habits’ under ‘Biology’ section below), bivalves like the blood cockle are more vulnerable to changes in water quality. Examples of instances where they might be adversely affected will be in the cases of ‘red tides’ and algal blooms. Red tides occur when there are great amounts of dinoflagellates (microscopic one-celled algae) (Figure 18) in the sea, tainting the sea red (Figure 19).
These dinoflagellates can be harmful to a variety of marine animals. There are a variety of effects, but for shellfish like Tegillarca granosa, high levels of toxins and low oxygen conditions that can result from these blooms can threaten their lives.

**Ecosystem Significance**

Since the blood cockles ‘eat’ the suspended organic material that is in the water, they also ‘clean up’ the waters they reside in, resulting in clearer waters. This special characteristic of many bivalves could be used by humans to filter out harmful bacteria in natural areas. One such example is of researchers thinking of ‘cleaning up’ Mountain Lake, a waterbody that is full of harmful bacteria by using mussels or clams. Many marine bivalves are also used as bioindicators to measure the health of an environment. As group of organisms that is usually ever-present and one that filters huge volumes of water in the environment (at the same time accumulating contaminants), such bivalves serve as important study material to assess characteristics and the ability of an environment to support life. In other words, bivalves are good bioindicators.

**Economic Significance**

Like many other species in the Anadara genus, the blood cockle is an important seafood, and is cultivated on a large-scale basis for economic purposes in countries like Malaysia and Thailand. This species is actually an ‘Anadarinid’, a ‘marine bivalve mollusc harvested commercially and on a subsistence basis in many warm temperate to tropical countries’. Globally, the aquaculture of Tegillarca granosa has been rising since the start in the early 1950s until 2014 (Figure 20).
Locally, Singapore relies heavily on the import of Blood Cockles from Malaysia\[^56\]. Singapore imports an average of about two thousand tonnes of Blood Cockles from 2014 to 2016 from Malaysia. However, the yield of Blood Cockles in the three major areas (Selangor, Perak and Johor) of blood cockles farming in Malaysia have been dwindling\[^57\] since as early as 2012\[^58\]. Heightened levels of water pollution seem to be the main culprit in reducing these numbers. Since Blood Cockles is an irreplaceable ingredient in many local dishes such as Char Kway Teow and Laksa, it is getting increasingly difficult for the supply from Malaysia as well as one source in Singapore to meet the demand here. One of the rising hypermarkets in Singapore, Sheng Siong, has noted that the price of blood cockle imports has on average, risen by half of its original price half a decade ago\[^59\]. Local sellers seem to be struggling to cover the extra costs. However, our local fishery, Ah Hua Kelong, situated in the East of Singapore seems to be alleviating the stress on supply since it seems that the waters in the East are unaffected by the water pollution\[^60\].

Asia

As a popular shellfish that is consumed widely in most of Asia, its cultivation forms a significant fishery industry in these Asian countries. China has practised cultivation of the blood cockle for at least 18 years (since 1999), especially on the coastal fringes from Zhejiang to Guangdong as a high-value seafood\[^61\]. The Tegillarca granosa (‘mud cockle’) was the most prized and extensively cultivated among the three major cultivations of blood cockles in the late 20th century, the other two species being Scapharca subcrenata and Scapharca brounthoni\[^62\]. In Indonesia, cockle production occurs on coast of West Sumatra, Central and South Java, East and West Kalimantan and other muddy bottoms in Sulawesi, Maluku and Papua\[^63\]. In 2009, the annual productions of the blood cockles was valued at US$23.72 million\[^64\].

Closer to home, Malaysia has been cultivating this species ever since 1948\[^65\]. In fact, the biggest cockle industry is in Malaysia, specifically, the state of Perak (Kuala Gula, Kula Sangga-Matang, Kuala Trong, Sungai Jarum)\[^66\]. In 2009, the annual production of blood cockles was valued at US$36.6million\[^67\]. Other major areas of cockle cultivation are in Kedah (Merbok), Pulau Pinang (Juru), Perak (Kuala Gula, Kula Sangga-Matang, Kuala Trong, Sungai Jarum), Selangor (Kuala Selangor) and Johor (Muar)\[^68\]. Then, it was popular as a cheaper source of protein in their diets\[^69\]. Places in Malaysia where there are significant culturing activities include Penang, Perak and Selangor\[^70\]. Other Asian countries that cultivate the blood cockles include South Korea, Taiwan and Thailand\[^71\].

Threats
The natural stocks of the blood cockle as an ecological species has been mentioned to be potentially threatened by a parasitic trematode. Such trematodes use bivalves as an intermediate host during its larval stages before moving on to carnivorous fishes that are their definitive hosts\[^{72}\]. As a cultivated seafood species, there are local and regional concerns that the harvests of farmed blood cockles are dwindling fast. As mentioned in the Economic Significance section, there have been reduced blood cockle harvests in the country with the biggest blood cockle fishery industries in the world, Malaysia. Decreasing harvests of blood cockles is largely suspected to be because of water pollution that flow through the intertidal into the sea\[^{73}\]\[^{74}\]. Being in the intertidal zone, these filter-feeders might have accumulated high levels of toxic from the wastes that are being washed down. Other theories include the increasingly fluctuating weather patterns in recent years\[^{75}\]\[^{76}\], resulting in unstable temperatures. Increased greenhouse gases is another threat that affects shelled marine organisms in general. Bivalve shells are made largely of calcium carbonate\[^{76}\]. When there are higher concentrations of acidic greenhouse gases like carbon dioxide in the atmosphere, these gases dissolve in the seawater, raising the pH of the water (Ocean acidification). The dissolved carbonic acid then react with the calcium carbonate of bivalves, effectively dissolving the shells of bivalves\[^{7}\]\[^{7}\]. Figure 21 shows us how badly bivalves (not just Tegillarca granosa) can be affected by ocean acidification.

![Figure 21: Study modelling potential risks of ocean acidification on the areas within reach of the California current ecosystem over 50 years (2013 - 2063) (Courtesy: Northwest Fisheries Science Center, NOAA Fisheries)](image)

Conservation Status
The conservation status for Tegillarca granosa has not been assessed, and hence not listed in the IUCN (International Union for Conservation of Nature) Red List. It is also not in the CITES database either. On a national scale, it is not listed in the Singapore Red Data Book (2008 edition). Despite there being threats, the Tegillarca granosa species might not be listed as a conservation priority because as of now because of the active aquaculture of this economically important species as a seafood. Also, there might still be a multitude of locations where they can still thrive.

Cultural and Culinary Significance

Singapore
The sea hum is an irreplaceable ingredient in popular local dishes in Malaysia and Singapore. One such dish is the Singaporean Laksa (Figure 22).
Along with coconut milk and fishcake, the sea hum is usually a signature ingredient in this dish that is usually found in most hawker centres in Singapore. This dish has origins from Peranakans living in the Katong area[78], hence also laden with heritage significance.

Another popular Singaporean dish which uses the sea hum is ‘char kway teow’ (Figure 23). The char kway teow is a Teochew dish that is widely available in hawker centres, and other casual dining establishments in Singapore. Although it has Teochew origins, its name ‘char kway teow’ means fried kway teow (a type of noodle) in Hokkien. This dish is representative of the mixing of cultures in Singapore, as well as other places like Selangor and Penang in Malaysia that also have their own versions of this dish[79]. This inexpensive dish has been eaten in Singapore ever since about 1950s.
Want to make your own Char Kway Teow? Links to the recipes of the various versions of Char Kway Teow can be found in the recipes section below! Otherwise, head over to the nearest Char Kway Teow stall in Singapore. One of the more famous Char Kway Teow stalls in Singapore is "Hill street char kway teow" (Figure 24).
Asia

In Malaysia, Malays like to eat it boiled or cooked in curry, while the Chinese boil to eat it with chilli sauce, and also with vermicelli. In Thailand, blood cockles are very popular and often consumed. Blood cockles are also sold as street food in Thailand, where semi-boiled varieties, ‘Hoy kraeng luak’ are preferred for their juicier texture. However, because bivalves usually have increased concentrations of harmful chemical and substances (mentioned in Health and Safety section), this practice has health implications.

In South Korea, the blood cockle is called ‘ggomak’, and is most frequently consumed in the winter, usually in January. A simple yet classic Korean blood cockle dish is the ‘ggomak muchim’ or blood cockles with soy sauce. A recipe for this Korean dish is linked under the ‘Recipes’ section. Actually, the Koreans use mainly three types of blood cockles, ‘pijogae’, ‘sae-ggomak’ and ‘cham-ggomak’. However, there is limited literature on the exact species of each kind. In general, the ‘ggomak’ is the Tegillarca granosa species (Oh, 2009). Also, one of the best places for tasty cockles in Korea would Beolgyo, in the Jeollanam province, South of South Korea. Cockle farming and cooking seem to be an important part of the economy in that area. Lastly, another way to eat cockles would be to order ‘ggomak jungsik’ or cockle table, a slew of different varieties of cockles served in different ways, served together with other side dishes.

There are so many dishes that uses the blood cockle as an ingredient. However, reducing stocks stemming from increased water pollution could make it increasingly harder to obtain it (mentioned in Economic Significance section). There have also been notices of stores no longer adding blood cockles into their lakasas. One such notice was found in a halal hawker-like food establishment in Singapore, Encik Tan (Figure 25).

How to pick cockles at the supermarket?

Fresh cockles usually:
- Do not smell bad
- are tightly closed
- close their shells when touched (Like in Video 2 below)

This information and more about the processes from harvesting to selling different kinds of bivalves at the supermarkets can be found at this link. Video 2 below shows how different individuals of blood cockles react to touch.

Recipes

Laksa: http://thehoneycombers.com/singapore/laksa-recipe-singapore-style/
Laksa (Beginner’s): http://rasamalaysia.com/laksa-recipe/2/
Char Kway Teow: http://www.noobcook.com/char-kway-teow/2/
Penang Char Kway Teow: http://www.geniuskitchen.com/recipe/penang-char-kway-teow-32468
**Taxonomy**

**Description**

**Informal description:**
Generally, this bivalve is relatively small and compact. Looking at the blood cockle from the top, the surface of its shell is deeply ridged with vertical lines that run down from its umbo to the head of the animal. From the lateral (side) view, the edges of the shell form an undulating (wave-like) pattern. Its umbo is also prominently protruded.

**Formal Description:**
The original description of this species was by Linnaeus in his book, *Systema Naturæ*, which was written in Latin. An English adaptation can be found in a journal article by Narasimham in 1998. The main descriptions are summarised in Table 2. Size of type specimen is under section on Types.

Genus description: ‘Shell equivalve or inequivalve with large radial ribs which are nodulated or smooth, ligamental area with chevron markings, taxodont teeth in single straight series, inner margin of shell crenulated and byssus present or absent’.

In summary, this just means that species under the genus Anadara have shells that might or might not be symmetrical to one another, with a distinct ribbed pattern. They have teeth that are in a straight line (Table 1 above in Anatomy section). *Some species in the genus can have byssus threads.*

**Table 3: Main descriptions of the species Anadara granosa, described by Narasimham, 1988**

<table>
<thead>
<tr>
<th>Shell</th>
<th>‘of medium size, fairly thick, ovate, convm, inflated, equivalve and inequilateral; dorsal margin straight, anterior end rounded, sloping ventrally, posterior end obliquely rounded and ventral margin concave’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>‘Height 75.4-90.0 percent in length (mean 81.3); width 66.0-82.0% in length (mean 73.6)’*</td>
</tr>
<tr>
<td>Teeth</td>
<td>‘with taxodont dentition in one straight series of short fine teeth which become slightly larger at extremities’</td>
</tr>
<tr>
<td>Adductor muscle scars</td>
<td>‘Posterior adductor scar elongately squarish and anterior scar similar but smaller’</td>
</tr>
<tr>
<td>Body</td>
<td>‘Soft body blood red in colour.’</td>
</tr>
</tbody>
</table>

*height and width are expressed as a percentage of shell length.

**Type Information**

The ‘type’ of a genus is a species that is deemed representative of the genus, while the type for a species is a specimen or individual that is deemed representative of the species. A type serves the function of being a reference of the all the attributes of the genus or species. There are many kinds of types, but for the blood cockle, there exist only a syntype. To find out more about types, click here.

The type locality is the Mediterranean Sea, according to Linnaeus (although disputed). Syntypes exist in Sweden, while original Linnaean specimen are kept by the Linnaean Society in London. The tampering of Linnaean’s shell collection after his death rendered the original specimen not useful as a type for the species.

Location of syntype: Zoological Museum, Institute of Zoology, University of Uppsala, Uppsala, Sweden

Description of syntype: Length: 45.7mm, Height: 37mm, Width: 31.8mm

The type species for the genus Anadara that was originally used for this species, is actually //Arca antiquata Linnaeus, 1758.

**Taxonavigation**

**Order: Arcida Family: Arcidae Genus: Tegillarca Species: Tegillarca granosa**

<table>
<thead>
<tr>
<th>Table 4: Hierarchy and taxonomic rankings</th>
<th>Taxonomic Hierarchy</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kingdom</td>
<td>Animalia</td>
<td>Animal</td>
</tr>
<tr>
<td>Phylum</td>
<td>Mollusca</td>
<td>Molluscs</td>
</tr>
<tr>
<td>Class</td>
<td>Bivalvia Linnaeus, 1758</td>
<td>Bivalves</td>
</tr>
</tbody>
</table>
Phylogeny

**Morphology-related phylogeny (Superfamily level)**

How do we use morphology to compare organisms?
Using morphology to determine how closely-related different species or groups of bivalves seem to be the more popular method, as opposed to using genetic methods (only utilised more recently). Comparing morphology is studying the form and anatomy of the organism in relation to another that you are comparing it with. For example, you can use the number of ridges that are on the shells of the bivalve to compare which are more similar to each other. However, it is important to choose a feature that has some evolutionary significance.

However, it is important to note that using morphology to distinguish species is essentially using the 'Morphological Species Concept' to group individuals to form separate species. There are many species concepts that are used by different taxonomists and scientists studying different organisms. For example, a concept uses the basis of interbreeding populations as a measure of being the same species (i.e. Biological Species Concept), while another, the Phylogenetic Species Concept sensu Mishler and Theriot uses the principle of monophyly to recognise a species. A brief explanation of the mentioned species concepts can be found [here](#).

In the case of the blood cockle, there is a study that uses anatomical features like type of gills and type of 'teeth' to compare the superfamily (Arcoidea) of the blood cockle to other bivalve superfamilies. In the case of these two traits, gill type gives relevant information about the age of when the organism evolved, while 'teeth' type is a very distinguishable structure that can be clearly defined and fall into a set number of categories for the bivalve Class. Such characteristics are important in choosing what features you would use to compare in a morphological analysis.

The mentioned study by Piazzi et al. in 2011[^89] made morphological analyses based on a matrix of A, gill grade, B, hinge, C, gill cilia, D, stomach type, E, labial palps, F, shell microstructure. From comparing all the features from A-F simultaneously, and then using maximum likelihood analyses and maximum parsimony to select the best-fit tree, the study ultimately came up with one phylogenetic tree, marked in differing colours in Figure 26 below.

[^89]: Reference to the study's source for further details.
Figure 26: A single phylogenetic tree based on a matrix of 6 morphological characteristics. The position of the Superfamily of *Tegillarca granosa*, Arcoidea among others is circled in black. Adapted from Plazzi et al., 2011.

From this phylogenetic tree, we can say that the superfamily Arcoidea is most closely related to the superfamily Pterioidea, the superfamily consisting of species like the pearl oyster. However, sometimes, some scientists prefer to use genetic studies instead of morphological because there might be less subjective discrepancies, and also because there are cases where two species could be undistinguishable. Now, we can look at a family-level genomic analysis for Arcidae, the family of *Tegillarca granosa*.

**Genomic-related phylogeny**

**Family level**

Using 18S rDNA genomic data, the family Arcidae is found to be the only family of bivalves that is not monophyletic (polyphyly of Barbatia, paraphyly of Pteriida, Pteriidae, Arcidae and Arcinae). 18S ribosomal DNA was used in the evaluation because mitochondrial DNA evolves more rapidly than nuclear DNA, and is less useful for earlier changes in its evolutionary history, and also, most genomic data available was of 18S rDNA. This is also found to be the case in another study by Plazzi et al. in 2011. However, the methodology of this study might not be the most foolproof. With consideration to the reasons stated above for the use of ribosomal DNA for this study, it might still be better if protein-encoding genes (some nuclear or mitochondrial genes) were used. This is because changes in a non-protein-encoding gene might not really reflect morphological or physiological characteristics of the organism, and therefore its evolutionary fitness and changes.

**Species level**

As for the species itself, there have been surprisingly little phylogenetic studies done. It was only recently in 2015 that the phylogenetic relationships below the level of Order Arcida are clearly defined using genetic data. In the 2015 paper authored by Combosch and Giribet, 55 species (6 out of 7 extant families, 19 genera) in the Order Arcida was used to study phylogenetic relationships using three nuclear markers (ribosomal: 18S rRNA, 28S rRNA ; protein-coding: histone H3). Three specimen of *Tegillarca granosa* was used in this study, (1) from Hainan, China, (2) from Wenzhou, China and (3) Rayong, Thailand. RAxML was used for maximum likelihood analyses, and support for nodes were evaluated using the Bayesian probability model. The tree is below (Figure 27).
Figure 27: Section of Fig. 3. in 2015 paper showing the monophyletic clade containing *Tegillarca granosa*. All included species are in the same family, Arcidae. Numbers at the nodes are indicative of the strength of the relationship at that node (posterior probability = pp), the closer the number is to 1, the higher the support for the relationship (Bayesian probability model). Asterisks mean that there is a pp of 1.

Adapted from Combosch & Giribet, 2015.

From Figure 27, we can see that the specimen from Wenzhou, China is significantly different from specimen from the other two localities for *Tegillarca granosa*. Since the pp values for the nodes determining relationships between the three specimen are high (pp of at least 0.9), further studies could be done to determine if there could be a different species arising from *Tegillarca granosa*, or possible subspecies. The two species in the genus *Tegillarca* (*Tegillarca granosa* and *Tegillarca nodifera*) that was included in this study form a monophyletic clade among various other species in the Order Arcida.

Another study was one done in 2013, using 12S rDNA, 16S rDNA and Cyt b genes of 7 different species of similar-looking blood cockles. Genetic analyses are crucial in the case of these species because morphological differences (usually using the number and type of ribs on the shell) change with maturity, and also because the number of ribs on blood cockle species are often found to be the same. The study yielded the phylogenetic tree in Figure 28 below. This is a good example when morphological methods fail.

\[ \text{Fig. 3. Phylogenetic tree of Arcida relationships based on Bayesian inference with MrBayes of three genes. Numbers on nodes indicate posterior probabilities (asterisks indicate a posterior probability of 1.0). Colors correspond to the 6 currently accepted families. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)} \]
This study uses the neighbour-joining method to put together the tree. After which, bootstrap analyses were done to determine the strength of each node (points of intersection on the tree).

**What is the neighbour-joining method?**

It is using an algorithm that takes into account the different tree lengths, and uses them to string together different groups of organisms or species based on how long or short their lengths are on the phylogenetic tree. This is hence, a way to choose the best tree, using the tree that has the highest optimality score. This method is especially useful in identifying certain groups that are very different/distant from other groups.

**What is bootstrapping?**

Bootstrapping is a statistical method to determine how well the original genomic data is explained by the resulting phylogenetic tree. In general, a bootstrap score is measured upon a 100(%). If a certain relationship is tested, and has a bootstrap score of 98 (%), this means that the relationship on the tree was 98% accurate in explaining the data, and hence has strong support.

Another method to determine support for nodes: Jackknife method

Hence, for the tree in Figure 28, the bootstrap values at the nodes preceding the output of Tegillarca granosa (circled in red in Figure 28) are rather high, this reflects that the relationships are very strongly supported. Tegillarca granosa has *rather distinct rDNA and Cyt b genes for a blood cockle*, as compared to other closer related species like Anadara antiquata, Scapharca inaequivalvis, S. kagoshimensis and S. globosa ursus that are clustered in a separate sister clade.

**Morphological vs Genomic phylogenetic comparisons**

Table 5: Morphological vs Genomic comparisons

<table>
<thead>
<tr>
<th>Morphological</th>
<th>Genomic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used for visibly different organisms</td>
<td>Used when individuals cannot be easily differentiated by eye</td>
</tr>
<tr>
<td>Accuracy of comparisons might be affected by differences in morphology at different life stages</td>
<td>Affected by different types of alignment softwares used for sequences.</td>
</tr>
<tr>
<td>Accuracy of comparisons might be affected by sexual dimorphism and intra-specific variability in morphology</td>
<td>Not affected by gender of specimen, although there might still be intra-specific variations.</td>
</tr>
<tr>
<td>Number of species determined depends on which part of the specimen the author decides to look for differences</td>
<td>Number of species determined depends on which part of the sequences the author decides to look for differences.</td>
</tr>
<tr>
<td>Number of species determined depends on how many traits the author identifies as a characteristic only of the species.</td>
<td>Number of species determined depends on different similarity thresholds decided by the author</td>
</tr>
</tbody>
</table>
Changes in scientific name of *Tegillarca granosa*

Changes to the species name are as follows:

- Changed to belonging to genus Anadara instead (Anadara granosa), this name is still rather frequently used. This genus was described by Gray in 1847.
- Finally, changed to its present name, *Tegillarca granosa*. The Tegillarca genus was described more recently in 1939 by Iredale.

Although there were so many changes, there is limited or restricted morphological or genomic research (some papers are in languages other than English) to support the changing of the names, or why the species was moved around different genera within almost 200 years.

Links to other types of species pages

**Species Page on Ark Shells:** http://www.wildsingapore.com/wildfacts/mollusca/bivalvia/arcidae/arcidae.htm


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45. Afifi-Brotohadikusumo (2002) N. Pinnotherid Infestation in Anadara antiquata (L.) and Anadara granosa (L.)(Bivalvia: Arcidae): The Physiological Consequences of Habouring a Symbiont. Dept. of Fisheries, Faculty of Fisheries & Marine Sciences, Diponegoro University

46. Afifi-Brotohadikusumo (2002) N. Pinnotherid Infestation in Anadara antiquata (L.) and Anadara granosa (L.)(Bivalvia: Arcidae): The Physiological Consequences of Habouring a Symbiont. Dept. of Fisheries, Faculty of Fisheries & Marine Sciences, Diponegoro University

47. Afifi-Brotohadikusumo (2002) N. Pinnotherid Infestation in Anadara antiquata (L.) and Anadara granosa (L.)(Bivalvia: Arcidae): The Physiological Consequences of Habouring a Symbiont. Dept. of Fisheries, Faculty of Fisheries & Marine Sciences, Diponegoro University


49. Afifi-Brotohadikusumo (2002) N. Pinnotherid Infestation in Anadara antiquata (L.) and Anadara granosa (L.)(Bivalvia: Arcidae): The Physiological Consequences of Habouring a Symbiont. Dept. of Fisheries, Faculty of Fisheries & Marine Sciences, Diponegoro University


55. The International Center for Living Aquatic Resources Management (1985). Biology and Culture of Cockles (Anadarinids), WorldFish

56. Afiati-Brotohadikusumo (2002) N. Pinnotherid Infestation in Anadara antiquata (L.) and Anadara granosa (L.)(Bivalvia: Arcidae): The Physiological Consequences of Habouring a Symbiont. Dept. of Fisheries, Faculty of Fisheries & Marine Sciences, Diponegoro University


This page was authored by Ang Ju Hui

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