CONNECT
WITH THE INDIAN INSTITUTE OF SCIENCE

Volume 6 | Issue 3 | September 2019

Monsoon and Evolution
How animals responded to changes in rainfall

MONTBLEX
The first national monsoon experiment

Monsoon Melodies
Rain in Hindustani music

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

ISSN 2454-6232

IN THIS ISSUE

EDITORIAL

India's former Finance Minister – and former President – Pranab Mukherjee once called the monsoon the country's "real Finance Minister". He was only half-joking. The well-being, economic and otherwise, of Indians depends on the monsoon in myriad and complex ways.

IISc has, over the years, led several pioneering efforts to understand and better predict the monsoon. In this issue of *Connect*, we recount some of those stories, featuring the work of researchers, past and present, at the Centre for Atmospheric and Oceanic Sciences.

Cycles of droughts and floods are now a disturbingly familiar part of the news in India. But these events are not entirely attributable to the monsoon's capricious nature. And they can be devastating, especially for those engaged in agriculture, which, in India, is still largely reliant on monsoon rains. But even with a normal monsoon season, there are still several months of the year that are dry, forcing people to migrate to cities in search of jobs that don't exist. The favoured solution is to build large dams and irrigation projects, creating its own set of problems, for the environment and for those displaced in the name of development. What if local, environmentally friendly, alternatives could be implemented instead – as an IISc scientist is doing in Bastar, Chhattisgarh?

Meanwhile in our cities, unsustainable use of water, including groundwater, and policies that disregard established knowledge have led to annual crises. One way the average citizen can mitigate this is to rely on the monsoon's bounty that falls on her own rooftop. *Connect* brings you these stories too.

But the monsoon is more than just the rain – it has, over millennia, shaped the biological diversity of the subcontinent. We ask how a monsoon, modified by climate change, might affect its varied lifeforms. The monsoon has also had a deep influence on our culture, including our music. We explore this and more in this issue of *Connect*.

TEAM CONNECT

Deepika S, Karthik Ramaswamy, Kaushal Verma, Manu Rajan, Nithyanand Rao, Rohini Krishnamurthy

CONTACT

Email: connect.apc@iisc.ac.in

Phone: 91-080- 2293 2066

Address: Office of Communications, Indian Institute of Science, Bangalore 560 012

http://connect.iisc.ac.in

Design: Magnetyz | **Cover illustration:** Ipsa Jain | **Printer:** Sri Sudhindra Offset Process

MONT

India's first major monsoon experiment

- Nithyanand Rao

Photo: Rudra Kumar

One of the towers used for MONTBLEX, showing its triangular lattice structure

The first national effort to understand the meteorological phenomenon

For about four months from May to September 1990, the Indian summer monsoon was the subject of unprecedented nationwide attention. While the monsoon winds raced from Kerala to the northwest of India in 35 days, less than its usual 45, researchers on land, air and sea belonging to over 20 institutions across the country were busy gathering data. Sensors on four towers – at Jodhpur, Delhi, Varanasi and Kharagpur – recorded data for 10 to 15 minutes every three hours, sometimes every hour during intensive observation periods, supplemented with data from sodars, balloons and tethersondes at these and other sites. The India Meteorological Department used its network of observing stations. The Indian Air Force did the same, and flew its AN-32 aircraft on sorties over land and over the Bay of Bengal, where ORV *Sagar Kanya* and its crew deployed their instruments. Meanwhile, INSAT clicked pictures from the sky.

BLEX

This was the Monsoon Trough Boundary Layer Experiment (MONTBLEX). There had been monsoon experiments before, but all of them born of international initiative. "MONTBLEX was the first major national experiment in the country which *India* had decided to do," says Roddam Narasimha, who conceived the experiment along with the late DR Sikka of the Indian Institute of Tropical Meteorology (IITM), Pune. "It was our own." Narasimha, professor at the Department of Aeronautical Engineering, was Chairman of the MONTBLEX Monitoring Committee.

He had been part of earlier monsoon field experiments too, leading the small group of researchers at IISc who went on to found, in 1982, the Centre for Atmospheric Sciences (now the Centre for Atmospheric and Oceanic Sciences, CAOS) at the Institute. One of these precursor experiments that set the stage for MONTBLEX was the Monsoon Boundary Layer Experiment (MOBLE), in 1979. MOBLE coincided with the Monsoon Experiment (MONEX), a large international effort to study the monsoon using some 20 ships and aircraft. MONEX resulted in a better understanding of rainfall on the west coast of India, including the effect of the Western Ghats.

Photo courtesy: Roddam Narasimha

K Narahari Rao, Roddam Narasimha and Sethu Raman at Digha, 1979

MOBLE was not officially a part of MONEX. "We were late entrants," says Narasimha, "and didn't have time to submit our proposal and get it accepted." So he led a group of researchers from IISc and National Aeronautical Laboratories (now National Aerospace Laboratories, NAL) who went ahead on their own, supported by ISRO, and planned their experiment to overlap with MONEX's intensive observation period. Their experiment marked the first time in India that an instrumented tower was used to study the role the boundary layer played in the dynamics of the monsoon.

The boundary layer of the atmosphere is the layer right next to the surface, whether land or ocean, with an average depth of 1 km but ranging from a few tens of metres up to 3 km. Because it's the closest layer, it is strongly influenced by the surface through exchanging heat, moisture and momentum, and this exchange happens through turbulent processes. Such turbulent energy transfer in the boundary layer is an important process, especially for tropical weather systems such as monsoons and cyclones. For this reason, numerical weather prediction models need to incorporate it, on as small a scale as possible. However, such phenomena, called eddy transport, occur in short bursts, and studying them requires detailed measurements of velocity, temperature and humidity in the boundary layer. And this is the data the researchers from Bangalore aimed to gather.

"I was curious about what the atmospheric boundary layer was like in India," says Narasimha. "It had not been studied at all – was it different in the tropics?"

For their experiment, Narasimha and his team – A Prabhu, BS Adiga, K Narahari Rao and Syed Ameenulla – had to first identify a site. "As one of the major objectives of the experiment was to make surface layer measurements during passage of a depression or cyclone (if possible)," they wrote in a report of their experiment, "it was necessary to choose a site where the probability of experiencing the event was as high as possible." So they looked for a suitable site on the eastern coast, as the Bay of Bengal, one of the hottest sea surfaces, gives rise to many cyclones.

They chose Chandipur beach, 20 km from the town of Balasore, Odisha, where they would have logistical and technical support from the Proof & Experimental Establishment of the Defence Research and Development Organization (DRDO). (Locally known as "Proof", it has been a testing ground for guns and missiles since colonial times.) The beach is unusual in that the water line moves about 3 km between high tide and low tide, and this enabled the team to set up their tower in the sea, half a kilometre from the high tide water line.

"I was curious about what the atmospheric boundary layer was like in India. It had not been studied at all"

But it wasn't smooth sailing. They had to troubleshoot the instruments (at three levels on the 10-metre tower), the battery powering them, and the wires carrying the data back to the station on the shore. The wind vanes on the tower were attacked by birds of prey and some were lost initially. For acquiring data from the instruments, they were using a Z80 microprocessor, bought from one of its earliest dealers in Bangalore, who was helpful enough to even send two of his men along with a backup microprocessor. There were some teething problems, this being their first experience with digitised data acquisition. However, says Prabhu, "every time there were problems we would sit down, go through the programs, identify the problem and rectify the system."

The team spent six weeks in Balasore. "Unfortunately," said their resulting report, "the weather during July 1979 was rather unusual, and no depression or cyclone was generated in the head of the Bay during the period." Nevertheless, they did gather valuable data. "That was a very tough, but an interesting and very enjoyable, experiment," says Prabhu.

Just up the coast from Balasore was Digha, where a team of researchers from the US were based as part of MONEX. One of them was Sethu Raman (then at Brookhaven National Laboratory), with whom the IISc team did another tower experiment a few months later, this time in Raichur, during the total solar eclipse on 16 February 1980. Solar radiation is the dominant driving force of the atmospheric boundary layer. And during a total solar eclipse, as the report of the experiment said, "the radiation from the sun is first switched off, and then switched on again, in a matter of about two-and-a-half hours."

The idea of the experiment was to study the boundary layer's response to the eclipse, and what they found was interesting. "For example," says Narasimha, "we found that small cumulus clouds disappeared as the eclipse moved towards totality, but reappeared as the eclipse receded – at about the same place where they were before, but they were now ragged, as if they had been torn apart." Just as unexpectedly, even four hours after the eclipse ended, the wind speed was an order of magnitude lower than on other days, whereas just before the eclipse ended it was slightly higher than usual.

The team of researchers for the total solar eclipse experiment at Raichur, 1980. (L to R) A Prabhu, Rudra Kumar (third), Roddam Narasimha (fourth), Sethu Raman (fifth), CR Prasad (sixth), BS Adiga (seventh), K Narahari Rao (eighth), Syed Ameenulla (tenth), Srikanth Padubidri (eleventh)

With the experience gained from these efforts, Narasimha and Sikka began planning for an experiment on a much larger scale. One problem with numerical models of the monsoon used for weather prediction was that the parameters for the atmospheric boundary layer they used were usually based on measurements done in mid- and high-latitudes elsewhere, rather than in the tropical region. To rectify this, they had to (as a later paper put it) fill the gap in the "knowledge about the boundary layer processes in the monsoon trough region" and "its linkage with the spatial and temporal variability of the large scale monsoon".

"The monsoon trough is sort of a row of clouds, a line along which convective activity is strong," says Narasimha. "That line moves from the south near the equator all the way up to the Himalaya, and takes 30 to 40 days." Sikka and Sulochana Gadgil (leading meteorologist and a former professor at CAOS), examining satellite pictures, proposed that

Photo courtesy: Roddam Narasimha

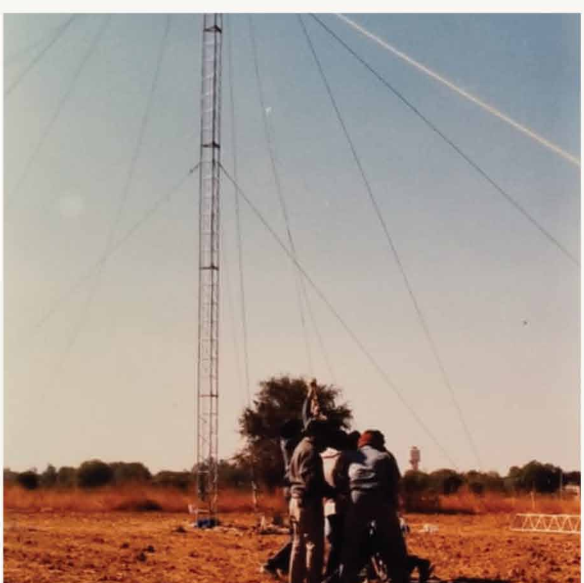
another trough would then form in the south and travel northwards, and the cycle repeats. "This was the first new idea that came entirely from satellite pictures," says Narasimha. "This movement was due to the monsoon trough. They said it's at the heart of the dynamics of the monsoon." The monsoon trough extends across the breadth of northern India.

A pilot experiment was conducted in 1989, on farmland near IIT Kharagpur, with a 30-metre tower fitted with instruments to measure wind speed, humidity, temperature and direction of wind, at six levels. The aim was to measure the mean and fluctuating components of wind velocity, temperature and humidity. The hardware and software for the instruments and the PC-based data acquisition were all developed at IISc.

"The instruments withstood the vagaries of the tempestuous weather at the site in 1989," said a paper reviewing the planning that went into MONTBLEX, "and the team had an opportunity to learn about possible problems when the data acquisition system failed due to lightning, power failure or theft of a section of the linking cable."

In preparation for the main experiment, training programmes were conducted at IIT Kharagpur, IITM and IISc. The main experiment in 1990 had 30-metre towers at the Central Arid Zone Research Institute in Jodhpur, IIT Delhi, BHU Varanasi, and IIT Kharagpur, all of them managed by Prabhu's team at IISc, who also received the data from the towers. Things began badly in Jodhpur where floods, "the worst in a hundred years", in late June disabled the tower for a few days, but it still gave the "cleanest and largest amount of data". For attending to this and other issues with the towers, Ameenulla and Rudra Kumar (then a PhD student at IISc) travelled back and forth among the four sites.

Photo: Rudra Kumar



The tower at Jodhpur being erected

"The time required to set right break-downs at any place," wrote Prabhu and his team in a paper on MONTBLEX instrumentation, "depended chiefly on the current location of the expert team along the network of the tower stations!" Just as hard, remembers Prabhu, was putting in long hours through the four months to ensure the data kept coming. "Given that there was only one group to handle all these four systems, it was very very tough," he says. "But I had an extremely dedicated set of people who worked hard to ensure that we got good data."

Photo courtesy: Syed Ameenulla

Montblex News

A bulletin of the MONTBLEX team.

No.1 MAY 1989 BANGALORE

A view of the tower showing the fetch of the wind

1.What is MONTBLEX ?

The **Mon**soon **T**rough **B**oundary **L**ayer **Ex**periment, acronymed MONTBLEX, is an intense multi-institutional effort sponsored by the Department of Science and Technology, Government of India, intended to probe the atmospheric boundary layer (ABL) over the monsoon trough region of the Gangetic plains. The project initiated in March 1987, may be described as the largest weather project originating from India and certainly among the largest boundary layer projects of the world.

The Atmospheric Boundary Layer is defined as the region of the atmosphere in which dynamical and thermodynamical effects of the earth's surface are felt. The processes in the ABL effect cumulus convection, sub-cloud layer convergence, pollution dispersal, land-air and air-sea interaction etc. The monsoon trough is the seat of cyclonic vorticity in the lower troposphere particularly along its eastern end over the north Bay of Bengal where organized moist convection prevails during the monsoon months. The disturbances move westwards and cause rain all over the Gangetic Plains. The western end of the monsoon trough is over West Rajasthan and adjoining Pakistan where dry convection with shallow clouds are seen. Very little information is available on the activity of the boundary layer processes associated with deep moist unsaturated and near-dry processes within the monsoon trough, understanding which is of primary importance for the investigation of the monsoon dynamics.

The main component of the

The racks of translators housed at the foot of the tower.

MONTBLEX News, a newsletter published from IISc during the experiment

That data was used by Narasimha and colleagues who found that the atmospheric boundary layer in the tropics had to be treated differently. "They don't follow the relations that are defined in the Western textbooks, for the momentum flux, for the surface friction, how much heat transfer happens, and so on," he recalls. This, he says, is because the process of convection is important in the tropics.

MONTBLEX, and subsequent monsoon field experiments, have had other enduring impacts too. "Each experiment enhanced the infrastructure facilities in the country, brought together scientists from different organizations to a common platform and also injected new people in this field," as a review paper put it. "It was a unique effort in which the Indian research community on its own conceived the programme and implemented it successfully in all its phases."

‘Ours was a small group, like one family’

– *Nithyanand Rao*

Photo courtesy: Roddam Narasimha

A Prabhu, R Narasimha, BS Adiga, K Narahari Rao and Syed Ameenulla at Chandipur beach, 1979

Syed Ameenulla, who joined IISc as a lab assistant and went on to be a technical officer, recalls his involvement in the Institute’s monsoon experiments

In the monsoon of 1979, Chandipur beach in Balasore, Odisha was host to a small group of researchers from Bangalore. The team, from IISc and the National Aeronautical Laboratory (NAL), were setting up a 10-metre tower fitted with instruments, coinciding with the international Monsoon Experiment (MONEX). Sometime during their six-week stay, researchers from the US based further up the coast at Digha visited their Indian counterparts.

"They were really surprised," says Syed Ameenulla, who was at the time a lab assistant in the Department of Aeronautical (later Aerospace) Engineering, IISc. The US researchers, who were recording their analog data on magnetic tapes, had found that the Bangalore team had digitised their data acquisition using a microprocessor and had more sensors. Ameenulla was part of the team led by A Prabhu (then an assistant professor) and BS Adiga (of NAL) that had designed and installed this computerised system for acquiring data from the instruments on the tower. Their experiment, initiated by Roddam Narasimha and named the Monsoon Boundary Layer Experiment (MOBLE), aimed to take measurements of the atmospheric boundary layer.

They had implemented "the first microprocessor-driven surface layer instrumentation system in the world"

'Ameenulla, however, was soon making his way back to Bangalore, to the University Visvesvaraya College of Engineering, for his practical exams as part of the BE in Electronics Engineering he was pursuing part-time by attending evening classes. Having arrived at IISc with a diploma in sound engineering, he went on to become a Technical Officer after his BE, wrote his Master's thesis based on his work on the instrumentation for the Monsoon Trough Boundary Layer Experiment (MONTBLEX) of 1990, and left in 1999 for the US. He retired in 2016 as the North Carolina State Climate Office's Associate Director and manager of its network of observation towers.

It was in 1974 that he joined as a lab assistant to BR Ramaprian, assistant professor in the department, tasked with developing instruments for boundary layer turbulence measurements in the wind tunnel. When Ramaprian left IISc, Ameenulla joined Prabhu, and was part of a small group in the department interested in the atmospheric sciences as well as wind tunnel experiments in the lab. MOBLE was the first of a series of field experiments that this group undertook to study the monsoon and the atmospheric boundary layer.

As a later paper put it, they had implemented "the first microprocessor-driven surface layer instrumentation system in the world." But it began inauspiciously. The tower and the instruments, all designed in-house, were sent to Balasore. "Prof Narasimha had left Bangalore early," Ameenulla recalls, "to receive the tower and make the local logistics arrangements." But floods in Andhra Pradesh meant that the mast from Bangalore, sent by road, did not reach Balasore. Narasimha and another member of the team, K Narahari Rao, managed to get a substitute tower locally made.

There were more hiccups in store. The tower was set up about half a kilometre from the coast, and could be approached only during low tide. Often, before they could finish working on the instruments, the high tide would set in. "I would be the first person to get out before the water reached my belly – because I am not a good swimmer – and Prof Prabhu was the last, getting out by swimming each time." On one such occasion, the high tide took away Ameenulla's footwear. "Prof Prabhu offered his footwear to me," Ameenulla recalls, "which was very touching."

Photo courtesy: Syed Ameenulla

Ameenulla, in February 2002

The instruments on the tower that they initially installed, at three different heights, started sending data, but not for long, as the communication cable to the shore was being corroded by the sea water, eventually cutting off the data transmission altogether. That wasn't all. "During low tide we found that the 60 Ampere-Hour battery was taken away by the high waves – which sometimes pounded our room on the shore too," says Ameenulla. "We had to find on-site solutions, which we did successfully."

Their departure from Balasore was not without incident either. All the instruments were packed into large boxes, and the group were waiting on the railway platform, knowing that the train stops at the Balasore station for only a handful of minutes. "At the last minute there was an announcement that the train would arrive on a different platform," recalls

Ameenulla. "We were shocked and started carrying the big boxes – each box on two heads – climbing the overbridge to get down on the other platform. We were halfway through when the train started moving. One of us got inside the train and pulled the chain, and the train conductor watched helplessly as we walked with the luggage on our heads!"

"If there were problems, we had to run from east to west and back"

MOBLE was followed by another tower experiment during the total solar eclipse in 1980. Ten years later came MONTBLEX, a vastly bigger enterprise. The experiment involved, among other observational platforms, four 30-metre towers with six levels of instruments – each level carrying up to six instruments – managed by the IISc group led by Prabhu. Three of the towers – at Jodhpur, Varanasi, and Kharagpur – were set up by the IISc group while a fourth tower in IIT Delhi was upgraded by them.

Though all the four towers were inside the campuses of research institutions, their hosts were responsible only for providing the sites and securing the instruments. If something went wrong, the task of fixing it, Ameenulla recalls, was "very challenging", and it fell to him and Rudra Kumar (a PhD student at IISc at the time) to do this. "For atmospheric measurements, dealing with even one or two sensors is troublesome," he says. "They fail and all kinds of things happen in harsh weather conditions. If there were problems, we had to run from east to west and back – myself and Dr Rudra Kumar were travelling, all the time, during the whole experiment of more than three months, shuttling back and forth." Quite apart from fixing errant sensors they also had to periodically visit each site to perform calibration checks.

After MONTBLEX, Ameenulla participated in several other field experiments as part of IISc research groups, co-authoring many of the resulting papers. These included VEBEX (Vegetation and Surface Energy Balance Experiment for the Tropics), INDOEX (Indian Ocean Experiment); and BOBMEX (Bay of Bengal Monsoon Experiment). During his time at IISc, he participated in field experiments in the US too, such as the Genesis of Atlantic Lows Experiment (GALE) in 1985-86 while on sabbatical leave from IISc. This was as part of the research group of Sethu Raman, a professor at North Carolina State University. (Raman was part of the Digha-based MONEX team from the US and later became Director of the State Climate Office of North Carolina.)

Ameenulla took another sabbatical in 1999 to upgrade the many towers, in different locations, of the North Carolina State Climate Office's Agricultural Meteorological Network to international standards. "But I could not finish that project within a year," he says. "I tried my best to convince the IISc administration to extend my leave for at least another six months if not a year. It did not happen."

This left him in a fix, and he eventually resigned his job at IISc to go back to the US and finish the work he had taken up there. "They created a position for me there," he says, "in the State Climate Office of North Carolina." Until his retirement in 2016, he was managing their network of observational stations forming the North Carolina Environment and Climate Observing Network (ECONet). When he joined in 1999, data was collected once a day, through telephone lines, and anyone wanting to access it had to request it. "Now we get the data online, updated every minute from all the stations," he says.

Though his work at the State Climate Office doesn't involve field experiments of the kind he used to participate in at IISc, he has worked for other agencies in the US, notably the Environmental Protection Agency (EPA). For the EPA, Ameenulla went to Ground Zero in New York, the site of the twin towers of the World Trade Centre that were destroyed in the 9/11 terror attack. This was to measure the air quality, soon after 9/11, using a small portable tower and a sodar system.

Photo courtesy: Syed Ameenulla

Ameenulla at his retirement function in May 2016 with Randy Woodson, Chancellor, NC State University

Ameenulla took his family with him when he left for the US. His wife, an electronics engineer, worked for AT&T. Two of their children have graduated from college and are employed, while their third child is still in college. Two decades after he left IISc, he recalls his time as part of IISc's atmospheric sciences group at Balasore fondly – "playing like kids" with Rao, laughing as Adiga quietly cracked jokes, being taken to a health centre by Narasimha in a defence vehicle when he fell ill. And working closely throughout his time at IISc with Prabhu, whom he calls his "real guide in academics and personal life".

‘An unusually successful cruise’

- Deepika S

A 2016 Indo-UK monsoon experiment collected a detailed set of data that is still being analysed

Participants in the Bay of Bengal Boundary Layer Experiment which took place in June-July 2016

Photo courtesy: PN Vinayachandran

On 27 July 2016, the oceanographic research vessel *Sindhu Sadhana* sailed back to Chennai through terrible weather after a month at sea in the southern Bay of Bengal. Field experiments in the ocean are often risky and challenging during the monsoon because conditions can be very severe – winds, currents, and waves can rock the ship. This makes deploying instruments and collecting data hard, also because researchers can become severely sea-sick and unable to work. Operations sometimes have to be cancelled if there is a risk to life and property; it can all be quite overwhelming. But this cruise – for the Bay of Bengal Boundary Layer Experiment (BoBBLE) – hadn't been like that at all.

It was, so to speak, smooth sailing. The *Sindhu Sadhana* carried 24 scientists from eight institutions in India and the UK, its captain and crew, and an exciting range of sophisticated instruments and equipment. News reports announced that BoBBLE would use "underwater robots" and a state-of-the-art aircraft to help predict the monsoon. They had had around three weeks of calm weather, and nearly everything in the 11.3 million dollar project went according to plan, even with an unexpected two-day delay (because a crew member on the ship fell ill and had to be picked up by the coast guard and taken back to land for an emergency surgery) and extremely choppy weather during the last week on their return – weather in which an Indian Air Force plane with 29 people on board disappeared over the Bay without a trace.

"It was an extremely – and unusually – successful cruise," says PN Vinayachandran, a professor at IISc's Centre for Atmospheric and Oceanic Sciences who led the fieldwork, with some excitement. "We have the best possible data! That's the main contribution from that experiment – we have a data set from the southern Bay of Bengal that covers a 700 km-long section over a period of one full month. We measured almost anything that we could, and it's the most complete sampling of that part of the ocean that I've ever seen in my career."

Why focus on the Bay of Bengal?

The goal of the experiment was to learn more about the Indian monsoon. This is important because it affects the lives of people in India and neighbouring countries like Pakistan, Bangladesh, Myanmar, Sri Lanka, and parts of China. Being able to forecast weather accurately could have significant consequences for agriculture as well as minimising damage to property and disruption of people's lives in the event of extreme weather.

The Bay of Bengal plays a crucial role in controlling the weather systems that make up the South Asian summer monsoon, which brings rain to India between May and September. Sea surface temperature (SST) is a key parameter in air-sea interactions that lead to the monsoon, and therefore determining SST is important for monsoon modelling. SST is influenced by various factors, including radiation and exchange of heat with the atmosphere. And a particular occurrence in the Bay of Bengal – large amounts of freshwater being brought in from the Ganga and Brahmaputra rivers, as well as from heavy rainfall over the mountains of Myanmar, which receive the heaviest rain during the monsoon and form the eastern boundary of the Bay of Bengal – has a significant effect on SST in the area. As

Photo courtesy: PN Vinayachandran

(From left) An unnamed member of the ship's crew, Jenson George, V Vijith, PN Vinayachandran and Thushara Venugopal operating a whinge used to lower a microstructure profiler to measure turbulence

Eric A D'Asaro, an oceanographer at the University of Washington, told the *BBC* in an interview: "Freshwater inputs from both rivers and a large amount of rainfall make the Bay of Bengal a rather unique place, and that is not properly being taken into account in the monsoon forecast models."

The Bay of Bengal plays a crucial role in controlling the weather systems that make up the South Asian summer monsoon

How does freshwater make a difference to the ocean in that region? The influx of freshwater into the northern part of the Bay dilutes the salinity of the sea water: while the mean salinity of the ocean is 35 grams (g) of salt for every litre of water, in the northern part of the Bay, this number can be as low as 20 g per litre (whereas in the rest of the ocean, changes in salinity are only in decimal places, Vinayachandran says). This creates a thin, lighter layer of water on the surface that absorbs heat and evaporates quickly. Researchers with the Ocean Mixing and Monsoon (OMM) Experiment reported finding a "sharp separation" between river water and seawater on scales ranging from 100 m to 20 km. Elsewhere, during the monsoon, strong winds cause the warmer surface layers to mix with the colder layers below, slowing down this process. But in the Bay of Bengal, the freshwater layer appears to act as a barrier to mixing, and therefore doesn't cool down. The temperature remains rather high at a threshold of around 28˚C even during the monsoon, which is conducive to convection.

BoBBLE begins

Vinayachandran, who joined IISc in 1999, and participated in a national monsoon experiment called the Bay of Bengal Monsoon Boundary Layer Experiment (BOBMEX) that year, says, "That was the first cruise where we were able to capture data in the northern part of the Bay showing the low salinity layer. After that, we learned that we also need to look at the southern part of the Bay, where very interesting things were happening. I was very keen on this because oceanographically it is a very dynamic region." The next such experiment in the Bay of Bengal was in 2009, another national programme, which took measurements in the northern and southern parts of the Bay. The weather was so bad that in some instances, data simply couldn't be collected. They had to shift from their chosen location and start over, leading to gaps in the data. A similar experiment was repeated in 2012.

The next opportunity for fieldwork in the region came in the form of funding from India's Ministry of Earth Sciences and the UK's Natural Environment Research Council (NERC). It took a year of planning before BoBBLE was carried out in 2016. "A lot of technological development had happened between 2009 and 2016," says Vinayachandran, and this was one of the main contributions from the UK universities. The "underwater robots" the media had referred to were gliders provided by the University of East Anglia that could be deployed and monitored electronically instead of manually, and could provide more data more frequently. They were configured in an L-shaped pattern using which the effect of currents on temperature and salinity in the region could be measured.

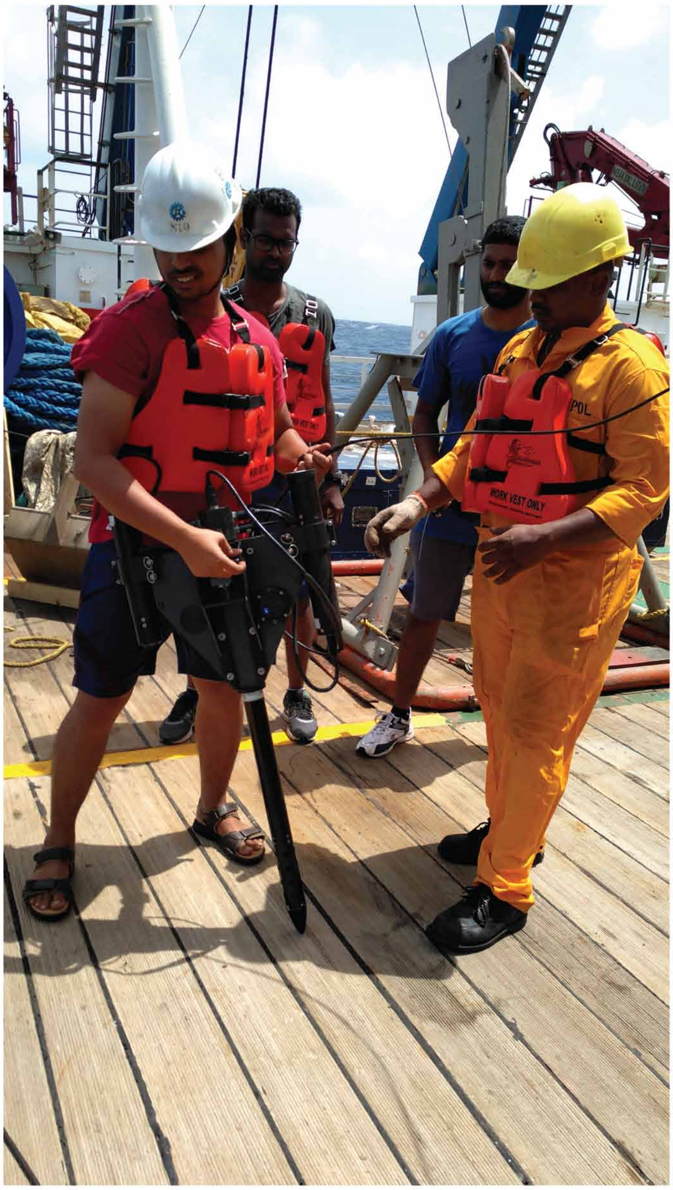


Photo courtesy: PN Vinayachandran

An underwater radio meter being readied for deployment

That wasn't all. Vinayachandran says, "We had near-perfect measurement of air-sea fluxes taken with a pair of automated weather stations, and one eddy covariance measuring system. That's the best measurement you can get for air-sea fluxes. Then we had a time series at one location, where we measured profiles continuously every three hours over a period of ten days. So we had turbulence measurements using a vertical microstructure profiler, which allowed us to calculate all the mixing happening. We had an instrument called Underway Conductivity Temperature Depth Profiler (uCTD) which you can use while the ship is running to measure the temperature profile." Vinayachandran counts seeing the first profiles of the region from the microstructure profiler and uCTD – which he was using for the first time – as one of the most memorable moments of the trip.

> *One major new finding was that the effects of freshwater are seen in the southern Bay as well, creating a barrier layer*

Another exciting moment he refers to has to do with the large Facility for Airborne Atmospheric Measurements (FAAM) aircraft that was used in the experiment, which he describes as being "as big as a passenger aircraft but instead of the rows of seats on either side it is fitted with instruments". There was one location, soon after the trip began, when the aircraft flew over the ship and took simultaneous measurements at the same location. "That gave us the opportunity to sample all the way from the top of the atmosphere, to the air-sea interaction, all the way down into the ocean," he says.

What have we learned from BoBBLE?

The results of the experiment were published in the *American Meteorological Society* journal in 2018. And analysis of that data is still underway. One major new finding was that the effects of freshwater are seen in the southern Bay as well, creating a barrier layer – although of a lesser intensity than in the north. Another achievement was being able to study a very strong current called the Southwest Monsoon current, which brings in heavy, cooler, saltier water from the Arabian Sea into the southern part of the Bay, and is crucial to maintaining the salinity level in the Bay. "Since it is heavier, when it comes into the Bay it slides below the freshwater layer, and has a core of high salinity water. We had known that such a core exists, but never knew its structure. We now have the first picture of that high salinity core – what its depth is and how it varies as a function of time," says Vinayachandran.

The BoBBLE team was also able to capture data on the structure and diameter of this current, and its interaction with a cold dome that develops in the Bay known as the Sri Lanka Dome, which is associated with upward movement of cooler water from below. They were able to measure this movement, and document how the Southwest Monsoon current acts as a limiting boundary at the dome, isolating it from the high salinity water coming in from the Arabian Sea.

All of these features help understand oceanography essential to SST (including how much radiation is absorbed by the mixed layer, contributing to SST), productivity in the ocean, oxygen distribution, carbon cycling, and other processes. "We had simultaneous measurements of all the processes contributing to SST," says Vinayachandran, "This has never been done before. This was our best achievement. Using careful calculation we have been able to show that ocean dynamics is very important for SST. This is key info that will go into models that will predict monsoons." This last aspect, he says, will soon be submitted as a paper for publishing, and is the biggest direct contribution to understanding the monsoon.

The intense one-month cruise saw participation from researchers at the University of East Anglia in the UK, IISc (where Vinayachandran has a team of about 13 people – students, project staff and project associates) and other institutions, and had material and logistical support from a range of players, including the National Institute of Oceanography in Goa, which provided the ship, the Indian National Centre for Climate Information Services (INCOIS), Hyderabad, the National Institute of Ocean Technology (NIOT), and the Ministry for Earth Sciences. "Without support from so many fronts it would not have been possible to do this," says Vinayachandran.

Decoding the signatures of monsoons past in fossils and genes

– *Karthik Ramaswamy*

Studying how a changing monsoon could affect our biodiversity

Photo: V Deepak

Sarada superba, *a fan-throated lizard, whose ancestors diversified in the Late Miocene*

Scientists predict that the current bout of climate change, induced by human activities, will severely impact the monsoon. How will the expected change in this weather system affect India's rich biological diversity? Given the complexity of both the monsoon and anthropogenic climate change, the answer is not simple.

Nonetheless, research emerging from diverse fields of biology – using both traditional and modern techniques – is providing us with valuable clues in our quest to address this critical problem. These studies are investigating how the monsoon climate, which underwent similar changes in the past, influenced the evolutionary fortunes of plants and animals in the Indian subcontinent.

The Monsoon

The South Asian summer monsoon is perhaps the most impressive meteorological spectacle on the planet. In just three months between June and September, the entire subcontinent receives three-quarters of its annual rainfall. What makes it even more dramatic is that even within this period, it is compressed into a total of just about 100 hours of copious rain.

The monsoon arrives religiously year after year. Even though we don't always have a "normal monsoon", it is reasonably stable over short periods of time. But this relative stability disappears as we zoom out and scrutinise it over hundreds of thousands, or even better, millions of years. Across such geological time scales, it shows up to be a fickle beast.

The monsoon is as old as the hills, literally. Its birth was triggered by the rise of a geological structure that defines the Indian landscape as much as the monsoon defines the Indian summer: the Himalaya. The Himalaya was forced into existence when the Indian tectonic plate collided violently with its larger Eurasian counterpart about 50 million years ago (mya), during a period geologists call the Eocene Epoch.

At this time, and even during much of the next Epoch – the Oligocene – the monsoon did not exist in the way we think of it today. What we had instead were weak winds which blew erratically from the Indian Ocean. It took another 25 million years or so – in the Oligocene-Miocene boundary – for the monsoon to find its feet. It was being propped up by the rising Himalaya, which was blocking the cold winds from the Arctic and northern Tibet, warming the land on the other side. The scorching hot temperatures during the summers created a low pressure area over the Indian subcontinent, drawing winds from the colder waters of the Indian Ocean. The Himalaya also helped the monsoon by serving as a barrier to the moisture-laden winds blowing from the south.

During the next 15 million years (from 25 to 10 mya), the monsoon flourished and became stronger. But this does not necessarily mean that rainfall increased. "When we talk about intensification of monsoon, what we mean is that much of monsoon winds occur during a certain period, and that's when we get all the rainfall," clarifies Praveen Karanth, whose lab at IISc specialises in applying molecular methods to understand how past climatic and geological events have shaped the composition and distribution of some of the subcontinent's fauna.

Rainfall was not just being partial to certain months of the year; it was also becoming increasingly patchy in its distribution. "The intensification of the monsoon also triggered aridification of large parts of India," says Karanth. As a result, the wet, closed subtropical forests that covered most of India started to diminish and become fragmented. By the late Miocene – about 10 mya – the landscape had become increasingly arid. Open dry habitats like grasslands were the new normal.

Both the climate and landscape of India have continued to transform past the late Miocene, but what transpired during this period has important lessons for us.

Fossils

A modified monsoon regime is likely to be upon us in the near future, if it already isn't. Several recent studies have shown how changes in rainfall patterns could affect the ecology and behaviour of plants and animals. However, in order to understand the broader evolutionary consequences of an altered monsoon climate, it would serve us well to look back in time.

While we have been able to reconstruct the planet's paleoclimate (using proxies which are frozen in ice, buried in sediments, or coded in tree rings), scientists are only now piecing together the story of how different groups of plants and animals – the latter being the focus of this article – responded to altered precipitation patterns.

The traditional way to address this problem would be to study fossils. For instance, in a 2015 paper, Raquel López-Antoñazas from the University of Bristol in the UK and her colleagues explored the fossil record of the subterranean Asian Bamboo Rat. These rodents, which eat roots of bamboo and other plants, are found in the eastern half of Asia, including Northeast India. But their fossils have also been recovered from many parts of North India and even Pakistan.

What the remains of the Asian Bamboo rats tell us is revealing. "Primitive" bamboo rats, which lived before about 23 mya (fossils can be aged using radiocarbon dating), had teeth that are described as brunodont and bracydont, suitable for crushing moist non-abrasive vegetation. And their skulls and skeletal structure, according to the authors, point to an above-ground lifestyle. But as the monsoon became stronger and forests disappeared, these animals were decimated. There was a massive drop in the number of species.

Then something curious happened about 10 mya – the rats made a partial comeback. The newcomers on the scene had novel dental adaptations, suitable for a more abrasive diet. Their teeth would allow them to feed by incision, followed by grinding, to eat dryer and tougher plants. The authors also claim that their skeletons reveal a subterranean lifestyle. By living in burrows, the rats could escape predators prowling the open landscape. It would also help in preventing water loss, and thus cope with the now prevalent arid environment.

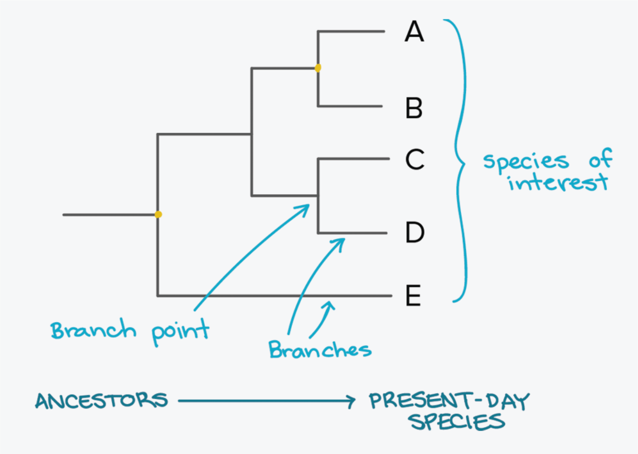
By the late Miocene – about 10 mya – the landscape of India had become increasingly arid. Open dry habitats like grasslands were the new normal

Fossil evidence in other groups too highlights a turnover in species during this period. However, the utility of fossils to understand our past is limited because the odds of an organism becoming fossilised is remarkably small, says Ullasa Kodandaramaiah, an evolutionary ecologist at Indian Institute of Science Education and Research (IISER) Thiruvananthapuram. Some put this number at one in a 100 million. And that's not surprising – only those with bones, teeth, shells, or woody stems can leave behind any remnants. Moreover, in order for an organism to become a fossil, it must be buried immediately after it dies, to ensure that its decay slows down or stops completely.

Phylogenies

Biologists have found more success in their quest to understand the evolutionary history of organisms – and how they coped with climatic changes – by building phylogenetic trees or phylogenies. "Although fossils have their own advantages, with phylogenetic methods, one has the potential to glean some information from a large number of species that exist today to understand what climatic conditions their ancestors lived in," says Kodandaramaiah.

The logic behind such a phylogenetic reconstruction is simple: all organisms on Earth are descended from a common ancestor (Charles Darwin called it "descent with modification"). Using this assumption, phylogeneticists work backwards – they use traits of the living organisms to determine their past. The tree they build is not unlike your family tree. But whereas a family tree comprises a group of related individuals, a phylogenetic tree has related species (or sometimes populations within a species).



A hypothetical phylogenetic tree

Traditionally, the traits that were used for such trees were typically morphological or anatomical. But since the molecular biology revolution, they have been replaced by gene sequences. Karanth spells out the reasons for this shift: "One, in molecular studies, we can generate a lot of data, and therefore get more information. Two, in molecular data, there's a lot more variation, which you want when building phylogenies." This is because if all the sequences are the same it would not be possible to determine how organisms are related to each other and how they diverged. And the third reason why, according to Karanth, molecular data is superior is because of something known as convergent evolution.

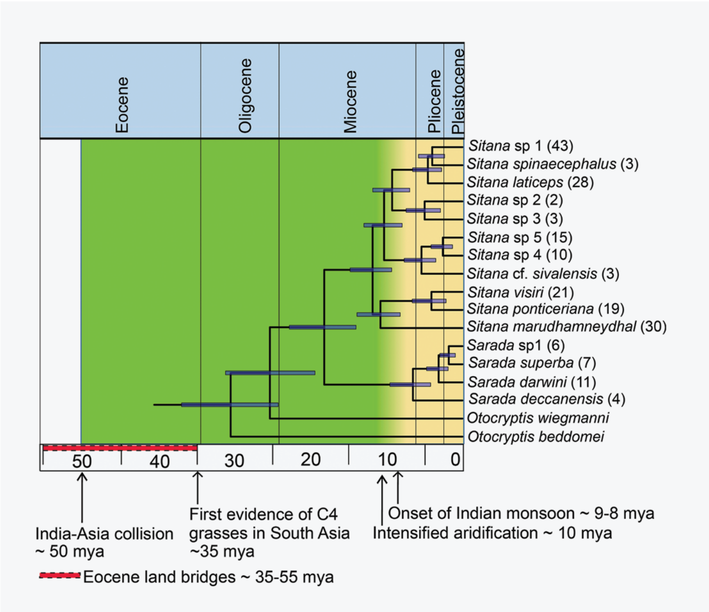
For example, wings have evolved in insects, bats, and birds *independently* (and not because they inherited it from their common ancestor). If we build a phylogeny using "wings" and other such convergent traits, we could end up with a tree which shows unrelated species being clubbed together. "An extreme example of this that comes to my mind are the vultures of the New World [Americas]," says Karanth. In the past, all vultures were grouped together, but recent DNA studies have revealed that New World and Old World vultures belong to different lineages with different ancestry. "This kind of convergence is not common in molecular sequences," he explains.

Once phylogeneticists decide on a set of genes that are ideal for constructing a tree, they sequence them for all the species of interest. The sequence data is then subjected to probabilistic methods (increasingly based on techniques called Maximum Likelihood or Bayesian Inference) to find the tree that best depicts how this group of species evolved.

Dating Divergences

Phylogenies are more than just visual representations showing the evolutionary history of a group of species. They can also be used to understand the origins of novel traits, classify species into evolutionarily meaningful groups (clades) and test other evolutionary hypotheses. One such question a tree could be used to address is when a group of species diverged from each other and whether this divergence coincides with what we know about changes in the environment. This is done using a technique called molecular or gene clock.

Image courtesy: V Deepak



A dated phylogeny of fan-throated lizards showing that diversification of lizards occurred in the aftermath of aridification brought about by changes in the monsoon

DNA sequences accumulate mutations with time. As more time elapses, there will be more changes," Karanth says. "So if two species exhibit very high genetic distance [calculated based on the number of differences in their sequences], then one can conclude that they have diverged from each other further back in time than species pairs that show very little distance." But this is only the first step in determining the time of divergence; it then needs to be calibrated. Though geological events are used at times for calibration, phylogeneticists typically rely on fossils. But you cannot use just about any fossil – only those closely related to the group, and can therefore be placed in the phylogeny, can be used for dating. Karanth explains the logic: "For example, if we know that there is 5% sequence difference between species A and B, and if we have a fossil dated at 5 mya that we know is the common ancestor of A and B, then the clock rate is 1% sequence difference per year." The clock rate can then be used to determine the divergence times for other species pairs based on the degree of genetic divergence.

However, there is an important caveat. "The rate of molecular evolution may change through time and in different parts of the phylogeny, and so it is important to have as many independent calibration points as possible," says Ishan Agarwal, an evolutionary biologist, who has studied several groups of lizards and amphibians, first during his PhD from IISc as Karanth's student, and then as a postdoctoral research at the National Centre for Biological Sciences and eventually at Villanova University in the United States.

One group of lizards that Agarwal investigated is a genus of geckos called *Cyrtopodion*. This group is considered palaearctic because it is thought to have come to the Indian subcontinent from the northern latitudes. But today, they are found in the arid zones of North and Northwest India. *Cyrtopodion*'s dated phylogenies reveal that they diversified between ten and five mya.

During this period, yet another lizard lineage that Agarwal studied, *Ophisops*, also experienced a similar evolutionary fate. These small grassland-dwelling lizards – there are at least 30 species including a few new ones discovered by Agarwal – dispersed into the subcontinent from the Saharo-Arabian region in the Oligocene. But the rates of diversification in this group too increased – there was an eight-fold increase in speciation rate – following the formation of grasslands in the Late Miocene.

V Deepak is also an alumnus of Karanth's lab. As a postdoctoral researcher at IISc (he is currently at the Natural History Museum, London, UK), he discovered the same story being played out in fan-throated lizards. These small, often colourful reptiles can be found scurrying across the dry landscapes of southern and eastern India, as well as Sri Lanka. There are 18 species of these lizards that are known to science belonging to two genera: *Sarada and Sitana*.

Deepak found that, though the group evolved about 26 mya, they underwent rapid speciation only eight to five million years ago, a period which marks the end of the Miocene and the dawn of the Pliocene. This diversification also occurred in the aftermath of intensification of the monsoon and the eventual aridification of India. What is more striking is that their closest relatives, called *Otocryptis*, belong to just three species, and are found in the more secluded wet forests of southwestern India and Sri Lanka. These are relics of a group of forest-dwelling lizards, which seem to have survived the age of aridification. But they didn't have anywhere near the kind of success their close evolutionary cousins did.

Photo: Ishan Agarwal

Ophisops kutchensis *(left) and its typical open habitat (right)*

In the course of their studies, Agarwal and Deepak have also described several new species – some of which do not show morphological differences (evolutionary biologists call them cryptic species). Traditional taxonomic methods, according to Deepak, have therefore severely underestimated species diversity. Their findings have other important lessons for us: grasslands and other open habitats support a healthy diversity of animal life. And many of India's grasslands are not degraded forests; they are natural habitats that have been around for millions of years and served as fertile ground for the proliferation of some groups of animals like lizards.

"In wet-adapted species, we see lowering of diversification, which hints at extinction events, whereas the dry-adapted species underwent rapid radiation"

But not all animals were as lucky as these lizards. Those that require the humidity and protection of closed forests had seen their best days. Shield-tailed snakes belong to one such group that was adversely affected, not unlike bamboo rats. Using similar molecular techniques, these burrowing snakes, endemic to wet forests of peninsular India and Sri Lanka, were studied by Vivek Philip Cyriac from Kodandaramaiah's lab. Once again, the study indicates a role for the prevailing climate in driving evolution: the rates at which shield-tailed snakes diversified decreased around 11 to 10 mya.

Cyriac feels that the shrinking of forests in this period could have reduced the available niches for these forest reptiles to diversify. "So it's intuitive that the contraction of forests that started during the late Miocene would have negatively influenced diversification in forest adapted species such as uropeltid [shield-tailed] snakes."

Photo: Vivek Philip Cyriac

A shield-tailed snake Uropeltis myhendrae *in its moist habitat*

In their paper, Cyriac and Kodandaramaiah, however, do not invoke aridification to explain what happened in the late Miocene. They suggest that it has to do with cooler temperatures that also occurred during this period. But Kodandaramaiah points out that aridification and cooling could have gone hand in hand, and the rates at which these snakes diversified could certainly have been affected by changes in precipitation directly or indirectly. "Unfortunately, to understand the effects of past climate change, one cannot rely on controlled experiments," he says.

To Karanth, the relationship between a change in the monsoon patterns and evolutionary changes is clear. "In wet-adapted species, we see lowering of diversification, which hints at extinction events, whereas the dry-adapted species underwent rapid radiation," he summarises. Agarwal agrees: "The late Miocene was an important time in India's history, a time of increased aridification and habitat change – with cool- or forest-adapted groups becoming more and more restricted in distribution and warm- or open-habitat adapted groups expanding their ranges and rate of diversification."

In spite of these takeaways, we are some ways away from a comprehensive understanding how a changing monsoon will influence the destiny of India's flora and fauna. For one, the dated phylogenetic studies at our disposal are skewed towards certain groups, particularly herpetofauna. They need to be replicated in other animal taxa, as well as in plants. Besides, the jury is still out on how exactly the monsoon will be affected by climate change. And when we add other factors like pollution and land-use change into the mix, the challenge ahead of us is formidable.

Why knowledge isn't the barrier to Wa conservation

Veena Srinivasan is a Senior Fellow at the Ashoka Trust for Research in Ecology and the Environment (ATREE), Bangalore, where she leads the Water, Land and Society Programme. Her research interests include the impacts of urbanisation on water resources, an issue that comes back to haunt major Indian cities and enter the national discourse every summer. In June, Srinivasan was at IISc to deliver a talk at the Interdisciplinary Centre for Water Research (ICWaR). Excerpts from an interview.

Leaving aside climate change and deficient rainfall, what are the systemic factors that contribute to water scarcity in urban and rural India?

The first thing to understand is that water availability is inherently stochastic. It rains more in some years, less in others. There is going to be variability, which changes because of climate change.

You could think of water scarcity as a long-term decline. For example, groundwater levels in Punjab – where people are irrigating their crops of rice and wheat – are going down. That's not actually scarcity, but water is nevertheless unsustainably used. But one day we're going to run dry, like a bank account.

What we more commonly think of as water scarcity is when human demand for water for various purposes – whether it's for urban use, agriculture, or even the environment – exceeds the amount of water available. You have a pie which is divided based on average availability, but your rainfall keeps on changing from year to year. So in a drought year, suddenly the pie has shrunk too much and there are too many competing demands. Most of the time, that's what we experience as water scarcity, which results in conflict.

One of the thorny issues which you identified as inhibiting our ability to address or mitigate water scarcity is what you termed the "fragmented governance of water". Could you give an overview of this problem and the ways in which it manifests in our cities?

The problem is not so much that governance is fragmented – you can't have a single agency which is in charge of everything. The problem is that the agencies have no mechanisms to coordinate on crucial decisions. We haven't figured out how to put in place processes which will force agencies to coordinate on specific issues where coordination is required.

How does this manifest? The job of the groundwater agency, the Central Ground Water Board, includes giving licenses – so they declare whether a district or a block is safe or critical or over-exploited, and they give industrial licenses based on that. Then you have the surface water agency, the Central Water Commission, which is responsible for managing the operation of dams. These are the national-level agencies but the same fragmented structure replicates at the state level also. The problem is that often they don't talk to each other. Often, they're

ter

– Nithyanand Rao

double counting the available water. One agency says, "I'll take that extra water from the stream, stick it into the ground and I'll solve my depletion problem," without realising that the extra water in the stream was being counted on when building that dam downstream. So the problem with fragmentation of governance is that they lack the processes to ensure that the assumptions that underpin their decisions are consistent with each other.

Similarly, stormwater typically falls under the municipal corporation – which makes the water plans for the city – and water supply and sanitation falls under the water utility, usually an independent parastatal board, which makes the sewage plans for the city. Often these two agencies work at cross-purposes.

Photo courtesy: ATREE

You wrote recently in the *Deccan Herald* that "decentralised components [such as wastewater recycling and rainwater harvesting] are viewed as temporary fixes by our water utilities, who dream of centralised piped water and sewerage." This is quite apart from the pipe dream of interlinking rivers. Why is there a fascination for large-scale, centralised projects?

It comes from your training and therefore what you're comfortable with. If you look at water utilities across the world, they tend to be staffed by engineers. But if you want decentralised wastewater recycling, you need people who have legal expertise, or instrumentation engineers, who can say what kind of monitoring framework you need to put in place to ensure that the people who are making commitments for treating wastewater are actually meeting them. This requires a certain kind of thinking about the design of institutions. Because we've designed our institutions – civic bodies and utilities – to have only engineers, nobody knows how to deal with a compliance plan for decentralised pieces. And therefore, they find it comfortable to create mega-infrastructure projects – like the smart city. I can understand why, if you're an engineer, everything which has purely engineering components is inherently going to be more comfortable for you.

We also need to change the training we give civil and environmental engineers. Somebody at the talk asked what it would take to combine green and grey infrastructure – how do you create a city which uses nature-based solutions instead of only using grey infrastructure? For that, you need to bring in people who know aquatic ecology, plants, landscape ecology. But this is not how we design either our utilities or our education system that trains the engineers they hire – which is where centres such as the ICWaR are relevant. Think about why civil and environmental engineering were put together as one department. It was because there was a vision of engineering which involved concrete and dams. A person who studies BTech in water engineering has to go through courses on concrete and strength of materials, design of culverts and pipes, but not courses on plants and aquatic species. So not surprisingly, the workforce that has been feeding into our utilities has people who have only acquired a certain set of skills. The longer-term change has to come from mixing it up a little bit.

You made another important point in your talk: We have had so many large projects, such as dams, completed over the last several decades but we haven't done any monitoring and evaluation of what impact these have had. What kind of evaluation did you mean?

Everything. Starting from simple things like comparing the project's DPR [Detailed Project Report] with what the project actually delivered, and asking if it was even half as effective as planned. Was the command area that was promised met? Were the environmental impacts anticipated? Were there unintended consequences? Were the mitigation measures put in place and were they effective? It requires many small studies to be done but none of that's ever been done.

So we don't know if fish ladders are effective, or what kind of fish they work for – and yet when we put new DPRs together we just recycle the same stuff. If you never actually went and checked if any of those things were ever put in place and if they worked, then on what basis are you making these plans for future projects?

You made a few points in the context of connecting science to policy – that we don't always require cutting-edge science to feed into policy, and that scientists often end up doing modelling for the sake of modelling, which may not connect to real-world situations. Could you elaborate?

A lot of science that we do on water doesn't necessarily feed into policy or isn't even useful in any way. On the other hand, even the existing research is not effectively used. There are a hundred papers in *Nature* and *Science*, and every hydrology journal since 1945, which are going to tell you that ground and surface water are connected. But then it's still not embedded into the DNA of our agencies. There you have to ask if our doing more cutting-edge research on, say, isotopic tracers on base flow in rivers is going to be the thing that's going to move the needle – I don't think so. I don't think that knowledge is the barrier.

One thing that the US does very well, which we're lacking in India, is how the National Academy of Sciences will often put out position papers on the state of the science on specific topics. It needs to say here are these big policy gaps and here's the state of science. And that doesn't have to be science that happened today. It's really a gathering of all the science on this subject which summarises what we know for sure at this point in time.

What an Adivasi village in Chhattisgarh can teach us about sustainable development

– Nithyanand Rao

An IISc scientist's work on a local solution for water and power

Photo courtesy: Punit Singh

The ram-pump in operation on the Ganeshbahar, Taipadar

Baliram Nag and I arrive on his bike at the Bastar District Collector's residence, at the end of a leafy, secluded road in Jagdalpur. As we make our way past the security guards, they greet Bali warmly and ask him where the "vaigyanik" is. Punit Singh arrives a few minutes later, having jogged from the hotel.

We are meeting the Collector to discuss the project Singh is implementing in Bali's village, Taipadar. Nearly ten years in the making, the project will deliver water for irrigation from Ganeshbahar Nala, a perennial stream close to the Adivasi village, using a ram-pump that works without electricity. The pump, in fact, worked successfully for about two months until heavy rain broke the makeshift dam the villagers had built. After a proper dam is built, a turbine, designed by Singh and gifted from Germany, will be installed.

Soon, Ayyaj Tamboli, the Collector, meets us and assures Singh and Bali of financial support, a sum of Rs 49 lakh already having been released for constructing a dam. He has also agreed to contribute Rs 75 lakh towards the pipelines for the turbine pump and a storage tank.

"This project will give us three benefits," Bali tells me as I ride with him back to the hotel. "Water for irrigation and drinking, and also electricity."

Earlier that morning, Bali and his friend Genu, who hails from a village upstream of Taipadar, had come with their bikes to take us to Taipadar, about 35 km away. The many small solar panels I spot in the fields en route were installed, Bali tells me, by the Chhattisgarh State Renewable Energy Development Agency (CREDA), which employs both him and Genu. They have installed solar panels in many villages in Bastar, including Taipadar, to pump water from borewells or to generate electricity sufficient for a few lamps in every home. As we approach Taipadar, villagers travelling in the opposite direction wave at Singh. This is his 14th visit to Taipadar in 2019, having made over 40 trips in ten years, doing the groundwork with Bali and others to make their dream a reality.

Heavy rain lashes Taipadar as we enter Bali's home, which, like others in the village inside the Tiriya forest reserve, isn't on the power grid. Bali, having lived in Jagdalpur for a few years with his wife and kids, now wants to move back to the village to be with his parents and brother, and see the project to completion. After the rain subsides, we make our way down to the stream and the makeshift dam that was breached in June.

Despite the perennial waters of Ganeshbahar (a tributary of the Sabari, which later joins the Godavari), the villagers have to rely on the monsoon for irrigating their crops, a situation not unique to Taipadar – less than 50 percent of the cultivable area in India is irrigated. Their Kharif crops – rice and pulses – are sown before the monsoon in June, and harvested by the end of the year. And though they do cultivate mustard in Rabi (sown in winter and harvested in spring), their productivity and income depends on the vagaries of the monsoon, forcing them to migrate to cities in search of jobs during the dry season. "They get very good rains during monsoons, more than India's average," says Singh, "But Taipadar is dry for eight to nine months."

Singh with the residents of Taipadar, after building the makeshift dam

The makeshift dam was constructed by the villagers, funded by Singh himself. He is an assistant professor at the Centre for Sustainable Technologies, IISc. CST was founded in 1974 as the Centre for Application of Science and Technology for Rural Areas (ASTRA) by Amulya Reddy, who realised that more research in science and technology does not automatically alleviate poverty. If jobs are to be created by industrialising, research had to be linked to industrial needs – but industrial needs, and therefore research, would always reflect the interests of the elite in a "dual society" like India's.

As an engineering student in Mysore, Singh struggled with this himself. He was introduced to Reddy's work during his college days, influenced by his seniors and teachers. He also read a great deal about the Narmada Bachao Andolan, but could not completely comprehend the rationale behind people opposing development projects. Curious, he took up an internship with Samvada, an NGO that mentors youth from villages. He had his first confrontation with the ideology driving large-scale development projects when he travelled to Kaiga in 1996, then in the midst of a movement against the proposed nuclear power plant. There, he met an old woman who had no trouble recognising the power lines that would carry away energy to Bangalore while her own home remained in darkness. Singh searched for an explanation from the manager in charge of the plant, only to receive an angry assertion that the electricity was not meant for the villagers.

Photo courtesy: Punit Singh

By then Singh had also read E.F. Schumacher's book *Small is Beautiful*, which influenced the appropriate technology movement worldwide in the 1970s. The movement, responding to the prevailing views of development, advocated small-scale, decentralised, environmentally sustainable solutions. Later, during (and after) his PhD at the Karlsruhe Institute of Technology, Germany, he was involved in several projects where he helped build turbine pumps to generate electricity for local use in Tanzania, Java, and several places in India. When he returned to India in 2009, Singh, with some of his friends, went on "yatras" to villages in Gujarat, Uttar Pradesh, Uttarakhand, Chhattisgarh, Kerala and Nagaland, to understand first-hand the problems that people face – one of which was water for irrigation.

"I saw the potential for micro-irrigation in all these places," Singh says. "But I asked myself – which place needs me the most? Where would nobody go? I chose this place [Taipadar] because the villagers told me that they need water and I felt competent that I can do something for them." However, Ganeshbahar didn't have a sufficient "head" (the elevation from which water flows) for a conventional turbine pump to work. So he worked on developing turbines for small streams for his Habilitation degree (a prerequisite before becoming a professor in many European countries).

And then he came across ram-pumps, which tap into the force of falling water to pump it uphill. The ram-pump, developed in the late 18th and early 19th century, uses nothing other than the kinetic energy of water to pump some of it, with a lower flow, to a higher point. Such a device has a chamber with, among other things, a "waste" valve and a delivery valve. When water in a ram-pump's inlet pipe encounters the waste valve, initially in a lowered (open) position because of its own weight, it lifts the valve, closing it. This closure of the valve causes pressure inside the pump to build up – the water hammer effect – and exceed that due to the water pressing down from outside on the delivery valve, causing that valve to open and let out some of the water. Because it is being pumped to a higher point, the flow soon reverses, closing the delivery valve, and creating another water hammer that moves back up the inlet pipe, sucking the waste valve downwards into the open position again. And then the cycle repeats.

The ram-pump's popularity waned after electricity arrived, though it is still manufactured on demand. For Taipadar, Singh bought a ram-pump from a US-based firm, which cost him about Rs 22 lakh, including the shipping charges. Since it was difficult to get funding, from institutions or from the government, for a project in its conceptual stage, he put in his personal money. He paid for the inlet and delivery pipes too.

The ram-pump, Singh says, is an ecologically gentle way of harnessing a river. "The technology that I bring in should make sure that the stream also exists," he says. "Of the water that is taken from the stream, only five percent is used for irrigation. The remaining 95 percent goes back to the stream." The small amount of water used for irrigation, Singh estimates, will increase the agricultural productivity of the village up to five times.

Photo: Nithyanand Rao

Bali and Singh on the banks of Ganeshbahar

The larger project will also see a turbine installed to generate electricity for the village. Two turbines, designed by Singh, were manufactured by a 150-year-old German firm, KSB, and funded by their Foundation. The turbines arrived in 2015, but have been lying "abandoned in the Kavapal forest," as a local news report put it – in their unopened boxes a short distance away on the bank overlooking the stream. "These turbines, when installed, can provide electricity to the village for ten months," claims Singh. But all this needs money – Singh estimates that the full project would need Rs 6 crore, of which only about Rs 2.5 crore has been raised so far.

Initially, the government wasn't supportive of the project. "They were discussing the project in terms of cost-benefits, that this would benefit only about 200 people and the cost was Rs 6 crore," says Singh. So he worked with the villagers to construct a makeshift dam of sand bags to prove that the ram-pump worked. And Bali and a group of young boys decided to do collective farming, a plan that is now stalled: the ram-pump ran from May 2019 until heavy rains in late June destroyed the dam. Tamboli, who took over as Bastar district's Collector recently, has now agreed to fund a proper dam, which will be built once the monsoon subsides.

I ask Tamboli if he thinks the project could be replicated elsewhere. "We can implement it wherever there are suitable conditions," he says, referring to the "head" required for the ram-pump to operate. And why does the project interest him? "Even if we exclude the turbine and the plan of generating electricity, we are spending only Rs 5,000 per head per year for irrigating one crop," he says. "If we have double cropping, that's Rs 2,500 per head per year. So it's economical from our point of view." These figures, he explained, are for the 200 people-strong Taipadar, assuming the maintenance costs are a generous Rs 10 lakh per year. He contrasted this with a borewell that costs about Rs 13,000 and serves only one farm. "It uses up groundwater while this project relies entirely on surface water and serves an entire village," he says. "That's the advantage."

But there are challenges other than financial too. We were on our way back to Jagdalpur when Bali and Genu take us to see the spot where Ganeshbahar joins the Sabari, from where the National Mineral Development Corporation (NMDC) will soon start drawing water for cleaning iron ore. A large concrete structure in the middle of the river is visible. The NMDC is building a processing plant on the Sabari that could imperil the Ganeshbahar's perennial nature. "I am very worried about how this will affect the water balance of the local environment," Singh says. He plans on doing a hydrological study with his PhD student, Siddhi, with help from river management experts from Germany.

The same NMDC employs Sukhram of Taipadar, whom we had just met before leaving the village. Sukhram stayed away from constructing the temporary dam, Singh says, possibly because he perceives the project as Bali's rather than the village's. This misconception may have arisen as it is Bali and his father – with other family and friends – who take the lead in implementing the project. It is Bali who has the training to maintain the system and it is through him that Singh has so far employed villagers for the construction work. What's more, the highest point in the village where the piped water from the ram-pump arrives – as it did for two months – happens to be land belonging to Bali's family. There, a tank will be built to distribute water to other farms through channels or pipes. One of those farms is being worked over by Sukhram as we approach; Singh waits for him with open arms and embraces him.

Singh with Bali and other villagers, with the pipe carrying water from the ram-pump

"Where have you been and why have you been staying away?" asks Singh. "Don't break my heart." Sukhram is initially evasive and, as Singh reminds him that the project belongs to the village, doesn't quite meet Singh's eye. "We have hired a tractor for the village, use it to till your land too," Singh tells Sukhram, holding his arm. Sukhram eventually appears to warm up and promises, with Bali standing nearby, that he will take part in the project and even leave NMDC when the work resumes.

Photo: Punit Singh

Word about Singh's work has spread, aided by local newspaper reports. The Collector of the neighbouring Sukma district saw a video of the ram-pump working in Taipadar, and invited Singh to see if something similar could be implemented in his district. So the next day, we travel to Sukma, passing by many Central Reserve Police Force (CRPF) camps on both sides of the excellent new roads. We notice that our vehicle doesn't have a license plate. "The white towels [on the seats] will show it is an official vehicle," Suraj, our young driver, assures us. We pass the spot where, in 2013, senior Chhattisgarh Congress leaders were killed in a Naxal attack, and then enter the Darbha valley, so thickly forested that mist surrounds us as we drive through.

In Sukma, we meet Jayant Kumar Lakra, Executive Engineer in the Water Resources Division. His career has taken him to all parts of Chhattisgarh, and he is clear why a long procession of development projects have failed in his state, as elsewhere in India. "Until and unless you involve the beneficiaries of your project," he tells us over dinner, "ask them what they want, and make them the managers, all your projects will fail."

Lakra's father was a central government employee; he belongs to a tribe that, through education, has managed to escape the life of subsistence that is the harsh reality for many other tribes in a state cursed by its abundant mineral wealth. I ask Lakra if he knows many Adivasis, other than himself, who are part of the district administration. "Zero," he says.

In Sukma, as in Jagdalpur, we saw businesses and shops run by people originally from outside Chhattisgarh, Adivasis being confined to working as hotel and restaurant staff. As Suraj later responded when we asked him if he had completed high school, "What's the point of studying more if there are no jobs?" adding that those who do study further tend to be targets for acts of "black magic" by envious non-Adivasis.

The next morning, Lakra arrives with three others on a jeep at the government rest house where we had stayed overnight. We exit Sukma on a narrow concrete road that leads to Konta. The construction of the road, Lakra informs us, claimed the lives of more than a hundred CRPF men. After about 13 km, we turn off the road to Girdalpara, a village of about 300 Adivasis. "They are hard-working people," says Lakra, seeing the many tractors parked by the side of the village's main lane. We proceed to the river bank, where we stand on an existing concrete embankment. Singh, while talking to boys who were swimming and fishing, estimates that the river's "head" is adequate to run a turbine – only during the non-monsoon months, when the village needs water the most.

Photo: Nithyanand Rao

Lakra and Singh, speaking to the residents of Girdalpara

Later, we meet with the men of the village. Lakra opens the conversation and then Singh takes over, explaining that the project, if implemented, would give them water for three crops a year compared to one now. He tells them about the Taipadar project, and how their fields wouldn't lie fallow during the summer. They agree to his proposal.

As we leave, I ask the villagers if the district administration has tried to implement irrigation projects before. They tell me that successive plans for water have never been implemented. But Chandan Kumar, the Collector of Sukma district, is positive. "We want to see Bastar develop," Kumar says. "There are a lot of streams here that we could put to use and such projects can help us achieve our goals."

Singh, too, wishes to see more such projects. "I have a dream that more competent researchers from Indian academic institutions participate in the challenges of our hinterland, first in understanding and then solving them – especially challenges related to water," he says. "There is an unparalleled joy in seeing satisfied beneficiaries that no awards or journal papers can give."

With inputs from Rohini Krishnamurthy

Why drain the rivers when you can catch the rain?

– *Neelima Basavaraju*

A look at how Bangalore can meet its growing water needs

Bangalore is not new to water problems: the city's water consumption is monstrously growing and its groundwater levels are rampantly depleting. Water pollution levels are a matter of grave concern, with Bellandur and Varthur lakes intermittently catching fire and spitting froth. The demand for water is snowballing day after day owing to the city's exponential growth, initiated by its global rise as a major technological hub of India. As reported by *Bangalore Mirror*, the city's population grew from 8.4 million in 2011 to a staggering 12 million in 2018, recording a whopping 30 percent growth rate in just seven years. A 2018 *BBC* report listed Bangalore as one of the world's 11 cities likely to run out of drinking water before long.

How long can a city like Bangalore, with a swelling population and never-ending property developments, feed on external river sources? Offering solutions to the crisis is AR Shivakumar, a former scientist at Karnataka State Council for Science and Technology (KSCST) at the Indian Institute of Science (IISc). Solely relying on the collected rainwater for all of his family's needs, he claims to not have used a single drop of municipal water in the last 24 years. His cost-effective rainwater harvesting (RWH) design and water management ideas implemented at his home could mitigate Bangalore's water woes.

The city's water needs and sewage system have been managed by the civic water body – Bangalore Water Supply and Sewerage Board (BWSSB), set up in 1964. Since its inception, BWSSB has implemented various projects to procure water and cater to the city's needs. Presently, a major portion of the water supplied to the city is being imported from the River Cauvery. The occasional water shortage is met by drawing water from borewells. As per the BWSSB figures, Cauvery water supply to Bangalore at the moment stands at 1,400 million litres per day (MLD). Further, to meet the water demands of the ever-expanding city, the Karnataka state government has allotted additional 10 thousand million cubic feet (TMC) of water through Cauvery Water Supply Scheme Phase V and 2.5 TMC water from the River Nethravathi through Yettinahole project. These projects, estimated to be completed by 2023, will provide an additional 975 MLD supply to the city. In addition, the state government plans to pump water from the River Sharavathi to Bangalore, which is being opposed by the locals and environmentalists.

Shivakumar's first experiment

It is in this context that Shivakumar's experiments on rainwater harvesting, which began while building his house in 1995, hold promise. At the time, he was working on various renewable energy projects at KSCST while also popularising rooftop solar water heaters. But before endorsing them to the public, he realised that he had to be convinced of their sustainability. "Unless you are happy with the technology you are promoting, it's not going to take off," he asserts. Consequently, he constructed his house incorporating all conceivable environment-friendly measures.

To begin with, Shivakumar researched people's daily water consumption, according to the World Health Organisation standards. He estimated that his family of four would require around 1.8 lakh litres of water in a year. He also collected Bangalore's rainfall data from the last 100 years and studied the monthly rainfall pattern. Through rainwater harvesting, he calculated that he could collect over 2 lakh litres of rainwater annually, which was more than sufficient to fulfil his family's needs. But he had to first figure out means to store the water. Soon, he worked out a solution: "To my surprise, I found out that there is hardly 100 days gap between two good successive showers of rain in Bangalore. So we planned to store 45,000 litres of rainwater to bridge through these 100 days," he explains.

To design his rainwater harvesting plant, he built a chain of storage tanks to stock the collected rainwater from the rooftop, diverting excess water to a shallow borewell. His plant amasses every drop of rainwater falling in the open spaces and directly recharges the underground water table, through the many percolation pits dug around his house in the garden. Since the rainwater falling on the roof gets mixed with dirt, leaves, bird droppings, and the like, Shivakumar designed (and patented) a simple pop-up filter which can be vertically mounted on the wall. This pop-up filter consists of a rainwater inlet, flush valve, filter element, and an outlet for filtered water. In the initial minutes of raining, rainwater is directed through the flush valve which lets the dirty rainwater flow out. After about five minutes, the flush valve locks automatically, pushing the water up through the filter element. The clean water then flows through the outlet and into the storage tank.

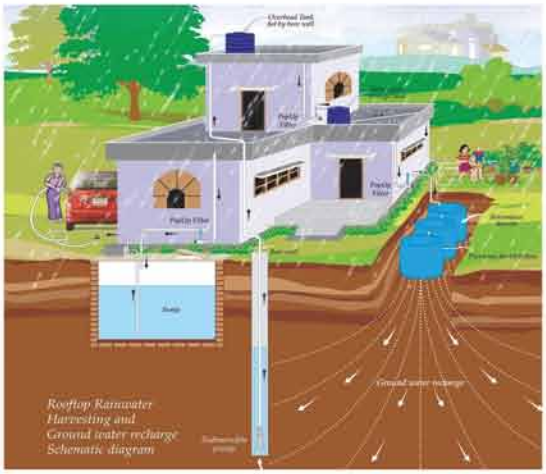


Image courtesy: AR Shivakumar

A schematic presenting various levels of rooftop rainwater harvesting and groundwater recharging

The cost incurred for building an RWH unit can be divided into three parts – installing channel pipes, filtration unit, and storage tank or percolation pits. Pre-mounted channelling pipes are used to drain water flooded on the roof. A pop-up filter costs around Rs 6,000 and the number of filters required depends on the volume of rainwater. A major portion of the expenditure goes into building the storage tank (which can be minimised further if the tank is built during the construction of the house itself). Houses or complexes devoid of space to build storage tanks can opt for installing recharge wells to inject rainwater into the ground – it requires very less space and money. When asked if it is cumbersome to maintain the installed RWH unit, Shivakumar states, "If you keep your roof clean, half the job is done. In addition, maintaining the filters as per manufacturer's specifications ensures clean water in tanks."

The bigger goal

Shivakumar's experiments don't just end with harvesting rainwater. Besides adopting minimal water consumption practices, his family recycles wastewater for secondary purposes like gardening and toilet flushing. Used water from the kitchen sink is collected in a container to water plants. Shivakumar has devised a simple, low-cost wastewater treatment unit on his roof for recycling grey water. The unit contains an aeration system, which removes bad odour from the used water coming in from the washing machine. Water is then stored in two open tanks with suspended plants growing on top to absorb detergent chemicals. The collected water is relatively clean and is used for toilet flushing.

Photos: Neelima Basavaraju

Shivakumar explaining the wastewater usage techniques: (left) water from washing utensils collected in a container to water plants, (right) treatment unit for recycling wastewater from the washing machine

A crusade for harvesting rain

After building a sustainable rainwater harvesting model at his home, Shivakumar became a strong advocate for RWH units. He led the rainwater harvesting division at KSCST by building prototypes and popularised the idea of rainwater collection across Bangalore and other parts of Karnataka. He was actively involved in the design and execution of RWH projects in landmark buildings such as the Vidhaana Soudha, High Court, Kidwai Hospital; and in government organisations like BWSSB, IISc, and Gandhi Krishi Vignana Kendra, to name a few.

Due to his continual efforts, he could persuade BWSSB to establish Sir M Visvesvaraya Rain Water Harvesting Theme Park at Jayanagar in 2011. Spanning over 1.2 acres of land, the park exhibits 26 different rainwater harvesting models, along with demonstrations of water conservation techniques, designed and developed by Shivakumar and his KSCST team. Help desks are set up at both the theme park and KSCST to provide information on rainwater harvesting to visitors. The centre has been conducting mass awareness programmes and provides technical training programmes on the execution of RWH methods to contractors and plumbers.

The road to a sustainable Bangalore

The civic body plans to induct RWH units in most of the state buildings, public parks, road pavements, and wherever feasible, showing that they are slowly warming up to the idea of collecting rainwater comprehensively. As per BWSSB, harvesting even 50 percent of the city's incident rainfall adds 10-15 TMC of water to the reservoir, adequate to sustain the supplementary demands.

But convincing the residents on its merits is still a challenge. Although BWSSB issues notice to those who don't comply with installing RWH units, residents have not strictly implemented it. BWSSB started penalising the offenders from February 2017 and the collected penalties (varying from 50 percent to 100 percent of total water bill) amounted to Rs 2.93 crore per month, as on May 2019. Elaborating on the situation, Shivakumar thinks that the easy availability of municipal water and the lack of restrictions on drawing underground water are to be blamed. "Why would they go for tedious options when they get clean water delivered to their doorstep at cheaper rates? Keeping the minimum price for the basic needs, the fares should be substantially raised for luxurious needs. Only then people will choose water-conserving measures," he adds.

Photo courtesy: AR Shivakumar, KSCST

Catch the drops while it rains!

In response, an engineer at BWSSB says that increasing tariffs don't always work. He explains, "People's views have to be considered while taking major decisions like increasing fares; otherwise they will protest." Some parts of Bangalore, he adds, are more open to RWH units than the others. "While some residents enthusiastically adopt RWH measures, some just set it up to abide by the law. The extended areas in the city's outskirts – where the BWSSB does not supply water and [where] groundwater is receding [due to unrestricted groundwater usage] – are increasingly switching to rainwater harvesting as compared to inner-city where BWSSB supplies water." The quantity of rainwater being harvested in Bangalore at present (storing and groundwater recharge inclusive), according to his estimate, is less than 10 percent – far lesser than the 50 percent target set by BWSSB.

Neelima Basavaraju, a former postdoctoral researcher at IISc's Solid State and Structural Unit, is a freelance writer

A celebration of rain

– Achintya Prahlad

Photo: Veena Gururaja

Achintya Prahlad during his r itu-chakra lecture-demonstration, accompanied by Abhijeet Bayani on tabla and Surya Upadhyaya on the harmonium

A workshop on Hindustānī music inspired by the monsoon by a vocalist who also wears a biologist's hat

I define myself as a musician with an academic approach. I have been a student of Hindustānī music since my childhood. Besides what I learned from my gurus, the well-known vocalist Geetha Hegde and Ojesh Pratap Singh, a professor of music, I am also self-taught: I learned by listening to different genres of music, songs in various languages, and by keenly observing nature and seasons during my years growing up on IISc's campus. Here's why I mention nature – Hindustānī music has an intimate connection with seasons, plants and animals. This is the meeting point of my passion for music and my interest in biology.

Though my PhD from the University of Göttingen was in biophysics, I have always felt the pull of music strongly, not only as a performer but also as an academic. This is what drew me to the Centre for Contemporary Studies (CCS) – now known as the Centre for Society and Policy (CSP) – which I joined as a visiting scholar in 2017, when Raghavendra Gadagkar was the Chair of the Centre. Here is where I began my musicological research, as well as what I like to term *music outreach*.

In January 2018, I joined Ashoka University, Sonipat, as a postdoctoral fellow. My job involves teaching both biology and music appreciation courses to undergraduate students, besides continuing my music research (this semester, I am also teaching a Sanskrit course). But during my semester breaks, I have kept coming back to CSP. This time, in June, I was again invited by Anjula Gurtoo, its current Chair, to be a visiting scholar. Being at the Centre has given a huge impetus to my musical journey.

The goal of my music outreach is to make my music, including several of its technical aspects, accessible to a wider audience

The goal of my music outreach is to make my music, including several of its technical aspects, accessible to a wider audience. I do this through my music appreciation courses, lecture-demonstrations and concerts. Even in my regular concerts, I make it a point to explain what my songs mean to the audience. My lecture-demonstrations always have question and answer sessions. I want listeners to develop a better understanding not just of the music but also the culture and traditions that shape it. My performances tend to be thematic, and I have often found myself inspired enough to compose something new for each event.

My audiences are mixed, and consist of musically knowledgeable people as well as those who are new to its technicalities. All my performances are designed to ensure that each person, irrespective of their background in music, goes back with something new. Based on the number of people who attend my performances and their responses, I would say that I have been successful in this regard.

The first lecture-demonstration by me was at CCS in December 2017, and was a general introduction to Hindustānī music for a lay audience. I covered most aspects of the Hindustānī tradition, ranging from swaras and rāgas to different genres – dhrupad, khayāl and thumrī-dādrā. Though I don't consider myself a representative of any particular gharānā, I am enamoured of dhrupad, especially the way the old Agra masters used to sing it. Their style has had a great influence on me.

My second CCS performance was in January the following year. Here, I broke with tradition. I began with Rāga Bhairavī, a favourite of mine, in dhrupad style. I sang an ālāp and a traditional bandish (composition) on Shiva. In my view, Bhairavī – typically relegated to the end of a concert – is a rāga that has great scope and is deserving of much more elaborate improvisation. Another reason for this unconventional approach is that, when sung as Shuddha Bhairavī, containing only the kōmal swaras (flat notes) and no additional notes – not even the tīvra rishabh (sharp variant of the second note) that is commonly inserted – this rāga presents a very serious atmosphere. I followed it up with the more light-hearted and lively Rāga Kalāvatī. And after a song of Purandaradāsa set to Bhīmpalāsī, I ended with a tarānā in Yaman Kalyān.

My first monsoon concert at the Centre was in July last year, when I sang the well-known monsoon rāgas Mēgh and Gau*d* Malhār, and concluded with a kajrī – a monsoon song originating from the folk traditions of northern India and laden with viraha, the pathos of separation from one's beloved. In Rāga Mēgh, I sang an ālāp and a dhrupad-aṅg bandish. This bandish is a beautiful example of the "varnanātmak" (descriptive) nature of dhrupad – to use a term popularised by the renowned musician-scholar KG Ginde in his lecture-demonstration on dhrupad-dhamār. It describes the story of Indra's fury that takes the shape of a storm, Krishna lifting up the Gōvardhana hill to protect his village from the torrential rain, and finally Indra bowing down before Krishna's might. As an academic, I find this story very interesting, since it is symbolic of a shift in religious practices – the old Rigvēdic gods being replaced by the gods of the Purānas.

This July, I experimented more with my lecture-demonstrations. I did four two-hour sessions. It was challenging, yet exciting. I again went with the theme of the monsoon, a natural choice given the time of year.

> *This July, I experimented more with my lecture-demonstrations*

The first session dealt with the Malhārs – the quintessential monsoon rāgas of Hindustānī music. In the second, I sang monsoon poetry in six Indian languages, covering a wide range of rain-related emotions: celebration of the lover's arrival home, childhood memories, a hilarious conversation between two frogs, the destructive aspect of rain, and so on. The third began with a detailed discussion of Rāga Dēsh. Dēsh is not a monsoon rāga the way Malhārs are, but it still occupies an important place in monsoon music, since it has several songs on rain. From Dēsh, I moved on to the related raga Sūr Malhār. The reason for placing this Malhār in the third session and not in the first was due to its closeness to Dēsh. Towards the end of this session, I sang bandish-kī-thumrīs on rain, and then kajrī and jhūlā. The latter – as the name suggests – is a genre of swing songs, and is closely connected to the festival of Sāwan Teej that is celebrated in northern India. One of the jhūlās I sang was my own composition in Rāga Māñjh Khamāj, which talks of Shiva and Pārvatī on a swing – in a sense "swinging" away from the usual Krishā-Rādhā or Rāma-Sītā themes. Here I have interwoven the culture of the north with that of the south, using symbolic references to the Madurai Mīnākshī temple.

In the fourth and final session, I gave the audience a glimpse of the complete ritu-chakra (cycle of seasons). I opened with a rāgamālā (multi-rāga song) composed by Chaitanya Kunte, a well-known contemporary musician. It is a celebration of Earth, constantly adorning herself in new ways and taking new forms in every season. After this, I took the audience on a musical journey through all the seasons in the calendar.

Most mausamī (seasonal) compositions in Hindustānī music talk of basant (spring) or barkhā (monsoon). There are a few compositions on autumn as well. However, bandishes on the extreme seasons of North India – winter and summer – are rare. For the winter segment, I presented two of my own compositions that were inspired by the German winter which I experienced for several years. The first one, in Rāga Tilak Kāmōd, is motivated by the pristine beauty of snow, and expresses a feeling of milan, or togetherness. As in the jhūlā that I sang earlier, this too expresses my love for syncretism. Here I compare snowball fights to the Hōlī festival. The second bandish, in Kīravānī, is about the cold, dark, viraha-filled nights of that season. Love becomes the blanket that provides relief. Winter is followed by springtime, and so the next segment had spring rāgas Bahār and Basant, two Hōlī songs, and chaitī (a traditional form originating in the eastern part of the north Indian plain and sung in late spring).

The summer segment again began with my own composition, describing the furnace-like winds that blow all day long during the months of Baisākh and Jēth. I composed this specially for the occasion. Normally it isn't easy for me to compose in such a short timeframe. But to modify an old saying, necessity is often the mother of composition. I chose to set this bandish to Laṅkadahan Sāraṅg – a rāga with fire in its very name. The piece is derived from my own experiences of the summer in Delhi and Haryana. The other bandish that I sang is an SN Ratanjankar composition in Ba*d*hans Sāraṅg. Sāraṅgs, while not seasonal rāgas, are often chosen by composers for summer bandishes – because they are sung at noon. I ended this session with a Mīrā bhajan on the monsoon, thus completing the ritu-chakra, and the month-long workshop.

My performances would not have been possible without the support of those who accompanied me on the tabla and harmonium: Sagar Bharathraj, Abhijeet Bayani, Santhosh Hegade and Surya Upadhyaya. I am also grateful to my gurus and all the people at CSP, who have supported me in my journey.

For me, coming back to IISc, where I spent a good part of my childhood, has been a wonderful experience. It's been even more special to perform here. I look forward to many more such musical conversations.

Achintya Prahlad is a visiting scholar at CSP. He comes from Ashoka University where he teaches biology and music appreciation to undergraduate students. You can find his performances on his YouTube channel here: https://www.youtube.com/user/forestswaras

Monsoon Melodies

– Chanchal Uberoi

Photo: IISc Archives

How Hindustani music composers depict the monsoon in abstract terms

Karen L Aplin and Paul D Williams have written about the influence of weather in classical music, cataloging pieces that evoke meteorological phenomena, ranging from the thundering storms depicted in Beethoven's *Pastoral Symphony* and Vivaldi's *Four Seasons* to the more serene meditations of Debussy's *La Mer* and Sibelius's aurora-inspired *Night Ride and Sunrise*.

I was trained in north Indian classical vocal music, so I was intrigued that Aplin and Williams only considered weather in "Western classical orchestral music." I wondered, How would any Indian with similar training react were they to listen to any of the recordings mentioned in Aplin and Williams' articles?

I expect that they would be reminded of movie sound effects that go with scenes of weather-related phenomena – thunder and lightning, violent winds, heavy rain, ships battered by wind and waves, snow or mud avalanches, and so on. The classically grounded Indian listener might only see "literalness" in the musical representation – and their suspicions would be confirmed were they to see some of the specialised instruments that Western composers deploy for effect, like the wind machine and thunder sheet. Given these two classical streams – Western and Indian – one may wonder, Does the cultural difference give rise to two different modes of listening?

[1] Aplin, K. L., and P. D. Williams (2011), Meteorological phenomena in western classical orchestral music, *Weather*, 66(11), 300–306; and Aplin, K. L., and P. D. Williams (2012), Whether weather affects music, Eos, 93(36), 347–348

Singing in the Rain

The Indian classical music tradition features numerous references to meteorological events that dominate the seasonal rhythm of Indian society: the annual monsoons. The monsoon winds bring life-giving rain across India, blowing from the southwest in summer and the northeast in winter. Monsoons are dynamic weather events, showing variety in the whoosh of winds, cloud formations, and stormy and sunny periods.

These phenomena have been a source of inspiration for poets through the ages, the most famous of them being the Sanskrit poet Kalidasa, who was active in or about the fifth century. His romantic poem *Meghadoota* ("The Cloud Messenger") is sung by a *Yaksha* – a demigod – who commits an infraction in daily rituals of worship. His mentor banished him into exile for a year on the hot plains of Madhya Pradesh in central India. During his exile, he cannot cavort with his beloved wife and friends, singing and dancing, defying gravity, on the cool alpine meadows of the Himalaya. Torn apart from his wife, he beseeches a large monsoon cloud to take a message to her in the town of Alaka, describing what it would see on its way northeastward.

The drama of the rainy season also extends to music and is a major tributary of the Hindustani (north Indian) classical raga system.

The Raga System

The raga system is very different from Western music theory. As the historian AL Basham writes in his book *The Wonder That Was India*, "There is no harmony in Indian music, and the melodies … never suggest a harmonic basis, as do many European melodies".

Indian classical music has a basic set of 12 notes that correspond approximately to the European chromatic scale, including sharps and their respective flats. A *raga* is made up of at least five notes (*swaras*) selected from the set of 12. Like choosing a major or minor key in Western music, this selection creates a certain mood or atmosphere.

But a raga goes much further, defining rules about when a swara can be used to create a melodic syntax. In each raga, certain notes are considered more important, somewhat analogous to the dominant and subdominant tones in a particular key in Western music. The raga also defines the precise pitch of a swara, which can vary on a microtonal level. Through these rules, the notes acquire relationships to each other as set by the character of each raga. The music "glides" from one note to another in a way characteristic of its raga's structure that is recognizable and nameable.

Over 30 ragas are mentioned in Bharata's *Natya Shastra*, a roughly 2000-year-old text on music, drama, dance, and aesthetics in general; today, there are hundreds. Over time, ragas have come to be associated with particular emotions and are rendered at particular times of the day or season. Such associations, mostly subjective, have been carried forward to the present day from early times.

> *Ragas have come to be associated with particular emotions and are rendered at particular times of day or season*

Raga Malhar: The Songs of the Rain

The onslaught of the rainy season, spectacular after a hot summer, has inspired a family of at least 36 ragas classified as Raga Malhar. (The name is derived from the Sanskrit words *mala* and *hari*, which literally mean "uncleanliness remover.")

Numerous lyrical compositions in ragas of the Malhar family describe the way that luxuriant green plants cover the landscape during the monsoon season. Three examples inspired by the monsoon phenomena, two by Tansen and one by a modern lyricist-composer following tradition, are given below. Taken from a collection published by Pandit VN Patvardhan, they are in the medieval Vraja language from the region of this name, southwest of Delhi. Each example contains first a transliteration of the words and then a free translation. The hope is that the transliterated version would be read so one feels the rhythm of the word setting. Their authors freely used onomatopoeia and alliteration – recall TS Eliot quoting from an Upanishad in *The Waste Land*: "*Datta, damyata, dayadhvam*," or "donate, control, show mercy." (That section of his poem, appropriately enough, was titled "What the Thunder Said.")

Moving Mountains

In the first composition, Tansen effectively uses the well-known legend from the *Bhagavata Purana* that relates how Krishna saved the village of Gokula from the wrath of Indra, the lord of heaven and the rain god – equivalent to Zeus and Uranus combined.

The villagers of Gokula used to have a huge, very expensive annual celebration in honor of Indra. Young Krishna asks his father Nanda why such celebrations are undertaken every year. Nanda says it is to appease the wrath of Indra, who could delay the rains or cause floods.

Krishna tells the villagers not to indulge in expensive celebrations, assuring them no harm will come to them. If they just followed their *dharma*, which is farming, they need not fear the wrath of any deity. Thus assured, the villagers do not celebrate any festivals that year, making no offerings. This displeases Indra, who sends down torrential rains. But Krishna lifts the Govardhana mountain and shelters all the villagers, their livestock, and, indeed, all creatures of Gokul for 14 days and nights. Indra accepts defeat. Bowing his head, he leaves, stopping the torrents.

This legend may mark a cultural transition from persons owing allegiance to the Vaidic powers (gods) to the characters and personalities – like Krishna – of the epic stories of the Puranas.

Note that the two-part names in the Malhar family mentioned in the headings below designate a raga formed by mixing the characteristics of Malhar with elements of another raga, creating intended effects. The formal names of the rhythmic patterns are called *taal*.

Raga: *Megh Malhar* (Cloud Malhar)
Taala: *Jhap* (Jhampa – a 10/8 rhythm)

Transliteration:

prabala dala saajey jhuka jhoom bhoomi par

vraja umad Ghana ghumad jhara indra bhaavo

barasata musaradhaara hota prahara

krushana giri kara dharaka gokula bacha-o

boondana sey dhara sabakee raksha karata

jeeva jantu pas(h)u pakshee ati sukha paayo

taanasena kay prabhu tumari gati adbhuta

sura pati adhina hoyey s(h)ees(h)a navaayo

Translation:

The mighty army has been arrayed on the ground straining to fight

With massed clouds lowering Indra poured torrents

Rain poured in torrents for four *praharas* (3-hour periods)

Krishna holding up the mountain saved Gokula

Thus holding, He protected them all from gigantic raindrops – insects, worms, animals, birds – all were happily saved

Tansen's Lord "Wonderful are your ways"

The Lord of the Heavenly Beings, rendered powerless, just bowed his head.

The Sounds of Mian ki Malhar

The second example is set in the raga Mian ki Malhar, a variation of the original Raga Malhar. Its popularity has superseded its roots to the extent that when "Malhar" is mentioned today, it actually refers to Mian ki Malhar. It inspired Ram Tanu ("Rama's body"), a legendary musician at the court of the famous 16th-century Mughal Emperor Akbar.

Mian ki Malhar uses two positions of the note *ga* (E), both flat and sharp, consecutively in a swinging, heavy tone reminiscent of thunder. Higher notes, two positions of *ni* (B), flat and sharp, are used in the Malhar family of ragas to imitate human speech. Rhythmic tones played on the percussion instruments tabla or phakawaj provide counterpoint. Combined with descriptions in lyrical form, stratagems of words and rhythm are used to reproduce the effects of the monsoon rain, thunder, and lightning. A well-trained singer with a deep voice can suggest such weather effects by creatively using lower sharps and flats.

Raga: *Mian ki Malhar* (Mr. Mian's Malhar)

Taala: *Teen* (16 beats)

Transliteration:

saavana ghana garajey ghooma ghooma

barasata s(h)eetala jala jhooma jhooma

hamsa chakora chahoo(n) disa doley

caataka keera kokila boley

naachata vara ati karata kikola

mora morani jhooma jhooma

Translation:

In the month of S(h)raavana, heavy clouds come around and thunder

They shower cool water as they move

jhuma jhuma

Swan and chakora dance around

In all four directions wherever you look

The chaataka, parrot, and the cuckoo "speak"

They dance well and make much din

The peacock and the peahen dance swaying

jhoom jhoom

The chakora is a mythical, pheasant-like bird. According to fables, it survives just by eating moonbeams. The chaataka is another mythical bird that soars, waiting to catch raindrops to quench its thirst.

Photo: Miltos Gikas, CC BY 2.0.

Photo: Koshy Koshy, CC BY 2.0

(Top) The chukar partridge, associated with the mythical chakora. According to fables, the chakora survives by eating moonbeams, and it is a symbol of intense, often unrequited, love. (Photo: Miltos Gikas, CC BY 2.0.) (Bottom) The Jacobin cuckoo is a harbinger of monsoon rains in northern India. It has been associated with the mythical bird chaataka, represented as a bird with a beak on its head that waits for rain to quench its thirst.

"Dark, Dark, Dark, Looms the Canopy of Clouds"

The third example was composed by the well-known classical singer Pandit Dinakara Kaikini. His daughter Aditi Upadhya recalled the moment inspiration struck: Her father walked every evening along a tree-lined route to the Hanging Gardens (on Malabar Hill in Bombay). On one occasion, it started to rain just as he reached the garden. Somewhat out of breath, he paused to rest, when bright sunshine broke out. Looking up, he saw clear blue sky and, looking down, realised that the clouds were so low the trees could not be seen – bright blue sky above, clouds below. Inspired, he immediately worked out a lyric in the raga Des Malhar.

Composition by Dinakara Kaikini:

Raga: *Des Malhar* (Countryside Malhar)
Taala: *Madhyalaya* (middle tempo) *teen*
Transliteration:
karee karee karee ghata chaayee
umad ghumad kar ghana barasata
vrka veleekee hariyalee
hansata dolata
pavamana kay sanana mein
jhoom rahee
nabhomandala mein aruna kiran
sheetala chandaa tim tim taarey
naheen dekh paayata kee sundarataa hein
abhaagey saarey
karee karee karee ghata chaayee
maan dharanee naachey t*haiyya thaiyya*
Translation:
Dark, dark, dark, looms the canopy of clouds
They gather and swell; then shower their heavy bounty
Trees and vines, garbed in green sprouts,
smile and sway in the whooshing wind
going *jhoom*
Up above, in the sheath of the sky, the rosy-rayed Sun, the cool moon, and every twinkling star
Barred from the sight of Earth's beauty
Pity them, how wretched they are!
Dark, dark, dark, looms the canopy of clouds.
And Mother Earth joins in with a happy dance that goes *thaiya thaiya*

The composers of these examples mix fantasy and folklore to describe the elements of weather and its effects on the flora and fauna. The ways they convey excitement through words, rhythm, and song stand in sharp contrast to the methods in Western classical music. It is the Indian concept of the raga, which generates atmosphere and mood from a template of tones, versus the Western method of painting with a harmony of sounds.

Chanchal Uberoi, who passed away recently, was a retired professor from the Department of Mathematics and the first woman dean at IISc.

UG and I

- Narmada Khare

An undergraduate (UG) instructor reflects on her experience teaching IISc's students

My students often complain that I answer their questions with more questions. I am convinced that they know why I do it, and aren't serious in their protests. Here are some examples:

Scene 1: First year UG lab, Subject: Microbiology

M was comparing growth curves of *E. coli* grown at 37˚C with those grown at 40˚C. He was surprised to find that the curve was steeper at 40˚C, suggesting that the bacteria were increasing in numbers faster at that temperature. This was unexpected. After all, *E. coli* live in the human colon, where the temperature is about 37˚C; so shouldn't that be the optimum temperature for their growth? The discussion at the end of the lab led to further questions: do these bacteria have some digestive enzymes that get activated only at 40˚C? Are bacteria growing faster at 40˚C because the culture media gets digested better at that temperature, while the food source in the colon needs 37˚C? Also, is growing faster a "good thing"?

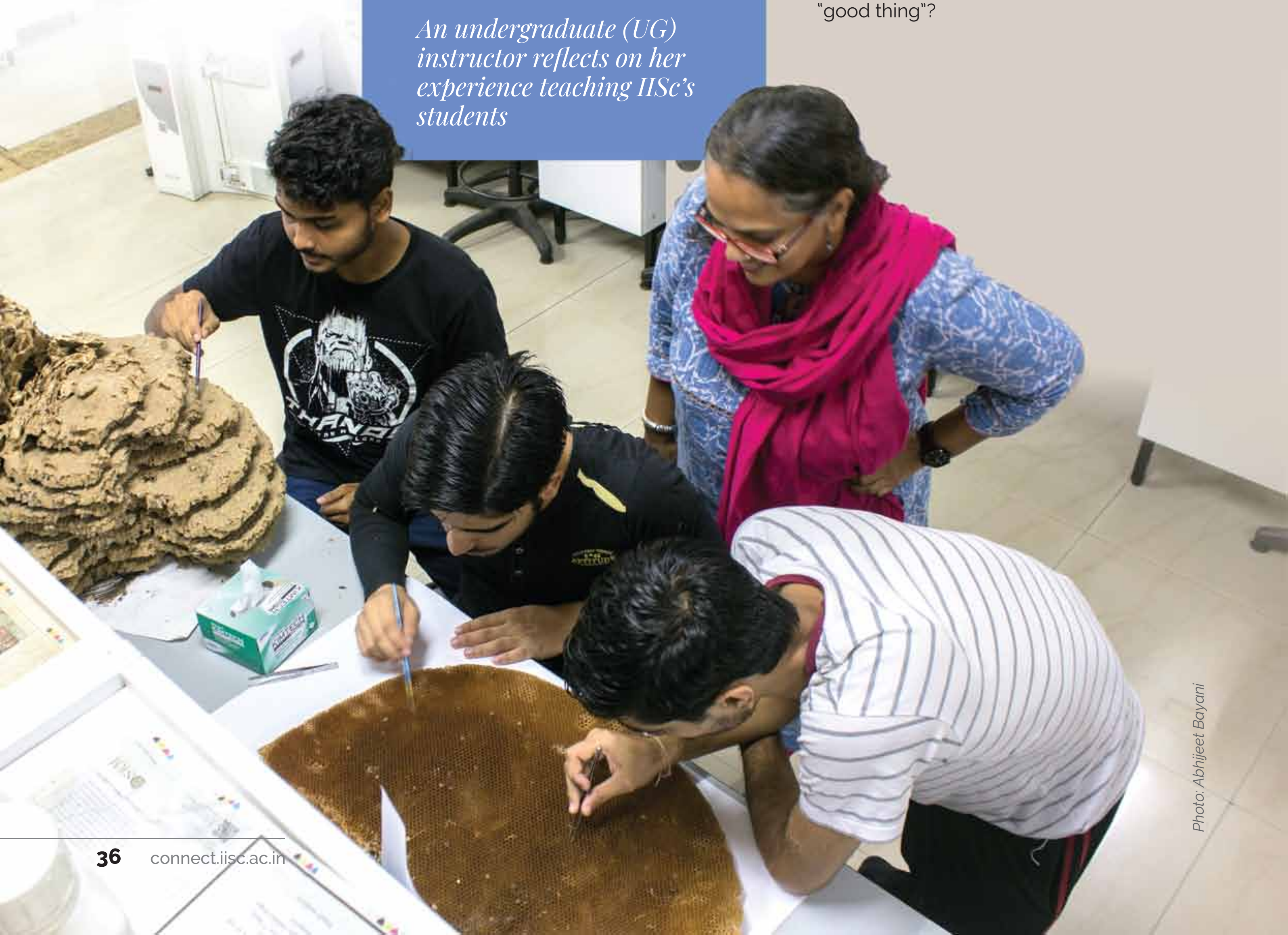


Photo: Abhijeet Bayani

Scene 2: First year UG lab, Subject: Biomolecules

K predicted that because a grapefruit is sour and an orange is sweet, the latter has more reducing sugars. She did a qualitative sugar assay, which showed that there was little to no difference between the reducing sugars in the two fruits. The conversation afterwards dwelled on the possibility that the extra sourness in a grapefruit is because of the presence of an acid, rather than the lack of reducing sugars. Also, a literature search led K to understand that both fruits contain vitamin C, which independently reacts with the reagent she was using, thus confounding the results. She now believes that the experiment must be repeated using a different assay.

I came to work in IISc on 12 August 2014 as a biology instructor in the UG programme, one of the most prestigious science institutes in the country. While it has always been coveted for its engineering and basic sciences departments, the country had not yet become aware of it as a place for undergraduate education. The UG programme was a new experiment for the Institute, and the batch of 2014 was only its fourth.

The position of an 'instructor' was a strange one. My brief was to handle the labs, to design experiments to go with the theory being taught in the classes. I knew I wouldn't get to do any research, nor teach theory classes. This latter was unfortunate, but I thought, "I'll anyway get to teach students in the labs." I was to make sure, with the help of teaching assistants, that the equipment and material for those experiments was available and in good condition, and then conduct experiments I had designed. Although a conversation with (and approval of) the theory teacher – always one of the professors at IISc – was necessary, I had quite a bit of freedom. Besides, I genuinely enjoy working with undergraduates. At this stage of their lives, they are still not cynical. I love being surrounded by their excitement and marvel.

The Student

There is a general feeling that for someone with a PhD degree and serious postdoctoral experience, being a UG instructor would be 1) a cakewalk, and 2) somewhat boring. A year spent teaching undergrads at IISER (Pune) had rid me of such misconceptions. This job is neither of these.

I will try to explain what happens in a casual chat with a UG student. If you start talking science, (not attendance or marks), you might as well say goodbye to that coffee you were stepping out to grab. You will never be done. Here's how some conversations have started for me: "Ma'am, I found a dead crow near Jubilee Garden. Do we have material for taxidermy?" "Ma'am, we were observing this colony of red weaver-ants, but we forgot to cover it over the night, and now the box is empty." "Ma'am, remember that green water I collected from the pond in the nursery... It's not cyanobacteria. It's *Euglena*. Can we extract chloroplasts from them?" "Ma'am, I made a spider robot. I wanted to see if having eight legs is better for moving along a web than having six legs...but the legs are too heavy, and now it refuses to move."

UG students will keep you on your toes. It is not enough to think you know something; you must be able to explain it till the logic becomes clear to them

UG students will keep you on your toes. It is not enough to think you know something; you must be able to explain it till the logic becomes clear to them. No hand waving will work. A conversation with a first-year undergrad that started with looking at bacterial cells under a microscope can quickly move to... different staining methods to antibodies to how they are made to animal ethics and to electron microscopy. The same conversation can branch out into Green Fluorescent Protein, and how to make fusion proteins and to the misfortune of Douglas Prasher. You will find yourself moving from lab-bench to the white-board, drawing graphs and checking facts on the desktop computer until either it is time for you to go home, or for them to go get a snack before their mess closes. There is nothing safe or easy about talking to a brilliant undergrad... and there is no dearth of those in IISc.

The Teacher

There is no doubt that it's the students who make IISc's UG programme different from others. However, I like to believe that it is also the instructors. IISc is somewhat unique in having an "instructor" position. I am not sure the "powers that be" really understand why the decision to create this position was so right. And that's unfortunate. An instructor is an experienced researcher who wants to engage in teaching undergrads. She has a lab at her disposal, and her time is dedicated to engaging students in scientific activities. Some may think, quite unwisely, that this is her lack of ambition. I want to state, and I am sure my colleagues will agree, that this is what we want to do.

Is it enough to just "want" to teach, though? It is equally important to ask what a teacher's role really is in this age of information. Every teacher must ask, "What can I offer a student that he can't find on the internet? Why should a student, who can easily watch a MOOC or a YouTube video sitting in her room, come and attend my class?" The answer must be: "To learn how to think." If it is not, we are wasting their time and ours. It is the teacher's responsibility to convert that mark-seeking machine into a thinking researcher. Here is where an instructor has an influential role to play. Science students must experiment. No matter how much literature they read, they won't intuitively know that water kept in an open beaker becomes more acidic overnight. They won't learn what a struggle it is to observe mating behavior of guppies till they watch them at it. For that, they need an instructor who will needle them with questions and show them the way around the lab to learn to find answers for themselves.

Photo: Abhijeet Bayani

Narmada Khare at her desk in her office

And The Rest

Some of us lift another responsibility that goes beyond science. Without being asked. This is even more relevant today. Many of our students need help to deal with life in IISc and learning how to make a life in science. Mental health, emotional breakdowns and want of an adult who will listen… these are common concerns. Instructors are willing to help, but are untrained. My colleagues and I often have a tremendous feeling of helplessness, hopelessness. We have tried to help students in great distress, but we aren't equipped. It will be extremely useful if the Institute arranged for the instructors to be trained to counsel teenage students.

And there's one other thing that IISc could do to get more out of instructors. An instructor's position is the most underrated and underutilised position in the Institute. There are three months in a year when we are relatively free. We could conduct workshops for school and college teachers. We could take the responsibility of creating the UG handbook. We could interview lab TAs; after all, TAs work under the instructors' supervision.

My reflections come from my experience of having been an instructor for five years. And now my time in IISc is nearing its end. These were great years from the perspective of my interaction with students. I made changes in the lab designs. It took me four years to say, "Yes, this is how this practical should be done". Four years to learn how to convey the excitement of discovery. I had to learn to remain detached without being impersonal, to dodge premature questions, to cut short lengthy arguments, to curb enthusiasm heading toward a dead-end. The nature of an undergrad is to play. The paths they explore may end up going nowhere, as is natural. It becomes an important task to give direction and structure to their fast-flowing curiosity.

In my students I see certain fearlessness, confidence, an assurance about the fairness of the world. I am humbled by it, but also know how fragile it is. All one can do is to prepare them for what may come, and hope their wonderment remains intact.

Narmada Khare has taught biology in IISc's UG programme for the past five years

‘Working at the Institute

GAVE US RECOGNITION’

– Kavitha Harish

Photo: KG Haridasan

Polamada Lalantika worked at the Institute for 29 years. She joined on 21 June 1973, at the age of 27, working as a Stenographer, Supervisor and later Superintendent until her retirement in 2002. She worked through an era of advancements in technology, moving from typewriters to computers, Gestetner-cyclostyling machines to Xerox machines, and even sent out the very first emails to be exchanged at the Institute! Here, she recounts her work and experiences at IISc.

When and why did you choose to join IISc?

After my diploma in Secretarial Practice at Kamala Nehru Girls Polytechnic, Hyderabad, I worked for a year in my college. I first came to Bangalore in 1966 and got married here. I started practicing shorthand with a certain Rao’s Institute, Malleswaram to improve my skills.

I joined IISc because my batch mate in the shorthand class, who was already employed here, suggested that I apply for Stenographer positions which were advertised at that time. My husband Adinarayana Setty was working at Kendriya Vidyalaya, Malleswaram, and we were staying in Malleswaram, which made it convenient for me to join this place. By then I had had two children too.

I started my career at the Institute as Stenographer with Prof PK Bhattacharya in the Organic Chemistry department and worked with him for about six years. Immediately after I reported for duty, the first question Professor asked me was how I could write 80-100 words per minute! He must have seen it on my shorthand course certificate. I informed him it was possible because shorthand is based on phonetic sound and that it is written using signs and symbols.

What was your experience working with Prof PK Bhattacharya like?

Prof Bhattacharya was known as a walking computer as he had a terrific memory. He was working on penicillin allergy. I still remember typing recommendation letters for his students for jobs abroad, which had chemical names that were two or three lines long. The students used to give me a treat when they were offered a job and Professor used to join us. After dinner, he would often drop me home and, being fond of drinking tea, would stay for a cup with us.

Professor was a member of the Indian Science Congress, which needed a lot of secretarial support, and I assisted him in this job too. One of his visitors, the late Prof Cyril Ponnamperuma from the University of Maryland, once visited the department and gave his letters dictated on a dictaphone (an early audio recorder) for me to use, which was fascinating. In those days, this instrument was new and was very useful.

Did you work in departments other than Organic Chemistry?

Yes, I was transferred to the RIC and CISL (Regional Instrumentation Centre, and Centre for Instrumentation and Services Laboratory, respectively, later merged to form what is now the Department of Instrumentation and Applied Physics). I was handling the portfolio of training programmes for teachers and employees of different universities, which were funded by the UGC, in addition to secretarial work to both chairmen.

Later, I was promoted to Supervisor and posted to the Centre for Theoretical Studies (CTS). I was the first Stenographer to get this promotion in the Institute's history (at the time) of 75 years. The main programme at CTS was the Visitor's Programme. I had the opportunity of meeting, among others, Prof ECG Sudarshan, the renowned theoretical physicist who was invited by Prof Satish Dhawan to found CTS. He had organised a conference which was attended by many distinguished scientists. I met many eminent scientists from all parts of the world at CTS during the five years that I spent there.

In 1990-91, I remember that computers were introduced in the office, and all of us were thrilled to work on them. Using computers (from Electronics Corporation of India Limited) helped us prepare documents, especially drafts of manuscripts for books and journals, and it made our work easier. The transition from using typewriters, and mathematical typewriters which have scientific characters, to using computers was a big one. And during lunchtime, we enjoyed playing chess on the computers, which was mind-blowing! In the same period, a Xerox machine was made available in place of the Gestetner, a cyclostyling machine for making copies, which required us to prepare stencils before making the copies. If there were any errors on these stencils, we had to use pink correcting fluid.

Photo courtesy: P Lalantika

Lalantika in 1969

What are your best memories of your time at IISc?

The first emails at the Institute were exchanged between me and my colleague Mrs Leelavathi at the ECE (Electrical Communication Engineering) department. There was another new concept introduced at the time, of using floppy discs to send documents between departments.

While working, I decided to pursue graduation, and along with my elder daughter I completed BCom. This led the IISc administration to post me to the Finance and Accounts department where I was part of the Scholarship and Cash sections. During this period I had the opportunity to go abroad to visit my daughter. I went to a bank where I saw a star mark at the working table of a woman employee. I came to know that it was a recognition for her sincere work. So I started a similar practice to motivate my staff here by providing snacks and small gifts on the last day of the month, but this continued for only a few months as it created some discomfort among people in other sections.

Once, in 1975, I had the opportunity to meet Prof Satish Dhawan at the Organic Chemistry department when he visited all the departments to convince employees to withdraw their strike. The employees were agitating against the administration's move to abolish the evaluation system in the Institute after implementing the 3rd Pay Commission. The evaluation system at the Institute was unique, giving employees higher grade/scale even without a change in their designation. The Institute staff were happy to see Prof Dhawan's simplicity and generosity.

I was involved in promoting the Women's Club (currently the Women's Forum) along with my colleagues, Mythra, Mallika, Suguna and others, which is now included in the Institute Great Day Committee (which organises celebrations on Republic Day, Founder's Day, Independence Day, Kannada Rajyotsava, Gandhi Jayanti and International Women's Day). We collect funds to provide books and uniforms to the top 10 female students of government high schools near IISc, every year on International Women's Day.

Photo courtesy: P Lalantika

During International Women's Day, 9 March 2009: From L-R: Lalantika, Prema, Prabha, Mallika, Mani Prabhakar, Kamala, Leelavathi, Munirathna and Vani Prabhakar

Prof Sulochana Gadgil was Chairperson of the Pre-Preparatory Programme (PPP) for the benefit of children of the Institute community. This school was helpful to children who later joined Kendriya Vidyalaya for Class I. She also initiated a baby crèche at IISc, and Prof CNR Rao inaugurated it. The crèche was a great help to all the employees, especially women employees. When I joined the Institute I wished there was such a facility to take care of my son, but it took several years for it to happen. On the day of its inauguration Prof CNR Rao told me I could leave my son in this crèche, and I had to tell him that my son had actually started college that day!

Is there anything else you wish to share with us?

Through CTS I was involved in typing (using a typewriter) the manuscript sent to the printer of the first book about IISc's history, *In Pursuit of Excellence: A History of the Indian Institute of Science* by BV Subbarayappa. Many versions were prepared and whenever the author sent us corrections, we (myself and Mr Fernandez from CTS) had to retype those pages on the typewriter. Mr Janardhan used to take Xerox copies. We are thankful to the author for acknowledging us in his book.

Working at the Institute gave us recognition, which I experienced during a visit abroad. In a shopping mall, seeing me wearing a saree, somebody called me over to find out where I am from and showed me a picture of the IISc Main Building to find out whether I can recognize it. When I told him that I was working at that place, he was very happy and stood up to show his respect for the Institute.

I am thankful to my family, especially my father-in-law who supported and encouraged me to join this temple of education. I was promoted to Superintendent and took voluntary retirement in 2002, in the first group of people to avail themselves of the Special Voluntary Retirement Scheme (SVRS).

How do you spend your time after retirement?

I keep myself busy. I was the first woman Board Member of the Pensioner's Association, IISc, and served for 10 years.

I have developed a new concept of designing Vedic games basing on our epics to create awareness about our culture, and this has become my hobby. I am also interested in summarizing books, aimed at inculcating a reading habit among children. I have around 10 books on distinguished people, spiritual readings, etc. For example, a book on Dr BR Ambedkar, which had more than 200 pages, was condensed to 15 pages. I also worked on a book on Sir M Visvesvaraya, and after reading the smaller version, children in our neighbourhood were impressed and wanted to visit his birthplace in Muddenahalli, which we did.

‘India is a classic laboratory to study a variety of earthquakes’

Photo courtesy: Kusala Rajendran

The Rann of Kutch

Kusala Rajendran, a seismologist at IISc, takes us into the world of earthquakes, and tells us why predicting them is far-fetched at the moment

Inspecting trenches in a no man’s land, at the India-Pakistan border, stood Kusala Rajendran and her husband CP Rajendran. Surrounded by the BSF jawans, the Rajendrans were donning the detective’s hat: they looked for evidence hidden below the surface, hoping that it would give them a glimpse into the past.

Much of this scene plays out every time the duo sleuth for clues on old earthquakes. Except that, when they are in less risky regions, they don’t have BSF jawans for company. Scientists who study past earthquakes like them are palaeoseismologists. Besides inspecting regions that are susceptible to earthquakes, a part of their research is devoted to assessing the seismic vulnerability of places where critical facilities like dams, chemical or petrochemical facilities and nuclear power plants are being planned. The Rajendrans are professors based out of Bangalore – Kusala Rajendran is at the Department of Earth Sciences in IISc and CP Rajendran is at the Jawaharlal Nehru Centre for Advanced Scientific Research’s Geodynamics unit.

Investigations at the Rann of Kutch

At the India-Pakistan border, the Rajendrans explored the white landscapes of the salt desert – Rann of Kutch – from 1997 to 2008. Two massive earthquakes have struck the region in recent memory: one in 2001 and before that, in 1819. "The British kept a record of the 1819 earthquake. We wanted to find out if the region experienced earthquakes before that," says Kusala Rajendran.

During this quest, they decided to dig about 15 trenches around a structure created by the 1819 earthquake. About 60-70 km long, 16 km wide, the structure is a natural dam named the Allah Bund. In two of the 15 trenches near a ruined fort around the Allah Bund, they finally found their gold mine: brick and charcoal pieces from an old civilisation, probably destroyed by an earthquake before 1819. Most often, palaeoseismologists hunt for cultural remains in earthquake-ravaged human settlements.

These remnants are often trapped in thin layers of sand, which distinctly stand out in the trenches, among other layers of sand and rock. This layer of sand called sand blows act as archives of tremors because they preserve materials that get trapped in them. The shear motion caused by seismic waves tend to increase the pore water pressure in the water-logged sand, forcing a jet of liquid sand – sand blow – out onto the earth's surface. As time goes by, new layers of sand settle over it, leaving it for palaeoseismologists to uncover.

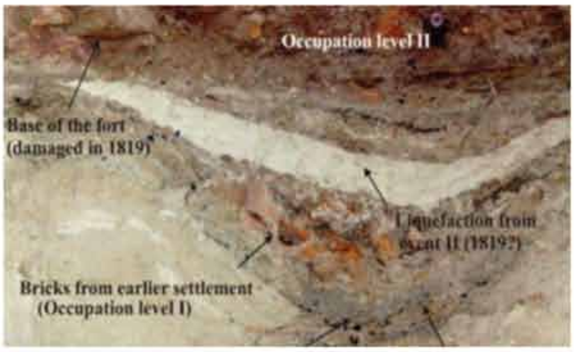


Image: Kusala Rajendran

The image is from a trench showing a layer of sand paler than its surrounding – the sand blow – with pieces of brick and charcoal.

Finding remnants mean that they can estimate the age of materials using carbon dating. "If we find a brick that is 100 years old," she says, "we can infer that the earthquake occurred after the brick was made, which means it is younger to the brick". To corroborate their findings, they also gather evidence from archaeology and history, allowing them to trace past earthquakes.

For instance, from their explorations at the Rann of Kutch, they predicted that an earthquake had occurred in the Kutch region about 1000 years ago. Later, they found a historical document that confirmed that an earthquake had indeed occurred in the region around 893 AD.

Photo: Manoj Sudhakaran

Kusala Rajendran

The advent of earthquake science

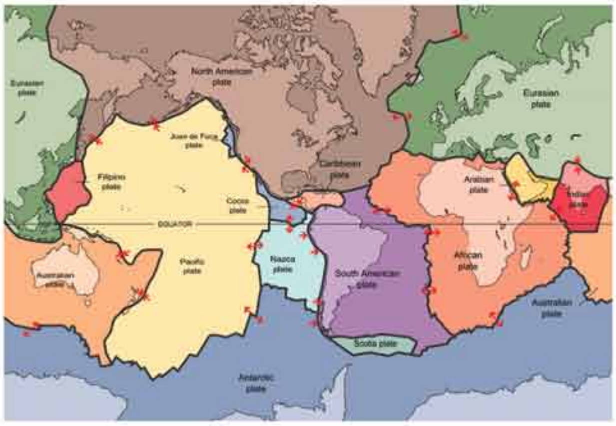
Besides investigating the history of earthquakes in a given place, Kusala Rajendran's research also attempts to learn more about the source of earthquakes: its depth and the amount of energy it releases.

Seismology is relatively young, unlike many other sciences. The theory that would lay the foundation for seismology was proposed in 1912, when a German geophysicist, Alfred Wegener, observed that continents on a map were shaped like pieces of a jigsaw puzzle that had been pulled apart. He deduced that continents are not static; they move. Although others made similar observations before, he was the first to gather evidence to support this theory. He presented his theory of continental drift in a book titled *The Origin of Continents and Oceans*. He claimed that all continents were once part of a single landmass called Pangea. This supercontinent separated into two continents, Gondwana and Laurasia, 175 million years ago, and eventually into the four major landmasses that we see today: Afro-Eurasia, the Americas, Antarctica and Australia. But this idea did not find favour with academics and was initially ignored.

Now we know that Wegener was right. But what he couldn't explain was why continents drift. He did not know that they move because they lie on the mobile tectonic plates, which make up the earth's outermost layer, the lithosphere – comprising the crust and uppermost region of the mantle. Giving tectonic plates its mobility is the flowing inner mantle, lying just below the plates.

At around the same time, scientists gradually began to learn more about earthquakes. The early 1900s saw the sprouting of several seismic stations around the world to measure these events. This paved the way for global collaboration among geologists. Then in 1935, Charles Richter developed the Richter scale, a method to measure the intensity of earthquakes, helping people understand the severity of an earthquake. Because it is a logarithmic scale, an earthquake measuring 6 on this scale is ten times larger than that measuring 5. "With this information, scientists began plotting earthquakes on a map, and they realised that they were not just spatially random, but were following certain patterns," she says.

Image courtesy: Scott Nas/ Creative Commons Licence/ Wikimedia Commons



Major and minor tectonic plates

Seismologists learnt that earthquakes occur in regions where tectonic plates meet, along their boundaries. There are seven major tectonic plates and several smaller ones. The major plates include the African, Antarctic, Eurasian, Indo-Australian, North American, Pacific, and South American Plates. When plates collide against each other, they release a massive amount of energy causing earthquakes. For instance, the collision between the Indian and Eurasian continental plates, which created the Himalaya, is an active earthquake zone. And when continental and oceanic plates collide, earthquakes like the one that caused the 2004 Indian Ocean tsunami occur. Here, the collision between the two plates pushed the oceanic plate beneath the continental plate, deforming the floor of the ocean, resulting in massive tidal waves. About 90 percent of them take place in regions bordering the Pacific, Juan de Fuca, Cocos, Indian-Australian, Nazca, North American, and Philippine plates, called the Ring of Fire.

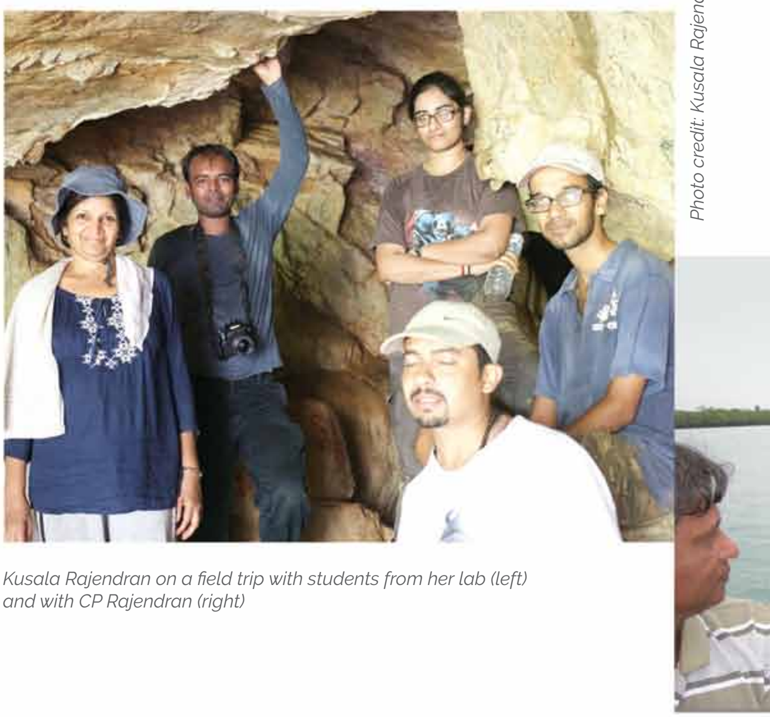
Exploring its unpredictability

Earthquakes, however, don't always occur near plate boundaries. In recent years, scientists have observed that they also strike regions within a plate, which were long considered immune to such attacks – the Stable Continental Regions (SCR). An example of an SCR is the Rann of Kutch, where the Rajendrans were fishing for evidence on past events. "We understood that earthquakes do happen in stable regions, and they can be dangerous, not because they are very large, but because they're unexpected. People are not ready; buildings are not constructed strong enough to withstand tremors, so the damage is massive."

Although significant SCR earthquakes have occurred in the eastern United States and elsewhere, in India, it was Maharashtra's Killari (Latur) – a region with no past history – that sparked an interest in SCR. This 1993 quake claimed the lives of 10,000 people.

Investigations revealed that even the stable regions of a tectonic plate harbour weak spots – cracks or fissures – called faults, where earthquakes strike. "When stresses from the plate boundaries are passed into the stable regions," Kusala Rajendran adds, "they will activate some of the pre-existing faults even in the so-called stable regions and generate quakes."

Photo credit: Kusala Rajendran



Kusala Rajendran on a field trip with students from her lab (left) and with CP Rajendran (right)

These weak spots are the result of years of tectonic activities in the earth's interior. According to Kusala Rajendran, continents have moved around several times during the long history of the earth: they have come together; they have separated; they have changed their geographic position; or they have given rise to new geologic formations, like the Himalaya.

Some of these plate tectonic motions have pushed tectonic plates away from each other – creating rifts in the landmass. Active rifts release molten hot rocks called magma onto the earth's surface, filling up space between the two separated plates. India is home to the Narmada valley rift, albeit a dead one, meaning there are no tectonic activities anymore. But there's a catch. Previous tectonic activities have created weak spots in the rift. So they can spur earthquakes, when activated, as we saw in 2001 in Gujarat and in 1997 in Jabalpur, Madhya Pradesh.

Investigations revealed that even the stable regions of a tectonic plate harbour weak spots, which are cracks or fissures – called faults, where earthquakes strike

Another stable region that continues to intrigue scientists is source of the 1967 Maharashtra's Koyna earthquake. With a magnitude of 6.3 on the Richter scale, it killed over 180 people. Scientists believe that the construction of a dam in 1962 triggered the quake, whose source was near the Shivaji Sagar Lake formed by the dam. Such tremors are referred to as reservoir-triggered earthquakes. Today, SCRs are garnering a lot of attention from the international scientific community.

According to Kusala Rajendran, India is a classic laboratory to study a variety of earthquakes. "She explains that the landmass of India sees an impressive diversity of earthquakes: quakes in the Himalaya due to continental-continental collision, 2004 Indian Ocean tsunami from the plate collision, Gujarat's devastating earthquakes triggered by reactivation of faults within a rift, Latur earthquakes by reactivation of faults that are not associated with a rift, and Koyna's reservoir-triggered quake.

Holy Grail of seismology

In spite of all that we have learnt over the past few decades, we are a long way from a comprehensive understanding of earthquakes, and also from the holy grail of the field of seismology: being able to predict earthquakes.

"We don't know enough about earthquakes, especially the physics behind the phenomenon, to accurately predict them,"' says Kusala Rajendran. She adds that as scientists learn more, they find that there are differences between them. So far, they haven't been able to make accurate predictions, including predicting the expected location, data and the size of the earthquake. It is a bigger challenge, particularly in the SCR regions because the intervals at which they strike are long, say over thousands of years in Latur.

But some scientists keep at it. But when they fail to forecast a quake, it can sometimes prove perilous to them. In 2009, six geologists were convicted of manslaughter, after failing to predict the 2009 earthquake in the Italian town of L'Aquila that killed 29 people. However, them have been acquitted now.

Kusala Rajendran believes that the reason we have not been successful in predicting earthquakes is because predictions are based on statistical models, which are built without a clear understanding of the dynamics of the earth beneath our feet. She explains, "Models are based on assumptions. We don't have the means to know what is happening in the Earth, as the earthquake source maybe 10 or 15 km deep in most cases. We have very little idea of the physical properties of rocks, or the nature of faults at that depth, not to mention their complex interactions. I don't believe that earthquake prediction is an easily achievable goal."

Although prediction may be challenging, monitoring is important. She says, "In the United States, for example, reservoirs are monitored carefully even at regions with low-level seismic activity." During her PhD, a nuclear power company funded a project at the University of South Carolina. As part of the project, she was tasked with maintaining seismic stations and providing reports of seismic activities around three reservoirs in South Carolina. She adds, "Such arrangements help healthy interactions between the industry and academia; it provides employment where training in research can be best utilised. Of course, these situations are driven by the existing laws of the country and its regulatory systems. Perhaps, this applies to many areas, not just in the case of earthquake monitoring."

‘Poetr
quiet

Photo: KG Haridasan

Jane Robinson was poet-in-residence this summer at the National Centre for Biological Sciences, Bangalore. Starting off as a biologist, she gradually turned to poetry and published her first book, Journey to the Sleeping Whale, *in 2018. She was at IISc in June for a talk, “Of Poetry & Science”. In this email interview, she talks about growing up in Ireland, the diverse influences on her poetry, and how she uses it to engage with environmental issues.*

Were you always interested in poetry while you were doing science? When and how did you make the transition to a full-time poet?

I always enjoyed stories and literature and, at the end of school, seriously considered pursuing art as a career. However, I decided to study science as it was interesting, logical and offered a path to a deeper and wider understanding of life. My reasoning was that while I could continue to read fiction, draw, sculpt or paint, it was unlikely that I would persist in scientific studies on my own. In many ways, this position was correct as I read widely outside science and dabbled in theatre. My engagement in science continued through graduate studies at Caltech: I got my PhD in biology for outlining a genetic pathway leading to an intracellular compartment within a cell, where molecules are degraded. As a cell biologist, I still marvel at the diversity of unicellular creatures, fungi and diatoms for instance, which are stunning in both their structures and their biology.

It is interesting to me now that while I was busy with biology research, I was subconsciously mulling over the idea of writing poetry though at that time, I did not have any overt interest in poetry, being more attracted to fiction and creative non-fiction. Italo Calvino was one of my favourite authors, perhaps because he not only bridged the gap between science and literature but also between fiction and other forms of literature such as poetry and essays.

y finds its own way,’

– Nithyanand Rao and Amit Roy

My transition to poetry was not immediate. I began by writing essays about environmental decay but, lured in by Seamus Heaney’s suggestion that ‘poetry is the mathematics of language’, I gradually learnt and practiced the craft of poetry.

Does your training in science have any influence on your poetry?

Yes. I approach each poem as a fresh exploration or investigation. Although the initial inspiration is frequently a matter of chance or emotion, I read around many topics in a logical way and this feeds into my writing. A poem is a human-made thing, as is a good experiment. But the craft of poetry reaches beyond logic and rhetoric to follow a path to often surprising resolutions. This is accomplished by following patterns of language, rhythm or sound to a place where the subconscious has a chance to speak.

Your work, with its stark imagery of an environment in distress yet one that is populated with life, from frogs and thylacines to whales, may be called “ecopoetry”. Could you tell us more about this genre of poetry, perhaps tracing its origins and dominant themes?

Ecopoetry is a neologism for a poetry that celebrates humans’ home place in nature, and in these times it has no choice but to note the destruction of that home or *oikos* (ecos). With origins in older and indigenous place-aware poetry, nature poetry gradually evolved into environmental poetry and came to be called ecopoetry. A broad range of both form and content along this continuum could be said to contribute usefully to the genre. Thus, ecopoetry attempts to convey all dimensions of: ‘reciprocity between human and non-human nature’ (J. Scott Bryson), ‘encounter between a human and his context’ (A. Oswald), and to lament our ‘lack of place awareness’ (W.S. Merwin). While J. Shoptaw goes further: ‘An ecopoem is environmentalist not only thematically, in that it represents environmental damage or risk, but rhetorically: it is urgent, it aims to unsettle.’ Some ecopoets attempt to conjure a more balanced future in which humans respect all species and appreciate the necessary complexity of ecosystems.

In the words of Jonathan Bate (*The Song of the Earth*, 2000), a central idea of ecopoetics is: ‘we must hold fast to the possibility that certain textmarks called poems can bring back to our memory humankind’s ancient knowledge that without landmarks we are lost.’ Interpreted with the perspective of humanity’s evolutionary history, Bate’s observation implies that without deep connections to plants, animals and a living wilderness, we are lost. Interestingly, these connections are richly represented in writings in diverse languages, ancient texts and local dialects. It is important to preserve these too, as without images and memories of what we are about to lose, we are lost.

A more general question is what environmental poetry contributes over similarly motivated prose. Bill McKibben who wrote *The End of Nature*, 1989, one of the first popular books about the climate crisis, about 25 years later commented on the limits of prose and suggested that poetry might be more successful. In a sense, poetry may be able to directly access deeper, and more ancient, emotional brain regions: bypassing defensive logical or analytical filters that must be navigated by prose.

Poems, if read and disseminated, can reach people directly and reconnect us to the stable source of our humanity. A poem does not pronounce but it explores, questions and suggests. It finds its own quiet way. It exists. There have been enough large-scale inventions, pronouncements and arguments – poetry hopes to sleep in your ear and catch hold of your imagination.

Were the environmental themes and the appearance of marine life in many of your poems triggered by any particular experiences, perhaps through your work as a biologist?

Naturally, my involvement with environmental and marine themes is influenced by experience. Freshly arrived in Pasadena, a suburb of Los Angeles, I was surprised how perfectly normal it was considered to be surrounded by asphalt, smog, freeways and concrete culverts, instead of by the quiet roads, trees, meandering streams and fields familiar to me in Ireland. The smog, of course, was acknowledged as a problem but not the infrastructure that caused it. Until I learned how to drive, I was restricted to Pasadena: rights to develop a potential Los Angeles-wide public transport system had reportedly been purchased and killed by Ford, who made and sold cars instead. The many quiet streets of Pasadena and perfectly groomed gardens and parks were an artificial paradise, a Hollywood set – really a damaged ecosystem, in which the native oak chaparral had been replaced first by the settlers' orange groves and then by upmarket real estate.

My fellow students at Caltech had flown in from different states or from different continents. Although my contemporaries were extraordinarily gifted scientists focused on biological problems, few of us knew names of the local wildflowers, birds, insects or trees, let alone their origins or ecology. The deeper I got into my genetic and cell biological research, the more aware I grew of this intellectual void, which I felt restricted the full development of a self-reflective and responsible society. I read some of the great North American essayists, many of whom had environmental concerns: Rachel Carson, Annie Dillard, Edward Abbey, Wes Jackson, Wendell Berry – and these led me in a different direction.

A fondness for marine themes likely comes from two sources. First, from the proximity of Dublin to the sea: growing up five kilometers from the coast, I swam in the sea during all seasons of the year and feel most at home with the smell of seaweed and misty sea breeze. Second, with my father, we sailed during summer holidays around the coast of Ireland in a twenty-foot boat and read seagoing adventure stories – anything from fiction, such as Erskin Childers' *The Riddle of the Sands* and Arthur Ransom's *We Didn't Mean to go to Sea*, to real-life reconstructions of historic voyages including Thor Heyerdal's *Kon Tiki Expedition* and Tim Severin's *Brendan Voyage*.

Photo courtesy: Jane Robinson

Pangur Bán, *built by Robinson's father*

Some of the poems in your collection, *Journey to the Sleeping Whale*, are about women scientists - Marie Curie, Rosalind Franklin, Martha Maxwell - and you mention Amelia Earhart in a poem too. What drew you to them?

I feel quite protective of a certain type of creative person who does magnificent work but somehow doesn't seem to get enough credit for it. More often these are women. Both Rosalind Franklin and Martha Maxwell fall into this category and both, oddly enough, died of ovarian cancer at a very young age. My poems allude to this but also to the frustration of having 'vultures come down' into their creative work and carry it away. Some other interesting women I have written about who didn't make it into this first book include Rachel Carson, author of *Silent Spring*, and the forgotten Irish poet, Madge Herron. As for Amelia Erhardt, for a while, I found her wildly beautiful and inspiring but there was also an element of doubt – a question about us adventurously sleepwalking into an extravagant, tragic and misguided future.

Growing up in Ireland, or perhaps when you decided to switch to poetry, did you have a role model?

My parents were both excellent role models but I particularly admired my father who liked to make things. When I was two years old, he made a canoe from wood and canvas and we went on an expedition down the River Loire in France. That was the first of many unusual family trips, navigating canals and coastlines in very small boats and camping here and there. My mother was a great cook and taught us many skills and games. Through her actions, more than through instruction, we learned to live a full life, thrifty with supplies and minimal in waste. My mother encouraged me in art and reading, while my father was very interested in science.

When I was twelve years old, my father decided to design and build a seaworthy boat to sail around the world. He made his initial designs at the kitchen table by sketching in pencil on the backs of cereal boxes and, over the next several years, built the boat by hand in the garden with help from friends and family. This took a long time but his boat, *Pangur Bán*, held up beautifully as he sailed around the world for several years and well over a 100,000 nautical miles. Sadly for me, this was after I had left home to study in America, so I was not part of these voyages. My father was concerned about climate change a long time before it became mainstream news and his travels were powered by wind alone, though there was a small engine to get the boat out of tricky situations when anchoring in harbour etc. My poetry collection, *Journey to the Sleeping Whale*, celebrates and commemorates this voyage in several poems and in the marine imagery threaded through the book.

Amit Roy is a PhD student at the Department of Physics, IISc

ABSTRACTS
IISc Photography Club