BIOME

ENVIRONMENT • SCIENCE • SOCIETY • TECHNOLOGY

ISSUE 01 | 2022

ISSUE 01 - 2022

CES BIOME

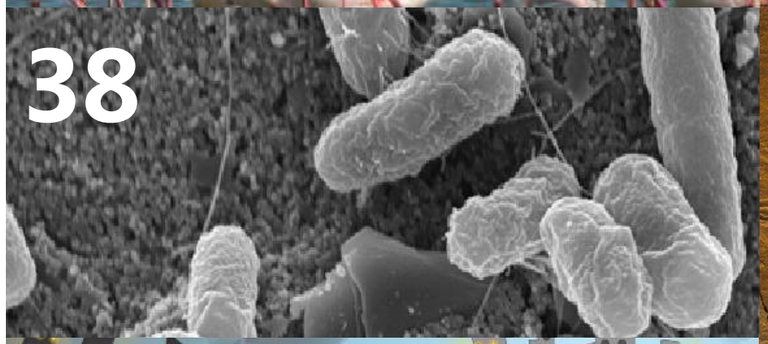
The CES BIOME is a biannual online magazine, which strives to provide verified and unbiased scientific knowledge to the general reader in a comprehensible manner through science, policy, news, and art related to environmental awareness.

Cover Art: Nadeela Hirimuthugoda

ON THE COVER: Crimson-fronted Barbet *Psilopogon rubricapillus* (Gmelin, 1788)

One of the 34 species of birds that are endemic to Sri Lanka, the Crimson-fronted Barbet, now also called Sri Lanka Barbet, is found mainly in the wet and intermediate zones of the island. A bird of the wooded areas, it may be observed up to an elevation of 1300 m above sea level, including the **Hantana** mountain range and the campus of the University of Peradeniya, where its slow **wok...wok...wok** or rapid **popopopop...popopop...popopopopopop** calls may be familiar sounds to an ardent birdwatcher. The bird is usually better heard than seen. The Crimson-fronted Barbet is a small-sized bird with predominantly green plumage and bright red forehead (part of its scientific name, *rubricapillus*, means 'red capped' or 'red crowed' from Latin ruber meaning red and capillus meaning capped or crowned). It also has orange around its eyes and throat. The base of the stout, strong bill has several tufts of bristles whose precise function is unclear. In fact, the first part of its scientific name comes from Greek psilos, meaning 'bare', and pogon, meaning 'beard'. The Sri Lanka Barbet usually lives in pairs or small groups. An entirely frugivorous species, it is attracted to trees when they are fruiting. It breeds mainly during the period from March to April. This elegant little bird undoubtedly adds color and beauty to the environment in which it lives.

Chaminda Wijesundara-Department of Zoology, University of Preradeniya



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ISSN 2950-6972

Editor-in-Chief's Welcome

Our mission

It is uncomfortable to think that we all are trapped in the only known habitable planet in our solar system or perhaps in the whole universe. Out of aprox. 13 million species living on earth, only one species, *Homo sapiens sapiens* became civilized and began to fast-track altering its environment to a point of no return. The quest of humans for world domination has led to an unprecedented level of ecosystem destruction and overexploitation of resources. With the current rate of utilization of limited resources and poor management, in the near future we might ended up fighting with our fellow humans for the last drop of fresh water and last ounce of sustenance. So, where should we start?

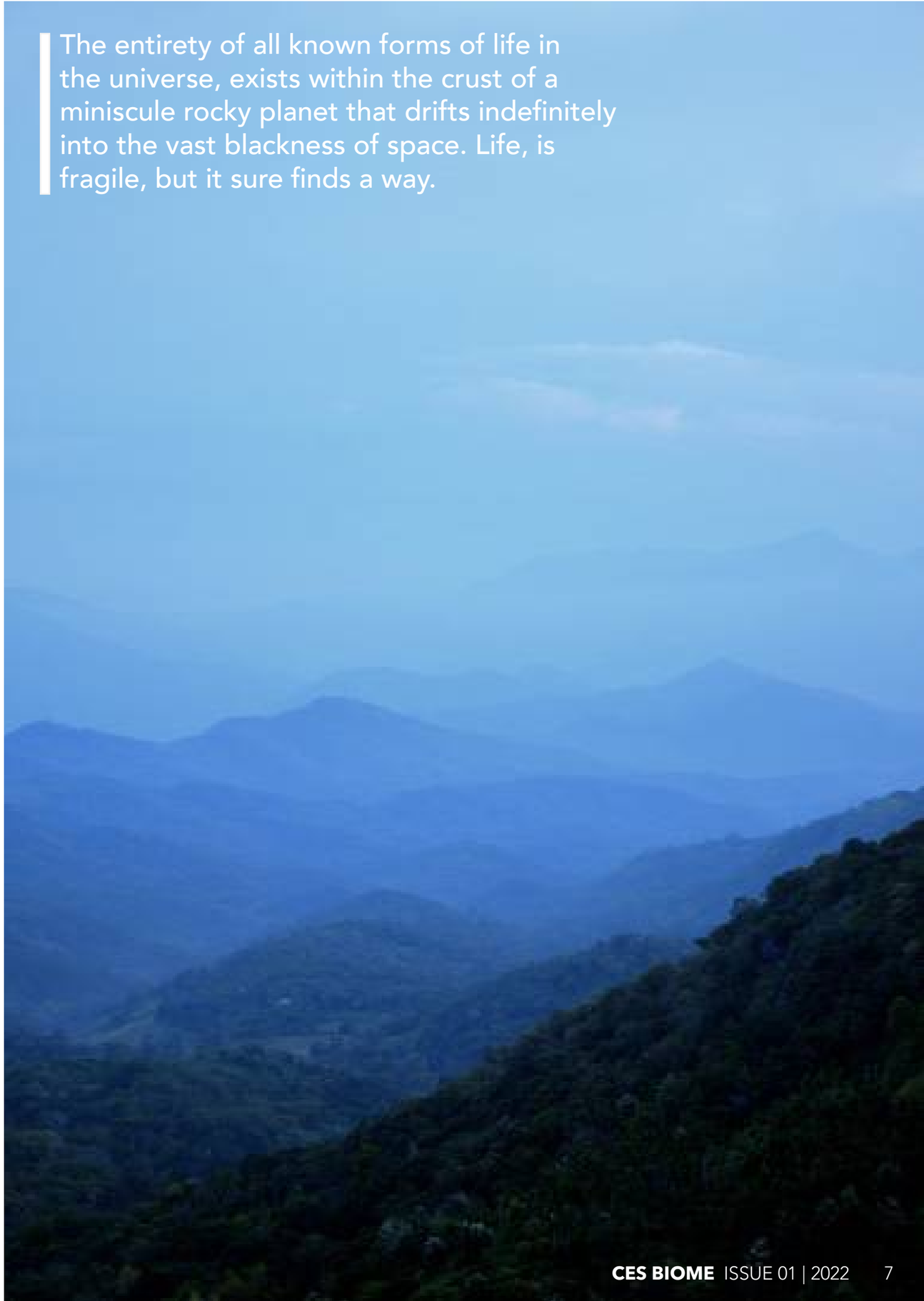
With the launch of CES BIOME, we are rekindling the urge for environmental awareness among people all over the world. Thus, I **welcome you to join with us** twice a year from 2022 onwards, to share the knowledge generated from environmental research and experiences and opinions of environmentalists. I hope that our effort on disseminating knowledge related to environment, would make a positive attitudinal change in the society to treat all life forms with respect and to wisely utilize natural resources, so that our future generations (not limited to humans) would not be deprived of the present-day comforts.

To kick-start the mammoth task of environmental awareness, in this issue, Professor Alwis opens discussion on the importance of experiential learning in environmental studies. Dr. Ukuwela summarizes the history of life on earth to remind us, that we are just one species which roamed the earth. Professor Marambe reports on the plans of COP26 to limit global warming to 1.5 °C above the pre-industrial era. You will be then exposed to how Dr. Turner and the team tackle seed supply chain logistics for restoration projects. Dr. Weeraratne and Professor de Silva report on mosquito breeding grounds, disease prevalence and control stratergies. How a virus made the air more breathable is explained by Dr. Elangasinghe. Even though our travelling was limited to grocery shopping during the pandemic, with the opening up of countries, Dr. Seelagama uncovers the greenwashing of so-called ecotourism. Having read Dr. Fernando's report on potential renewable energy production by microbial fuel cells, you are invited to continue exploring the rest of the interesting content.

Nalin Gama-Arachchige

Editor-in-Chief
CES BIOME

> The entirety of all known forms of life in the universe, exists within the crust of a miniscule rocky planet that drifts indefinitely into the vast blackness of space. Life, is fragile, but it sure finds a way.



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Director's Message

Introduction to CES

I am very pleased to send this message to the inaugural issue of CES BIOME, the digital magazine of the Center for Environmental Studies (CES). The CES was established in 1992 as a separate center of the University of Peradeniya to contribute to an environmentally informed and responsible society. Over the last three decades, the CES has rendered a valuable service both to the University and to the nation in the field of environmental education by conducting training programs and offering diverse consultancies. The CES was founded with the intention of disseminating sound environmental knowledge, developing skills necessary for efficient environmental management and inculcating sustainable environmental attitudes among the university students, professionals and the general public. The CES acted as the main academic entity that provided training in conducting environmental impact analysis for development projects since its introduction to Sri Lanka in the early 1990s. In doing so, it developed a close relationship with the government agencies, civil society, private sector and international organizations. The CES also contributed to improving general and professional environmental training both at undergraduate and postgraduate levels and played a key role in the dissemination of environmental information and research knowledge by assisting the University to implement a sustainable Environmental Management System.

It has been a long-awaited event to publish a magazine by the CES to disseminate contemporary knowledge and novel research findings in Environmental Science to the general readership. Therefore, the Board of Management of the CES has decided to publish CES BIOME as an online magazine from 2022 to fulfill the aforesaid requirement.

I would also like to take this opportunity to thank the Editorial Board of CES BIOME for their hard work and dedication for launching this magazine as planned. I sincerely wish CES BIOME to be very popular among those who love the environment and sustainable living.

Tilak Hewawasam

Director/Center for Environmental Studies
University of Peradeniya

Courses Offered by
Center for Environmental Studies (CES)
University of Peradeniya

Short Course
ISO 14001:2015
Environmental Management System

Course Content
- Environmental Management Systems and ISO 14001:2015
- Environmental Policy and Planing of EMS
- Implementation of EMS
- Checking and Management Review
- Environmental Management System Auditing

Duration
4 Days

For
Anyone who's interested in ISO 14001:2015

Short Course
Environmental Awareness

Course Content
- Introduction to Environment
- Environmental Issues
- Environmental Acts, Laws, and Policies
- Environmental Sustainability

Duration
5 Days

For
Postgraduates
Undergraduates

For More Details
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Regreen Hantana: Restoration of Degraded Lands

Deforestation and forest degradation cause cascading detrimental effects on biodiversity, ecosystem services and human wellbeing. Thus, it is crucial to restore degraded ecosystems in the world to reinstate ecosystem services provided by them for the future. The Centre for Environmental Studies (CES) of the University of Peradeniya has taken up the challenge to restore 6 ha of degraded lands in Hantana Environmental Protected Area (HEPA) under the 'Regreen Hantana Project (2022-2024)'. Presently, HEPA provides many ecosystem services including provisioning, regulation, cultural and supporting services. Moreover, the university community use this area as an outdoor laboratory to teach, learn and research on environment-related topics.

The aim of the 'Regreen Hantana Project' is to restore degraded sites in HEPA to reinstate ecosystem services for the future. More than fourteen native plant species have been already identified as potential plant species to transplant into the degraded site, which is located in between two woodland patches in Hantana. The transplantation of native species into the restoration site is scheduled to be conducted in November 2022. The multidisciplinary research component of the project including monitoring and evaluation is managed by a team of experts including academic and academic support staff members of the University of Peradeniya. Further, this project is conducted involving all stakeholders (Forest Department, Central Environmental Authority, local community, University community, private and public funding institutions) from project initiation.

Regreen Hantana Project will assist to achieve national and international commitments pledged under BONN challenge and will contribute to Sustainable Development Goals directly (Goals 3, 6, 13 and 15) and indirectly (Goals 4 and 14).

Thilanka Gunaratne (PhD)
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Image credits: Jagath Gunathilake, Tharosha Rajaratne, Thilanka Gunarathe, Nalin Gama-Arachchige

OPINION

Wake up to Experiential Learning – Living Lab with the Surrounding

The Real Opportunity in Environmental Studies and Research

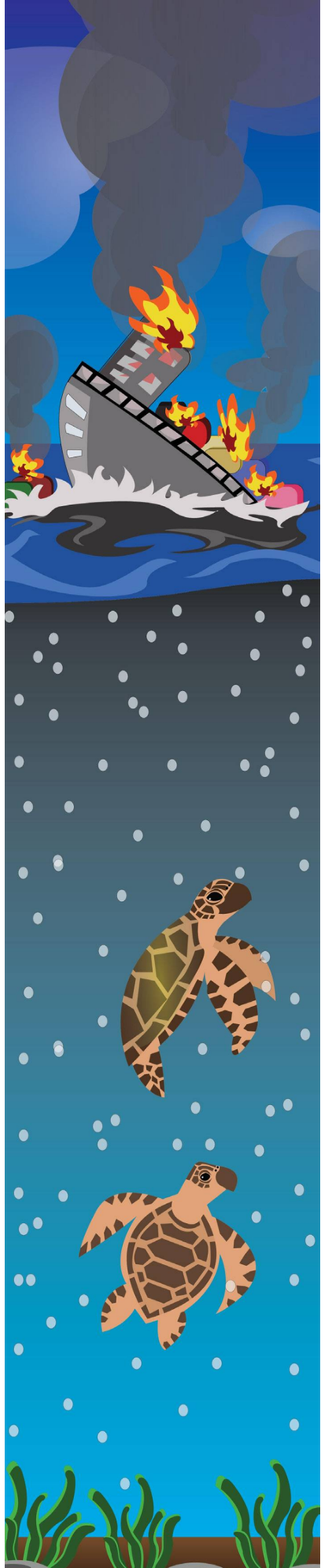
By Ajith De Alwis, PhD
Department of Chemical and Process Engineering, University of Moratuwa

One accusation that is coming our way as university academics is that we are not turning out graduates of value to the industry. This is not an attempt at entering into an argument over this comment through CES BIOME but an effort to highlight an aspect that we perhaps have ignored. There is no question that a graduate as an output from the university makes his or her presence felt by the individual or team contribution.The country moves forward with such inputs and that is universal knowledge. We also say that science-based decision-making plus high science literacy paves the way for the kind of development that we aspire to, to become a reality. Unfortunately, we observe that our society is much less appreciative of science and technology though one may crave for a smartphone and a high-definition TV display. We observe that as a result there is a widespread brain drain of certain groups of graduates from the shores of Sri Lanka to outside economies and they invariably become significant contributors to the economies to which they are migrating. Frequent observations of this phenomenon in some way lays bare the argument of the relevancy of the teachings in the university system at least in some sectors.

There is an element in university life that we appear to miss out. Instead of wasting reams of paper or disk space on endless theorems and proofs and formulas why not transform the teaching environment into a learning environment and propagate engagement for better learning. The engagement is with real-life scenarios and in fields like the environment, the lab can easily be the outside. With engagement, much more connectivity develops as well as perhaps a stronger bond as well and should lead to a reduction in brain drain. We just cannot live with the understanding that our graduates grow with one foot in Sri Lankan Airlines.

Experiential learning through participating in real issues and converting those into learning opportunities as well as turning the university into a living lab where there are more interactive exchanges than spending time on benches is the thesis indicated here. I find significant similarities when I see the classroom structures that are getting proposed with Industry 4.0. This is quite possible in environmental research and studies as the environment is right around us all the time and so much is going on at any given time.

Currently, in Sri Lanka, we have an economy that no one is happy to say is their own. Yet it is the upliftment of this economy that is going to salvage the nation and there is no other option. Can we connect and learn by doing? Just considering the public universities at any time in a year there may be more than 30,000 projects of different kinds. Consider the number of conferences and journals coming out of universities and even departments and faculties? An analytical look at the contents is quite revealing. Can we look at critical and emerging issues as research topics where we are not aware of the answer but have to dig deep and identify? Most of the time we settle down into doing projects where we almost at the beginning are aware of the answer or engage with too simplistic problems where certainly there is no problem in ensuring the degree at the end of the period. Such engagements hardly bring any value. The state must understand the importance of engagement of this human resource as those represent the future leadership. In connecting this resource to the outside the staff has the responsibility. Imagine the impact of relevant engagements and due to collaboration results quickly find their way as solutions. These are scenarios of potential impact similar to the power of compound interest. Remember Einstein who said that understanding compound interest is more difficult than the theory of relativity which he coined as the 8th wonder of the world!



Drawing: Chathura Jayaweera

The concept is especially recommended for environmental study programs. To explore this mechanism, consider the recent X-Press Pearl disaster off the coast of Colombo. This has been identified as the worst chemical and plastic-based maritime accident. Can we learn environmental science through engagement here? Yes of course. Not only one can learn science, technology, and law you will be learning crisis management and leadership through a unique event. The world's worst maritime event has appeared on our doorstep and with significant impacts. We are immersed in a quagmire of scenarios and there is so much to do. I would have loved to see the mobilization of resources such as research vessels belonging to the University of Ruhuna and Ocean University in addition to the research vessel of NARA – Samudrika – engaged in planned coordinated studies. The law has a definitive way of proceeding and it appears that it is unkind to the aggrieved in instances when the aggrieved is suffering due to a lack of resources. The penalty could be so severe to the aggrieved due to some of these technicalities, even though it is not a fault of theirs. A solution is for those who are learning in this space to converge to extend support and assist. This has to be done with control and in a planned manner as otherwise, the convergence of so many can ruin the environs and the results too. However, that too is learning through participation. It is indeed exciting to hear that tissue samples from the infamous 1919 Spanish flue survived to be analyzed after 100 years with the superior technology of the day leading to the disclosure that it was a bird flu variant. A significant number of turtle deaths during the accident period and this as an abnormal event is clear when compared with past data. Yet the abnormality must be connected with hard scientific data to the event in question. That is the reason for the title as we seek this relationship. As a whole ecosystem was affected the gamut of samples to be studied is not simple and the web of connectivity from the chemical cocktail that was unleashed from the ship through the fire, explosions, and release was so many. Sample collecting and archival in Sri Lanka need serious improvement. Experimental science is getting reduced to observing video clips and this is significant from a skill perspective. X-Press Pearl is

indicating the importance of early as well as consistent engagement. The accident offers to learn across many sectors – from biology, and chemistry to physics, from metallurgy to epigenetics, from local laws to international laws and conventions. One single event can have so much packed into one and indeed as this is globally significant. Someone's comment – albeit a research scientist – Yes we did watch it on TV to me indicates the disconnect of professional response and responsibility and this is not a behavior that has happened overnight but as a result of a way of learning. Today the purpose of coming to a university is so narrowly defined the entry is only what matters and after a while the position and the perks. X-Press Pearl is just one event even though that is one major event. Even taking the LPG issue that gripped the country for a while – this refers to the exploding burners and leaky cylinders and not the queue happening as now- had so many learning opportunities. I was happy to hear the statement of a young biogas developer recently who said that an installation of a biogas unit at home is one major unique selling point to be the multiple learning opportunities provided by a single unit – waste management, energy management, fertilizer and soil conditioner production, etc. This of course needs people to be able to see the trees with the forest and is a result of education that has been delivered with meaning and through the awakening of senses.

We have almost always agreed to multi-lateral environmental agreements from Montreal to Minamata. In our national communications, we use emission standard values in calculating the national contribution. However, when we calculate, we hear significant disagreements over library values (e.g. the estimation of methane emission from paddy fields). Also, there are interesting comments made over certain national standards being more stringent than EU standards. These are perhaps deviations that have come in from projects which have no life afterward but the errors may get perpetuated. An important contribution from universities would be the study of such standards and values and there could be an enormous learning opportunity as well as direct benefits to the regulator. More connectivity between regulators and students would result as well. The relevance of studies and research would be more. Concerning the Minamata convention, Sri Lanka stands between the two biggest emitters of mercury – India and China. It is of definite interest for us to know how much mercury emissions from these countries are affecting us. The University of Peradeniya has the only mercury measurement station in the whole country. A single researcher alone has a lot on his or her table to engage full time. If there is volunteer involvement you will have learning plus contribution again of high value. In the field of environment, so many examples could be stated to support the living-lab concept. Students can also make wherever they are residing into environmental monitoring stations. Those who are coming from a biological background enable generate a national biomonitoring network.

> “Within the university, the undergraduates should have strong connections to the postgraduate community with their research and study programs

Within the university, the undergraduates should have strong connections to the postgraduate community with their research and study programs. Through that linkage, the undergraduates should find more purpose in what they are studying otherwise, it is more or less abstract and rote learning. We are more worked up about documentation than on inculcating a passion for learning. When the environment changes to a living-in lab the transformation is possible. Otherwise, in today's context, education is been reducing to WhatsApp exchanges and photo sessions.

When the whole outside becomes your lab there is an enormous amount of resources that have been activated to support one's development. When there is an appetite for the incorporation of findings back as solutions then growth is an outcome. I remember hearing of Charles Darwin the student – the exercise to go out and collect some samples of life and bring them in. In one instance for sheer lack of space, the young Darwin placed a beetle in his mouth and the finding was a beetle with a peroxide generation possibility – the Bombardier beetle. Of course, he was also known for tasting each of the animals that he was studying. Now in the 21st century, we are seeking bio factories and these are nature's lessons for these possibilities. The lesson here is there are so many lessons to be had from nature as it has evolved over millions of years while finding and perfecting answers along the way. Man has tried to overcome challenges by sheer use of generated knowledge but ignoring nature. The disconnect needs to be reversed and for finding answers to tomorrow's questions that is why learning from and going back to nature is a strong recommendation. In environmental science, this is a real opportunity. The implementation of this comes from embracing experiential learning.

A Brief History of Life

By Kanishka Ukuwela, PhD
Department of Biological Sciences, Rajarata University of Sri Lanka

The planet Earth, which we live in, is home to an exceptional array of diverse organisms ranging from single cellular microbes to enormous organisms such as blue whales and California Redwoods. It is estimated that the planet Earth harbors about 10 million to 14 million species, of which only about 1.2 million are presently documented. Humans have always been interested in understanding how all of these endless forms came to be and especially their own roots. This is a 3.5 billion year old story still in the making for which I will try to simplify and summarize in nearly three thousand five hundred words.

The currently accepted theory to explain the origins of the biological diversity (=biodiversity) on earth was proposed by the British Naturalist Charles Darwin and Alfred Russell Wallace in 1858. According to this theory, all life on earth that exist today including all that have become extinct in the past, originated from a single common ancestor that acquired gradual transmissible (heritable) changes in successive generations through millions of years. Apart from the multitude of evidence for this theory called 'evolution', biologists reason that all living organisms on Earth must share a single last universal common ancestor (LUCA), because it would be primarily impossible that two or more separate biological lineages could have independently developed the many complex biochemical mechanisms common to all living organisms (Figure 1). Hence, LUCA is considered to be the most recent population of organisms that all organisms on Earth share common ancestry.

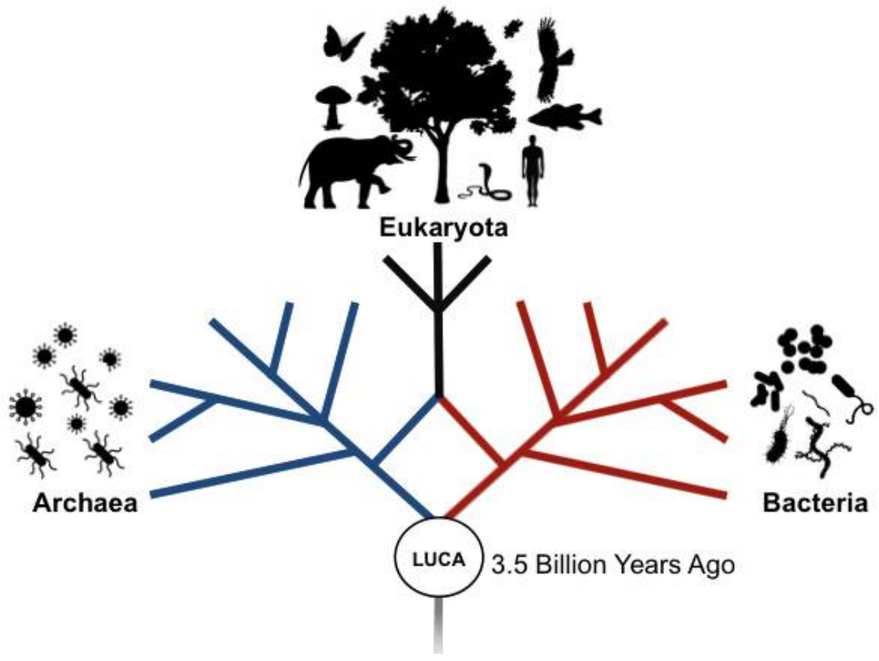


Figure 01. LUCA, the most recent ancestor from which all organisms on Earth descends and the three main lineages (domains) of life it eventually gave rise to.

Geological evidence, isotopic analyses of elements on earth and radioactive decay rates suggest that the Earth formed around 4.54 billion years ago. However, the oldest rocks on the Earth are estimated to be 4.28 billion years old. Cells, which are common to all life, are the basic structural and functional unit of life forms. The oldest undisputed evidence for fossilized cells that are believed to be of bacteria is dated to be 3.5 billion years old. It is thought that cells emerged from non-living chemicals and many theories have been proposed to explain the origin of cells. One of the popular theories suggest that chemical reactions that occurred in the ancient Earth produced many of the simpler organic compounds, including nucleotides and amino acids, that form the building blocks of life. An experiment by the two American chemists, Stanley Miller and Harold Urey in 1953 demonstrated that such molecules could form in an atmosphere of water, methane, ammonia and hydrogen. However, these chemical systems created in the laboratory fall far short of the minimum complexity for a living organism or even a simplest cell for that matter. Though many hypotheses are available, it is still a great mystery how natural processes helped to create self replicating cells packed with complex molecules such as DNA and RNA that pass information from generation to another and proteins.

Of the earliest bacteria that evolved on Earth, some (e.g. Cyanobacteria) developed the ability to synthesize simple carbohydrates from atmospheric carbon dioxide with the help of sunlight 2.4 billion years ago. This process termed photosynthesis, which is also common to all plants today, produced Oxygen as a by-product. This catalyzed a sudden, dramatic rise in atmospheric oxygen globally; making the environment less hospitable for other microbes that could not tolerate oxygen (anaerobes). This rise of global oxygen levels, which caused a remarkable transformation in the Earth, is called the Great Oxydation Event. Evidence for this Great Oxidation Event is recorded in changes in seafloor rocks that lack iron as they were removed as a result of oxidation due to the presence of Oxygen in the system. Rocks older than the Great Oxidation Event bear iron while rocks dating to after the event do not have iron in minerals that they are made of. Evidence of these ancient photosynthetic bacteria was preserved as hard structures called "stromatolites" as they made sticky mats of microbes that trapped sediments into layers about 2.4 billion years ago. Stromatolites could be seen today in places like Western Australia, Western Canada and Namibia (Figure 2). The earliest cells were very simple like bacteria and cyanobacteria, as they did not have very specific intracellular structures (organelles) to carry out specific functions. Especially

Figure 2. Stromatolites, fossilized mats of 2 billion years old cyanobacteria in Shark Bay, Western Australia

structures to store hereditary material (nucleus) and carry out photosynthesis (chloroplast) and aerobic respiration (mitochondrium). Such cells without organelles are called prokaryotic cells. It is hypothesized that an aerobic prokaryote and a photosynthetic cyanobacterium that started to live in a larger prokaryote in a symbiotic relationship (endosymbiosis) after being engulfed by the larger prokaryote lead to the formation of mitochondria and chloroplasts respectively. Structural and genetic similarities between certain aerobic prokaryotes, cyanobacteria and mitochondria and chloroplasts strongly support this idea. Molecular clock analyses (a method that estimates ages of biological lineages using mutation rates in DNA) estimate that endosymbiosis may have occurred about 2 billion years ago. Cells with a nucleus and organelles such as mitochondria and chloroplasts are termed eukaryotic cells and are however present in the fossil record from 1.8 billion years ago. These early unicellular organisms gave rise to three distinct biological lineages which are now recognized as the three domains of life by biologists; Bacteria, Eukaryota and Archaea (Figure 1). The domain Bacteria contains organisms with prokaryotic cells including cyanobacteria and bacteria while the domain Archaea comprises a distinctly unique evolutionary lineage of microorganisms with prokaryotic cells (Figure 1). All organisms that bear eukaryotic cells, which include both unicellular organisms and multicellular organisms such as plants, fungi and animals, are placed in the domain Eukaryota (Figure 1).

About 600 million years ago (mya), unicellular organisms began living together, probably due to the benefits such as efficient feeding and to gain protection from being bigger giving rise to multicellularity. Living in groups enabled these multicellular organisms to sustain the needs of the group by each cell carrying out a specific task leading to the division of labor. DNA based genealogical studies (molecular phylogenetics) suggest that multicellularity has evolved independently at least 25 times in eukaryotes and also in some prokaryotes, like cyanobacteria. However, complex multicellular organisms evolved only in six eukaryotic groups: animals, symbiomycotan fungi, brown algae, red algae, green algae,

> About 470 mya, a multicellular species of green algae left the ocean colonizing land and giving rise to land plants

and land plants. Multicellular organisms such as animals have evolved a high diversity of cell types (100–150 different cell types), compared with 10–20 in plants and fungi. To reproduce, true multicellular organisms had to produce reproductive cells (i.e. sperm and egg cells) that develop in to larger individuals upon fertilization through development and growth.

About 470 mya, a multicellular species of green algae left the ocean colonizing land and giving rise to land plants (Embryophytes). The evolution of land plants was one of the most important events in the history of life on Earth. This event had enormous effects on the environment of planet Earth by altering atmospheric composition, soil formation and hence affecting the climate and biogeochemical cycles. Fossils and molecular clock analyses indicate that the earliest plants may have looked like mosses and liverworts (bryophytes) that we see in moist places today. These early plants however, did not have typical roots, stems, leaves and most importantly specific tissues to transport water and food and thus were limited in size and distribution to moist habitats. About 420 mya, a new type of plants (vascular plants/ tracheophytes) with tissues to transport water (xylem) and food (phloem) along with strategies to control the loss of water appeared on earth. Once these features had evolved, there was an extensive diversification of land plants between 408-362 mya giving rise to earliest tracheophytes including club mosses and ferns, which are also common today (Figure 3). However, these plants were small and lacked flowers, seeds or woody tissue. The first real trees with woody stems bearing seeds (gymnosperms) evolved a little later about 300 mya. Though these gymnosperms (e.g. cycads, conifers) were the dominant land plants in the Jurassic period (208–145 mya), flowering plants (angiosperms) that appeared

Image credit: James St.

Figure 3. A fossilized fern, one of the earliest tracheophytes

Image credit: Rick Sharloch

Figure 4. The Ediacaran fossil *Dickinsonia costata* from Flinders Ranges, South Australia

around 200 mya became the dominant plants in the Cretaceous period (145–65 million years ago). With nearly 300,000 species, flowering plants are the most diverse plants on Earth today and they owe their success to the presence of flowers, fruits with seeds, and a distinctive life cycle. The angiosperm flowers especially with colours and adaptations made sure they are pollinated by various strategies.

Meanwhile, a group of heterotrophic (organisms that depend on other organisms to obtain food) unicellular organisms known as choanoflagellates began to form clusters and cooperate to form the first multicellular animals. This hypothesis is supported by similarities of choanoflagellates to certain cells in multicellular animals and their DNA. It is believed that the very simple aquatic organisms called sponges (phylum: Porifera) were the first multicellular animals to have evolved and the oldest fossils of sponges dates back to 580 million years. The first complex multicellular animals with organized and differentiated multicellular structure also began to appear during this time in the Ediacaran period (600-538 mya).

The Ediacaran animals were small (millimetres to metres) and displayed a variety of body forms (Figure 4). The period between 538–485 mya (Cambrian Period) was one of the most significant periods for the evolution of Earths' biodiversity. Within a short period of 13–25 million years in the Cambrian Period, animals representing almost all major animal phyla (both invertebrate and chordates) evolved. This rapid emergence of a plethora of diverse forms is termed the Cambrian explosion. The rapid explosion of diversity resulted in the emergence of varied body forms with hard body parts like shells and spines and life styles such as burrowing, attached and free living. At the same time, a move towards the evolution of more active animals, with defined heads and tails for directional movement to pursue prey also occurred.

The chordates, which also originated during the Cambrian explosion, comprise animals with a notochord (a flexible rod formed from material similar to cartilage), nerve chord, rudimentary vertebrae, and a well-defined head and tail. They mostly include the well-known

animals with a vertebral column; modern day fish, amphibians, reptiles, birds and mammals. However, the earliest chordates lacked jaws (jawless fishes) and they depended on filtering water to feed. The first jawed chordates appear in the fossil record about 445 mya, which diversified in the Devonian period (420-360 mya). In some of these jawed fishes, the notochord was replaced by a bony vertebral column, producing the vertebrates. However, the only vertebrates that were present during this time were three groups of fish, cartilaginous fish (chondrichthyes), the ray-finned fish (actinopterygii) and lobe-finned fish (sarcopterygii). By the middle of the Devonian, it is believed that several droughts and also oceanic competition led some lobe-finned fish to leave water, eventually establishing themselves as terrestrial tetrapods (four-limbed animals). The limbs of these tetrapods, which supported them on land evolved from fins and this was the origin of the amphibians, the first tetrapods. The change from a body plan evolved for breathing and traversing in water to a body plan to move on land is one of the most profound evolutionary changes known and it is called one of the 'great transitions' of life (Figure 5). The Carboniferous period (360–298 mya), which followed the Devonian

> "The change from a body plan evolved for breathing and traversing in water to a body plan to move on land is one of the most profound evolutionary changes

vertebrates. Amphibians were still highly dependent on water since they had to go back to water to lay eggs, as their eggs did not have protective membranes including a shell to prevent desiccation. About 20 million years later, a group of amphibians gained the ability to lay eggs covered with protective membranes (amniotic egg), which allowed them to lay eggs on land. These animals that laid amniotic eggs are termed amniotes and they eventually gave rise to three distinct lineages of terrestrial vertebrates; reptiles, birds and mammals. Reptiles comprise turtles, crocodiles, lizards, snakes, tuataras and extinct dinosaurs. Reptiles increased in their diversity and dominated the world in the Mesozoic era (consists of Triassic, Jurassic and Cretaceous periods) and thus is termed as the age of the reptiles. The Mesozoic reptiles were mostly dinosaurs, a diverse group

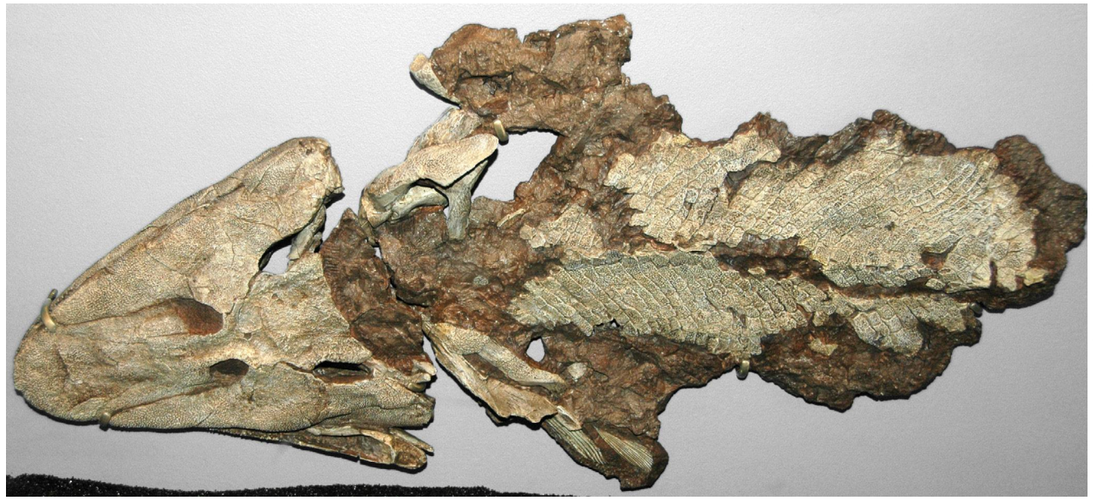


Image credit: James St.

Figure 5. *Tiktaalik roseae*, a 375 million year old fossil lobe-finned fish from Canada that shows intermediate features between fish and early amphibians.

period (429-329 mya), is sometimes called the age of the amphibians since amphibians diversified and became the dominant terrestrial

of small (5 cm) to enormous (40 m) animals that were popularized by the novel Jurassic Park by Michael Crichton and the movie of the same

Image credit: Denise Chan

Figure 6. *Archaeopteryx lithographica* from Germany is an ideal transitional fossil between non-avian dinosaurs and birds.

name. Dinosaurs were either herbivorous or carnivorous and egg layers and some of them even had their bodies covered with feathers like birds. Some of these smaller dinosaurs with feathers initially began to glide short distances either to chase prey or to evade predators. This is believed to be the birth of birds and transitional fossils dated to be 150–120 million years old having both dinosaur and bird like characters have been found (e.g. *Archaeopteryx*) (Figure 6).

Evolution of flight is another great transition of life. Because birds evolved from dinosaurs, birds are also called avian dinosaurs while the typical dinosaurs are called non-avian dinosaurs. The reign of the dinosaurs on earth lasted for nearly 250 million years, and at the end of the Cretaceous period (145-66 mya) all of the non-avian dinosaurs became extinct most likely due to an asteroid impact that caused volcanic eruptions (Cretaceous-Paleogene extinction event). However, some of the avian dinosaurs (i.e. birds), crocodiles, lizards, snakes and amphibians survived this extinction event and today lizards (7000), snakes (3900) and birds (11000) are the most diverse groups of vertebrates in the world.

There was another lineage of vertebrates that survived the Cretaceous-Paleogene extinction event. Their origins date back to a group of reptiles of the late Carboniferous period which had a skull different from other reptiles that gave rise to dinosaurs, birds, crocodiles, turtles, lizards and snakes. This distinct group of reptiles gave rise to mammals in the Triassic Period, which include animals that we are very familiar with including us. Mammals

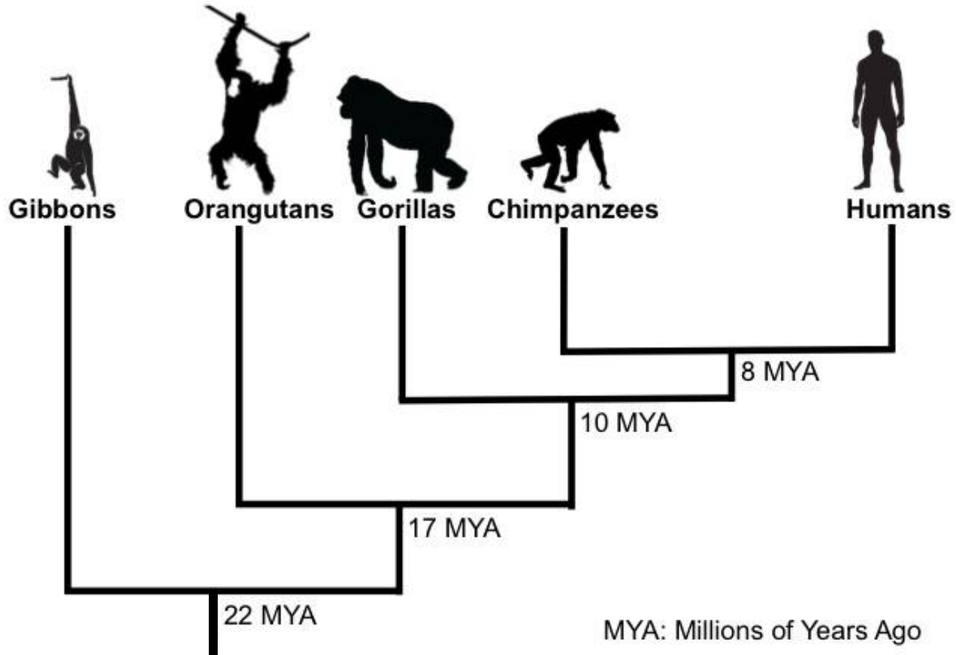


Figure 7. Hypothesized evolutionary relationships of apes based on DNA. The lineages that gave rise to humans and chimpanzees separated about 8 million years ago.

are generally, hairy, give birth to live young and feed their' new born with milk produced in the females mammary glands. However, the earliest mammals were egg layers and descendants from some of these egg-laying mammals (monotremes) are still in existence today in Australia and New Guinea. Mammals were a diminutive and a secretive group of animals in the Mesozoic era, but they diversified and became the dominant group when the non-avian dinosaurs became extinct at the end of Cretaceous. Two more distinct lineages of mammals (placental mammals and marsupials) also evolved in the Jurassic Period. The placental mammals contains the vast majority of extant mammals and are distinguished from marsupials by having a fetus carried in the uterus of its mother to a relatively late stage of development. Placental and marsupial mammals (e.g. Kangaroos, Koala, Opossums) diversified into many new forms throughout the Paleogene (66–23 mya) and Neogene (23–2.58 mya) periods filling ecological roles vacated by the dinosaurs. Around 74–63 mya, a group of small terrestrial mammals developed large brains, acute color vision, a shoulder girdle that allows a greater degree of movement in the shoulder joint, and dexterous hands as an adaptation to life on trees. These early arboreal mammals gave rise to the group of mammals that we today call primates, and they include lorises, tarsiers, monkeys, gibbons, gorillas, orangutans, chimpanzees and us. About 8–7 mya, some of these large tree dwelling primates left trees and gradually evolved for bipedalism. It is not exactly known why these large primates we call great apes left trees, but it is believed that decreasing tree cover due to increasing dryness caused by global climatic changes may have caused these tree dwellers to abandon a life on trees. Bipedalism, the ability to walk on two legs is one of the earliest human defining traits and it is estimated to have evolved about 4 million years ago. Genetic and fossil evidence suggest that this transition from trees to ground occurred in Africa and thus is considered to be the birthplace of humanity. However, long before anatomically modern humans (*Homo sapiens*) arose about 300,000 years ago, it is believed that nearly 10 to 20 ancestors of humans existed on earth. However, the closest living relatives of modern humans are chimpanzees, which shares nearly 99% of their DNA with us. But this does not mean that we evolved from chimpanzees, but rather we shared a common ancestor with them about 7–8 mya (Figure 7). Modern humans who evolved in Africa then dispersed all the over world and along the way developed tools, language, culture and civilization.

Evolution of life on Earth was not without setbacks. The setbacks were caused by extinction events, which are widespread events of rapid loss of biodiversity on Earth. Such an event is indicated by a distinct change in the diversity and abundance of multicellular organisms in the fossil record. It occurs when the rate of extinction exceeds the rate of speciation (i.e. evolution of new species from extant species). Scientists believe that life on Earth has experienced at least five major extinctions. Extinctions are not all bad for the biological diversity on Earth. It is a natural process that paves way for entirely new groups of organisms to establish on Earth. Such as the Cretaceous-Paleogene extinction event that took place 66 mya, which allowed the surviving mammals and birds to proliferate and become dominant groups of animals on Earth. However, the Earth is currently going through its 6th mass extinction caused by anthropogenic events. The current rate of extinction of species is estimated at 100 to 1,000 times higher than natural extinction rates. The earliest examples for human mediated extinction come from the extinction of megafauna (i.e. large terrestrial animals that are >46 kg) following human colonization of Australia, New Zealand and Madagascar. Though humans mainly caused these early extinctions in these islands through hunting, the major contributors to species extinction today are habitat loss, overharvesting, introduced species, pollution and climate change. Since all organisms on earth are intricately linked to each other through ecological and biogeochemical processes, at least for our own sake, we need to ensure the continued persistence of ecosystems and the organisms that live in. Thus, it is high time that we begin to take steps towards reducing the extinction rates to natural levels for our own existence.

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The Outcome of the 26th Conference of Parties of the United Nations Framework Convention on Climate Change

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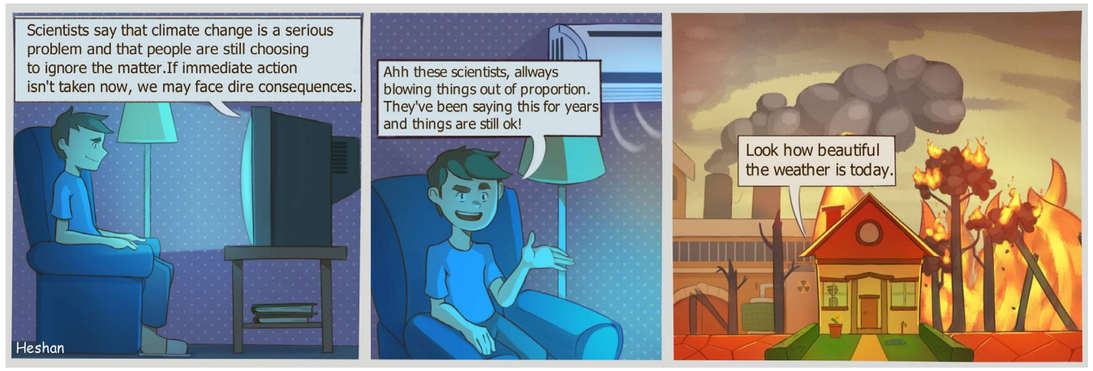
The United Nations Framework Convention on Climate Change (UNFCCC), one of the three Rio Conventions of 1992, was set out to stabilize greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system. The UNFCCC provides the basic legal framework and principles for international climate change cooperation and negotiations. The UNFCCC was also the first multilateral agreement on climate change to reduce GHG emissions. Under the UNFCCC, the industrialized countries and countries undergoing the process of transition to a market economy (Annex I Parties; UN, 1992) have agreed to regularly report on their climate change policies and measures and submit an annual inventory of their GHG emissions to the Conference of Parties (COP), which is the supreme decision-making body of the Convention. The Non-Annex I Parties (UN, 1992), however, were reporting on their adaptation and mitigation actions in more general terms and less regularly to the COP, provided that they receive the necessary funding. The 26th COP was held in Glasgow in United Kingdom in 2021.

The Paris Agreement (PA) under the UNFCCC, which was the outcome of the negotiations launched in 2011 at the 17th COP in Durban, South Africa, was adopted in December 2015 and entered into force in November 2016. Sri Lanka became a signatory to the PA on 22 April 2016. The objective of such negotiations was to develop a legal instrument applicable to all Parties to cut GHG emissions and to be implemented by 2020. The PA, which aims to strengthen the global response to climate change by keeping a global temperature rise this century well below 2 °C above pre-industrial levels, added a new dimension to the consideration of agriculture and food security under the UNFCCC.

The PA was able to bring all nations into a common cause for the first time, to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries. The agreement explicitly acknowledges the need to promote and ensure environmental integrity and calls on Parties to conserve and enhance GHG sinks and reservoirs, including biomass, forests and oceans, as well as other terrestrial, coastal and marine ecosystems, while promoting and ensuring sustainable development. The PA not only reiterates that the need to ensure food production is not threatened while reducing GHG emissions, but also recognizes the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the impacts of climate change.

COP26 objectives:

The 26th COP (COP26) at Glasgow was held with the primary objective of securing global net-zero, i.e. total emissions are equal to or less than the emissions removed from the environment, by mid-century and keep a maximum of 1.5 °C of warming within reach. The objectives included accelerating the phase-out of coal and mobilizing at least USD 100 billion in climate finance annually. With nearly 200 countries participating, the two key highlights of the 13-day long COP26 were (a) completing the rulebook of the PA, providing the guidelines on how the PA is delivered, and (b) signing the Glasgow Climate Pact setting out what to be done to tackle climate change.



Drawing: Heshan Abayakoon

At the commencement of Glasgow summit, the commitments made by the country parties had placed the world on a trajectory for about 2.7 °C by the end of this century, well beyond the 1.5 °C goal. However, pledges committed by India during the initial days of the conference to reach net-zero emissions by 2070 and generate 50% of its energy from renewables by 2030 helped the world to lower the trajectory to 2.4 °C.

A careful analysis of the commitments made by the global community in their GHG emission reduction efforts indicates that the temperature rise by the end of this century could be kept to around 1.8 or 1.9 °C, falling short of the expected maximum of 1.5 °C. The 2030 targets set by major emitting countries such as Australia, China, Saudi Arabia, Brazil and Russia were very weak, without credible pathways to achieve their net-zero targets.

By the end of COP26, 151 countries, including Sri Lanka, had submitted the updated climate plans in the form of Nationally Determined Contributions (NDCs), showing the conditional and unconditional efforts to cut emissions by 2030. Despite the low carbon footprint of the country with a per capita GHG emission of 1.02 tons in 2010, a global cumulative GHG contribution of 0.03% in 2019, and being highly vulnerable, Sri Lanka has committed to increasing forest cover up to 32% by 2030 and reduce GHG emissions by 14.5% from 2021 to 2030 from Power (electricity generation), Transport, Industry, Waste, Forestry, and Agriculture, and to achieve carbon neutrality by 2050. These efforts include 4% unconditional and 10.5% conditional emission reduction commitments compared to Business-As-Usual (BAU) scenario.

The Glasgow decision thus, calls on countries to revisit and strengthen their 2030 targets by the end of 2022 to align them with the temperature goals of the PA. The decision also requests all countries to submit long-term strategies for 2050 (those countries who have not done it yet) aiming for a just transition to net-zero emissions around mid-century. Parties have agreed to have the next round of climate talks in November 2022 (COP27) in Sharm el-Sheikh in Egypt, with stronger commitments to put the world on track for 1.5 °C.

> “ Sri Lanka has committed to increasing forest cover up to 32% by 2030 and reduce greenhouse emissions by 14.5% from 2021 to 2030

COP26 outcome on climate action:

The conference at Glasgow was the first time in the COP history that coal or any other fossil fuel had been mentioned as a cause of climate change. The parties finally agreed to use the language "phase down" the use of unabated coal (coal that is not mitigated with technologies to reduce the CO_2 emissions) rather than a "phase out", deviating from one of the key objectives of having COP26. This would result in a 76% decrease in planned new coal power plants. Furthermore, more than 135 countries committed to "halt and reverse forest loss and land degradation" by 2030. The Glasgow Climate Pact, which is not legally binding, comprised a series of decisions and resolutions that were build on the Paris accord, but do not include what each country must do to tackle climate change. Some of the highlights of COP26 are,

- The Paris Rulebook was completed after six years of negotiations.
- Parties (countries) agreed to phase down unabated coal power and end inefficient fossil fuel subsidies.
- More than 100 parties aim to reduce methane emission by at least 30% by 2030.
- 137 parties agreed to halt deforestation by 2030.
- India announced net-zero emissions target by 2070.
- China and USA, the two world's largest GHG emitters, announced that they will boost the cooperation on climate action to keep the goals of the PA within reach.

COP26 outcome on climate financing:

At the beginning of COP26, the developed country parties were not able to provide the USD 100 billion a year target in climate finance, which was promised a decade ago. However, the parties agreed to reach the target within the next two years. Making a significant change in the focus on climate financing, COP26 made developed countries agree to at least double the financing of climate adaptation by 2025. It would amount to at least USD 40 billion and is a significant milestone in addressing the imbalance between funding for mitigation and adaptation efforts. Usually, the adaptation finance amounts to only 1/4th of the total climate finance. As a result of the COP26 negotiations, the Adaptation Fund received unprecedented new pledges for USD 356 million, representing almost three times its mobilization target for 2022. the Developing Country Parties welcomed this decision that would benefit economic sectors, especially agriculture. The Least Developed Countries Fund (LDCF) also received USD 413 million in new contributions. However, more international climate finance is needed to help developing countries increase their resilience to the climate impacts. The UN Environment Programme has estimated that adaptation funds will need to quadruple by 2030 from today's USD 70 billion.

Furthermore, the COP26 also succeeded in having commitments totaling to USD 130 trillion in private capital to net zero, and USD 1.7 billion was pledged for indigenous people and local communities to make them more climate resilient. The country parties created a new dialogue to discuss funding possibilities for loss and damage (L&D; to avert, minimize and address loss and damage associated with climate change impacts, including extreme weather events and slow onset events). Though insignificant in quantity, Scotland pledged USD 2.6 million and Belgium USD 1.1 million to address L&D. These pledges were the first of their kind. The country parties also agreed to operationalize and fund the Santiago Network on L&D, established at COP25 in Madrid, Spain. The L&D is likely to be one of the more significant issues leading up to the COP27 summit in Egypt.

Conclusion:

The COP26 outcome increased the ambition to keep the PA's aim to limit global warming to 1.5 °C above pre-industrial levels. The Glasgow Climate Pact made countries agree that carbon emissions should fall by 45% by 2030 to meet the 1.5 °C goal. The COP26 failed to phase out coal power though the President of COP26 had urged negotiators to "consign coal power to history", but ended up with phase down. Although the Adaptation Fund received an enhanced commitment, the COP26 did not resolve the climate funding challenge. There seems to be a long way to go in achieving financial commitments.

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Drawing: Heshan Abayakoon

Enhancing Seed Supply of Native Australian Species for use in Restoration

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Seeds of wild plant species are at the heart of landscape-scale restoration which in the UN Decade on Ecosystem Restoration is becoming of paramount importance. To enhance the utilisation of valuable wild seeds, restoration seedbanks are becoming a vital instrument globally to support the remediation of human caused environmental problems. As a consequence, these seedbanks represent a significant ongoing investment in restoration capacity though at their heart lie many challenges. Seedbanks by their very nature are repositories of precious seeds most of which is currently wild harvested, so require best practice management to sustainably source and maintain high quality seeds as well as their delivery to site in a form where they will readily germinate. Low seed quality, and limited seed numbers as well as poor understanding of seed biology and ecology can frustrate attempts to re-instate biodiverse plant communities either through direct seeding or the ex situ use of seeds for the production of greenstock (i.e. seedlings) for later field planting. With the growing recognition of the importance of landscape-scale ecological restoration in biodiversity protection comes increasing demands for biological and technical knowledge of seeds and in particular, their responsible and sustainable sourcing, harvesting, storage and use.

The production of seeds represents the culmination of resource investment in a series of high-risk life stage transitions (i.e. flowering, pollination, seed maturation) that can significantly stress *in situ* plant populations. Consequently, plants may be unable to compensate for sudden losses in seed outputs as a result of excessive harvesting. Overharvesting from wild populations, both in scale and frequency, can lead to altered regeneration dynamics and population declines which may be exacerbated when populations are under additional pressure such as fragmentation, weed encroachment and herbivory. Such declines could potentially lead to a loss of resilience for the whole ecosystem, particularly as climate change is expected to reduce seed production rates and alter seed maturation and in situ seed persistence across many different ecosystems. The impact of overharvesting is likely to be particularly pronounced for short- lived non-clonal plant species, for which high-intensity annual harvesting can increase local extirpation. If species are pushed beyond their adaptive capacity, the adverse impacts of systemic overcollection on wild seed production will become increasingly pronounced, and the cumulative depletion of seeds over multiple seasons may push species with short generation times and narrow bioclimatic niches closer to extinction thresholds.

Consequently, a critical aspect of managing seeds for use in restoration is the sustainable sourcing of seeds. In recent times, the global demand for restoration services and in particular, wild seeds have increased significantly with many thousands of tons of native seed now required each year to support global restoration efforts. Currently, the vast majority of seeds used for restoration are sourced from wild populations often at levels

well above what is sustainable in the medium to long term. Ethical seed sourcing now represents a core issue in responsible restoration practice which has at its heart many different elements to consider. Solutions include the introduction and active enforcement of regulatory frameworks controlling seed sourcing from wild populations, advancement of seed enhancement technologies and precision delivery systems to reduce seed wastage and critically, the development of seed farming capacity and in particular seed production areas (SPAs) to transfer reliance of seeds harvesting from wild collection to agronomy-based *ex situ* production systems that reduce collection pressure on wild populations.

The use of seeds in minesite restoration

Seed-based approaches underpin the ecological restoration of post mining landscapes with a critical aspect of these works being the broadcasting of diverse mixes of native seeds after ground works have been completed. Resource extraction companies often depend upon restoration seedbanks to supply native seeds for rehabilitation and restoration programs. Although many native species can be re-established in the post mining environment via spreading stockpiled topsoil, the availability and integrity of topsoil can vary markedly among different ecosystems and mining approaches. As such, the supplementary sowing of native seeds remains critical to the rapid reestablishment of native species and, importantly, to the reassembly of self-sustaining ecosystems.

Nevertheless, one of the major factors affecting minesite restoration is seed availability as many species are difficult to collect sufficient numbers of seeds. Collection of seeds from wild populations can be affected by various abiotic and biotic factors that impact seed productivity. For example, like agricultural systems the harvesting of wild seeds is often impacted by natural conditions, such as drought, heat waves and fire which can affect pollination, seed set, maturation, viability and ultimately, seed quality. As well, collection can also be negatively impacted by seed predation (e.g. insects and fauna) and by human actions such as roadside maintenance, controlled fires, and animal movements. Consequently, due to the large volumes of seeds required annually for restoration works and escalating environmental pressures on native plant populations, other more reliable and sustainable sources of native seeds are becoming more desirable to supply the substantial volumes of seeds needed for current and future minesite restoration programs.

Seed production areas

Seed Production Areas (SPAs) are purpose designed for the cultivation and ultimately the large-scale production of wild seeds from a range of species which are managed using principles and approaches typically seen in agriculture and horticulture production systems. The rationale for a SPA is to reliably provide high quality seed for use in the production of greenstock or for direct seeding onto restoration sites.

The advantages of SPAs include:

- Improved consistency and reliability of seed availability.
- The production of seeds from species that are rare or difficult to collect sufficient amounts from wild populations.
- The production of large volumes of seed that can be stockpiled for use across different projects and years.
- Reduction in harvesting pressure from vulnerable wild populations
- Genetically appropriate mother stock sourced from suitable provenance boundaries.
- Reduction in collection and processing costs.
- Enhanced seed quality by providing ideal seed maturation conditions and the control of pests and diseases.

For example, Alcoa Australia began to explore and develop SPAs in southwest Western Australia back in the 1980's as a way to bolster and manage the amount of native seed available for restoration purposes following bauxite mining. A range of species and approaches were trialed over many years and as the ideas and horticultural expertise developed and matured, emphasis was placed upon the cultivation of a range of common understory species that were in short supply. Multiple plants of target species were maintained in pots on benches where they could be intensively managed and regularly inspected for health, growth, pests, diseases and reproductive status as well as watered regularly, fertilised and pruned as needed (Figure 1).

Figure 1. Collection of >50 different clonal lines propagated from field collected cutting material (representing most of the remaining in situ plants) of the critically endangered *Androcalva perlaria* (Malvaceae) established as an ex situ potted collection which were used to produce over 100,000 viable seeds for conservation purposes and scientific study.

Wild species by their very nature are highly diverse and horticulturally unknown so more often than not there is a steep learning curve when it comes to the successful cultivation of native plants for the production of seeds. Critically, the development of a range of agronomic techniques centred around optimising irrigation, fertiliser application and horticultural management of plants needs to be individually tailored for each species incorporated into the SPA. Moreover, effective methods of seed harvesting may also need development and the impact of cultural conditions on seed quality, seed dormancy and germination capacity all need to be quantified and clearly understood. For example, Alcoa Australia produced over 8 kg of native seed from their potted native plant collection in 2003/03 consisting of ~10 local native understory leguminous species. As well, for the species *Banksia dallanneyi* overall productivity under nursery conditions was found to be much higher compared to field-grown plants as cultivated plants had much lower seed predation rates and higher seed set due to better growing conditions (i.e. regular watering and fertiliser) highlighting the benefits of using SPAs.

A variation on this approach is the in situ establishment on old agricultural land of SPAs for priority species as a solution to supply large

volumes of native seeds in marginal rainfall environments. Over the last few years, a team of scientists from Curtin University's ARC Centre for Mine Site Restoration (CMSR) has helped to install a proof of concept Indigenous-owned and operated native seed farm to help supply Australia's growing land restoration needs (Figure 2). The CMSR joined with MEEDAC (Midwest Employment and Economic Development Aboriginal Corporation), Greening Australia and Green Values Australia to start-up the SPA on a property operated by MEEDAC and provided by Karara Mining Limited near Morawa, Western Australia.
It is envisioned that this recent greenstock planting will supply both seeds and cutting material of important understory species for large-scale use in restoration, species which are currently unable to be sourced in the quantity and quality required at present. The species planted in phase one of the project include understory species such as *Scaevola spinescens*, *Eremophila clarkei*, *Thryptomene costata* and *Dodonaea inequifolia* that while common across the local landscape are difficult to reliably collect seeds from in the quantities needed for restoration purposes. Already there are plans to expand the seed farm to include up to an additional 20 additional native species with the farm employing local Indigenous people in all phases of the SPA, from management to planting, harvesting and processing. It is expected that the current suite of species under cultivation will develop their first seed crop over the next two years with more plantings planned over the next 18 months. It is envisioned that the SPA business and community model developed by MEEDAC will become a template to be rolled out for other indigenous communities around Australia in years to come.
Guinea flowers (*Hibbertia* spp. - Dilleniaceae) are usually small to medium shrubs, that are common throughout Australia but have their centre of diversity in South-west Western Australia. They are surprisingly common throughout the different heathland and woodland communities across this region so

Figure 2. Staff from MEEDAC planting greenstock of a range of native understory species to be used as part of a seed farm to produce seeds for use in minesite restoration. The site consists of old agricultural land and is located near Morawa about 300 km north of Perth in Western Australia. The climate is semi-arid Mediterranean with long hot summers and mild short wet winters.

are an important group to reinstate during restoration. Of particular interest for several mining companies is *Hibbertia amplexicaulis* which while an important framework species regenerates poorly from respread topsoil so is typically underrepresented in restoration sites following mining. Consequently, *H. amplexicaulus* seeds when available are added to direct seeding mixes which are broadcast across restoration sites as part of restoration work. Nevertheless, while common across the local vegetation communities, seed set is surprisingly low due to poorly understood reasons. Locally occurring *H. amplexicaulis* are generally healthy and appear to flower freely with an abundance of pollinating insects present though seed viability is often poor. With this in mind, a pilot study was undertaken to quantify the feasibility of managing in situ plants in a way that may enhance seed production. To achieve this aim, a slow-release fertiliser was applied to boost plant growth and an insecticide used to control seed devouring insect pests. To this end, replicate sites were pegged out and within each, four quadrats were established. Each quadrat was then subjected to one of four treatment combinations consisting of: 1) control (no treatments applied); 2) fertiliser (8 kg per Ha); 3) insecticide and 4) combination of fertiliser and insecticide. The fertiliser was applied once in mid-winter (July - peak flowering time), while the application of insecticide commenced in early spring (September) and reapplied every 6 wks thereafter, until seed collection in summer (December). Seed production was assessed on 20 randomly selected *H. amplexicaulis* plants with all fruits removed to quantify the number of seeds produced per flower, the number of seeds produced per plant, seed viability and seed mass.

Results from this trial were encouraging as seed production was clearly enhanced in some treatments (Table 1). There were significant improvements in both the average number of seeds per flower and per plant (three-to-four-fold increase) derived from the insecticide treatments with seed fill also showing substantial improvements as well, rising from ~60% in the treatments devoid of insecticide to >90% for both insecticide treatments. In comparison, the application of fertiliser appears not to have made a difference whatsoever to either seed quality or production.

Table 1. Seed productivity for in situ plants of *Hibbertia amplexicaulis* following the application of fertilizer and/or insecticide.

Treatment	Av. no. (± SD) seeds per fruit	Av. no. (± SD) fruits per plant	Av. no. (± SD) seeds per plant	Av. seed fill (% ± SE)	Av. seed wt (mg ± SD)
Control (no treatment)	1.6 ± 0.3	2.3 ± 0.4	3.6 ± 0.8	58.5 ± 12.4	8.5 ± 0.2
Fertiliser	1.3 ± 0.5	2.3 ± 0.3	3.2 ± 1.3	49.5 ± 12.4	8.4 ± 0.4
Insecticide	3.6 ± 0.2	3.0 ± 0.4	10.9 ± 1.7	91.5 ± 1.7	8.6 ± 0.4
Fertiliser + insecticide	3.7 ± 0.6	3.7 ± 0.6	11.2 ± 1.6	91.1 ± 1.7	9.1 ± 0.2

Discussion

Seed supply is a significant and ongoing issue for wild species with efforts now underway across the globe to develop and optimise seed production areas to supply the chronic shortage of wild seeds for global restoration efforts. Restoration is frequently undertaken in regions where native vegetation has been widely cleared, degraded or fragmented, rendering these ecosystems disproportionately prone to the combined impacts of seed harvesting, habitat fragmentation and climate change pushing species beyond the point of no return. As well, numerous animals including unique insects, birds and mammals are heavily reliant on wild seeds to support their populations so a reduction in diverse native seed resources can lead to marked declines in many other species due to tropic cascades.

Consequently, the potential to massively increase the supply of wild seeds via SPAs and the elimination of seasonal variation not only improves seed sourcing security but may also enhance the quality of the seeds that are available due to improved growing conditions and implementation of effective pest and disease management. Startup costs may be

significant at first, as will the initial investment in capacity building to learn how to both propagate and cultivate these species on a commercial basis. Nevertheless, in the medium to long term once these issues are addressed the costs of seeds are expected to significantly fall as supply becomes more sustainable and production approaches streamlined.

Nonetheless, given the relative complexity of establishing a SPA, the initial selection of species for farming needs to be carefully considered which will make or break overall success. It is therefore recommended that the following questions be used to guide species selection: 1) is the species an important framework taxa?; 2) is it difficult and/or costly to collect sufficient viable seeds?; 3) is the species likely to be amendable to cultivation?; 4) is reproductive maturity attained within a reasonable period of time? and; 5) does the species have any specialised/unusual pollination requirements that may impact its capacity to set seeds under ex situ conditions? The task at hand cannot be overstated and as the size and complexity of global restoration initiatives increases, there is a pressing need to develop new and innovative approaches based on agronomics to supply the amounts of wild seeds urgently needed in a more sustainable and environmentally friendly way. Only through the adoption of such science-based approaches will the aspirational targets for global restoration efforts be fully realised leaving an enduring environmental legacy for future generations to enjoy.

Acknowledgements

Dr. Shane Turner and Dr. Simone Pedrini were funded under the Australian Research Council Industrial Transformation Training Centre for Mine Site Restoration (ICI150100041) and by Curtin University (as is Professor Kingsley Dixon). I would like to offer my sincerest thanks to MEEDAC for information supplied in regards to the MEEDAC s eed farm and would like to acknowledge the traditional owners of country throughout Australia, and their continuing connection to land, sea and community and pay respects to them and their cultures, and to elders past, present and emerging. I would also like to say thanks to Dr. David Willyams (formerly from Alcoa Australia) for background information provided about Alcoa Marrinup nursery and to Brad Stokes (formerly from South32) and South32 for the use of field sites and support for some of the worked described in this article.

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Image credit: Nalin Gama-Arachchige

Mother Nature Speaks to the Humans

You are gifted with a brain and heart
That I could not have in my life;
Yet you are dumb and heartless people
'Cause, you never heard my cry.
You call it pretty smart and brilliant, so many boastful lies.
Day by day, I kept losing
My right to be alive.

You cut several trees for the sake of buildings
Which ran into the sky.
You throw me out more toxic gases,
While you fly and drive.
You drop garbage wherever you want,
Yet you follow S5.
And you said it is developed,
But you never know you destroy my life.

I am begging on my knees
To save myself, yet belong to you and me.
Please harm me less and let us go green
To protect me for your child.

-Cheshani Sachithra
Department of Sociology
University of Peradeniya

Drawing: Pathum Piyumal

Bacteria for Electricity Generation in Microbial Fuel Cells

By Eustace Y. Fernando, PhD
Department of Biological Sciences, Rajarata University of Sri Lanka

Microbial Fuel Cells are renewable energy devices

Ever wondered if there's a method to convert the chemical energy of organic waste materials directly into useful electrical energy in a single conversion step? Microbial fuel cells (MFCs) can do just that. MFCs are bio-electrochemical devices that can directly convert the chemical energy of biodegradable organic material (substrates) directly into usable electrical energy using microorganisms in a single convenient step. They have the potential to become great sources of renewable energy to rival the utility of tried and tested renewable energy sources such as biogas. MFCs also offer other fringe environmental benefits such as organic waste disposal and acting as wastewater treatment systems. In other words, MFCs can produce electrical energy from the organic chemical constituents of wastewater, thereby purifying polluted water in the process. Despite all of this promise, MFC technology is still considered a "new" technology where there is a lot of room for improvement.

The concept of MFCs was demonstrated as far back as the year 1911, by Professor Michael Cressé Potter of Armstrong College, Newcastle, England. Potter demonstrated that a small electrical charge can be produced by the anaerobic microbe, brewer's yeast (*Saccharomyces cerevisiae*) in a two-chambered contraption he devised. The same concept was demonstrated by Potter after 1911 several times by using different microbes such as *Escherichia coli*. Potter's work received little attention at the time of reporting. A similar set of results using an earlier version of MFC system were reported by the American bacteriologist Barnett Cohen in the year 1931. Cohen's experiments demonstrated that connecting MFC half-cells in series had a cumulative effect on voltage production where, he managed a voltage output of 35 V and a current output of 2 mA. After these initial studies, there was a very long lag in the research output related to MFCs, in 1977 when Karube and his partners demonstrated the utility of anaerobic bacterium *Clostridium butyricum* for electricity production in MFCs. At that time in the 1980s, the molecular mechanisms that governed the electrical energy production within MFC systems was poorly understood. Since then, MFC research has flourished and satisfactory working models on bio-electrochemical mechanisms that govern electrical energy production by MFC have emerged.

How do MFCs work?

At the heart of any MFC system are the microbes that are catalyzing a set of electrochemical reactions for electricity production. A conventional set-up of a MFC contains two discernible compartments; an anode compartment and a cathode compartment (Figure 1). Although in the latest systems, the cathode compartment has been taken outside of the aqueous cathode chamber and turned into a dry (air breathing) cathode.

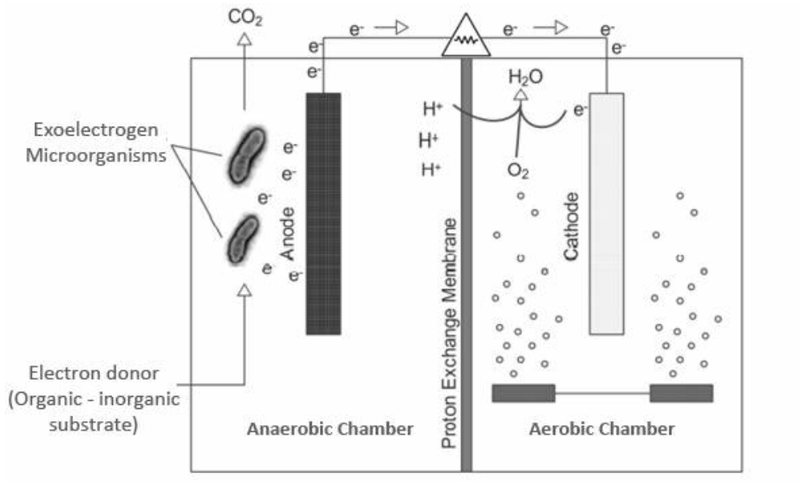


Figure 1. A schematic representation of the components and the electron and charge flow within a typical two-chambered MFC system.

The vital microorganisms reside within the anode chamber. They oxidize various substrates and release metabolic electrons in the process. Some of these reactions can be summed-up as shown in expression-1, if one assumes that the anode microorganism in MFC utilizes glucose as the sole source of carbon and energy. At the anode;

$$C_6H_{12}O_6 + 6H_2O \text{ ----------> } 6CO_2 + 24H^+ + 24e^- \text{ ---(1)}$$

These metabolic electrons that are released by the microorganisms as products are then picked-up by the anode and passed through the external circuitry of the MFC system, into the cathode. When electrons pass through the external circuit, a current is generated and the energy dissipated as a result can be harnessed to do useful work.

In conventional MFC systems, the cathode compartment is entirely an abiotic chamber where only abiotic oxygen reduction reaction (ORR) takes place in the presence of a noble metal catalyst such as platinum or palladium (expression-2). For this purpose, atmospheric oxygen must be continuously supplied to the cathode by active aeration of the medium.

At the cathode:

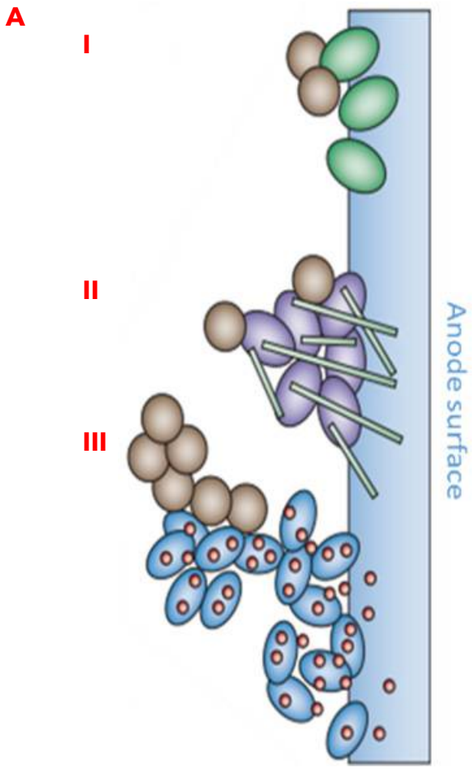
$$4e^- + 4H^+ + O_2 \text{ ----------> } 2H_2O \text{ ---(2)}$$

How do microorganisms transfer electrons to the anode?

The key to functionality of any MFC system is the ability of microbes in the anode compartment to shuttle electrons outside their cellular membrane into the anode. The current scientific understanding on this aspect agrees on two working models to describe this phenomenon.

These models are direct electron transfer and indirect electron transfer. Direct electron transfer is further sub-divided into electron transfer via conductive bacterial nanowires and electron transfer through direct surface-to-surface contact between the bacterium and the anode electrode material (Figure 2A, I and II. During electron transfer via nanowires, special conductive bacterial appendages made up of proteins transport electrons many nanometers away into electron acceptors such as anode (Figure 2B). Direct surface-to-surface electron transfer is much more straightforward in which microbial permanent biofilms made on anode allows the bacterial outer perimeter and the anode to come into direct contact. This direct contact, with the help of membrane-bound conductive cytochrome proteins of bacteria then allows metabolic electrons to hop over to anode.

The indirect mechanism of electron transfer



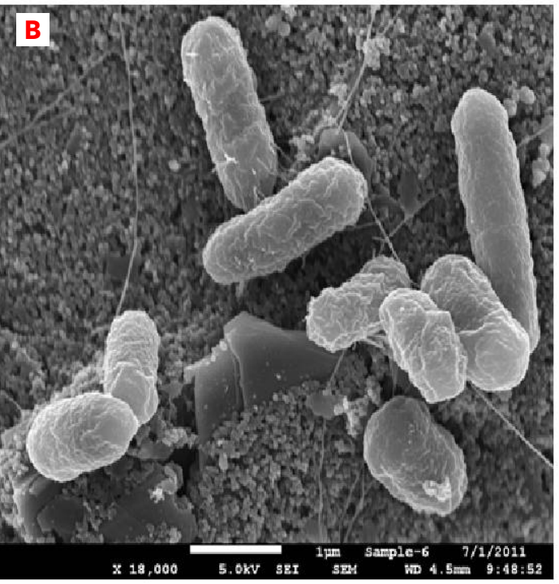


Figure 2. (A) a schematic representation of electron shuttling mechanism models currently available and (B) a scanning electron micrograph showing electrochemically active bacteria attaching onto electrode surfaces using conductive appendages known as bacterial "nanowires".

relies on reversible and water-soluble electron shuttling molecules to fetch metabolic electrons between the anode and the bacterium (Figure 2A, III). These natural electron acceptors could be naturally made compounds by the bacterial population such as flavonoid molecules, humic acids, phenazine molecules and natural quinone molecules. Well-known examples of microbes to use naturally produce electron shuttling molecules are *Shewanella oneidensis* utilizing quinone and flavonoid type of mediator molecules and Pseudomonas aeruginosa making use of phenazine type mediators to shuttle electrons to the MFC anode. Artificial mediator molecules such as quinine, phenoxazine, phenozine, phenothiazine and thionine could also be exogenously added to the anode electrolyte in order to drive extracellular electron transfer by the bacterial populations within microbial fuel cell anodes.

What bacteria can conduct extracellular electron transfer reactions in MFCs?

Not all microorganisms possess the ability to transfer their metabolic electrons outside their cellular membranes into entities located in the extracellular milieu. This metabolic capability bears the formal technical term "exo-electrogenesis" in scientific literature. Although it is not limited to certain species of bacteria, this ability is only limited to microorganisms including a limited number of species of cyanobacteria, yeasts and very rarely, some species of algae. Exo-electrogenesis has hitherto not been observed and reported in plants. The current general scientific consensus is that higher plants and animals always transport their terminal electron acceptors (such as oxygen) inside their cellular membranes and that they are incapable of conducting exo-electrogenesis.

Naturally occurring exo-electrogenic molecular mechanisms were first identified and scientifically characterized in three main bacterial species; *Shewanella oneidensis, Geobacter sulfurreducens* and *Geobacter metallireducens*. In their natural habitats, these bacterial species such as *Shewanella oneidensis, Geobacter sulfurreducens* and *Geobacter metallireducens* utilize insoluble terminal electron acceptors such as Manganese oxides and Iron oxides contained within anaerobic marine and lake sediment environments. These insoluble terminal electron acceptors are

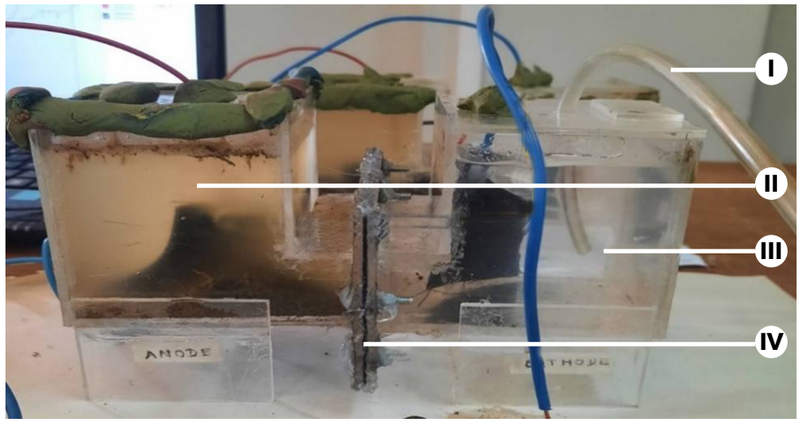


Figure 3. A conventional two-chamber MFC system used for fundamental and applied MFC studies at the Rajarata University microbial electrochemistry unit (MEU), Sri Lanka.

incapable of solubilizing themselves into aqueous ionic forms and traversing into intracellular spaces of such bacteria. Therefore, these bacteria have evolved a special metabolic capability to transfer their metabolic electrons into insoluble electron acceptors such as manganese and iron oxides that are located outside their cellular membranes. Organic substrate oxidation coupled to the reduction of insoluble manganese oxides in marine and lake sediments by bacteria such as *Shewanella* spp. and *Geobacter* spp. can be summed up as shown in the expression – 3.

$$CH_2O + 2MnO_2(s) + 4H^+ \text{-------> } 2Mn^{2+}(aq) + H_2CO_3 + 2H_2O \text{ ---(3)}$$

In other words, these microbes are capable of respiring solid iron and manganese oxide containing rocky minerals. MFCs exploit this eccentric metabolic ability of these exo-electrogenic bacteria and places an anode poised at a higher redox potential to act as the insoluble terminal electron acceptor in place of iron or manganese oxides that they naturally use.

Types of MFCs and their usage

The most basic and the conventional type of MFC is the two-chamber type used for fundamental research. They can also be used to test basic operation during scaling-up of MFCs. For example, it can be used to test operational parameters during scaled-up operation such as continuous flow mode, flow rates, organic loading rates and others by doing limited scale-ups such as pilot-scale reactors. Two-chamber systems essentially contain anode and cathode compartments (both containing ion-conductive liquid) and a cation permeable membrane separating the two compartments. Additionally, it contains two electrodes where electron exchanges take place and an external circuit connected to a resistance and other monitoring devices for real-time monitoring of electrochemical performance of the system (Figure 3).

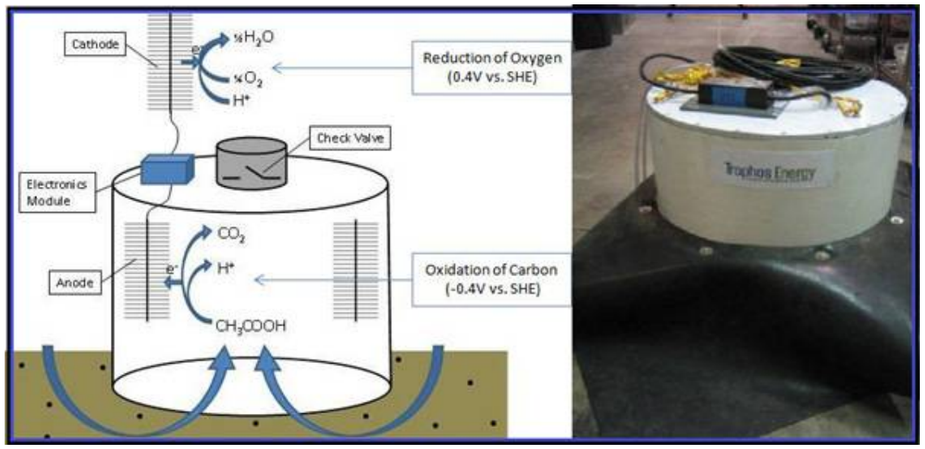


Figure 4. The working principle of a benthic MFC system and a benthic MFC system to be deployed in marine sediment for remote sensing applications (Guzman *et al.*, 2010).

Apart from the conventional two-chambered MFCs used commonly in research (Figures 1 and 3), there are several other types of MFCs in use. Primary among these are benthic (sediment) (Figure 4) MFCs and single-chamber MFC systems (Figure 5). Benthic MFC systems are advantageous in terms of their installation and subsequent maintenance. They are easy to install in marine or lake sediments, require little to no subsequent maintenance and are great for powering remote monitoring devices and biosensor devices. In terms of operability, benthic MFCs are passive and require no additional energy input. For example, their cathodes are not actively aerated and molecular oxygen for ORR in the cathode electrode is obtained passively (Figure 4).

Another type of MFCs is the single-chamber air-breathing MFCs, sometimes referred simply as single-chamber MFCs. These MFCs have completely done away with the aqueous medium of cathode and has brought the cathode electrode out into the surface of the fuel cell. By doing so, it conducts the ORR passively without expending energy for active aeration of the cathode. At the same time, single chamber MFCs usually deploy relatively large cathodes; maximizing the surface area available for conducting the ORR (Figure 5).

Due to the aforesaid reasons and many other reasons such as the large anode electrode surfaces available for exo-electrogenic bacteria,

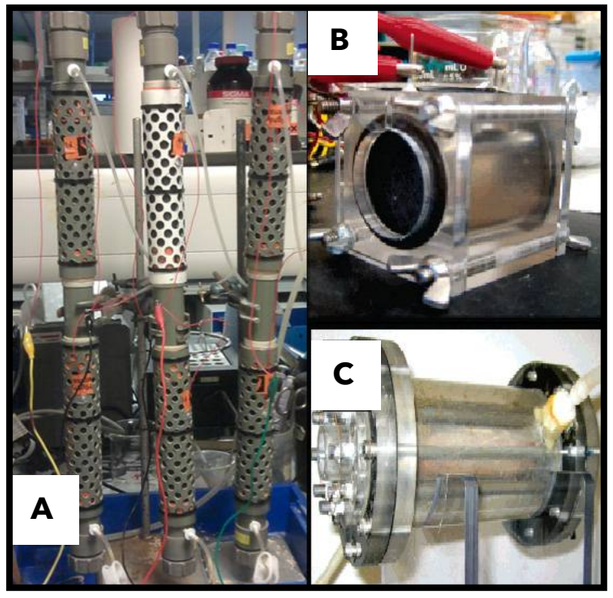


Figure 5. (A) tubular up-flow type single chamber MFC systems for continuous flow operation; (B) rectangular type single chamber systems for batch operation; C) single chamber MFC with an inner concentric type cathode for continuous flow operation. (Logan *et al.*, 2006)

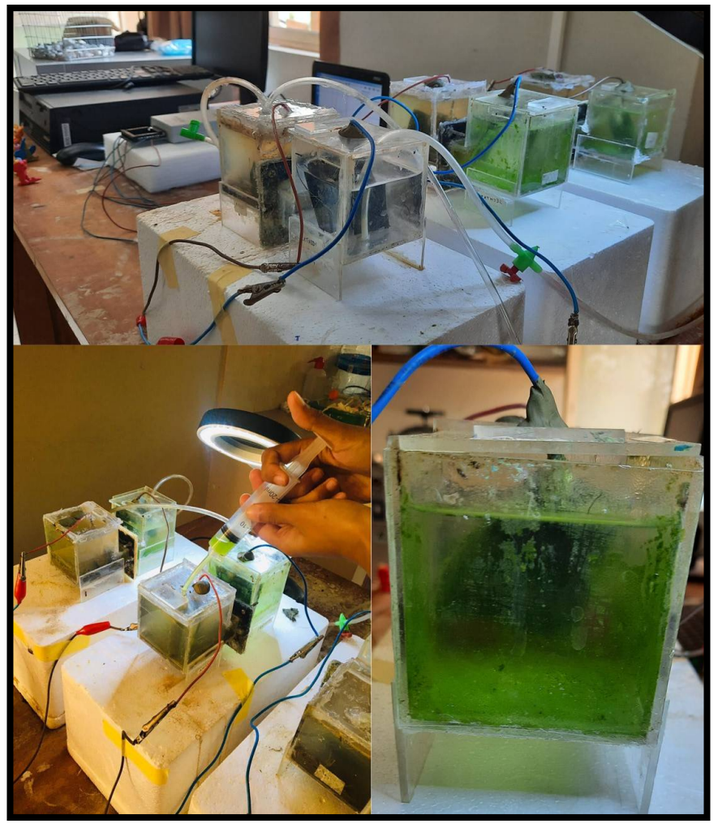


Figure 6. Several different photosynthetic microbial fuel cell (PMFC) types used at the MEU of Rajarata University, Sri Lanka to investigate fully sustainable and cost-effective utilization of MFC systems.

single-chamber MFCs are among some of the best performing MFC types. They are reported to be capable of producing power densities in excess of 1.3 W m^{-2} (54 W m^{-3}), when operating optimally.

Current applications of MFCs and examples of up-scaled MFC systems

MFCs have a great potential to be used as standalone wastewater treatment systems or to complement existing wastewater treatment systems such as activated sludge systems, anaerobic digesters and membrane bioreactors (MBRs). On the contrary, they are not yet suitable to be used as standalone power generation systems to produce large amounts of electrical energy. This is because the amount of electrical energy produced by MFCs is comparatively much lower compared to other related systems such as hydrogen (chemical) fuel cells. In this regard, MFC systems are still in their infancy of development and they still require several breakthroughs in order to produce substantial quantities of electrical power to become a viable system that can be utilized in practical applications. For comparison, hydrogen fuel cell stacks are capable of powering transportation systems ranging from small cars to buses and Lorries. MFC stacks by comparison, are only capable of powering small DC powered devices such as small robotics, drones, small electronic devices and wireless sensors powered by MFCs for remote monitoring applications.

The scaling up of MFC systems is almost always done in a modular manner rather than using a linear scale-up approach. In other words, almost all scaled-up MFC systems utilize multiple small MFC units connected in series rather than using a single larger volume MFC system. This is mainly because the theoretical maximum voltage of any single MFC system will not exceed 1.14 V. The maximum theoretical voltage across anode and cathode ($E^0_{cathode} - E^0_{bioanode}$) of a single air–cathode MFC is 1.14 V (assuming NADH is the electron shuttle, $E^0_{bioanode} = E^0_{NADH} = -0.32$ V and assuming that molecular oxygen is the electron acceptor, $E^0_{cathode} = E^0_{oxygen} = +0.82$ V vs. standard hydrogen electrode at neutral pH, respectively)

(Electromotive force = $E^0_{cathode}$ - $E^0_{bioanode}$). This value is often lower in real-world MFC systems. The best performing MFC units exhibit voltage outputs ranging from 0.8 - 1.0 V. Therefore, for all practical purposes, higher voltages and higher current outputs are obtained using MFC stacks connected in series and parallel.

There are several reported instances where MFC systems were scaled-up to the extent where they are suitable for practical applications. Emefcy Ltd. is a start-up company in Israel which specialized in the use of modular scale-up of MFC systems to simultaneously generate electrical energy while treating wastewater. Their proprietary MFC design is assembled into modular wastewater treatment units and the electrical power generated through this system is fed-back into the electrical grid of the wastewater treatment plant where most of the electricity needs of the Emefcy Ltd. operated wastewater treatment plants could be met.

New developments in MFC research and related research conducted in Sri Lanka

MFC related bio-electrochemical systems indicated several advances along a handful of new avenues in the past decade. Primary among these are the derivative bio-electrochemical devices such as microbial electrolysis cells (MECs) and microbial electro-synthesis cells (MESCs). MECs for instance conduct bio-hydrogen or bio-methane production at a lower energy input. They reverse the electrochemical processes that operate within MFCs and consume a small electrical power input to biologically produce hydrogen or methane at a much lower energy cost than producing these gases in abiotic chemical processes.

MESCs on the other hand uses a form of microbial electro-catalysis to produce industrially relevant organic compounds such as acetate, butanol, butyric acid ethanol and many others by reducing inorganic compounds such as carbon dioxide within the cathodes of bio-electrochemical devices. This phenomenon is referred to as microbially-assisted electro-catalysis and it relies on a supply of small amount of electrical energy to the electrode where the reduction of CO_2 takes place. This method of synthesizing organic chemical from inorganic ones is seen as holding great promise for applications of biofuel production such as bio-butanol, bioethanol and biodiesel.

There is a limited volume of research undertaken in Sri Lankan universities into the areas of bio-electrochemical systems, MFCs, their fundamentals of operation and their applications. Primary among these is the Microbial Electrochemistry Unit (MEU) at the Faculty of Applied Sciences, Rajarata University. It was established with a minimal amount of resources in 2019 but it has already contributed to the molecular level identification of hitherto unknown electrochemically active microbiota from Sri Lankan lake sediments. The work conducted at the MEU also developed a novel growth and isolation microbiological medium for exo-electrogenic bacteria.
Currently, photosynthetic and fully sustainable MFC (PMFC) systems utilizing cyanobacteria are actively being researched at the MEU at Rajarata University, Mihintale. These cyanobacteria are used in the MFC cathodes for the dual roles of capturing and fixing CO_2 using solar energy as well as to replace the expensive noble metal catalysts used in the ORR in the cathode. It brings about the additional benefit of producing large amounts of usable biomass that can be used as a cheap substrate for the exo-electrogenic microorganisms residing in the anode compartment (Figure 6). The use of photosynthetic cyanobacteria and their ability to evolve molecular oxygen during photosynthesis also eliminates the need to continuously aerating the cathode compartment of the MFC to supply a terminal electron acceptor.

Another line of inquiry at the MEU is to investigate the addition of statin class chemical compounds such as simvastatin and atorvastatin into the mixed microbiota containing MFC anodes. These exo-electrogenic microbial populations when they are sourced from the natural environments such as lake or marine sediments, contain significant populations of methanogenic Archaea. These methanogenic Archaea divert available carbon substrates in MFC anodes into competing metabolic pathways such as methane generation. This leads to a degradation of electrochemical performance of MFC systems. Statin-class compounds are known selective inhibitors of Archaeal microbial communities and their action in MFCs is currently studied.

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Ecotourism Un(explained)

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Ecotourism is now the buzz word in the tourism industry around the globe. All sorts of tourism enterprises are keen to stamp the ecotourism label on their businesses because this label could help sell their products and services more. A peep into these ecotourism bandwagon products and services however suggests that ecotourism is perhaps the most misconceived word in the entire tourism industry.

Ecotourism is usually misunderstood and misrepresented to be synonymous with nature tourism. This misunderstanding sets the perfect backdrop for the green-washing of the tourism industry. Green-washing of tourism is the misleading portrayal of tourism goods and services as environmentally friendly through their marketing strategies. There is nothing more than deceptive marketing in green-washing of tourism products. The danger of green-washing is that even though if practiced well, ecotourism can be the key approach to sustainable tourism compared to mass tourism, green-washing of tourism can be even more hazardous than mass tourism itself. This is why it is important to clear the misconceptions shrouding the concept of ecotourism. This piece of work is therefore an attempt to un(explain) the misconceptions surrounding ecotourism and bring to the front stage, the dangers of green-washing of tourism.

What is ecotourism?

Contrary to the popular misconception, ecotourism is not only about nature. Nature is undoubtedly the lifeblood of ecotourism, but it is important not to forget it is only one out of seven principles breathing life into the concept. Ecotourism can be defined as, "Responsible travel to natural areas that conserves the environment and improves the welfare of the people". This simple definition shows that there is more to ecotourism than only conserving the environment. Ecotourism pivots on seven principles and these seven principles blend environmental, social and economic sustainability together:

1. Involves travel to natural places

For tourism to be ecotourism, activities will have to be based in a natural setting. A visit to a man-made theme park does not therefore qualify as ecotourism, but climbing Lakegala would.

2. Minimizes impact

Ecotourism activities and projects should strive to minimize the negative impact on the environment that mass tourism usually entails. This is why ecotourism entertains fewer numbers of tourists and involves a slow tourism approach to reduce the carbon foot-print.

3. Builds environmental awareness

This is perhaps the biggest difference between ecotourism and nature tourism. Nature tourism is nothing more than visiting natural places. Nature tourists may leave an enormous carbon foot-print in the natural places they visit. Ecotourists on the other hand are environmentally sensitive. They have a higher level of awareness and understanding about the environment they are visiting. It is important to note that environmental awareness should be present not only in the tourist but also in the hosts. This includes the local community, school children, tourism business owners and other multiple stakeholders of the area. Tourism is the lifeline of many communities and nature is the asset on which the industry is running.

Image credit: Nalin Gama-Arachchige

Lakegala, Meemure, Sri lanka

Belize for example is popular among tourists for its sandy beaches and blue ocean. The beaches are Belize's most important attraction and without them, Belize would no longer be attractive to tourists. Many tourism enterprises would run out of business, and many would lose their jobs. Unfortunately, this is exactly what happened to Belize. As it rose in popularity, Belize failed to create environmental awareness among guests and hosts, emphasizing the importance of conserving the environment they were making a living on. Thus even though Belize was one of the first countries to adopt the ecotourism approach, it is one of the most polluted destinations in the world today. Ecotourism in other words provides the perfect justification to protect the nature on which many a people survive.

4. Provides direct financial benefits for conservation of the natural environment

In projects governed by ecotourism principles, the income generated through the sale of entrance tickets and other forms of funds raised are channeled to conserve the environment. For example, the lion's share of the income generated by the sale of entrance tickets to wildlife parks should be used to conserve the fauna and flora of the park.

5. Provides financial benefits and empowerment for local people

One of the biggest challenges of the tourism industry is that many of the tourist dollars that are spent by foreign tourists leak out of the local economy in the process of purchasing supplies from overseas, paying salaries for foreign employees and exporting the profit by foreign-owned tourism enterprises. Unfortunately, leakage is higher in developing countries than in the developed countries despite the fact that dollars earned through tourism play a larger role in developing country economies. Unlike mass tourism enterprises, ecotourism enterprises are local and small scale. Dollars spent at such businesses are more likely to stay in the economy, providing direct financial benefits to local people than foreign owned Multi-National Corporations. Economic independence is a key ingredient in instilling empowerment in the local people.

6. Respects local culture

Ecotourism activities do not stop at promoting cultural awareness. The next step of building awareness is promoting respect towards different cultures, traditions and practices.

7. Supports human rights and democratic movements

According to the World Tourism Organization (UNWTO) promotes tourism for peace and understanding. Boycotting destinations that violate human rights, break democracy and discriminate against ethnic and racial groups can be a way of supporting democratic movements and protecting human rights. It has been proven time and again how ecotourism is better environmentally, socially and economically than using the same resources for some other industry for the sake of economic development:

A study in South Africa found that net income from wildlife tourism was almost eleven times more than that from cattle ranching, and job generation was fifteen times greater. In Kenya, it is estimated that one lion is worth $ 7,000 per year in income from tourism, and an elephant herd is valued at $ 610,000 annually. A 2001 study found that in the Turks and Caios Islands, spiny lobsters are … more valuable in the water, for ecotourists, than trapped for the dinner table. A study in Icealand found that the economic value of whale watching worldwide is $ 1 billion, far more than any financial gain that would come from hunting should Iceland resume commercial whaling (Honey, 2008).

However, going through this list of ecotourism principles, one may think that it is a Herculean task to find a single tourism project that sticks to all the seven principles. Such misgivings are perhaps not totally unfounded. Even the founders of the Ecotourism Society, Costas Christ and David Western doubted if it is humanly possible to bundle all aspects of ecotourism into one tourism project. This is why different projects embrace different aspects of the concept but hardly any single project handle them all at once.

Ecotourism in reality

Drawing: Chathura Jayaweera

Ecotourism has metamorphosed into what it is today, shedding much of its essence, diluting its multifaceted nature and losing its depth. In practice, ecotourism has become more synonymous with nature tourism, paving the way to considerable abuse of the term. Many tourism enterprises would very much like to tag themselves with the ecotourism label because they could sell their products faster with the label of ecotourism than without.

Why do products with the ecotourism label sell better? This is because lately, it is generally accepted that modern day tourists are environmentally conscious. This premise became widely popular when booking.com released their report on Where Sustainable Travel is Headed in 2018, making ecotourism the bandwagon that every tourism enterprise wanted to hop on to. This report claims that 87% of the global travelers would like to travel sustainably. For a large 46% of such tourists, travelling sustainably meant lodging at an eco-friendly or green accommodation facility. This explains why tourism businesses are keen to adopt the ecotourism label. Hotels of various standards use this label as a marketing strategy to sell their products and services to the environmentally conscious tourists who may think that by lodging there, they are helping to protect the environment. Log cabins made of solid wood that require trees to be felled, chalets built on raised platforms on flowing rivers and streams, concrete buildings that have trees growing on top of them, all qualify as green accommodation in the eyes of the tourists. These can be very deceptive because some of them carry certifications by recognized tourism authorities in the destination. Large chain hotels, conglomerates and Multi-national Corporations running tourism businesses that are nothing but eye candy have better chances of being acknowledged by regulatory authorities as eco-friendly or sustainable than small scale, locally owned enterprises that are truly eco-touristic in their practice. Small scale locally owned enterprises attract direct financial benefits to the local community with minimal leakage. They serve local cuisine made with local ingredients. These businesses promote the local culture and provide an authentic cultural experience to the tourists unlike large enterprises.

Honey, in her book Ecotourism and Sustainable Development, has shown how big players dominate the tourism industry and not only get away with environmentally damaging practices, but also hoodwink practically the entire world to believe they are actually protecting the environment. For example, Princess Cruises was fined $500,000 in 1993 for dumping millions of pounds of refuse into the oceans when they were disclosed by the Greenpeace. Only a few years later, Princes Cruises was honoured with ASTA 's Smithsonian Magazine Environmental Award for their commitment towards protecting the environment (Honey, 1999: 40). Large companies are very powerful even with all their environmentally damaging practices, making it impossible for small enterprises to compete against them in the tourism industry.

Green washing of tourism

Just as much as whitewashing denotes a deliberate attempt to conceal incriminating facts about a person or organization to save the reputation, green washing denotes casting a green shade over enterprises to enhance their reputation as environmentally friendly business, when in fact they may not be so. Green washing is not a scandal that is limited to the tourism industry. The farce put up by some companies to reduce the amount of plastic used in their products is one such example. Many restaurant chains simply switched from plastic straws to paper straws while the cups they served beverages remained plastic. It is disconcerting that instead of protecting the environment, manufacturing paper straws destroys the environment at a faster rate by forcing thousands of acres of trees to be cut down. Restaurants in East Asian countries that serve disposable wooden chopsticks do the same damage to the environment. The Yale School of the Environment has shown that more than 3.8 million trees in China are felled to manufacture disposable chopsticks for China, Japan, South Korea and the USA. Sadly, these forests are also the habitats of the endangered Pandas.

In the tourism industry, as explained in the foregoing section, green washing is a tendency resulting from the misinterpretation of the concept of ecotourism that it is all about nature. Green washing not only sweeps the vices of tourism under the mat, but also turns a blind eye to all the other important principles and aspects of ecotourism. Organizations that green wash their tourism activities capitalize on customers'/ tourists' growing interest to travelling sustainably. Green washing is the mere "sticking of the ecotourism label" as explained before, as a marketing strategy.

Green washing is a dangerous phenomenon to begin with. It paves way for large, rich and powerful players to not only dominate the industry, but also manipulate it. This is the complete opposite of what is expected from ecotourism. Green washing of tourism can mislead tourists to believe that they are supporting a kind of sustainable tourism, while they are not. In other words, green washing of tourism can mislead tourists to believe that ecotourism is synonymous with nature tourism because of the haphazard and excessive use of the word "green", which represents nature. In its worst form, tourists will patronize tourism goods and services such as accommodation services that are damaging the environment instead of protecting it. Thus green washing

> "Lack of awareness is not the only reason that prompts tourists to patronize tourist services that are not sustainable.

does not protect any of the three components: not even the environment with all the over-emphasis on nature. Hotels built in the middle of a jungle by clearing a patch of trees are not practicing ecotourism in any sense of the word. Log cabins or raised cabanas built on waterways are environmentally damaging from their very inception. They do not qualify even as green tourism let alone ecotourism. Large hotels that import ingredients for foreign recipes do not support local agriculture, food culture or the local economy. Companies that take tourists on mountain hikes and light up campfires using the wood in the forests nearby that might cause wildfires are practicing neither ecotourism nor nature tourism.

The deluded tourist

One reason why tourists may behave this way is because they lack knowledge about what sustainability is or what ecotourism means. Most tourism entrepreneurs also lack this knowledge and the right attitude to practice ecotourism. Destinations, specifically developing country destinations lack knowledgeable and multilingual tour guides that are qualified enough to impart such knowledge to their guests.

Lack of awareness is not the only reason that prompts tourists to patronize tourist services that are not sustainable. Practicing ecotourism requires a certain attitude, will to make a change, desire to help the needy and the

Table 1. Top global obstacles to traveling more sustainably

Obstacle	Percentage
Costs – not being able to afford the extra expenditure	42%
Information / lack of certification – not knowing how to make my travel more sustainable	32%
Time – travelling sustainably would be too time consuming	22%
Destination – travelling sustainably would limit travel to less appealing destinations	22%
Luxury / comfort – sustainable travel does not meet the level of luxury / comfort accustomed to	20%

Source: https://globalnews.booking.com/where-sustainable-travel-is-headed-in-2018/ (Accessed on 19th June 2022).

stamina to make sacrifices to make those changes happen. Even though there is definitely a rise in the number of tourists supporting green, slow and sustainable tourism than in the past, it is questionable how much sacrifice and compromise tourists are willing to take for the sake of supporting sustainable tourism. The booking.com report on Where Sustainable Travel is Headed in 2018 says that travelers are willing to absorb the extra cost to ensure that they are traveling sustainably. Browsing through the data, one cannot be very sure of this: Nearly half of the sample (42%) had testified that the biggest obstacle to travelling sustainably is the extra cost that might incur. Apart from the "costs" travelers have noted that sustainable traveling would be consuming too much time because it involves slow modes of travel such as bicycles and walking. Travelers have also noted that sustainable travelling makes travelers compromise their satisfaction by traveling to less appealing destinations, and foregoing certain luxuries that may be damaging to the environment in the long run. For example, even though a small percentage of people travel on aircrafts, they are responsible for about 2.4% of the carbon dioxide emissions in the atmosphere. This accounts up to about 5%of global warming. UK Department for Business, Energy and Industrial Strategy (BEIS) shows that a single passenger traveling on a domestic flight may produce about 150 g of carbon dioxide per kilometer, taking the same trip on an intercity train will produce about 50 g per kilometer. Needless to say that traveling by air is several days faster than traveling by train, and the decision to travel by train will entail some sacrifice or compromise. Ecotourists will also have to make compromises when dinning, shopping and picking places to visit. They do not shop at branded stores, but patronize small local stalls that sell locally made products. They do not dine at restaurants like McDonalds, Pizza Hut or KFC but eat at local restaurants that serve regional cuisine. They prioritize nature, the economy and the people of the destination over their comfort.

The problem is that a very large number of tourists do not want to make these sacrifices but still want to show that they are sensitive about the environment. Very little thought is spared for the local community or their economy in this process. Thus it is clear that what we have today are not real ecotourists. What we are left with are misinformed and misguided travelers. This is why we still have a fair demand for helicopter tours to the peak of Mount Everest, which can be not only environmentally very damaging, but also extends next to nothing to the local economy. This is also why chain hotels and restaurants thrive in developing countries. These tourist services are managed by large and powerful Multi-National Corporations that can push small and medium enterprises out of business, which is detrimental to the local economy. The effect of Multi-National Corporations on the local economy is more pervasive than this. Multi-National Corporations not only absorb tourist dollars that should have been channeled to the local economy, but also cause leakage of tourist dollars out of the region. Sources show that unfortunately, leakage is higher in developing countries that depend more on tourism than in developed countries. This is mainly because most Multi-National Corporations that are head-quartered in developed countries are operating in developing countries. Thus it is evident why it is argued that tourism businesses managed and run by large corporations are

not the ideal type to practice ecotourism. Small and medium scale enterprises are the best for ecotourism. On a similar note, Free and Independent Tourists (FITs) who seek an authentic experience and patronize local niche type of tourism are healthy for ecotourism than people who travel in large groups and check into popular large-scale tourist enterprises and prefer mass tourist attractions.

Conclusion

Ecotourism is the most suitable type of tourism to ensure sustainability of the industry. It also lays the foundations for environmental, social and economic sustainability of a community. However, ecotourism is a very much misconceived concept among both tourism entrepreneurs and tourists. Many assume that ecotourism is synonymous to nature tourism, and this misconception has paved the way to green washing of tourism, or deceptive labelling of tourism goods and services as environmentally friendly. Green washing also totally neglects the important social and economic aspects of the concept. The biggest danger of green washing is that it allows big industry players to continue to dominate the tourism industry, driving small and medium scale players out of business, deceiving the public and engaging in practices that are harmful to the environment, society and economy of the destination.

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Green and Sustainable 5G/6G for a Connected World

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Wireless services are expected to bring significant changes across multiple sectors in the modern society such as education, transport, healthcare, education farming and industrial automation. With the increasing popularity of smartphones, eBook readers, Internet-of-Things (IoT) and due to the proliferation of social networking applications, contemporary 5G and emerging 6G mobile radio systems are expected to connect billions of users and devices across the world. Inter-connection of such a large number of devices and networks poses serious challenges to the network designers. For example, the traffic generated from each system must be assigned to access points if congestion issues are to be avoided. To this end, advancements in wireless communication networks have been made to improve quality-of-service (QoS) metrics such as the latency, coverage, and reliability.

However, the operation of these wireless systems comes at the price due to numerous challenges. One of the main issues is the high energy consumption, as networks are becoming increasingly complex and dynamic. In this context, addressing the excess energy demand and improving the energy efficiency of communications is a serious problem. Not only power control and simple base station on/off approaches but also many other factors such as transmission scheduling, resource allocation, network design, and user association influence the high energy consumption of wireless cellular systems. As a result, the information and communication technology (ICT) industry has stressed the need to develop energy-efficient and sustainable solutions to manage new wireless services.

Moreover, the threats that arise against the environmental balance cannot be ignored as well. This is observed mainly through pollution and the depletion of natural resources. The emission of excessive quantities of greenhouse gases such as carbon dioxide, carbon monoxide, nitric oxide and methane to the earth's atmosphere, as well as water contamination due to the operations of the ICT sector need to be reduced to combat the climate change. With these concerns, the term "Green and Sustainable Communication Networks" comes into practice with the aim of connecting the global population while at the same time reducing the harmful emissions and resource consumption, increasing revenue and savings opportunities to contribute to the economies of countries. Artificial Intelligence (AI) and the recent advances in electronics, signal processing and big data algorithms are promising to accelerate the implementation of sustainable network solutions. In the rest of the article, energy-efficient green communication techniques related to the implementation of modern wireless systems will be explained.

Green Solutions for Sustainable Networks

Energy harvesting communications

For systems with a large number of IoT devices, it is not realistic to permanently connect all devices to the electric grid. Thus, energy harvesting plays a crucial role in achieving green and sustainable operation of such IoT devices. To this end, harvesting from sources

such as solar, wind, geo-thermal, vibration, and temperature gradients is possible to power up wireless devices. Energy harvesting approach is a better alternative to power sources that support applications in underwater and remote locations of the planet where the use of batteries are impractical and dangerous. Moreover, reduced use of batteries and associated electronic components would constitute as an effective solution for the ICT industry to tackle the e-waste problem to some extent.

AI techniques

AI techniques including machine learning and deep learning will play a pivotal role in making the future mobile radio networks greener and more sustainable. For example, such AI techniques would empower the network designers to perform dynamic resource allocation (power and spectrum) leveraging on the use of vast amounts of data extracted from real-time circumstances of network operation. In general, network parameters are related to each other in extremely complex ways, which cannot be represented using a tractable mathematical model. However, with the use of AI techniques, these complex networks can be represented using data-driven models. To this end, novel deep learning and reinforcement learning methods are expected to deliver significant advantages compared to conventional solutions based on statistical analysis and optimization. In addition, AI models can predict the changes in network parameters required in advance to avoid potential performance degradation. A large number of connected users will enable the collection of massive data resources to adopt and develop AI methods to realize automatic network management. These improvements will be advantageous for achieving the goals related to the latency and reliability of data transmission while at the same time reducing the energy consumption of communication.

Massive MIMO and small cells

In order to address the challenge of supporting high data rates anytime and anywhere while reducing the energy use, wireless technologies of massive multiple-input multiple-output (MIMO) and small cells provide a great support. The massive MIMO technique refers to the deployment of a very large number of antennas at the base station, thus improving wireless networks' spectral and energy efficiency. This enables a considerable reduction in the network energy consumption in the uplink by having more antennas that can receive the signal and in the downlink through the use of beamforming techniques. Towards the end-user, the low-powered small cell stations, which are compact and designed to complement conventional base stations in populated areas, can provide high data rates by reducing the transmission distances between the small cell base station and the user. In addition, this technology will also improve coverage by dense deployment of low cost small cell base stations, increasing the battery life of wireless devices.

Cloud computing techniques

The development of cloud infrastructure redesigns the traditional networks and provides both technical and economic benefits and exciting sustainable environmental initiatives. Cloud computing promotes green communication by allowing the use of IT-related tools and data center facilities to recycle the hardware to some extent and to reduce the energy consumption of ICT.

Driven by the energy crisis, global warming concerns, and unprecedented demands for wireless services, researchers and industry are continuously searching for greener solutions for the future generations of wireless networks. They are looking for energy-efficient technologies and energy-saving system architectures that can reduce the energy consumption for a bit of information transmitted. The previously mentioned techniques will play critical roles in designing and maintaining such complex distributed systems in the near future.

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Nature Art by AI

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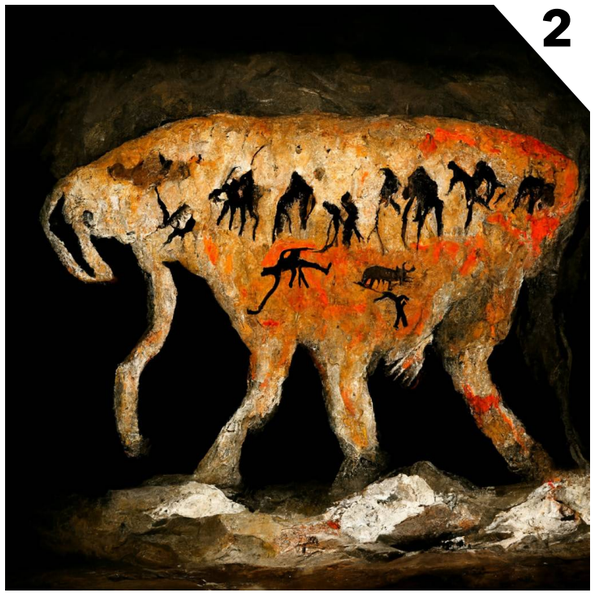
Have you ever dreamt of being a world-class artist like Pablo Picasso, Salvador Dalí, or Vincent van Gogh? Do you know that, now you can be an artist with zero skills?! Perhaps, I may be exaggerating here. With a bit of imagination and a whole lot of support from our virtual friend, Artificial Intelligence (AI) at MidJourney.com, you too can create remarkable artwork within seconds for free (limited trials).

Mid Journey is a new AI-powered tool that turns any textual description into artwork. Though there are several text-to-image generators, most of them are not open for the public. However, very recently, Mid Journey launched its open beta version for public to try. In Mid Journey, you have the freedom to create any artwork using any kind of art style and media.

With zero talent in art, instead of using pencils or paint brushes, me and my colleagues have attempted to create some artwork on the theme of 'environment' for the CES BIOME. We entered simple descriptions of artwork we wanted to create (e.g. 'Environmental pollution drawn as cave painting by pre historic humans') to the prompt and let the AI do the work for us. Within few seconds we were presented with four versions of the requested art and then using 'upscale' option we were able to add more details to the images. Even though we could not create a masterpiece like 'Starry night' by van Gogh, we were pleasantly surprised with the final outcome of our amateur artwork. We invite you to enjoy our (and AI's) art pieces and to try the text to art generator at MidJourney.com.

AI Art 1. 'Environmental Pollution' as a cave painting by Tharosa Rajaratne



AI Art 2. 'Sixth Mass Extinction' as a cave painting by Tharosa Rajaratne

AI Art 3. 'Forest Fire in Mediterranean Ecosystem' by Tharosa Rajaratne

AI Art 4. 'Water Pollution' by Tharosa Rajaratne

AI Art 5. 'Habitat Fragmentation' Dreamwork style by Tharosa Rajaratne

Image credit: MidJourney.com

AI Art 6. 'Tropical Rainforest' by Buddhika Weerasinghe

AI Art 7. 'Sinharaja Rainforest' by Tharosa Rajaratne

AI Art 8. 'Tigers by the Waterfall' by Subodha Range

AI Art 9. 'The Functioning Ecosystem' by Duleepa Mendis

Image credit: MidJourney.com

In Search of Avian Migrants....

An Expedition to Mannar to Witness Our Avifaunal Guests

By Kushini Kalupahana
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Sun rise over a wetland ecosystem frequently found in Mannar

The season of the migrants, which lies between September and April, brings forth a plethora of avifauna into the country. Sri Lanka lies within the Central Asian migratory flyway, providing migrants a favorable resting and feeding ground during their mission to avoid the harsh winter conditions.

Our journey begins on mid-January 2022, during peak migratory season. We join up with the gang in Kandy and embark on our road trip to Mannar. After a six-hour drive, a couple of food breaks, and two pull-overs for speeding (The police are very concerned about the cattle and mules becoming road-kill, which apparently is an increasing issue in the area with the new wider roads leading North), we arrive in scenic Mannar.

Early next day, we head off to Vankalai bird sanctuary, commonly known as the Mannar bird sanctuary, a protected area declared as a Ramsar wetland site. Our main target was to locate the flock of greater flamingos (*Phoenicopterus roseus*) that were residing in the wetland since last month. Sure enough, the line of pink caught our eye from a distance. We were lucky enough to glimpse them from a short distance as the birds had waded to the wetland bank with shallow water. Camouflaged clothing, silence, and our stealth walk behind the bank shrubs allowed us to get within an earshot distance of the birds.

A large flock of greater flamingos in the Vankalai bird sanctuary

The greater flamingo, the largest and most widespread species of flamingo, migrates from Africa, Europe, the Middle East, and even Northern India during the wintering months. They spend several months in warmer climates like Sri Lanka until the spring arrives in their breeding grounds. These migrants can be seen in the salt lagoons and salt pans of Mannar, Jaffna, and even Bundala National park.

The striking pink coloration of the flamingo occurs due to their dietary preference. The carotenoid pigment present in the crustaceans and algae they eat brings out a pinkish coloration in their plumage, which deepens with age.

[The bright pink coloration of flamingo feathers]

After spending a good couple of hours with these birds we continued on to our next destination, Thalaimannar. Thalaimannar, a settlement on the northwestern coast of Mannar Island, once served as a gateway for trade and travel between India and Sri Lanka. It holds a scenic sandy shore ecosystem, scattered with mangroves, seepweeds, and beach creepers and rich in diverse marine life such as limpets, crabs, and shellfish. It is also a safe haven for numerous migratory shore birds that arrive from the Northern hemisphere.

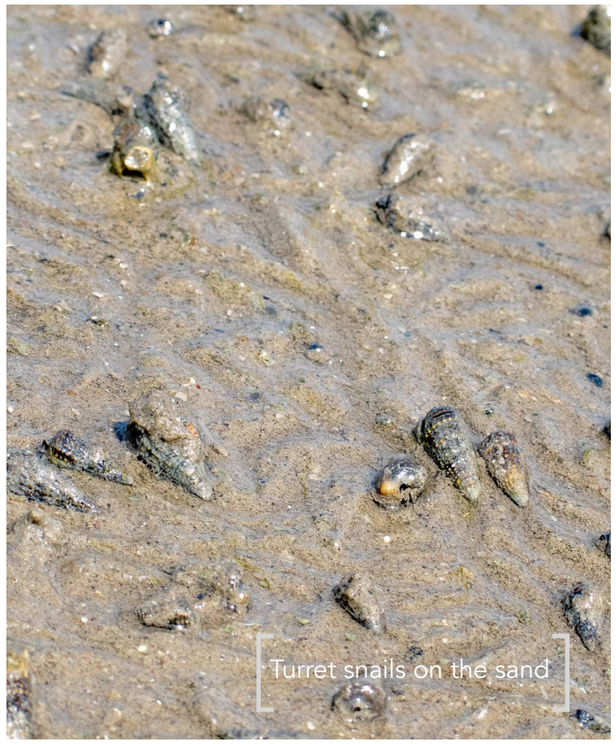
Sandy shore ecosystem with seepweed and creepers

Seepweed mat (*Suaeda* sp.) on the sandy beach

Mangroves with their visible pencil roots aka pneumatophores

Adam's Bridge National park

Our journey took us to the far west corner of Thalai Mannar towards the Adam's Bridge, which is now declared a national park. Geological evidence suggests that Adam's Bridge once interconnected Manner Island, off the northwestern coast of Sri Lanka, and Rameswaram Island off the southeastern coast of India. The 30 km long bridge is technically a chain of limestone shoals surrounded by a shallow sea which was allegedly passable by foot.

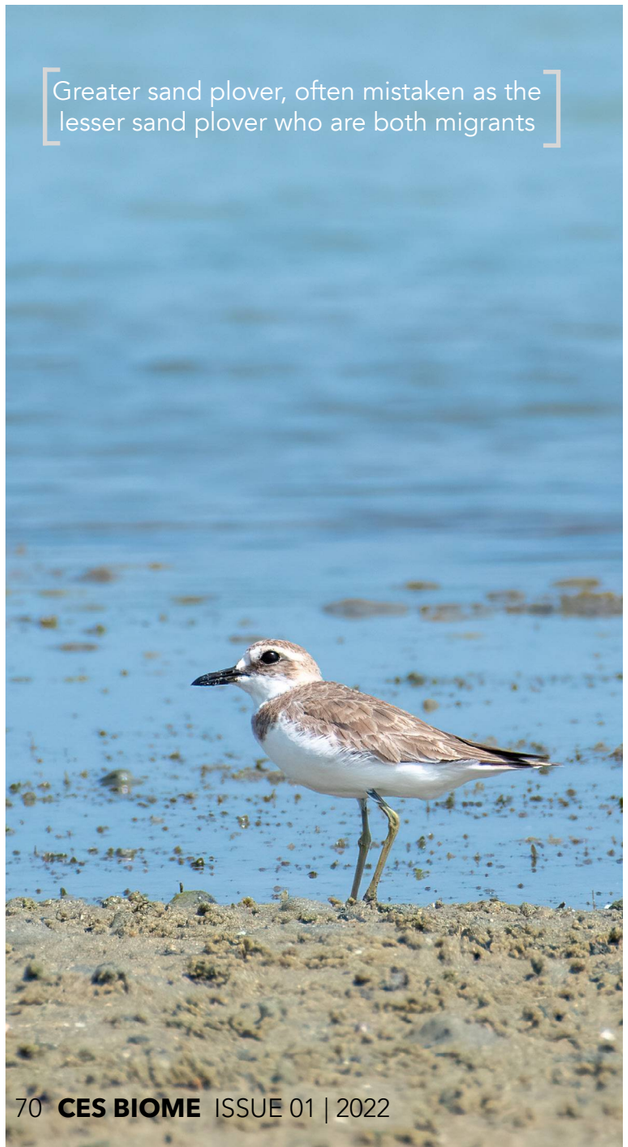


Turret snails on the sand

The miles of sandy beach that house a great abundance of marine critters like crabs, limpets, and shellfish attract flocks of shorebirds to the area. Most small shorebird species will flock together and even fly away together at the sense of danger. Greater sand plovers (*Charadrius leschenaultia*), Lesser sand plovers (*Charadrius mongolus*), terek sandpipers (*Xenus cinereus*), wood sandpipers (*Tringa glareola*), little stints (*Calidris minuta*), and ruddy turnstones (*Arenaria interpres*) are some smaller migrants that prefer the sandy shore rather than the open water.

A flock of ruddy turnstones in flight

A pair of wood sandpipers



Greater sand plover, often mistaken as the lesser sand plover who are both migrants

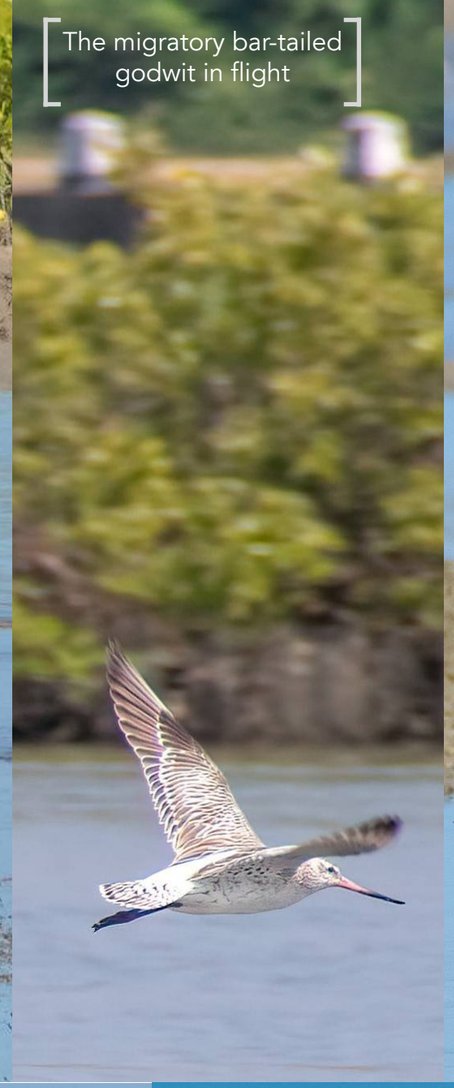
Terek sandpiper with a characteristic slightly upturned beak

Small shore birds like lesser sand plover and little stints flock together

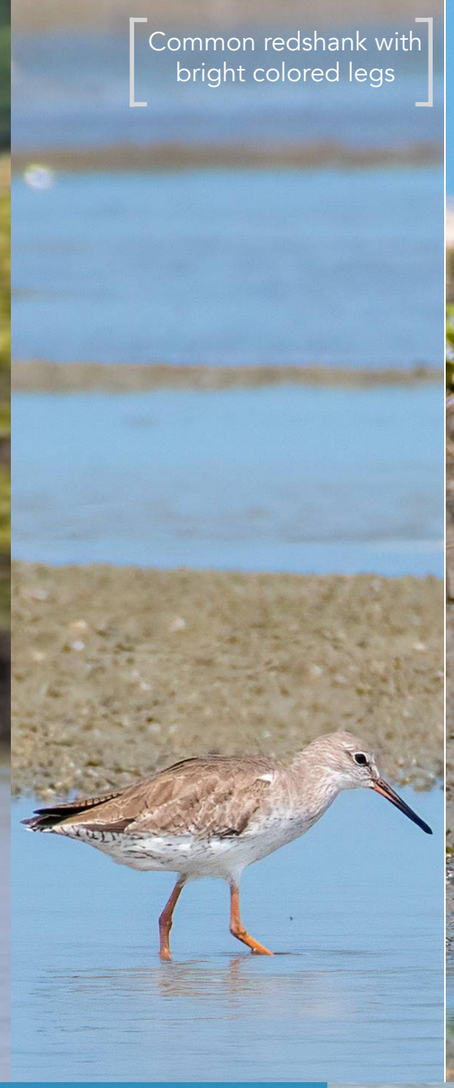
Larger wading birds like the Eurasian whimbrel (*Numenius phaeopus*), bar-tailed godwit (*Limosa lapponica*), and common redshank (*Tringa tetanus*) are seen in deeper water as they have taller legs and longer beaks that do not restrict them to the beach. Some rare finds during my visit were the Grey plover (*Pluvialis squatarola*) and the pin-tailed snipe (*Gallinago stenura*).

Seagulls and terns are other groups that fly thousands of miles to seek refuge in temperate coastlines to avoid harsh winters. Brown-headed gulls (*Chroicocephalus brunnicephalus*), Heuglin's gulls (*Larus heuglini*), and caspian terns (*Hydroprogne caspia*) were some migrants observed in this coastal environment.

Eurasian whimbrel with a long curved beak



The migratory bar-tailed godwit in flight

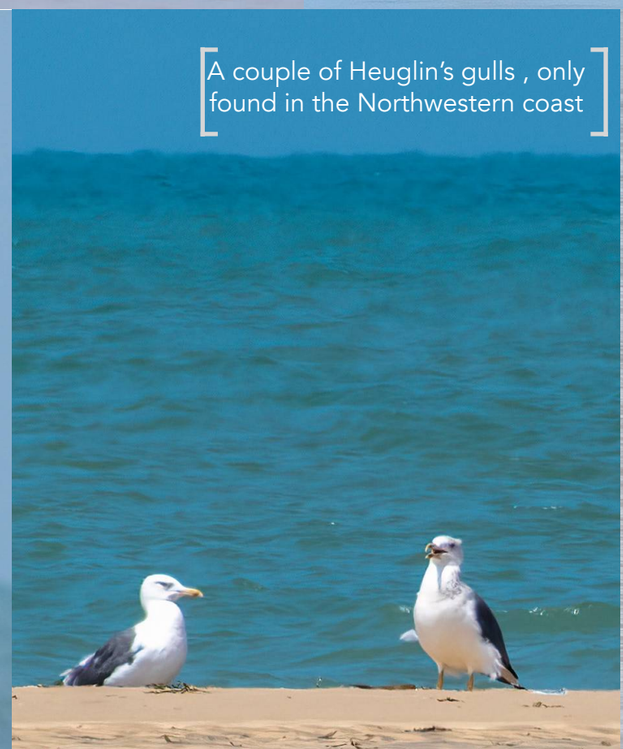


Common redshank with bright colored legs

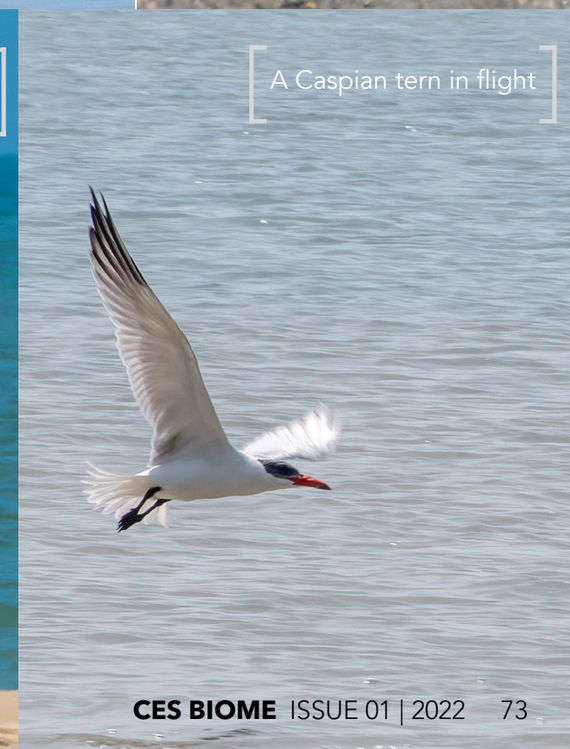
Grey plover against a mangrove mudflat

An elusive pintail snipe hidden among tall grasses

Brown-headed gull flying over the open ocean



A couple of Heuglin's gulls , only found in the Northwestern coast



A Caspian tern in flight

On our way back, we made sure to stop at the famous baobab tree in Pallimunai. It is a non-native plant that was believed to have been accidentally introduced by Arab merchants who brought baobab fruits from East Africa to feed their camels. This protected tree is over 700 years old and measures about 60 feet around, making it the oldest and largest baobab in Sri Lanka and giving it the local name of 'Ali gaha'.

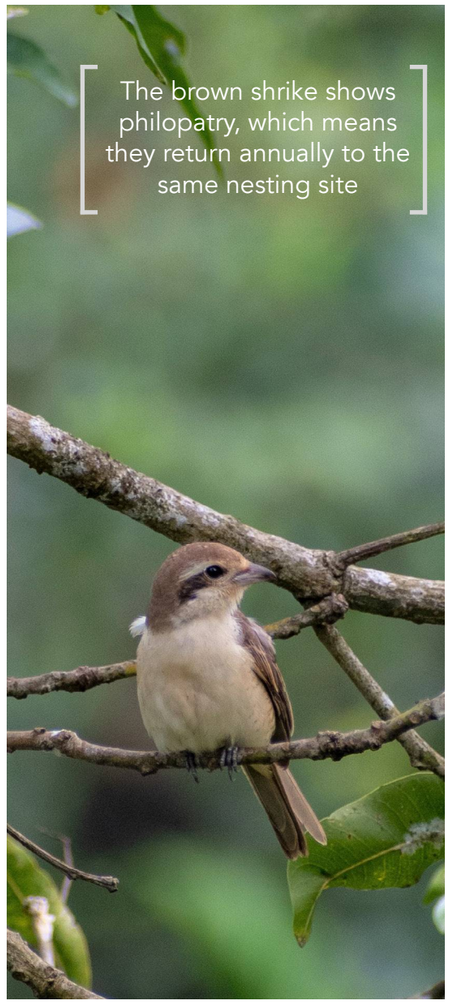
The final destination for the day was the scenic Doric bungalow at Arippu, which was once the home of Frederic North, the first British Governor of Ceylon. The mansion, which was later used by several government officials and superintendents is now in a dire state due to negligence and harsh coastal conditions. But the beauty of the ruins and scenery is still intact, especially during the sunset, which we were lucky enough to witness.

Apart from the migratory shore birds, thousands of terrestrial songbirds also migrate to Sri Lanka during the wintering months. During our journey, we came across numerous migratory passerines such as the brown shrike (*Lanius cristatus*), Indian paradise flycatcher (*Terpsiphone paradisi*), Asian brown flycatcher (*Muscicapa dauurica*) and brahminy starling (*Sturnia pagodarum*).

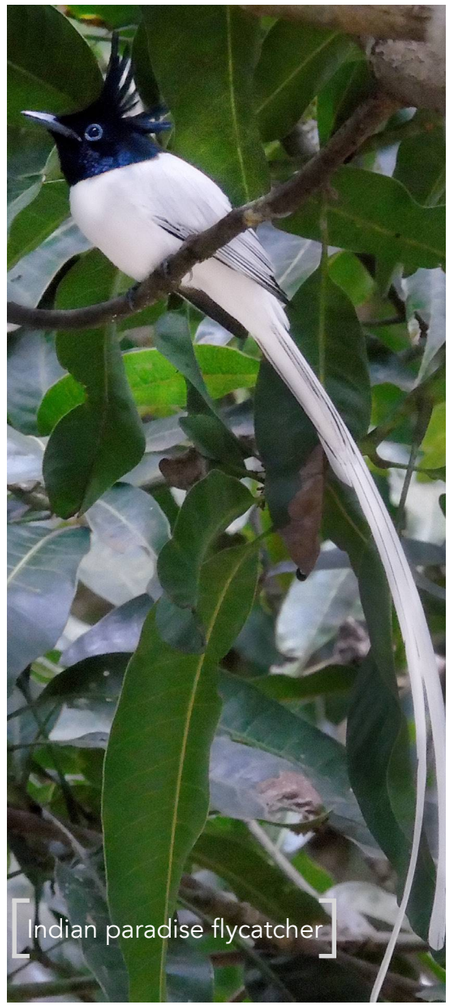
After witnessing the mass flamingo migration with our own eyes and also spotting several dozens of other smaller migrants, I believe our search for migrants on the Northwestern coast was a success. Comming across the flamboyant flamingos one last time under the setting sun on our way back was the perfect wrap to our adventure.

The famous Baobab tree in Pallimunai

Ruins of the Doric bungalow

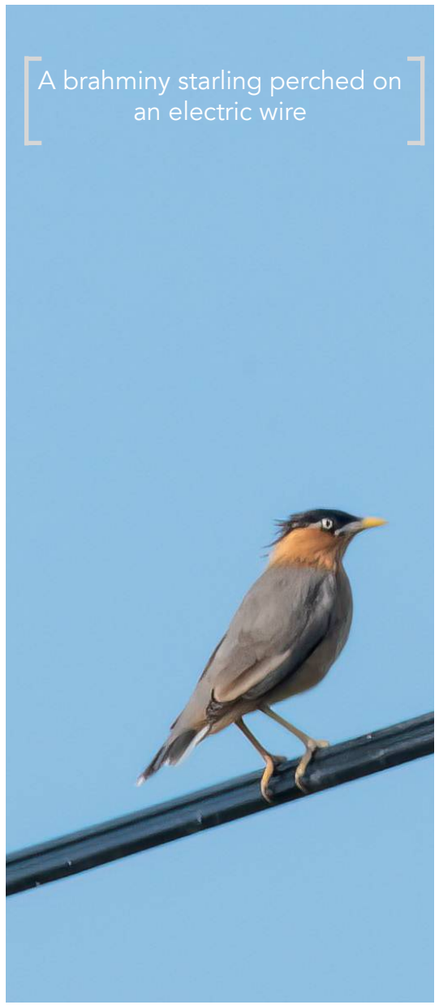


The brown shrike shows philopatry, which means they return annually to the same nesting site



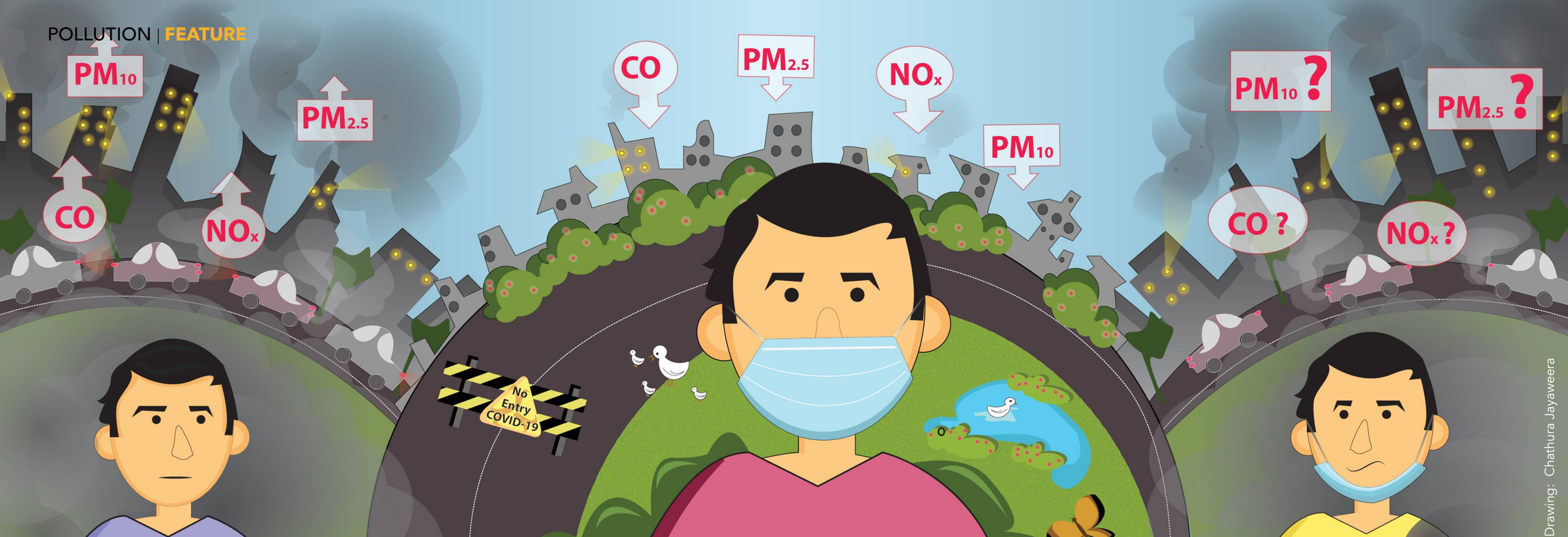
Indian paradise flycatcher

Asian brown flycatcher, a small passerine migrant



A brahminy starling perched on an electric wire

Photography: Kushini Kalupahana



Drawing: Chathura Jayaweera

COVID-19 Lockdown: Is it a "Blessing in Disguise" to Teach Us Lessons to Combat Air Pollution?

By Anushka Elangasinghe, PhD
Department of Chemical and Process Engineering, University of Peradeniya

Air pollution, "The invisible killer"

Inhalation of polluted air causes diseases such as stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, asthma and sometimes death. In many urban centers, people live in places where the World Health Organization (WHO) air quality standards are not met. Outdoor air pollution was estimated to cause 4.2 million premature deaths worldwide in 2016. Some 91% of those premature deaths occurred in low and middle-income countries. We think air is polluted only when we see the black smoke. But most of the air pollutants are colourless or does not show their existence when mixed with air. Therefore, we breathe them unknowingly. Without our knowledge we get exposed to many harmful air pollutants while indoors and outdoors.

Traffic related emissions, industry stack emissions, open burning of agricultural waste, open burning of waste (including incineration), dust storms, volcanic eruptions are some of outdoor sources of air pollution. Motor vehicle traffic is a huge problem in major cities all over the world. Many people spend a considerable amount of time held in traffic either by car, bus or riding a motor bike. Apart from those who are travelling in vehicles, pedestrians and people living in close proximity to busy roads and highways are also getting affected by the heavy traffic. Traffic makes people vulnerable to many health risks such as accidents, noise related stress and health problems related to air pollution.

All the fossil fuel driven motor vehicles emit lot of harmful gases and particulate matter from its tail pipe. Primary gaseous pollutants that emit directly from the vehicle tail pipe are oxides of nitrogen (NO/NO_2 commonly called as NO_X), carbon monoxide (CO), sulphur dioxide (SO_2), unburned fuel as volatile organic components (VOC) and carbon dioxide (CO_2). Apart from these gases, soot particles of elemental carbon of different size are added to the atmosphere. While the coarse fractions of these particles get deposited fast due to gravity, the fine fraction of particles less than 10 micrometre

(PM_{10}) is held in suspension for a long time. Particulate matter less than 2.5 micrometre ($PM_{2.5}$) can enter our respiratory tract giving us many respiratory related problems. They can also travel large distances in the atmosphere. Particulate matter less than 0.1 micrometre ($PM_{0.1}$) that are called ultrafine particles are very harmful to human health leading to deadly diseases.

In addition to outdoor air pollution, indoor smoke is also a serious health risk for some 2.6 billion people who cook and heat their homes with biomass, kerosene fuels and coal. Especially in Sri Lanka, poor ventilation inside houses, use of unclean fuel such as firewood, absence of chimneys or vents in households mainly when using firewood, burning of polythene and plastics inside houses to initiate fire when using firewood for cooking, lighting mosquito coils and incense sticks inside households and cigarette smoking inside houses also create a lot of respiratory related health problems.

When concentrations of air pollutants are above the national standards or WHO permitted levels, we call the air quality is unfavourable. Usually the governments use a colour code to warn people about the adverse nature of the air that they breathe.

Air quality is closely related to the earth's climate and ecosystem. For example combustion of fossil fuel is also a source of greenhouse gas emission. Therefore policies to reduce air pollution, offer a win-win strategy for both climate and health, lowering the burden of disease attributable to air pollution, as well as contributing to mitigation of climate change.

COVID-19 Pandemic Lockdown: "shadows and light"

COVID-19 pandemic is one of the biggest global public health emergencies in recent centuries. As of today 6.29 million people have lost their lives due to this deadly disease worldwide. 530 million people have contracted the virus. Those who already had respiratory related health issues were more vulnerable in getting infected. Therefore, in cities where air quality was bad and where many people were having respiratory related issues, the infection rate was high. However, there are lot of confounding factors that decide the spread of the COVID-19 virus and hence the relationship

> "Unusually low air pollution levels during lock-down periods have provided Environmental Scientists a data set to understand what atmo-spheric reactions happen in the sky and what should be done to improve regional air quality. Lockdowns have offered lessons on the kind of world we want to build after the pandemic.

between air pollution and spread of COVID-19 virus is not well established.

The threat of COVID-19 spread caused global health emergencies, forcing governments to take unprecedented decisions, including the lockdown of cities, specific states, or whole countries. The lockdown enforced people to stay where they were, and only essential services were being allowed. Schools and universities in many places around the world were closed to in-person sessions and switched to an online delivery mode, and for many employed across both the private and public sectors, work from home was also expected. Social distancing and travel restrictions were strictly imposed, especially during the first wave of the pandemic. Restricted vehicular movement, closure of industries, and other activities resulted in a significant reduction in anthropogenic emissions of air pollutants. This led to an improvement in the air quality of many cities worldwide, which was a very difficult task to achieve despite several emission control measures taken by the governments to control air pollution.

Pandemic lockdown air quality improvement: studies around the world

During the pandemic lockdown periods, as a result of limitation of all major anthropogenic activities that were prominent sources of air pollution, an improvement in air quality was observed globally. This was obviously seen during the first stage of lockdown in countries where stringent restrictions were made to control human moment. However, the emissions from natural sources, household sources and energy production related sources still contributed to air pollution in many regions. Therefore in the wake of the pandemic, it provided an unexpected ecological experiment with a data set for scientists to understand the effect of traffic and industrial related emissions on top of natural emissions and energy related emissions and provided a baseline data set to study different scenarios including atmospheric reactivity to control air pollution in different cities.

Scientists around the world used satellite images or ground level air quality data to understand air quality improvement during the pandemic lockdown. Figure 1 shows ESA satellite images showing the reduction in NO_2 concentration over China during the month of February 2020 compared to that of in February 2019 and February 2021. According to several research studies, a NO_2 concentration reduction of about 70% was observed in China while slightly different reductions were observed from its different provinces.

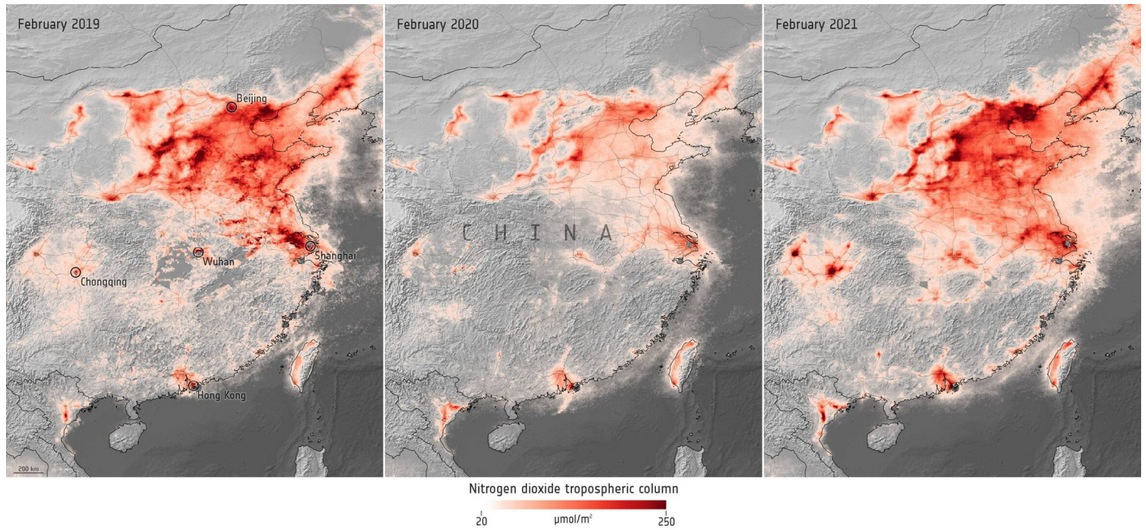


Figure 1. Monthly average NO_2 concentrations over China in February 2019, February 2020 and February 2021

Image credit: Contains modified Copernicus Sentinel data (2019–21), processed by ESA, CC BY-SA 3.0

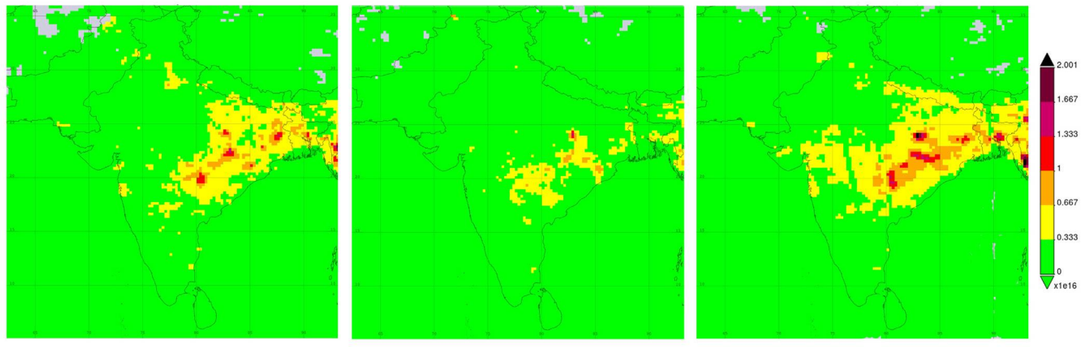


Figure 2. NO_2 column (from the surface to the top of the tropopause) levels (in mol. cm^{-2}) over South Asia during the last week (26^{th}–29^{th}) of March 2019, 2020 and 2021, respectively. (Imagae credit: Images were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC.)

Figure 2 shows NASA satellite images that depict reduction of NO_2 concentration over South Asia in March 26-29, 2020 compared

to same period during 2019 and 2021. Data on NO_2 levels from ground level monitors tell a similar story. It has been reported that there has been a 50% improvement in overall air quality index (AQI) over South Asia during this first phase of strict lockdown. According to Reuters, New Delhi, India experienced "the longest spell of clean air on record" during the lockdown. When the overall AQI is concerned, the research studies report that there has been a 41% reduction in Delhi, 16% reduction in Dhaka, 32% decrease in Kathmandu and 33% reduction in Colombo. The reduction was clearly seen with respect to the NO_2, CO and SO_2 concentration. However, the reduction was different in these cities as a result of the contribution from thermal power plants to the total air pollution load that was continuously running during the lockdown.

However, when it comes to $PM_{2.5}$ concentration, little reduction compared to other gaseous pollutants was observed. It reflects the fact that $PM_{2.5}$ has a complex source structure and not all sources of $PM_{2.5}$ were affected by the economic lockdown. Even though there was around 50% reduction in $PM_{2.5}$ pollution in some provinces of China during the lockdown, a haze event with secondary aerosol formation and an increase of O_3 and SO_2 concentration was reported due to house hold and energy sector emissions and adverse meteorological conditions. Similarly, according to studies by different research groups, capital cities of Iraq, Spain, Brazil, New Zealand, Italy, United States and Argentina also reported up to 50% reduction in NO_2 levels. However, due to presence of natural sources of VOC and due to the reduction in NO concentration in the atmosphere and in the absence of its complex reactions in the presence of sunlight (conversion reactions of NO and O_3 to form NO_2) an increase in the ozone (O_3) concentration has been notified in most of urban areas of these studies.

Learning from the COVID-19 lockdown to obtain clear skies in post pandemic era

While the environment may have convalesced during these early lockdowns, experts do not expect it to last unless we take strict measures to change the way of living. When humans

> Even though concentration of some gaseous pollutants showed a remarkable reduction during the lockdown, $PM_{2.5}$, the most dangerous pollutant showed moderate reductions or complex reduction patterns in many countries suggesting that $PM_{2.5}$ has a complex source structure and not all sources of $PM_{2.5}$ were affected by the economic lockdown.

were locked indoors the nature thrived and the wild animals were seen on streets. It taught us the importance of sustainable life style we had in olden days. It taught us the ultimate result of the hunger for becoming rich and going behind physical comfort and wasting of energy resources for achieving these comforts.

News on clear skies and waters during lockdown periods created a wave in social media, which could help to engage the new generation for ecological protection. Milan city of Italy, a historical city struggling with urban smog, showed remarkable improvement in air quality during lock down are now planning ways to reduce car use. A rapid public transport system needs to be implemented in all major cities to reduce use of private cars. A better traffic plan, a stringent emission control plan and a vehicle emission testing programme and proper control of industrial emissions is a must to combat air pollution. A hybrid way to work from home on a rotation basis with a system to monitor the work progress, a combined physical and online school and universities and online business meetings can indirectly reduce the traffic on road hence reduce the air pollution emissions. Cycling and E-cycling should be promoted and infrastructure such as bicycle lanes should be constructed by the government so that people travelling short distances can do so. School system should be improved so that children living several kilometre of distance should be admitted to a school so that they can walk, take the school bus or cycle to the school. Policies and investments supporting cleaner transport, energy efficient homes, power generation, industry and better municipal waste management would reduce key sources of outdoor air pollution. Below are the WHO recommendations to combat air pollution and to achieve clear skies that we saw during the lockdown.

Industrial sector: Clean technologies should be introduced to reduce industrial smoke stack emissions. An improved management plan should be introduced for urban and agricultural waste management, including capture of methane gas emitted from waste sites and use as biogas.

Power generation sector: Use of low emissions fuels and renewable combustion-free power sources (like solar, wind or hydropower) should be increased. Co-generation of heat and power and distributed energy generation (e.g. mini-grids and rooftop solar power generation) should be introduced.

Household Energy sector: Access to affordable clean household energy solutions for cooking, heating and lighting should be ensured.

Transport sector: It should be shifted to clean modes of power generation, prioritizing rapid urban transit, walking and cycling networks in cities as well as rail inter-urban freight and passenger travel.

Urban planning: Energy efficiency of buildings should be improved while making cities more green and compact and thus energy efficient.

Municipal and agricultural waste management: Strategies for waste reduction, waste separation, recycling and reuse or waste reprocessing should be introduced and existing programmes should be introduced. Improved methods should be introduced for biological waste management such as anaerobic waste digestion to produce biogas. Where incineration is unavoidable, then combustion technologies with strict emission controls are critical.

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Estimation of Environmental Assesment Endpoints Through Environmental Modelling: A Cost-Effective Method

By Thiloka Ariyasena, PhD
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In order to minimize the harmful effects caused by the chemicals released to the environment, the concentrations of the chemicals in the natural environmental systems such as soil, water, air and sediment should be determined and the hazard levels should be identified. Similarly, as significant amounts of chemicals are involved in many industries including the cosmetics, food, textile and pharmaceutical industries, monitoring the amount of chemical waste produced in those industrial reactor systems, and the amount discarded by the reactors to the environment is of primary importance.

Environmental risk assessment procedures established by the United States Environmental Protection Agency (U.S. EPA) and European Union (EU) evaluate the risk exerted by a chemical on the environment. Both U.S. EPA and EU procedures consists of four steps, which are hazard identification, dose-response (effect) assessment, exposure (fate) assessment and risk characterization. In environmental risk assessment, assessment endpoints are used. An environmental endpoint is an expression of an environmental value to be protected, defined as an ecological entity and its attributes. Determination of the chemical concentration in the environmental compartments plays a significant role in the dose-response assessment and exposure assessment steps. In dose-response assessment, the extent of the damage caused to human health with respect to the concentration of the chemical administered is evaluated. In exposure assessment, concentration of the chemical which comes in contact with the subject is evaluated together with the frequency of the contact and the duration of the contact.

> An environmental endpoint is an expression of an environmental value to be protected, defined as an ecological entity and its attributes.

A chemical can enter into human and animal bodies through four major routes, i.e. inhalation, absorption, ingestion, and injection. For example, chemicals in water can be transferred into the bodies of aquatic organisms, mainly through absorption and ingetion. Chemical contaminants may occur in various concentartions in water, sediment, soil, air, or food and may get accumulated in an organism through the process of bioaccumulation. Therefore, when determining the concentrations, rigorous measures should be taken to carry out the proper sampling procedures, and the number of replicates should be sufficient to obtain an accurate average value. This task becomes tedious in environmental studies, as there may be multiple exposure routes, and due to the possibility of chemicals to get dispersed in the environmental compartment, and transferred between two environmental compartments. Therefore, a significant amount of technical, economical and human resources is needed to determine the environmental end point values. Environmental scientists both in the developed and developing countries find this a challenging task. As a solution to this problem, properly developed environmental models are used to get an initial estimation of the environmental end points prior to experimental determinations. Using the models, the number of experimental trials, and therefore the cost, are greatly reduced as the experimenter is already aware of the range of values within which the true value for concentration lies. Quantitative structure property relationships (QSPR) are one such category of environmental models that can be used to estimate the environmental end points.

> QSPR is powerful analytical method for modeling and prediction of physicochemical and structural properties of molecules.

In QSPR, a chemical property is chosen as the response variable, and it is modelled as a function of physiochemical and structural properties. A diverse range of environmental endpoints including soil-water distribution, nonspecific toxicity to fish and eye-irritation levels can be determined using QSPR. The environmental models built using QSPRs can be categorized into two as local models and global models. Global models are constructed by considering relevant global factors. For example, if skin irritation levels are considered, in order to form a global model, the global factors such as age, health, genetic factors, dietary factors etc.. should be considered. For a local model, considering only the factors relevant to the local population under study will give an accurate estimate of the endpoints relevant to the local population and matrix.

Large quantities of toxic organic chemicals are released to the environment each year from the industries. Toxic substance control act has listed over twelve thousand organic chemicals which lack effect or exposure data. Effect and exposure assessments of the numerous chemicals included in the listing is almost an impossible task due to the limitation of the resources and therefore the high cost needed. Due to this reason, the QSRPs play an important role in estimating the environmental and physicochemical endpoint values for these chemical compounds both in the natural environment and in the areas where extensive industrial activities are involved. Due to the economical feasibility, this method is well suited for developing countries.

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Drawing: Pathum Piyumal

Human-Elephant Conflict with Reference to Mahaweli System C

By Nadeesha Jayathunga (BA)
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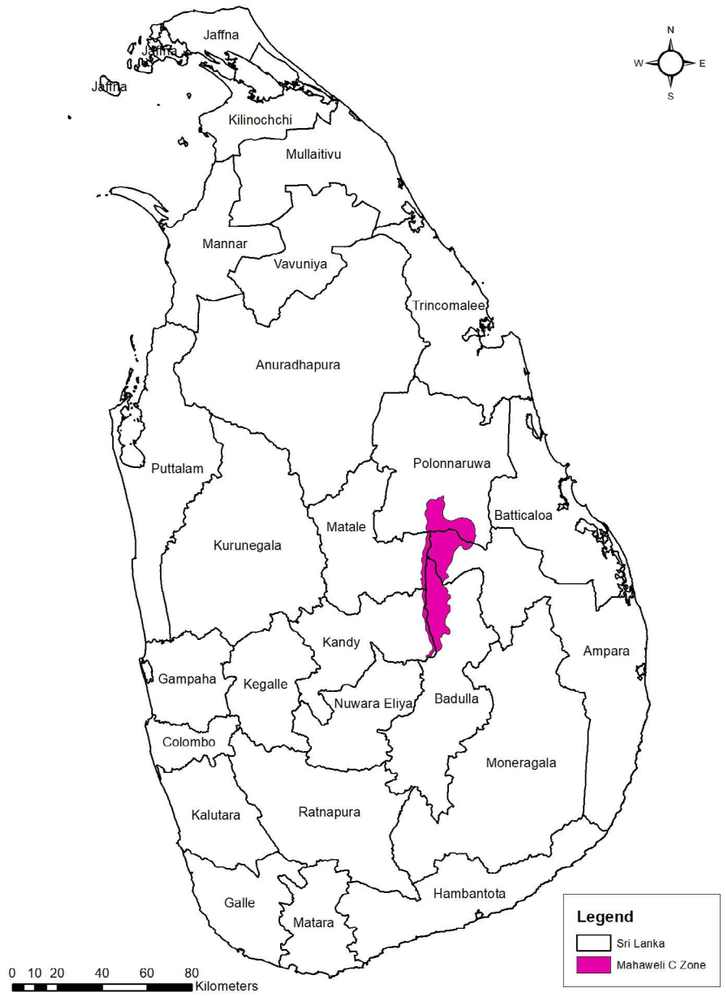
There is a strong cultural bond between the Sri Lankan people and elephants that dates back more than 5,000 years. Domesticated elephants were used in religious activities, transportation, constructions and even in warfare. Even though, there were no records of any conflicts between humans and wild elephants in the past, with the implementation of the accelerated Mahaweli project in 1978, human-elephant conflict (HEC) in dry-zone of Sri Lanka became a major issue. In Sri Lanka, the HEC can be demonstrated to be a social problem because it possesses nearly all the defining characteristics of a social problem. Consequently, this conflict has direct and indirect effects on society and the environment. Both humans and elephants have lost their freedom to live.

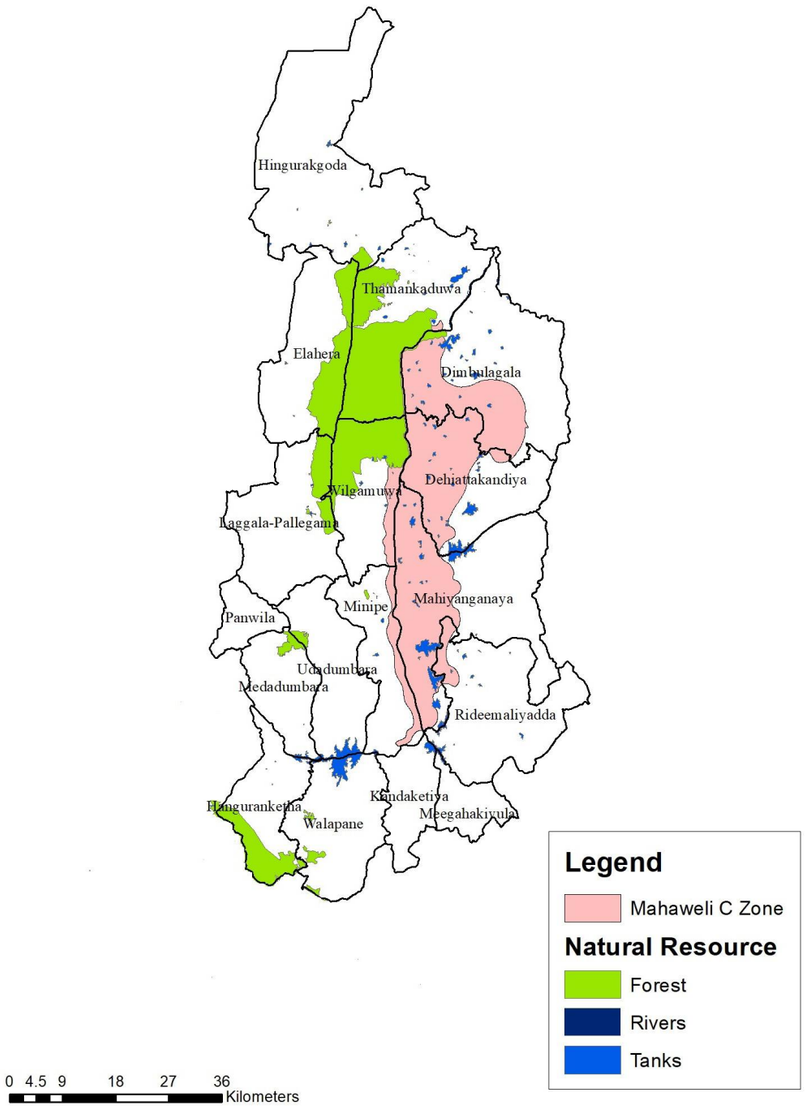
From an ecological perspective, elephants are considered to be a 'keystone species' in the ecosystems they inhabit, as they maintain the vegetation structure and biodiversity. They also play a role as an 'umbrella species'. Thus conservation of elephants will automatically ensure the conservation of other species that co-exist in the same habitat. However, a review of Sri Lanka's recent past demonstrates that the expanding human population and diminishing forest cover provide a systematic threat to the survival of elephants. Further, Sri Lankan governments' agrarian economic policies have contributed significantly to the destruction of elephant habitat and their ancient wilderness, as well as the escalation of human-elephant conflict.

Location of the Mahaweli System C, Sri Lanka



According to the scientific literature, the seven most prevalent causal explanations for HEC were identified. It is important to note that some of these ideal categories are not mutually exclusive.

1. Colonial legacy as a historical cause
2. Poaching
3. Population growth and habitat loss
4. Crop raiding and socio-economic grievances
5. Problem elephants
6. Agriculture modernization – failed cohabita tion
7. Neoliberal conservation and social justice

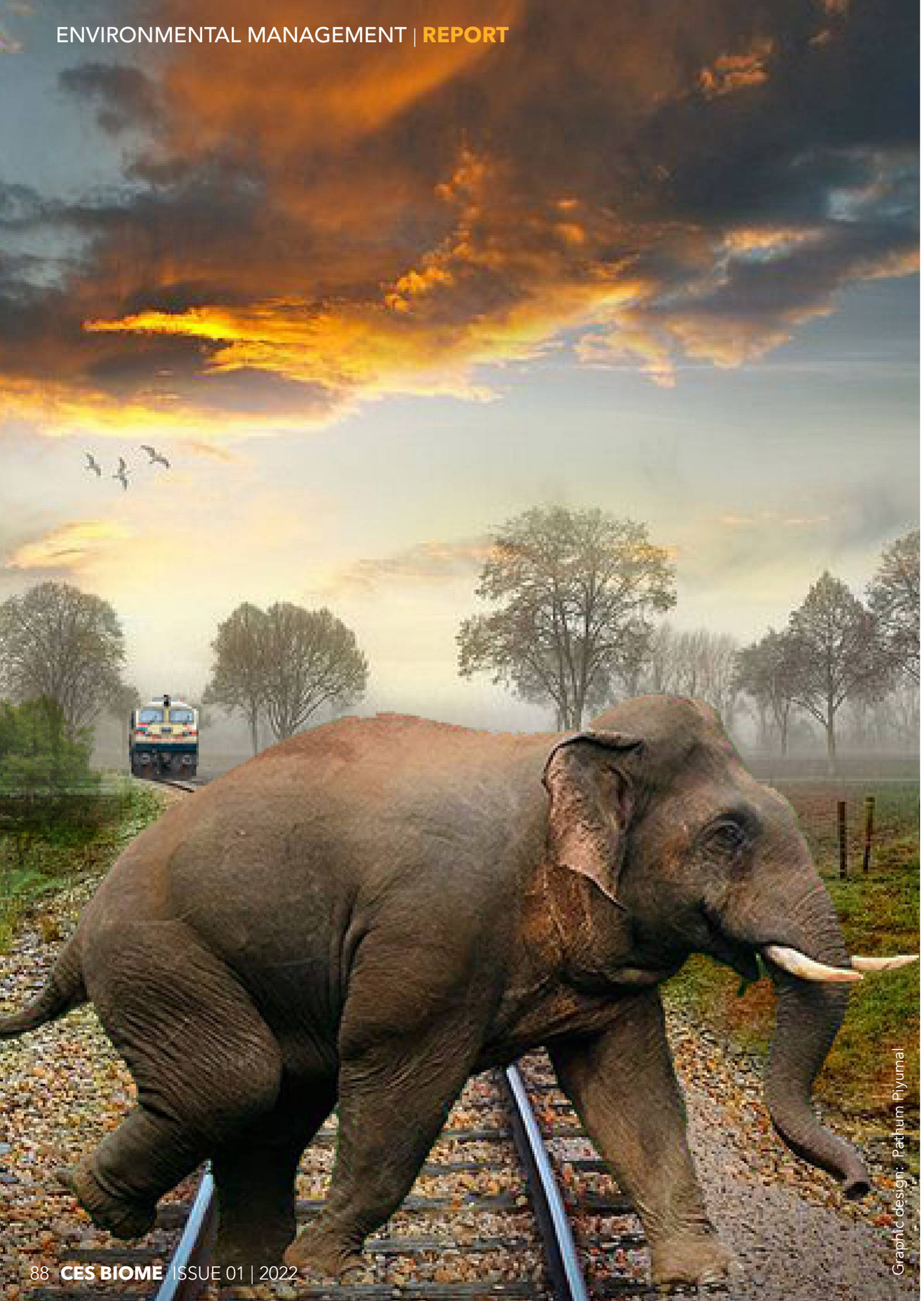


Distribution Pattern of Elephants in Mahaweli System C

The Asian elephant is considered one of the world's few remaining big herbivores. The Sri Lankan elephant, *Elephas Maximus Maximus*, is the largest of the four subspecies of Asian elephants. In terms of elephant distribution in Sri Lanka, the Mahaweli wildlife region recorded the largest number of elephant sightings compared to the other five wildlife regions. 29.8% of all elephants spotted in Sri Lanka have been documented in the Mahaweli region. In the meantime, 13.1% of tuskers and 243 places where elephants were observed were recorded in the Mahaweli region. The entire Mahaweli region is within the elephant's range and habitat and has a high conservation potential. In the Mahaweli C region, the elephant reserve is quite large and mostly made up of the two forest divisions of Wasgamuwa National Park and Maduru Oya National Park.

Considering the elephant corridors in the Mahaweli, there are two elephant corridors within the Mahaweli C system, the Ulhitiya corridor, which connects Maduru Oya National Park to Wasgamuwa National Park, and the Hungamalaoya corridor, which connects Maduru Oya National Park to Flood Plain National Park. These two elephant pathways in the Mahaweli C system are currently inoperable due to human settlements and developments in these protected regions. Additionally, electric fences were installed along these elephant pathways to reduce human-elephant conflict. There is an electric fence in the Mahaweli C region. This 62-kilometre-long electric fence prevents elephant migration between Maduru Oya National Park, Wasgamuwa National Park, and Flood Plain National Park.

> An animal corridor is a relatively narrow strip of habitat which allow animals to migrate between two larger habitats. Corridors are essential for migration of animals between isolated populations, promiting incresed, genetic diversity to maintain viable populations.



Graphic design: Pathum Piyumal

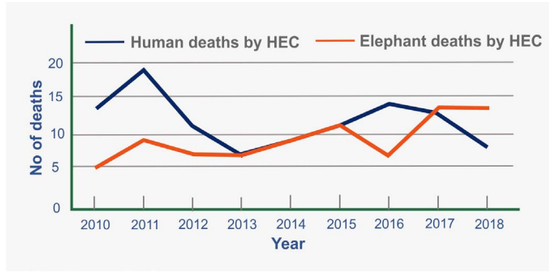
Human-Elephant Conflict (HEC) in the Mahaweli System C

Three most HEC-vulnerable patches in the Mahaweli C system have been identified through the geographical distribution analysis. These spotted areas encompass Nuwaragala, Giradurukotte, and Henanigala. The Hungamala Oya and Ulhitiya elephant routes are currently closed by electric fencing in Nuwaragala and Giradurkotte, two of the three selected sites. According to the evidence that the conflict between people and elephants is caused by the closing of elephant corridors, due to the expansion of human settlements.

Both humans and elephants are suffering due to HEC. Between 2014 and 2017, according to the Department of Wildlife Conservation, 305 humans and 971 wild elephants died due to HEC. The use of weapons, electric shocks, *Hakkapatas*, poisoning, and train accidents are some of the causes of elephant deaths. However, the leading causes of elephant mortality between 2014 and 2017 were gunshots, and use of *Hakkapatas*. Thus, between 2014 and 2017, almost 60% of wild elephants died because of direct actions by people.

Human-elephant conflict (HEC) has been a severe environmental and societal problem in the Mahaweli C region for decades. Elephant migrations into human settlement areas are becoming increasingly frequent and pose a significant threat to human lives, property, and agricultural fields. Human-elephant conflict is defined as the incursion of elephants into human communities, resulting in the destruction of human lives, property, and croplands, as well as the deaths of both parties.
When people clear the forests on a larger scale, the availability of sufficient food and water within the remaining forest regions decreases, forcing elephants to leave the jungle and raid crop-cultivated fields and cause damage to nearby properties. Once elephants began crop-raiding in a region, it would be difficult to stop them, and they would likely continue to strike periodically.

Elephants appear to be most active between 16:00 and 22:00 during the night. During these hours, elephants have been recorded raiding crops in Mahaweli C system communities. During field observations, inhabitants in Giradurukotte, Dehiattakandiya, and Nawa Madagama were transported by elephants that are typically spotted during these peak hours. So, the lack of street lamps along roads is a factor in the deaths of people caused



Source: DWC, 2018

Figure 2: Comparison of human and elephant deaths caused by the human-elephant conflict in Mahaweli system C

by elephant attacks. Figure 2, illustrates that the annual number of human deaths in the Mahaweli system C is more than the number of elephant deaths. Human and elephant mortality has escalated significantly as a result of the conflict between these two entities.

Management of HEC

When considering the management practices for mitigating HEC in the region of the Mahaweli system C should re-establish the above-mentioned two elephant pathways to facilitate elephant circulation. Currently, humans have encroached upon these two elephant corridors and use them for paddy agriculture and house gardens. The objective of management should be to preserve the corridor's function while permitting other land uses.

- Limiting human activity and food availability along and near the corridor
- Increase the most favourable food sources for elephants at the corridor's end to allow for faster elephant transit through the corridor.
- Allowing corridor width to be increased through regeneration and the protection of vegetated patches and remnants by excluding or reducing stocking rates and reducing

the frequency of hazard reduction burns.

- Enhancing the ecological value of corridors through weed and feral animal management.

In conclusion, people's irresponsible behaviour, such as approaching wild elephants when intoxicated, disturbing elephants, and excessively chasing them, is the cause of many HEC-related deaths. The majority of HEC-related human deaths are preventable if sufficient safeguards are adopted. The mass media play a significant role in bringing attention to HEC and changing public opinion. Instead of making HEC incidents seem more interesting than they are, the media should responsibly report them by explaining the real causes and circumstances that led to them.

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Image credit: Nalin Gama-Arachchige

Mosquito Breeding Grounds and Disease Burden in Sri Lanka

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Rapid urbanization and un-planned land use patterns is often associated with the emergence and spread of vector-borne diseases as it creates favorable environments for blood feeding insect vectors to complete their life cycle. Among the world's well-known vectors, mosquitoes are at the top of the list. These are two winged flies, which transmit many life threatening pathogens. A total of 3603 species of mosquitoes (family: Culicidae) belonging to two subfamilies (Anophelinae and Culicinae) and 113 genera have been identified and are abundant in tropical and temperate regions of the world. The abundance and the diversity of mosquitoes in different environmental settings is influenced by the availability and diversity of breeding sites. Human activities increase the availability of breeding sites (artificial containers), blood meal resources, and resting sites of mosquitoes and thereby the abundance and the distribution. Female mosquitoes feed on animal and human blood, through which mosquitoes are able to transmit many pathogens that cause diseases to humans and wildlife. Dengue, Chikungunya, Malaria, Japanese Encephalitis (JE), Lymphatic Filariasis and Yellow Fever are some of the well-known mosquito borne diseases in the world and according to recent World Health Organization reports, 17% of the infectious disease burden in the world is due to mosquitoes.

Mosquito-borne diseases

Malaria is an ancient and a widely spread mosquito-borne disease in the world. The association of land use patterns and malaria transmission are well documented and the habitats created due to irrigation canals, agricultural practices and deforestation increase the abundance of malaria mosquitoes, as they prefer such habitats as breeding sites. Nearly 3.5 billion people living in 95 countries are at risk of being infected with the malaria pathogen, and 90% of the cases are reported from the African region. April 25th is considered as "World Malaria Day" and many countries organize activities on this day with the focus of reducing malaria. Nearly 241 million malaria cases and 627,000 malaria deaths were reported only in 2020. The relatively high death rates reported in 2020 is linked to the COVID 19 pandemic as regular monitoring of breeding sites was hindered. Human malaria is caused by four species of single celled protozoan pathogens (*Plasmodium falciparum, P. vivax, P. malariae,* and *P. ovale*). Mosquito species belonging to the genus *Anopheles* act as vectors of these pathogens.

Lymphatic Filariasis is one of the major public health problems in the tropics especially in the South-East Asian Region. Nearly, 863 million people living in 47 countries are at risk of getting infected by Lymphatic Filariasis. Rapid and unplanned urbanization create ideal microhabitats for filarial vector mosquitoes as well. Polluted water storages and effluents of industries and agricultural lands facilitate the proliferation of vector mosquitoes of filariasis. The oily and rusty stagnant water bodies rich with PO_4^{3-} or NH_4^+ are preferred by filariasis vectors. Three nematode species; *Wuchereria bancrofti, Brugia malayi* and *Brugia timori*, have been identified as the causative agents of Lymphatic Filariasis. Microfilaria worms of *W. bancrofti*, which usually live in the lymphatic system of humans is the major parasite of human filariasis while *Brugia malayi* is responsible for filariasis of wild and domestic animals. The microfilaria is transmitted mainly by mosquitoes belonging to genus *Culex*. *Anopheles* species and *Aedes* species also have been identified as vectors respectively in rural areas and islands in the pacific.

Japanese Encephalitis is a viral disease endemic to temperate and tropical zones of Asia. The flavivirus belonging to the family Flaviviridae, is transmitted to human hosts by the bite of an infected mosquito. *Culex tritaeniorhynchus* and *Cx. gelidus* are the major mosquito species responsible for transmitting the virus. *Culex vishnui, Cx. pseudovishnui* and *Cx. fuscocephala* have also been identified as vectors of the disease. In addition to the mosquito vector, the life cycle of the virus involves several intermediate vertebrate hosts, such as pigs and birds. The resting and breeding sites of these mosquito vectors are rice fields.

Dengue is a mosquito- borne viral disease which threatens nearly half of the world's population. Around 100-400 million dengue infections occur annually in tropical and sub-tropical regions of the world. The dengue virus (DENV) is a single stranded arbovirus that belongs to genus *Flavivirus* which occurs as four serotypes, DENV1, DENV2, DENV3 and DENV4. The breeding sites of dengue mosquitoes are any open containers of varying sizes that can contain water. A high correlation between urbanization, availability of breeding sites and prevalence of dengue is well documented in the world. In forested habitats, tree holes are the more frequently reported breeding sites of these mosquitoes.

Mosquitoes and disease prevalence in Sri Lanka

Mosquitoes are a highly diverse and abundant group of insects distributed throughout Sri Lanka. The tropical climatic conditions prevailing throughout the country favor the successful completion of mosquito life cycle and survival. Mosquito breeding sites created *via* agricultural practices and urbanization influence the population density of mosquitoes in the country. At present, 159 mosquito species and 19 genera have been reported in Sri Lanka and a significant number of these mosquitoes are vectors of many diseases. Malaria, Lymphatic Filariasis, Japanese Encephalitis (JE), Dengue and Chikungunya are the major mosquito-borne diseases reported in the country.

Malaria was the most devastating disease in the 1930's in Sri Lanka. *Anopheles culicifacies* and *An. subpictus* are respectively the primary and secondary vectors of malaria in Sri Lanka. The breeding sites of malaria vectors are irrigation canals, rice fields, flooded fields,

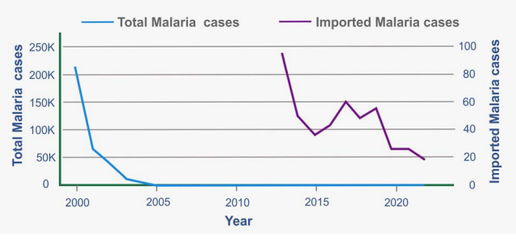

Figure 1. Malaria cases reported during 2000 to June 2022 and imported cases after elimination of local malaria in Sri Lanka (Data source: Anti-Malaria Campaign, Sri Lanka)

pastures, rock pools and rivers or stream margins. There were outbreaks during 1980 to 2000 due to the abundance of breeding sites in dry zone areas with the new irrigation schemes. An estimated 1.5 million people were infected and 80,000 deaths were reported during this period. The disease was controlled successfully during 1958-1963 with the introduction of the synthetic insecticide DDT. Continuous use of DDT, however, caused high resistance to the chemical in mosquitoes. DDT is currently banned in many countries due to the negative impact on the environment *via* bio-accumulation. Indoor residual spraying of Malathion started in 1975 and pyrethroid insecticides were introduced in 1994. The Primaquine drug was introduced to malaria patients and the disease condition gradually decreased and was effectively controlled. Local cases have not been reported after 2012, and WHO declared Sri Lanka as a Malaria free country in 2016 (Figure 1). According to recent reports, 26 imported malaria cases have been reported in 2021 and the authorities are

on alert as there is a high risk of getting the disease back in the country. One of the major vectors of malaria in India is *An. stephensi,* and this species was recently discovered from northwestern coast of Mannar in Sri Lanka.

Culex quinquesfasciatus is the major mosquito species in Sri Lanka that transmit *Wuchereria bancrofti* from person to person. Filariasis was endemic to districts of Western and Southern Coastal areas and recorded the highest numbers of annual cases. These areas were therefore, considered as the "filariasis belt" and the breeding sites of *Culex* vectors were abundant mainly due to the coconut industry. The disease has been controlled *via* a mass drug administration programme initiated in 2002. The introduced drug (diethylcarbamazine and albendazole) could reduce the parasites density and prevalence in the blood of infected individuals to a level that cannot be transferred to another host. In 2016, the WHO recognized Sri Lanka as a filariasis free country. The vector control programs are administered by the Anti-filaraisis campaigns in Sri Lanka and control strategies are mainly centered on chemical insecticides to control larvae and adult stages. The elimination of mosquito breeding sites is the other main strategy in diseases control.

Japanese Encephalitis (JE) is another major mosquito borne disease reported in Sri Lanka and *Cx. tritaeniorhynchus* is the major vector of JE. *Culex pseudovishnui, Cx. gelidus, Cx. fuscocephala, Cx. whitmorei,* and *Mansonia uniformis* are known as minor vectors of the disease in the country. The first JE outbreak in the country was reported in 1984-1987 with 812 cases and 192 deaths. The disease condition was controlled with effective mosquito control programs. In 1988, an immunization program was introduced against JE by vaccinating children of 1-10 years old. In addition, an immunization programme was introduced for pigs as well. Rice fields are the main breeding sites and resting sites of *Cx. tritaeniorhynchus* and the extensive use of pesticides in rice fields may have caused the reduction in mosquito density.

In Sri Lanka, *Aedes aegypti* and *Ae. albopictus* are the major mosquito vectors of the dengue virus. The climatic, geographical, environmental and social conditions of the island provide favorable conditions for the survival of both the vectors and the virus. Two major annual peaks of dengue incidences have been identified in the country during the two monsoon seasons; i.e. South-West monsoon season from late April-September and North-East monsoon season from October to December. Dengue vector mosquitoes mostly inhabit urban environments and are more likely to utilize man-made artificial water-holding containers as breeding sites. Ornamental containers, discarded receptacles, flower pots, plates and roof gutters are the most preferred breeding sites. The first dengue outbreak in Sri Lanka was reported in 1965-1966 with 26 cases and 6 deaths. The majority of those cases were reported from the western coastal belt of the country. Dengue cases began to increase in early 2000 and the second outbreak was reported in 2004 with 15,483 cases and 87 deaths. During the 2009 epidemic, 35,007 cases and 346 deaths were reported. The average annual cases of dengue have been reported as 25,000 for last few decades (Figure 2). The largest dengue outbreak in Sri Lanka was reported 2017 and more than 186,000 cases were reported with 440 deaths. Colombo and Gampaha districts in the Western province of Sri Lanka recorded the highest annual dengue cases followed by Kurunegala and Kandy districts. According to 2022 reports, number of dengue cases are increasing dramatically in the country (Figure 2). Vector control is the most effective approach to control the diseases and all control programs are administered by the Anti-Dengue units in Sri Lanka.

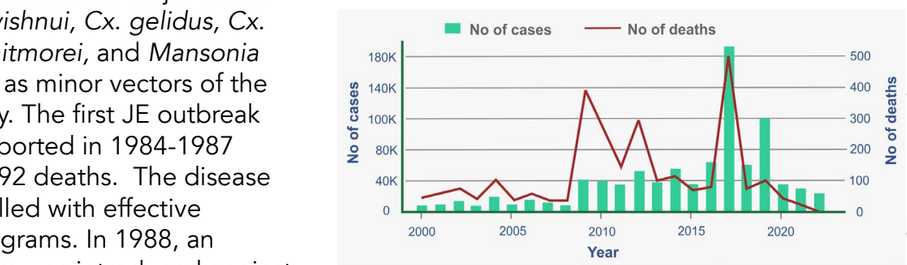

Figure 2. Dengue cases and deaths reported in Sri Lanka during 2020 to June 2022 (Data source: Epidemiology Unit Ministry of Health)

Control strategies of vector mosquitoes

The main mosquito control strategy in the country is by the use of organochlorine, organophosphate, carbamate or pyrethroid insecticide chemicals that help control both adults and larvae. Pyrethroid insecticides have higher demand at present due to its rapid action, higher insecticidal activity and low mammalian toxicity. Permethrin, deltamethrin, cyfluthrin, lambda-cyhalothrin, etofenprox are the major types of pyrethroids used and they are applied as either residual spray or space spray. However, there are many environmental issues of chemical insecticides due to toxic residues in food, water, air and soil. Larvivorous fish species [*Poecilia reticulate* (guppy), *Aplocheilus* spp. (nalahandaya), *Rasbora daniconius* (dandi) and juvenile stages of *Tilapiya* spp.] predatory copepods, microbes (*Bacillus thurengiensis isralensis*, Bti) are effective biological control agents of mosquito larvae with minimal environmental issues. Novel approaches of mosquito control programs include the use of endosymbiotic bacterials (*Wolbachia* strains) and other microbes that reduce the survival and the life span of mosquitoes. Sterile insect technique (SIT) is another approach of mosquito control that involves release of large numbers of sterile male insects into the field. Application of nano-technology in mosquito control programs including use of synthetic and green nanoparticles are also encouraging. Environmental friendly botanical insecticides are getting more attention in mosquito control programs as an alternative to chemical insecticides. The most effective approach is the removal of mosquito breeding and resting sites *via* environmental management. Awareness programs and community cleanup programs to eliminate mosquito breeding places are vital to reduce the size of mosquito populations. Continuous assessment and monitoring of control approaches will ensure effective management of mosquito populations and in turn mosquito borne diseases.

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The K9s and the Clan!

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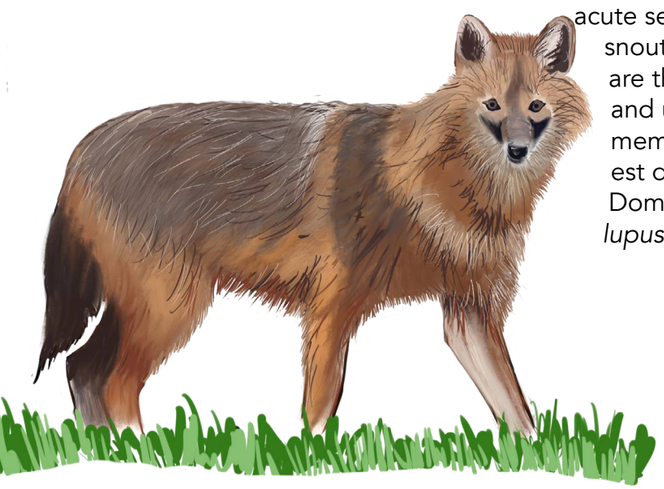
Have you ever wondered who your pet doggy's relatives are? Do you know there are about 165 species in its clade? Isn't it surprising to hear they are distributed all over the world including frozen Antarctica? Come-on! Let's browse through the directory of the canines and the clan!

The Suborder Caniformia comes under the mammalian order Carnivora (in Latin, 'flesh devourer') and comprises of the 'dog-like' animals, such as wolves, bears, dogs and the aquatic pinnipeds. Probably the most noticeable characteristic distinguishing them from all other mammals is the presence of four carnassial teeth in the front of the jaw. Possession of single-chambered or partially divided auditory bullae composed of a single bone is another main feature of caniforms. Further, they generally have non-retractile claws and tend to be plantigrade (walking with the podials and metatarsals flat on the ground).

Typically, there are nine living families classified under the Suborder Caniformia, namely; Canidae (dogs, foxes and wolves), Ursidae (bears), Procyonidae (raccoons and coatis), Mustelidae (badgers, weasels and otters), Mephitidae (skunks), Ailuridae (the red panda) as well as the aquatic pinnipeds, which include the families Odobenidae (walruses), Phocidae (true or earless seals) and Otariidae (eared seals: fur seals and sea lions) (These pinnipeds are thought to be descendants of caniform ancestors and are hence classified under this group).

Family Canidae

Family Canidae or canids, commonly known as canines includes wolves, dogs, jackals, foxes and coyotes etc. This family comprises about 34 species which belong to 14 genera, distributed worldwide except in Antarctica. The only wild member of the Order Carnivora found in Australia is included in this family; the dingo. They have an acute sense of smell, deep-chested bodies, long snouts and moderately long legs and feet. Canids are the most sociable animals of all the caniforms, and usually found as packs. The most familiar member of the family, the dog records the highest diversity in body structure of all mammals. E.g.: Domestic dog (*Canis familiaris*), Grey wolf (*Canis lupus*), Golden jackal (*Canis aureus*).



Family Ursidae

Family Ursidae, or simply the bears are the largest of all land caniforms. They range in size from small sun bears that weigh around 45 kilograms to large polar bears that weigh up to 700 kilograms. Ursids are robust animals covered with a thick layer of hair. They have small, rounded eyes and a very short tail. Each of their feet has five digits with claws that are long, sharp and recurved. Their conservation status ranges from the endangered giant panda to the very common black bear. There are around 8 species placed in 5 genera. They are widely distributed, occurring in a variety of localities ranging from Arctic ice to tropical cloud forests in North and South Americas, Europe and Asia. E.g.: American black bear (*Ursus americanus*), Sun bear (*Helarctos malayanus*) and Giant panda (*Ailuropoda melanoleuca*).

Family Procyonidae

Family Procyonidae, which includes the raccoons and coatis, have a relatively short snout, medium to long tail and short, yet erect ears. They have a keen sense of smell. Both their forefeet and hindfeet have five digits with short and curved claws. In some species, these claws can be partially retracted. Procyonids show a wide variation in body size, ranging from less than one kilogram to 20 kilograms. These are omnivorous and are dietary generalists that can survive in a variety of habitats, including human civilizations. However, they are restricted to the New World. This family includes 18 species in 6 genera. E.g.: North American raccoon (*Procyon lotor*) and South American coati (*Nasua nasua*).

Family Musteli-

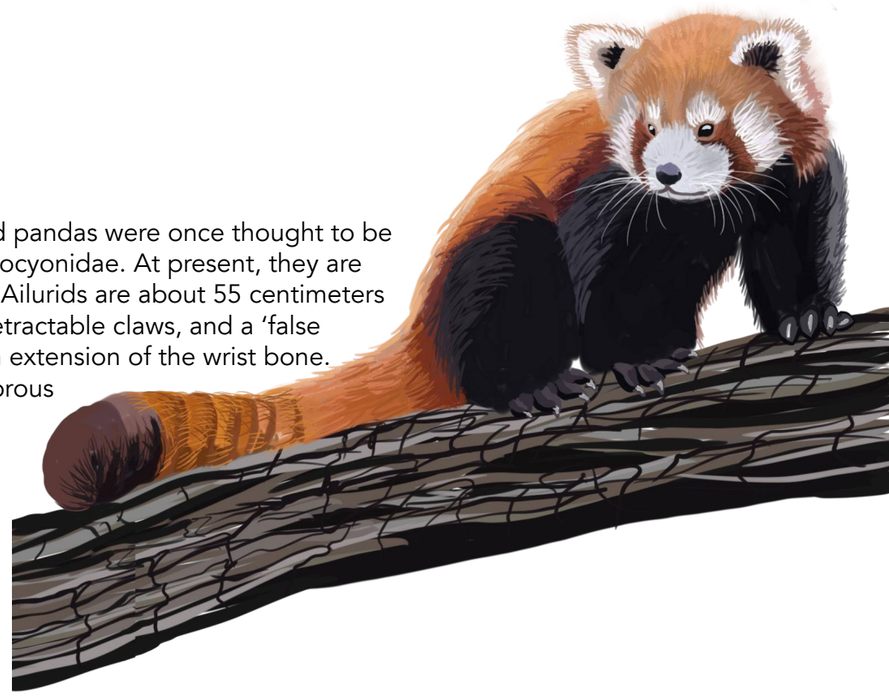
Family Mustelidae, which includes the weasels, stoats, minks, badgers, otters and wolverines is the largest family that comes under the Order Carnivora. It contains 56 species distributed in 22 genera. They commonly have elongated bodies with short legs and a short snout, and well-developed anal scent glands. They show a vast variety in size; from the weasels which may weigh around 35 to 250 grams, to the sea otters which may reach 45 kilograms. Mustelids are found in all continents except Australia and Antarctica, and are absent in Madagascar and oceanic islands as well. The members are well-known for their aggressive hunting behavior and (usually) streamlined body. E.g.: European badger (*Meles meles*), North American river otter (*Lutra canadensis*) and Wolverine (*Gulo gulo*).

Family Mephitidae

Family Mephitidae, the skunks and stink badgers, who were once classified under the Mustelidae, is now a group of its own. Living members of this family are easily identified by their unpleasant odors and striking color patterns. Commonly black or brown, they typically have a prominent and distinct pattern of white fur on their face, back, and tail, either as stripes or spots. All members of the family Mephitidae have well developed scent glands that produce noxious odors to discourage predators. They tend to have a broad, squat body, a long rostrum, short limbs and tough claws. Further, they have a characteristic thickly-furred tail. They are primarily omnivorous and nocturnal. This family contains 4 genera with 13 species. E.g.: Palawan stink badger (*Mydaus marchei*), Sunda stink badger (*Mydaus javanensis*) and Striped skunk (*Mephitis mephitis*).

Family Ailuridae

Family Ailuridae, or the red pandas were once thought to be part of either Ursidae or Procyonidae. At present, they are placed in their own family. Ailurids are about 55 centimeters long. They possess semi-retractable claws, and a 'false thumb' which is actually an extension of the wrist bone. They are habitually herbivorous mammals, specialized as bamboo eaters. They are native to southern China and the Himalayas in Nepal. This family contains only one genus with a single species, the lesser (or red) panda (*Ailurus fulgens*).



Family Otariidae

Family Otariidae, commonly known as the eared seals are pinnipeds that are characterized by the possession of a pinna, which is a small furry earflap that is absent in the true seals of Family Phocidae. Sometimes, they are called sea lions or fur seals. Otariids are adapted to a semi-aquatic lifestyle. When swimming, they use their elongated forelimbs which are modified as flippers to propel their body through water. However, they switch to a terrestrial mode of life for resting and breeding purposes. They have the ability to invert their hind-flippers under the body, assisting locomotion on land or ice. There are 16 extant eared seal species, divided among 7 genera. Otariids are distributed in Pacific and south Atlantic areas. E.g.: California sea lion (*Zalophus californianus*), South American fur seal (*Arctocephalus australis*) and New Zealand fur seal (*Arctocephalus forsteri*).

Family Odobenidae

Family Odobenidae, which includes walruses, is the only non-seal pinniped. Besides, it is the only pinniped with tusks. Similar to the other pinnipeds, walruses have both forelimbs and hindlimbs differentiated as flippers to facilitate swimming. They have a thick lipid layer in their skin to minimize the heat loss. Even though they are mostly aquatic, they arrive on land (or ice) to reproduce and raise their offspring. Walruses are circumpolar, but they are concentrated in geographically isolated areas, with little or no chance of interbreeding. Only a single recent species of walruses (*Odobenus rosmarus)* makes up this family.

Family Phocidae

Family Phocidae, generally known as the true or earless seals, are pinnipeds that are characterized by the absence of a pinna, or the external part of the ear, which is found in otariids. These animals have a silky streamlined body, which is an adaptation for their aquatic life. They show a side-to-side swimming motion involving their hind-flippers and posterior body. Unlike the otariids, they cannot invert their hind-flippers forward under the body. Thus, they exhibit a slow and awkward movement on land. About 52% of all pinnipeds are phocids. They are widely distributed along coastlines above 30° N and below 50° S latitudes. Some species are found in intermediate tropics, and a few in freshwater lakes and rivers as well. This family contains 19 species in 10 genera. E.g.: Harbor seal (*Phoca vitulina*), Grey seal (*Halichoerus grypus*) and Hooded seal (*Cystophora cristata*).

There are about 300 extant species under the Order Carnivora. They occur naturally on all biogeographic regions except Australia (the Dingo was introduced to Australia around 4,000 years ago). Perhaps, this might be the most interesting group of animals for many. Ecologically, they play a major role in food webs, both as prey species and apex predators, contributing largely to the balance of the ecosystems. However, currently they are suffering an overall decline worldwide. Therefore, it is time to pay attention to the conservation of carnivores.

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Graphic Design: Nadeela Hirimuthugoda

Are Ferns Edible? The Story of Two *Diplazium* Species in Sri Lanka

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Ferns and their uses

Ferns are an important element of biological diversity, and it is an attractive group of plants that produce spores instead of flowers or seeds. They are mostly preferred wet and shady environments and are largely concentrated in tropical rainforests. Unlike seed plants, ferns do not have high economic significance. A limited number of species are used as food, medicine, and ornamentals. The information on different uses of ferns is still in the hand of indigenous communities across the globe without exploring. Although ferns have been used in traditional cuisines for a long time, information on their pattern of usage, nutritional properties, and recipes is lacking. Edible ferns are some of the most commonly collected wild food plants around the world, with stems, rhizomes, leaves, young fronds, and shoots, and sometimes the whole plants used for food. Around 144 fern species are said to be used as a source of food and flavorings all over the world. However, the edible potential and economic values of ferns have been largely ignored.

Uses of ferns in Sri Lanka

Despite its small land size, Sri Lanka harbors nearly 390 pteridophyte taxa (ferns and allied species). Ranil and Bussmann (2021) have reported 37 species with medicinal, food, ornamental, and other uses. Among them, *Acrostichum aureum, Blechnopsis orientalis,* and *Diplazium esculentum* are the only known edible fern species in Sri Lanka. Except for *D. esculentum*, the other two species are locally common, but underutilized. From an informal discussion with communities around the buffer zone of the Kanneliya Man and Biosphere Reserve, it has been found that immature fronds of *Neprolephis* spp. and *Dicranopteris linearis* were used as food, both fried and in curry, by their ancestors. However, out of the edible ferns reported worldwide, *D. esculentum* (Figure 1) can be considered as one of the most commonly consumed fern species.

Image credits: (A) 歐陽秀華 (B) Hong and (C) George葳士

Figure 1. (A) a mature frond of *D. esculentum*; (B) the plant habit; (C) The young tender fronds (fiddleheads) after harvesting. (Source: Global Biodiversity Information Facility, https://www.gbif.org).

Diplazium esculentum: the most commonly consumed fern species

Diplazium esculentum is belonging to the family Athyriaceae and is native to Tropical & Subtropical Asia to South-west Pacific. It is naturalized in Australia, Africa, and North America (Figure 2). Though its medicinal and nutritional properties (Moisture (89.34%); Fat (0.25%); Fiber (5.05%); Ash (1.33%); Vitamin C (21.38 mg g^{-100}); Protein (3.84%)) have been well studied, its different food recipes are still in different ethnic groups without the attention of ethnobiologist. The upper shoots/ fronds of *D. esculentum* are commonly used as vegetables. The young fronds are blanched, boiled, or stir-fried and, in some cases, pickled.

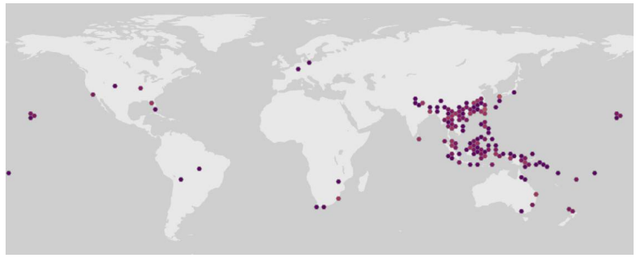

Figure 2. Global distribution pattern of ***D. esculentum***; native range has demarcated using a brown colored circle (Source: Global Biodiversity Information Facility, https://www.gbif.org).

They are served as a vegetable salad, soup, or stew. Young fronds are usually cooked before consumption to avoid bitterness and the flavor is like that of over-cooked asparagus. Moreover, young fronds can be dried and used for cooking. The bundles of the crisp, yet tender, new fronds can be found in Asian markets. Moreover, *D. esculentum* has been recognized as a pharmacologically diverse ethnomedicinal plant. Their young fronds and leaves are used in folk medicine by different communities for the treatment of several diseases including diabetes, smallpox, asthma, diarrhea, rheumatism, dysentery, headache, fever, wounds, pain, measles, and high blood pressure. Though it is rich in medicinal and nutritional properties, it still remains as a neglected and underutilized species in Sri Lanka.

Diplazium esculentum in Sri Lanka

The genus *Dilazium* is represented by 12 species in Sri Lanka and all are mainly confined to streamside banks and in wet open places across the wet zone. Out of all *Diplazium* species, *D. esculentum* is the only known species which consume as a vegetable in Sri Lanka. The young tender fronds of the fern are generally referred to as fiddleheads or croziers. The fiddleheads of *D. esculentum* are cooked with coconut milk and other spices. It can also be served as a side dish after frying with onion. However, different uses and various food recipes are still available in traditional communities.

According to previous records, it shows a restricted distribution pattern in Colombo,

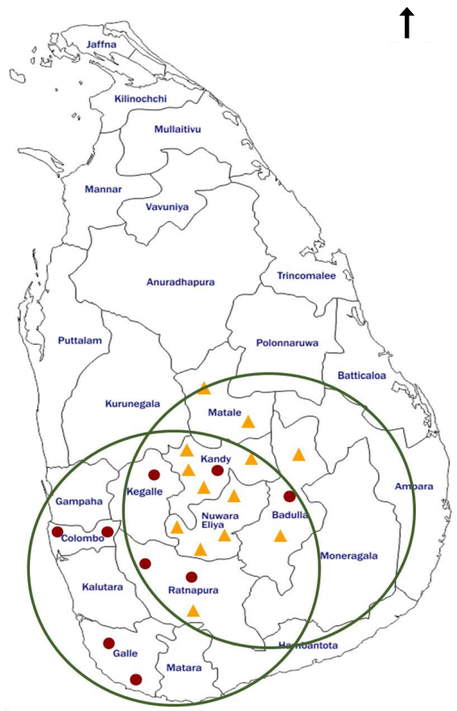

Figure 3. General distribution pattern of *D. esculentum* (●) and *D. dilatatum* (▲) across the wet zone of Sri Lanka. The overlapped area might be suitable to initiate the commercial cultivation of both species due to its preferable climatic and soil characteristics.

Kegalle, Kandy, Badulla, Ratnapura, and Galle districts (Figure 3). It has been defined as a Near Threatened (NT) species by the National Redlist – 2020. Though it has high food value, it is not readily available in the market. There are no reports available on its commercial cultivation in Sri Lanka. Apparently, the common name, Miyena–dalu (Miyena = wilting; dalu = immature fronds/ leaves) is used due to its fast wilting after harvesting of immature fronds. However, it is important to investigate its potential to popularize as a commercially cultivated leafy vegetable in wet zone agricultural systems because the species has well adapted to a wide range of environmental conditions across the wet zone. Though *D. esculentum* is not a commercialized and highly consumed vegetable, it is still used as a vegetable due to its unique taste and appearance of immature fronds.

Other potential *Diplazium* species in Sri Lanka

Diplazium diltatum is a close relative of *D. esculentum* and a popular vegetable among some ethnic groups in few Asian countries (Figure 4). In Sri Lanka, it is relatively common in forests from 900 to 1650 m altitudes (Map 2). Unlike *D. esculentum*, *D. dilatatum* does not occur in lowland areas and it is mainly distributed in central highlands of Sri Lanka. Despite its popularity in several countries, *D. dilatatum* is still not well recognized as an edible fern or vegetable in Sri Lanka. Apart from its taxonomic and ecological significance, it has not been studied for its food, medicinal and ornamental values. However, its nutritional and phytochemical properties have been well studied in some other countries. Analysis of dietary nutrients and elements revealed that *D. dilatatum* could be used as a fiber supplement and can supplement the daily dietary needs of Cu, Fe, I, Mg, Mn, Mo, and Zn for human beings. Available literature indicates that the edible fronds of *D. dilatatum* are greater in Fe, P, K, and protein than some commercial leafy vegetables such as Amaranth, Asparagus, Celery, Coriander, Lettuce, and Spinach. The mineral content has also been reported to be several times greater than that present in many commercial leafy vegetables. Moreover, most of the toxic and heavy metals such as As, Al, and Cd accumulation were found to be within permissible limits in *D. dilatatum*. They can be reduced through cultivation practices, thus *D. dilatatum* is safe for human consumption. Therefore, *D. dilatatum* has a greater potential as a supplement food to overcome the future nutritional deficiencies of people.

Image: 艾草

Figure 4. Frond of *D. dilatatum* (Source: Global Biodiversity Information Facility, https://www.gbif.org).

Future prospects

The wild and weedy species which were used in the past have disappeared due to the changes to land-use systems, the use of improved hybrid seeds, and rapidly changing food habits. The lack of traditional knowledge on food values and cooking methods to minimize nutrient losses is also rapidly disappearing. Currently, some indigenous vegetables are becoming popular both among the rural and urban populations due to their therapeutic and food values. There is a growing public awareness regarding the value of these green leaves as providers of dietary fiber, vitamins, and minerals that are essential for maintaining good health. Therefore, the ideal strategy will be to promote these as home garden crops as well as large-scale commercial cultivations aiming at future food and nutritional security.

Edible ferns are low-cost indigenous vegetables and can be available throughout the year. In addition, in developing nations, various types of edible wild plants are exploited as sources of food that can contribute substantially to protein, minerals, vitamins, fibers, and other nutrients. Owing to the dietary nutrients and elemental profile, these underutilized vegetables can be popularized for commercial cultivation as high-potential leafy vegetables. Moreover, edible ferns provide income generation to local communities and ensure future food and nutrition security. Moreover, these multi-valued resource plants are threatened by habitat destruction, land-use change, over-harvesting, over-grazing, and invasive species. Thus, it is important to disseminate knowledge on diversity, food and nutritional potential, economic potential, medicinal value, and conservation value of these species. Further, research work could be conducted for standardizing agronomic practices for the commercial cultivation of both *D. dilatatum* and *D. esculentum* and for their sustainable management and utilization.

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AI art 'Eddible Ferns' by Nalin Gama-Arachchige

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