Abc Taxa

Sri Lankan Seaweeds
Methodologies and field guide to the dominant species

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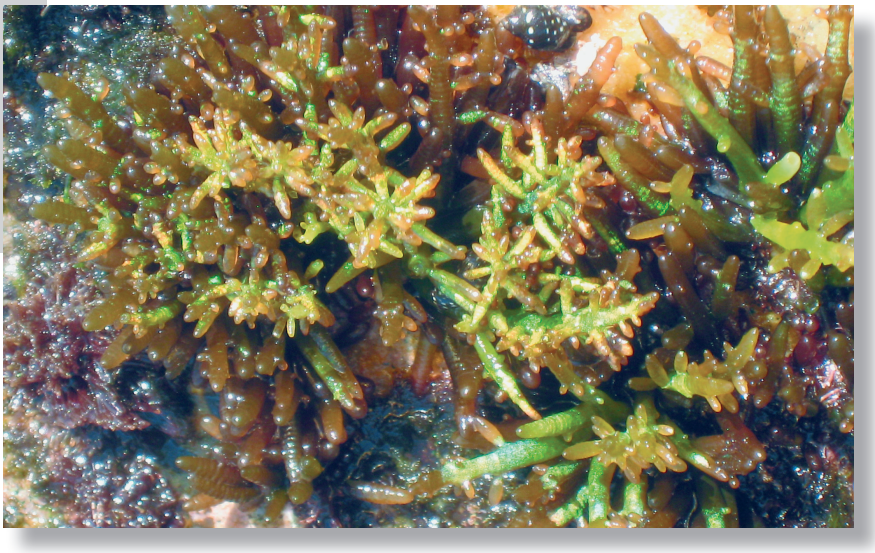
Frederik Leliaert
Olivier Dargent
Rasanga Gunasekara
Olivier De Clerck



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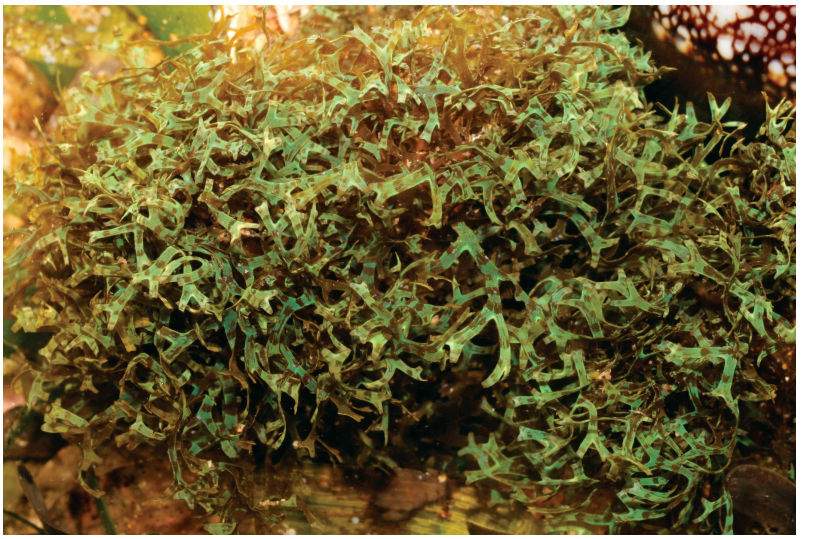

by

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Cover illustration: Iridescent *Champia ceylanica*. This page, *Dictyota ceylanica* with banded iridescence.

Preface

The 2008 Olympic Games held in China had been prepared with an unprecedented sense to perfection. However, a couple of months before the start, marine algae belonging to the genus *Ulva*, were at the point to obstruct the games' sailing events.

A gigantic bloom that struck Qingdao bay in late June marked its presence. Some 130,000 people and more than 1,000 boats were mobilised to clear an astounding 13,000 km^2 slick of algae. At the end, more than one million tons of sea lettuce was removed and buried.

Such an algal bloom can happen anywhere and anytime if the conditions are right: excess of nutrients (particularly phosphorus ran-off from fertilised agricultural land), warm coastal water, and plenty of sunlight. Some algal blooms can be very harmful when excreted toxins contaminate the water. In such cases, mussels and other edible bivalves turn detrimental induced by their filtering mode of life.

Algae have an important and direct impact on our daily life for many reasons. In Asian countries, they form a direct food source for millions of people. In western societies, cell wall extracts, better known as carrageenans, agar and alginates, are widely used in cosmometics, food and pharmaceutical industries, where they are used as emulgators, stabilisers and gelling agents.

Professor Eric Coppejans of Ghent University has studied marine algae for more than 40 years. His collecting trips encompass virtually all seas, with a special focus on the Indian and West Pacific ocean. Eric Coppejans is not only a renowned scholar; he also has that invaluable quality to disseminate his state of the art knowledge with zeal towards fellow scientists and students, especially those from developing countries.

All authors combine a thorough knowledge of the field with an exquisite taxonomic experience including molecular systematics. It thus comes as no surprise that one of them, Dr Frederik Leliaert, was key to the identification of the Qingdao bay algae. As for the algal reference collections of Ghent University, they are so rich in taxa and so well managed that they act as a world-class showcase towards the value of a taxonomic collection.

Abc Taxa offers an excellent opportunity to present the authors summary of field and laboratory techniques for the study of seaweeds, complemented with a detailed taxonomic overview of the dominant marine algal species living along Sri Lanka's 1,600 km coastline.

This sixth volume of *Abc Taxa* offers students and researchers a practical and comprehensive guide to a diversity rich group of marine organisms of utmost importance as primary producers and biological indicators, but often neglected due to lack of accessible and pertinent literature. The numerous excellent illustrations, mainly by Olivier Dargent, make this volume attractive even to the layman.

Dr Jackie L. Van Goethem

Honorary Head of Department at RBINS

ප්‍රස්තාවනාව

වර්ෂ 2008 දී චීනයේ පැවති ඔලිම්පික් තරඟ පෙර විරූ නොවූ උත්කර්ශවත් අන්දමින් පැවැත්වීමට කටයුතු සූදානම් කරන ලදී. කෙසේ නමුදු එම උළෙල ආරම්භ කිරීමට මාස දෙකකට පමණ ප්‍රථම උල්වා ඝනයට අයත් කරදිය ඇල්ගාවක් ඔරු පැදීමේ තරඟ ඉසව්වලට බාධා කරන තත්ත්වයට පත්විණ.

තරඟ පැවැත්වීමට නියමිතව පැවති කුයින්ඩාඕ බොක්ක අවහිර වන පරිදි මෙම ඇල්ගාව අති විශාල ලෙස වර්ධනය වීම ඊට හේතුවයි. වර්ග කිලෝමීටර් 13000 ක වපසරියක් ගත් මෙම විශ්මය ජනක ඇල්ගාව ඉවත් කිරීමට මිනිසුන් 130000 ක් හා බෝට්ටු 1000 ක් යෙදවීමට සිදුවිය. අවසානයේදී ඇල්ගේ ටොන් මිලියනයකට වඩා ඉවත් කොට වලලා දමන ලදී.

අතිරික්ත පෝෂ්‍ය ද්‍රව්‍ය (විශේෂයෙන්ම පොහොර යෙදූ වගාබිම්වලින් සේදී එන පොස්පරස්), වෙරළාසන්න උණුසුම් ජලය, සහ ඕනෑතරම් හිරු එළිය, ඇතුළු අවශ්‍ය තත්ත්වයන් නිසි පරිදි ඇතිවිට මෙබඳු ඇල්ගී අධිවර්ධනයන් ඕනෑ තැනක ඕනෑම කාලයක ඇතිවිය හැක. ජලයට විෂ ද්‍රව්‍ය මුදා හරින ඇතැම් ඇල්ගීවල මෙබඳු අධිවර්ධනයන් ඉතා හානිකර වීමට පුළුවන. එබඳු අවස්ථාවල බෙල්ලන් සහ ආහාරයට ගතහැකි වෙනත් ද්වි කපාටිකයින් ඔවුන්ගේ පෙරා බුදින චර්යාව හේතුකොට ගෙන ආහාරටය නුසුදුසු හානිකර තත්ත්වයට පත්වේ.

කරුණු රාශියක් හේතුකොටගෙන ඇල්ගී අපගේ දෛනික ජීවිතයට වැදගත්වන සෘජු බලපෑම් ඇති කරයි. ආසියාතික රටවල මිලියන සංඛ්‍යාත ජනතාවකට එය සෘජු ආහාර ප්‍රභවයක් වේ. බටහිර සමාජය කැරපිනේස්, ඒගාර්, හා ඇල්පිනේට්, ආදී වශයෙන් දන්නා සෙල බිත්ති නිස්සාරකයන් ඇල්ගීවලින් ලබාගෙන බහුල වශයෙන්ම සුවඳ විලවුන්, ආහාර, සහ ඖෂධ කර්මාන්තයන්හිදී තෙලෝදකරණය, ස්ථිරකරණය හා පේල තැනීම ආදී අරමුණු සඳහා යොදා ගනී.

ගෙන්ට් විශ්වවිද්‍යාලයේ මහාචාර්ය එරික් කොපජෙන්ස් වසර 40කට වඩා වැඩි කාලයක් ඇල්ගී සම්බන්ධව අධ්‍යයන කටයුතු සිදු කොට ඇත. ඔහු ඉන්දියානු හා බටහිර පැසිපික් සාගර කෙරෙහි විශේෂ අවධානයක් සහිතව සත්‍ය වශයෙන් ලෝකයේ සියළුම සාගරවල ඇල්ගී නිදර්ශක එකතු කිරීමේ චාරිකාවල නියැලී ඇත. මහාචාර්ය එරික් කොපජෙන්ස් නුදෙක් කීර්තිධර විද්‍යාර්ථයෙකු පමණක් නොව තම සුවිශේෂී දැනුම විශේෂයෙන්ම සංවර්ධනය වන රටවල සමකාලීන විද්‍යාඥයින් හා ශිෂ්‍යයින් අතර බෙදා හැරීමේ අමිල ගුණයෙන් ද යුක්ත මහත්මයෙකි.

මෙම ග්‍රන්ථයෙහි සියළුම කතුවරයන් අණුක වර්ගීකරණය ඇතුළු වර්ගීකරණයන්හි අත් දැකීම් සහිතව මෙම ක්ෂේත්‍රයේ හසල දැනුමක් ඇති විශ්ෂ්ටයෝ වෙති. එය පුදුමයට කරුණක් නොවන්නේ චීනයේ කුයින්ඩාඕ බොක්කෙහි ඇල්ගාව හඳුනාගත් ආචාර්ය ෆෙඩ්රික් ලෙලියට්ද ඔවුන් අතරෙන් එක් අයෙකු වීම නිසාය. ගෙන්ට් විශ්ව විද්‍යාලය සතු ඇල්ගී තක්සෝන රාශියකින් පොහොසත් මනාව පවත්වාගෙන යන නිදර්ශක එකතුව ලොව විශ්ෂ්ට වටිනාකමකින් යුතු ඇල්ගී වර්ගීකරණ එකතුවක් ලෙස සැලකිය හැක.

ශ්‍රී ලංකාව වටා වර්ග කිලෝමීටර් 1600 ක් වූ සමුදු තීරයේ පවතින ඇල්ගී විශේෂවල වර්ගීකරණය සම්බන්ධව දළ විශ්ලේෂණයක් ක්ෂේත්‍රයේදී හා පරීක්ෂණාගාරයේදී ඒවා අධ්‍යයනය කරන ආකාරය සම්බන්ධ කරුණු සාරංශ ගත කොට ඉදිරිපත් කිරීමට ලැබීම ඒබ්සී ටැක්සා (*Abc Taxa*) ලද අනර්ඝ අවස්ථාවක් ලෙස සලකනු ලබයි.

ශ්‍රී ලංකාවේ කිලෝමීටර් 1600 ක දිගින් යුත් වෙරළ තීරයේ ප්‍රමුඛ ඇල්ගී විශේෂවල සාගරවල විස්තරාත්මක තක්සෝන විද්‍යාත්මක විවරණයකින් ද සම්පූර්ණ වූ මුහුදු ඇල්ගී අධ්‍යනයට යොදා ගනු ලබන ක්ෂේත්‍ර හා විද්‍යාගාර තාක්ෂණයන් පිළිබඳව සාරාංශයක් ඉදිරිපත් කිරීමට ඒබ්සී ටැක්සා (*Abc Taxa*) මගින් කතුවරයන්ට මහඟු අවස්ථාවක් ලබාදී ඇත .

ඒබ්සී ටැක්සා හි මෙම හයවන වෙළුම පර්යේෂකයන් හා ශිෂ්‍යයින් හට පෙව නිදර්ශක හා ප්‍රාථමික නිෂ්පාදකයින් ලෙස පරම වැදගත්කමක් සහිත කරදිය ජීව කාණ්ඩයක් පිළිබඳව සවිස්තරාත්මක මග පෙන්වීමක් කරනු ලබයි. ප්‍රධාන වශයෙන් Olivier Dargent විසින් ඉදිරිපත් කර ඇති අනර්ඝ ඡායාරූප හා රූප සටහන් විශාල සංඛ්‍යාවකින් ද සමන්විත මෙම වෙළුම ආධුනිකයන්ට පවා ආකර්ශනීය වනු ඇත .

ආචාර්ය ජැකී එල් වැන් ගොතම්,
RBINS හි සම්මාන අංශ ප්‍රධාන

முகவுரை :–

2008 ம் ஆண்டு சீனாவில் நடைபெற்ற ஒலிம்பிக் போட்டு எப்போதாவது ஏற்பாடு செய்யாதவாறு மிக ஒபர்வான மட்டத்தில் நடைபெற்றது. எனினும் போட்டி சடைபெற இரு மாதங்களுக்கு முன்னர் உல்வா வர்க்கத்துக்குறிய கடற்பாசி, படகுப் போட்டி நிகழ்ச்சிக்கு இடையூராகிவிட்டது.

போட்டி நிகழ்ச்சி நடைபெற நியமிக்கப்பட்ட குயின்டாஒ பொக்கையில் கடற்பாசி அடர்த்தியாய் கடர்ங்குந்தமை இத்தடைக்கு காரணமாயிற்று 13,000 கி மி^{2} அடர்ந்த இப்பாசிற் தட்டை அகந்த 130000 பேர்களையும்1000 படகுகளையும் ஈடுபடுத்தலாயின. எற்றில் ஒரு தொன் மிலியனுக்கும் அதிகளவு பாசி நீக்கப்பட்டு புதைக்கப்பட்டன.

மிகுந்த போஷாக்குகள் (குறிப்பாக உரமிடப்பட்ட விதைநிலங்கள் குழுவுண்டு வரும் பொசுபரஸ்) கரையோர வெப்பநீர், அதிக சூரிய ஒளி ஆகியன போதியளவு பெறப்படும் போது இவ்வாறான பாசிகள் படர்ந்து வளரும். சிலவகை கடற்பாசி நச்சுத் திரவத்தை வெளியிடும் போது அது நீரில் கலந்து பல ஆபத்துக்களை வினைவிக்கும். இவ்வேளைகளில் சிப்பிகள் உற்கொள்ளக்கூடிய இருகவாடங்களுடையன வடித்து உண்ணும் முறையினால் உண்ணும் போது தீய விளைவுகள் ஏற்படும்.

பல காரணங்களை முன்னிட்டு கடற்பாசி எம் அன்றாட வாழ்வில் நேரடியான தாக்கங்களை உண்டாக்கும். ஆசியான் கண்டத்தைச் சார்ந்த நாட்டு பல்லாயிரக் கணக்கான மக்களுக்கு அது உணவு உற்பத்தி ஸ்தானமாகிறது. மேற்கதிய நாட்டவர்கள் கரஜீனன்ஸ், ஏகார், ஆல்ஜினேட்ஸ் போன்ற மருந்து தொழிற்சாலைகளில் அவற்றை திரவமாக்கல், ஸ்திரப்படுத்தல் போன்றவிற்றுக்குப் ரியோகிப்பர்.

கென்ட பல்கலைக்கலகப் பேராசிரியர் எரிக் கொபர்ஜீன்ஸ் 40 வருடங்களுக்கும் அதிகமாக கடற்பாசி கம்பந்தமாக ஆராய்ந்துள்ளார். அவர் எல்லாக் கடல்களிலும், இந்து, பசுபிக் சமுத்திரங்களில் விஷேடகவனத்துடன் கடல் பாசி சூழ்வதை ஆராயும் பயனத்தை மேற்கொண்டார். இவர் பிரபல்யம் வாயிந்த ஒரு விஞ்ஞானி மட்டுமல்லாது தனது நுன்னறிவை விஷேடமாக வளர்ச்சியடையும் நாடுகளிலுள்ள சமகால விஞ்ஞானிகளுக்கும் மாணவர்களுக்கும் புகட்டக் கூடிய நற்குணசீளாராகவும் விளங்கிளர்.

இந்நூயின் எல்லா ஆசிரியர்களும் அனுமூலக்கூறுகளை இனங்காணுதல் சம்பந்தமாக நேர்த்தியான அனுபவத்தைப் பெற்றவர்களாவர். சீனாவில் குயின்டாஒ பொக்கை பாசியை கண்டு பிடித்தவர் ஆசிரியர் ப்ரெட்ரிக் லேலியட் என்பவர் என்பதால் இது அதிசயமல்லவே.
கென்ட் பல்பலைக்கலகத்துக்குரிய மிகுந்த கடற்பாசிப் பரிசீலனைத் தொகுப்பு உலக அதி உன்னத இனங்காணல் தொடுப்பாபப் பருதப்படும்.

இவங்கையைச் சூழ வர்க கி. மி. 1600 சமுத்திரஅருகிலுள்ள பாசி வர்க்கத்தை இணங்காணுதல் தொடர்பாக ஆய்வுகூடங்களில் மேற்கொள்ளப்பட்ட ஆய்வுகளின் சாராம்சத்தை முன்வைக்க ஏபீசீ டாக்சா மூலம் ஆசிரியர் குலாமுக்கு பெரும் சந்தர்பம் கிட்டியது.

ஏபீசீ டாக்சாவின் ஆறாம் பகுதி ஆராய்ச்சியாளர்களையும் மாணவர்களைஞும் அக்கஜீவி வேற்றுமையின் ஆரம்ப சிட்டிக்காட்டிகளாள, அதன் முக்கி வழிகாட்டியளாக கருதுகின்றது. எனினும், பொருத்தமான போதனைகளின் பற்றாக்குறையும் சிலவேளைகளில் தென்பட்டன. ஒலீவியர் டாகன்ட் மூலம் வெளியிடப்பட்ட உன்னதமான எண்ணற்ற விளக்கப்படங்கள் பயிற்றுனருக்கும் பாமாருக்கும் மிக்க கவர்ச்சிகரமானவை.

ஆசிரியர் ஜாகீ எல் வான் கோதமி
RBINS இலாகா தலைவர்

Table of contents

1. Purpose of this book

In the first place, this book is meant to provide a summary of field and laboratory techniques in phycology (the study of algae), and their ecosystems. It also gives a glance to the dominant species of marine algae present along the coast of Sri Lanka. In addition, it should, therefore, be clear that the species described and illustrated here are only part of the marine flora of Sri Lanka, not at all a comprehensive Flora. It is an easy-to-use guide to the identification of the most frequent seaweeds, intended to be used by biologists, students, amateur naturalists, and others interested in the marine life of this island.

The taxonomic part covers the different groups of marine macroalgae (Chlorophyta or green algae, Phaeophyceae or brown algae and Rhodophyta or red algae). Numerous smaller seaweeds (mostly epiphytic ones) and turf algae (low, dense mats of grazed algae) are omitted although they can locally be a very important component of tropical and subtropical marine ecosystems, especially in heavily grazed areas. Encrusting coralline algae are not included as they are not well studied in the region and are mostly not easily identified by simple observation and descriptions. The prokaryotic blue-green algae (= Cyanophyta or Cyanobacteria) are not covered either.

Although the Sri Lankan seaweed flora has only been sporadically studied, it seems to be relatively rich, with about 440 taxa, belonging to 148 genera currently recorded along a coastline of 1585 km (Baldwin *ed*., 1991; Silva *et al*., electronic version).
The correct identification of seaweeds mostly requires the study of microscopic structures (see chapter 8.7). Therefore this guide represents a compromise between ease of use and technical detail. The photographs of the macroalgae in their natural environment, sometimes combined with herbarium and/or microscope pictures as well as the relatively detailed descriptions should enable anybody to identify these most frequent seaweeds in the field.

We do hope that this book may lead to an increased interest of local scientists and enhance the study of these beautiful and intriguing marine organisms. Although they generally go unnoticed, they are extremely important as primary producers along the shores as well as providing food, shelter, spawning areas and living biotopes for numerous animals.

2. Sri Lanka

2.1. Introduction (after Wright, 1994; Höfer, 1995; Perera, 2006)

According to the *Mahavamsa*, the modern history of Sri Lanka starts in the fifth century AC, with the arrival of Prince Vijaya together with 700 followers in Mannar. They called the island 'Thambapanni' (copper-coloured sand). These Buddhist Simhalese (originally from N India) are the ancestors of the actual Sinhalese majority of the population of the island who replaced the prior inhabitants, the Veddahs. The Greek sailors could not pronounce 'Thambapanni' and called the island 'Taprobane'. The seafarers of old Arabia called her 'Serendib', a word that has since evolved into the soothing state of mind known as serendipity (the faculty of making happy and unexpected discoveries by accident). Latter-day adventurers came up with the nickname 'Pearl of the Orient'. Another romantic, descriptive name for the island is 'The teardrop of India'. Marco

Polo called it 'the finest island of its size in the world'. In the 8th and 9th centuries the Moors had achieved a dominant commercial position but remained unobtrusive.

The first permanent Tamil settlements (coming from the Indian mainland) occurred in the 10th century AD, but mostly in the 12th century, without dislodgement of the original Sinhalese population. In the 13th century more violent invasions took place with the help of Tamil and Kerala mercenaries, resulting in the permanent dislodgement of the Sinhalese power from N Sri Lanka and the confiscation of lands and properties. These factors lead to the foundation of a Tamil Kingdom in that part of the island, next to several other Kingdoms, with a deliberate policy of peaceful migration of more Tamils.

The island was later called 'Ceilao', a corruption of 'Sinhala-dvipa' by the Portuguese, who ruled the coastal provinces during less than 60 years in the early 16th century; they introduced Roman Catholicism. The Dutch drove the last Portuguese from the island in 1658. They called the island 'Ceylan' and introduced Dutch Calvinism. In 1796 the British supplanted the Dutch in the coastal areas. They managed to control the Kingdom of Kandy in the Highlands in 1815, becoming the first European power to rule the whole island, now called 'Ceylon'. They introduced English calvinism. The British were unable to persuade the Sinhalese to work cheaply and willingly on the plantations, so they imported large number of Tamil labourers.

In February 1948 the island celebrated the return to its independence from foreign domination in a smooth and peaceful way. In May 1972 the country's name was finally changed to 'Sri Lanka' (officially the Democratic Socialist Republic of Sri Lanka), meaning 'Island of Happiness'. Its capital is Sri Jayawardenepura Kotte, the commercial capital being Colombo where the international airport and major marine harbour are situated. The population was about 20 million people in 2005. The languages are Sinhala, Tamil and English, each with their own alphabet. The religions are mostly Buddhist, but also Hindu, Christian and Muslim. The time zone is GMT + 5 ½ hours.

2.2. Location

Sri Lanka is located in the Bay of Bengal, in the northern Indian Ocean (Fig. 1), sharing the same continental shelf as India. The northernmost point of the island is Point Pedro. Talaimannar (at the tip of Mannar peninsula) is only 48 km apart (SE) from Dhanushkodi in India, separated from it by the Palk Strait in which numerous sandbanks and small limestone shoals form 'Adam's Bridge'. According to temple records, this natural causeway was formerly complete, but was breached by a violent storm in 1480. The island is situated between 5° 55' and 9° 50' N latitude and 79° 42' and 81° 52' E longitude. The drop-like island is 435 km long and 225 km at its widest part, totaling a surface of 65 610 km^2 and a coastline of 1585 km. Dambulla, famous for its ancient cave temple, marks the geographical centre of the island. The old harbour town of Dondra represents the island's southernmost tip. Beyond the lighthouse of Dondra Head there is not a single speck of land before the ice of Antarctica.

2.3. Geography and geology

The northernmost half of Sri Lanka is composed of a huge plain. The central part of the island is dominated by hills and mountains, culminating to 2524 m (Pidurutalagala, close to Nuwara Eliya). In some parts of the south, hills almost reach the coastline.

Fig. 1. General position and map of Sri Lanka with indication of sampling sites (red dots). Modified from map Base 802514 6-00, Library of Congress, Geography and Map Division, Washington, D.C.: Central Intelligence Agency, 2000 (digital id: http://hdl.loc.gov/loc.gmd/g7750.ct001762).

More than 90 percent of Sri Lanka's surface lies on Precambrian strata, some of it dating back 2 billion years. The metamorphic rock surface was created by the transformation of ancient sediments under intense heat and pressure during mountain-building processes. The theory of plate tectonics suggests that these and related rocks forming most of south India were part of a single southern landmass called Gondwanaland. Beginning about 200 million years ago, forces within the earth's mantle began to separate the lands of the Southern Hemisphere, and a crustal plate supporting both India and Sri Lanka moved toward the northeast. About 45 million years ago, the Indian plate collided with the Asian landmass, raising the Himalayas in northern India, and continuing to advance slowly to the present time. Sri Lanka experiences few earthquakes or major volcanic events because it rides on the center of the plate.

Actually, the rock floor of Sri Lanka is composed of gneisses and schists topped with a layer of graphite, crystalline limestone and quartzites. Several places are rich in gems (rubies, sapphire, amethyst, zircons, tourmalines, topaz, …) resulting in numerous gem pits in the middle of paddy fields (e.g. in the Ratnapura area).

The substratum of the sandy beaches (Fig. 2A) and lagoon bottoms can either be fine grained and of geological origin (erosion of rocks, Fig. 2B), coarser coral sand (Fig. 2C) or be composed of large calcified segments of decayed *Halimeda*, a green seaweed, the so-called *Halimeda*-sand (Figs 2D, E). The pore diameter increases relative to the amount of each sand-type, resulting in a different interstitial fauna.

Fig. 2. Sandy beach and soft substrates. A. Sandy beach (Kalutara); B. Colourfull, fine-grained sand of geological origin (Batheegama); C. Coarse coral sand, partly covered with some drift *Halimeda gracilis* plants and *Halimeda* sand (Weligama); D. Pure *Halimeda*-sand (Weligama); E. Seagrasses (*Cymodocea rotundata*) growing in *Halimeda* sand in a lagoon (Weligama).

2.4. The coastline

The major part of the West coast N of Colombo as well as of the E coast is composed of extensive sandy beaches (Fig. 3A), lagoons (Fig. 3D) and estuaries (Figs 3E, F). Along the sandy beaches, interrupted beachrock platforms can be present over long stretches, mostly parallel to the beach and close to low water mark (Fig. 4A). The landward margin of the visible part of these beachrock platforms is frequently covered by a thin layer of sand, evolving in a mostly rather steep beach (Fig. 4B). Some of the beachrock platforms are provided with numerous rock pools (Figs 4C, D). Locally a narrow, shallow lagoon can be present between the platform and the beach (Figs 4E-H). The seaward side of the platforms, generally abruptly ends with small vertical cliffs (0.5-2 m high), split up by crevices (Figs 5A, B). They are exposed to severe surf, forming a habitat with surf-resistant species (Fig. 5C).

Fig. 3. Coast types. A. Sandy beach and a few rock outcrops in the sea (Hambantota); B. A wide bay (Dickwella); C. An enclosed bay (Nilwella); D. Chilaw lagoon; E. An estuary; F. Estuary, sandy beach and small dunes (Hambantota).

Fig. 4. Beachrock platforms. A. Extended beachrock platforms at about low tide level (Chilaw); B. Extended beachrock platforms breaking down, at the foot of a steep beach (Chilaw); C. Intertidal pools on the beachrock platform (Chilaw); D. Intertidal pools on the beachrock platform and lagoon (on the right hand side; Beruwela); E, F. Broken-up beachrock platform and small lagoon (next to Dickwella Resort peninsula); G. Beachrock platform and narrow lagoon (Koggala); H. Beachrock platform and broad lagoon (Beruwela).

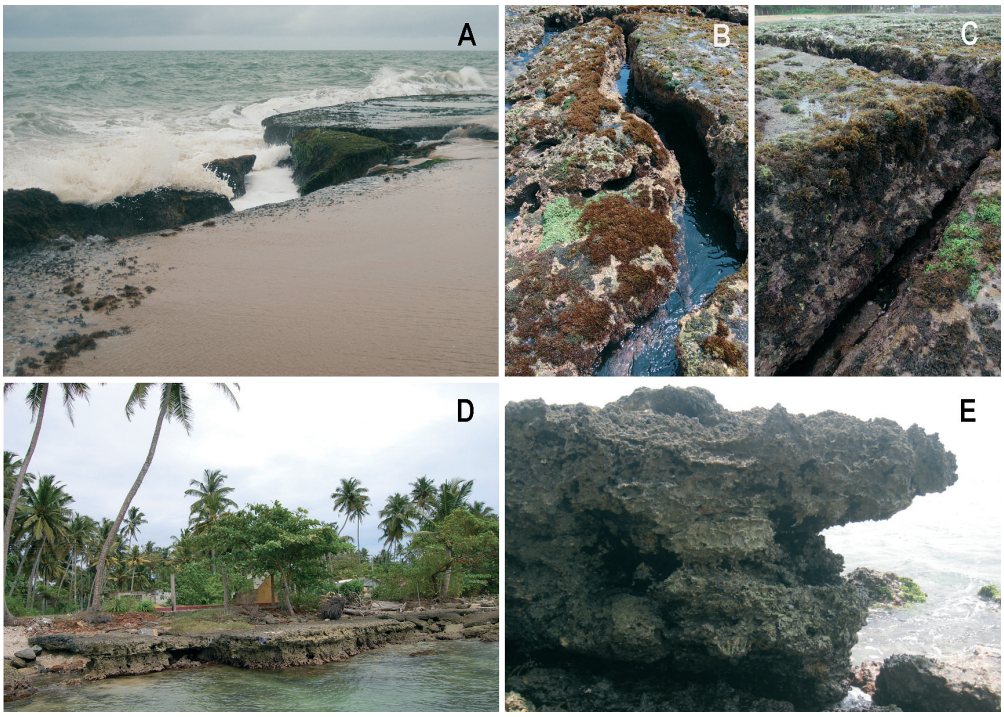

Fig. 5. Coast types. A-C. Broken-up beachrock platform with vertical walls covered by a typical surf-resistant seaweed vegetation (A, B. Chilaw; C. Hikkaduwa); D. Small cliff wall as the result of the erosion of a fossil reef (Polhena Beach, Matara); remark: the effects of the 2004 tsunami are still visible on land; E. Detail of a small eroded cliff wall of a fossil reef (Polhena Beach, Matara).

The southern coastline is characterized by the alternation of rocky coasts (Fig. 6A), rocky peninsulas (Fig. 6B), rock boulder areas (Fig. 6C) and wide or narrow sandy bays (Figs 3B, C; 6D, E). Some coast stretches are composed of small cliffs of eroded fossil coral (Figs 5D, E). A few places (Weligama, Hambantota/Usangoda) are characterized by short but high cliff walls (Figs 6F, G). Coastal dunes are rare, but if present they can be well-developed as in parts of Yala Park (Fig. 6H). Small islands (Figs 7A, B) or protruding rock boulders (Figs 7C, D) are scattered along the coast.

Submarine rock reefs and isolated submerged rocks are present all around the island. Real coral reefs are rather rare (e.g. Bar Reef at Kalpitiya (Fig. 7E), the lagoon reefs of Galle, Weligama, …). The once famous Coral Gardens in Hikkaduwa almost completely died off after the 1998 El Niño. In general, the sublittoral coastline drops gradually.

Fig. 6. Coast types. A. Rocky coast during the SW-monsoon (Dickwella); B. Surf-exposed peninsula (Tangalle); C. Rock boulders with a dense seaweed vegetation and marked zonation (Nilwella); D, E. Rocky peninsulas alternating with sandy bays fringed by beachrock platforms (Tangalle); F. Cliffs at Weligama; G. Cliffs alternating with sandy beaches (Usangoda protected area, Hambantota); H. Dunes alternating with beachrock and intertidal rocks (Yala).

Fig. 7. Coast types. A. Coastal islands (Beruwela); B, D. Large rocky outcrops in the sea and coastal beachrock platform (B. Koggala; D. Beruwela); C. Coastal island in Weligama Bay; E. Healthy coral reef close to Kalpitiya (Bar Reef).

2.5. Climate and seasons

Sri Lanka's climate is tropical. In the north-western parts of the island, there are some extremely hot areas, where temperatures occasionally climb above 38°C. Frost can occur on the highest mountain peaks, and snow has only rarely been observed. The coastal areas are subject to an almost continuous seabreeze, limiting the temperature to 30°C in daytime most of the year (up to 33°C in April) and 27°C at night (with a rare 22°C occurring occasionally). At Kandy (altitude 450 m) mean temperature drops to 20°C, whereas Nuwara Eliya (altitude 1890 m) can be as cool as 16°C. The 'seasons' are defined by the monsoons. They are seasonal winds that carry rain with them. These 'trade winds' were already used by the Greeks (1st century A.D.) for sailing.

The SW-monsoon brings heavy and prolonged rains from the Indian Ocean along the SW-coast between mid (to late) May and September. It enters the island in an area between Chilaw (N of Colombo) and Hambantota (in the south). The clouds hit the central highlands where they cause huge rains (locally up to 5000 mm per year) resulting in turbid coastal water (Figs 8A, 7B). On the other side of the mountain crest there is a rainshadow resulting in a dry season along the East coast. The second season (the Convectional Cyclonic Period or intermonsoonal months) occurs in October and November. Even then, sudden afternoon showers and thunderstorms can be abundant (Figs 8B, C), resulting in inundations, landslides and more turbid coastal water. Inversely, the NE-monsoon brings agriculturally significant rainfall from the Bay of Bengal to the northern and eastern parts of the country between December and March. The West coast is mostly dry in that period, but even then, late afternoon or night showers can periodically be frequent. During the convectional convergence period (mid April to late May) the island comes under the influence of the Inter Tropical Convergence zone. This is a constant daily weather sequence with bright clear mornings that induce convectional activities leading to the formation of rain clouds by early afternoon and thunderstorms in the late afternoon. The pre-monsoonal period (mid April to late May) has transitional weather patterns. During this time Convectional weather is gradually suppressed by the surges of the South West monsoon.

The coastal region East of Hambantota is much drier, resulting in a different, 'savanna-like' coastal vegetation.

Fig. 8. Thunderstorms and effect on coastal water turbidity. A. Turbid coastal water after heavy rains (Unawatuna); B, C. Late afternoon thunderstorms arriving during the SW-monsoon (Dickwella).

2.6. Currents, seawater temperature, salinity, tides and wave action

Indian Ocean surface currents are mainly controlled by the monsoon. Two large circular currents, one in the northern hemisphere flowing clockwise and one south of the equator moving anticlockwise, constitute the dominant flow pattern. During the winter monsoon, however, currents in the north are reversed.

Satellite images show that the average seawater surface temperature around Sri Lanka is between 26 and 28°C, being somewhat higher along the northern coast. It has been shown that individual seaweed species distributions over a biogeographic scale are overwhelmingly limited by seawater temperature regimes. Several tropical species are present in the Jaffna area but have not been observed south of Kalpitiya.

The maximum tidal range for the Sri Lankan coast is about 70 cm (Dayananda, 1992). There are two tidal cycles per day.

Along the southwest coast, both the swell and the waves are highest between May and September, this is during the SW-monsoon. The direction of the swell is very constant all over the year, approaching from the south, being 2.5 to 3.0 m high and with a frequence of about 16 seconds. The direction of the short waves is strongly influenced by the monsoons. During the SW-monsoon they vary from SW to W. Their height increases from April onward, reaching a peak in June-August and decreasing again to November (Scheffer *et al*., 1994).

Best underwater visibility is from March to April.