Science Last Fortnight

The Songs of Humpback Whales
Deciphering themes and phrases

Bishwajit Chakraborty, CSIR-NIO, Goa has been studying the geomorphology and habitats of the bottom of the Arabian Sea for decades now. The humpback whale, *Megaptera novaeangliae*, found in the Arabian Sea, is a bottom dweller, occasionally rising to the surface, to the surprise of mariners from ancient times.

Image: Wikimedia Commons

Male humpback whales have complex songs lasting 10 to 20 minutes, which they repeat for hours. Bishwajit's fascination with the huge whales took a new turn when Shyam Kumar Madhusudhana joined NIO. Shyam Kumar was into the pattern recognition of underwater audio signals.

They teamed up with G. Latha, NIOT, Chennai, an expert in mathematical modelling. The team started studying humpback whale songs a few years ago.

The team selected a site near the Grande Island, off the Goan coast in the Eastern Arabian Sea to record humpback whale singing activity. They used integrated recording equipment with a SongMeter 3 Marine autonomous recorder, calibrated at the National Institute of Ocean Technology, Chennai. The scientists detected whale vocalizations on six of the nine days of experimental recordings.

The humpback uses frequencies ranging from 21 hertz to 12 kilohertz. The team examined spectrograms – visual representations of the spectrum of frequencies of a signal as it varies with time – to analyse the recorded audio signals. They also developed a Matlab program for analysing vocalization spectrograms. Some parts of the recording were contaminated by the sounds of marine vessels in the area as well as by different fish choruses and these had to be discarded if the signal-to-noise ratio was too low. The researchers annotated the repeated units in the remaining audio segments. They identified 26 units that are repeated and found minor variations in some units.

Then they used a trial and error method, using sets of different combinations of units to find themes, correcting themselves when errors were detected. The scientists thus identified nine recurring themes. Then they catalogued the vocal repertoire of humpback whale song in terms of phrases and themes. The sequence of units in each phrase type was seen to be consistent across all occurrences with minor variations caused by the variations in the units themselves. The scientists say that they could not yet reconstruct the songs completely since the recording unit cycles lasted less than typical songs.

In humpbacks, it is males who produce their characteristic songs, considered to have a role in mating. Acoustic monitoring of whales can provide a measure of the relative density of this mostly invisible population sighted only at the beaching and stranding of individual whales. The data can be used to estimate absolute density, including mean group size, and maximum radius for detection. The recorded data, for example, suggest that there were times when the whales were about a kilometre from the recorder.

Further research with such techniques can contribute to our understanding of stock assessment and the species assemblages of whales in Indian waters, says Bishwajit Chakraborty, NIO.

There is a need to deploy acoustic monitoring devices in the Arabian Sea. If we get enough data, we can use machine learning techniques to decipher the syntax and song structures, says Shyam Kumar, NIO.

Extreme Rainfall Patterns
Indo-Gangetic Plains

The Indo-Gangetic Plain is very fertile and highly populated. Since agriculture in the region depends on the monsoon, any change in rainfall patterns affects agricultural productivity and, hence, the economy.

Last fortnight, a team from the Banaras Hindu University in collaboration with scientists at IIT-Bombay and the Amity University, Jaipur reported the range of rainfall variability at the regional and local scale.

They collected high-resolution daily gridded rainfall data of 1901–2010 from the India Meteorological Department. The Department classifies monsoon days into eight categories. The researchers re-classified rainy days into no rain, moderate, heavy and very heavy rain days. They found an increase in frequency of moderate rainfall and a decreasing trend in heavy and very heavy rain. This was more prominent during the withdrawal period of the Indian summer monsoon.

During the monsoon, there are short dry spells. Sometimes, dry events are prolonged. Similarly, there are short and prolonged rains. The researchers found that dry spells and prolonged dry spells remained more or less constant. However, short and prolonged rain events have decreased over the Indo-Gangetic plain.

The team also examined yearly and decadal rainfall events under month and season-wise variability. They found significant inter-annual and inter-decadal fluctuations in the frequency and magnitude of rainfall. Rainfall variability was lower in July.

The frequencies of rainy days and rain events have decreased in the last half-century, say the scientists.

Though the research does not pinpoint causative factors for the variations in rainfall, understanding rainfall event patterns can help plan agricultural activities. The results could also be useful for disaster and drought preparedness in the Indo-Gangetic

plain, says Rajeev Bhatla, Banaras Hindu University.

Groundwater Drought
Ghataprabha river basin

The Ghataprabha river basin, in north-western Karnataka, is drought-prone. In such areas, groundwater availability plays a critical role. However, overuse for irrigation can lead to groundwater drought.

To understand groundwater drought in the region, Abhishek A. Pathak and B. M. Dodamani from the National Institute of Technology, Karnataka studied annual and seasonal groundwater levels in the river basin.

They took the monthly water level data of 70 wells from the Department of Mines and Geology, Karnataka. The data contained continuous observations of more than 25 years from 59 wells. Statistical analysis showed an average annual decreasing trend of 0.21 metres in groundwater levels.

Based on groundwater level fluctuations, the researchers categorised the area into three clusters. Cluster 1, with average groundwater contour at 600 metres, is dispersed all over the area. Cluster 2, with average groundwater level contour at 553 metres, is in the eastern part. And cluster 3, with average groundwater level contour at 720 metres, is in the south-western part.

The researchers used the standardized groundwater level index from a representative well in each cluster to assess drought characteristics. They found that all clusters had experienced several severe droughts. Some droughts were more than three months long. The longest drought event was observed in 2003–2005. In all clusters, the team also observed severe drought during 2000–2003. They correlated this with rainfall deficit in these years.

Severe drought in clusters 1 and 2 has become more frequent in the last two decades. Clusters 1 and 2 also show significant diminishing trends of groundwater and are more prone to severe droughts. The report can help predict and manage groundwater drought in the Ghataprabha river basin.

Cereal Crop Production
Load on freshwater usage

After the Green Revolution in India high yielding cereals, rice and wheat, replaced other cereals such as millet and sorghum to meet increasing demands. Such high yielding cereals demand more water. Hence, freshwater depletion is a major concern. Around 91% of freshwater today is drawn for food production in India.

Recently, a team of researchers from institutes across India, UK and Germany analysed the trends in cereal production and water use from 2005 to 2014 in India. Taking five major cereals – rice, wheat, millet, sorghum and maize – they gathered data about crop production, area and irrigation statistics from various governmental sources. The team found that, though harvest area increased by only 1.8%, cereal production increased by 26.4%, during the period.

The increase was dominated by rises in the *kharif* production of rice and the *rabi* production of wheat and maize.

The researchers used an online water assessment tool for estimating water use for the cereals. The tool combines user inputs like location, crop and soil information, with available global climate, crop and soil data in a model to give crop freshwater use as output.

During 2005–2014, water use for cereal production decreased by 6.6%. The decrease coincided with increase in yield and decrease in evapotranspiration.

Improved yield was found in the north for sorghum and millet, and, in the central region, for wheat, rice and maize. One of the reasons for yield improvement was the shift in the harvest season from *kharif* to *rabi*. Though the shifting removes dependency on the uncertain monsoon, it increases irrigation. Surface and groundwater use in *rabi* were 4–30 times higher than that in *kharif*.

Wheat and rice showed the highest surface and groundwater use. Overall, wheat and rice production consumed the most – approximately 80% of total water. Low yielding sorghum and millet showed lowest surface and groundwater use. Maize was the only cereal with low soil moisture, surface and groundwater use.

The researchers stress that switching from rice and wheat to maize, sorghum and millet could substantially reduce surface and groundwater requirements for cereal production in India. Thus, turning to maize, millet and sorghum may improve the efficiency of water use. Improving yields of sorghum and millet would be crucial to maintain production levels.

Amphibians in the Andaman
Indian bullfrogs invade

In the early 2000s, the Indian bullfrog, *Hoplobatrachus tigerinus,* native to the Indian subcontinent, was accidentally introduced to the Andaman Islands. The Indian bullfrog is very competitive and has high reproductive potential. The tadpoles are predatory and eat the tadpoles of other species and are often even cannibalistic. By 2017, the frog was widely distributed in human habitats, agricultural lands and plantations. Are endemic frog species there under threat? There is scarce information on how invasive amphibians impact recipient ecosystems.

Image: Raju Kasambe via Wikimedia Commons

N. P. Mohanty from the Andaman Nicobar Environment Team, and J. Measey, from South Africa decided to see how the Indian bullfrog's tadpole

affects other endemic frog species populations. So they collected the eggs of the Indian bullfrog and of two other endemic frogs – *Microhyla chakrapanii* and *Kaloula ghoshia* – from paddy fields and plantations.

When the eggs hatched, the researchers divided them into seven groups. Three consisted of only a single species, two had two species and one group had all three. They released the seven groups into separate artificial ponds. The team monitored tadpole survival in each group and found that Indian bullfrog tadpoles ate up all *M. chakrapanii* and *K. ghoshia* tadpoles.

Though this was a laboratory study, the situation is expected to be the same in natural environments. Even though the Indian bullfrog is now concentrated mainly in human habitats, a boom in its population can extend its reach in the islands.

Mohanty and Measey propose screening at ports and jetties for the removal of bullfrog juveniles and steps to reduce the movement of the species to other islands. But the steps are not easy to take.

The Indian bullfrog is edible. Commercialising and harvesting them can stabilise endemic frog populations and provide livelihoods. However, the species is protected under Indian laws. Perhaps policies that recognise the differences in the impact of wildlife in different ecosystems need to be formulated to overcome such problems.

Caesarean Section
Push or Patwardhan's method?

Caesarean section can be done in the first or second stage of labour. It is more complicated if done in the second stage where it poses health issues to both mother and baby. Doctors adopt various methods for safe delivery in second-stage caesarean section such as pull, push, Patwardhan's and foetal pillow method. But which one is better for mother and baby?

Recently, researchers from the JIPMER, Puducherry compared the outcomes of the push and Patwar-

dhan's methods. In the push method, an assistant pushes the baby's head through the vagina and disengages it. In Patwardhan's method, the baby's shoulders are delivered first, followed by body, feet and head.

The team dug up hospital data of more than two years. 298 deliveries. 221 babies were delivered using the push method and 77 using Patwardhan's method. Both showed similar maternal health complications: extension of uterine incision, postpartum haemorrhage, sepsis and blood transfusion requirement. However, the rates of neonatal sepsis and neonatal intensive care admission were higher in babies delivered by Patwardhan's method.

These results are different from those of previous studies which report neonatal outcomes to be similar in the Patwardhan's method and the push or pull method. The researchers mention that, since earlier studies compared Patwardhan's method with a heterogeneous group delivered with either a push or a pull method, they might have introduced a bias. In contrast, the team has compared Patwardhan's method and the push method only, in patients with comparable baseline characteristics.

Being a retrospective and record-based study, it has its limitations such as the unequal number of cases in the two groups. The team suggests more controlled comparative studies for robust evidence of the safety and benefits of a particular method to use in second stage caesarean sections.

Iron Ore Mine Overburden
Vetiver detoxifies

Mine overburden, soil waste from mining, releases heavy metals into soil and groundwater. Consuming contaminated groundwater causes irreversible damage in humans and other living organisms.

Seshu and Umesh Lavania of the University of Lucknow have been working on Vetiver grass, *Chrysopogon zizanioides.* The grass has been reported to detoxify polluted soil and water. So the duo collaborated with Anita Mukherjee and her Ph D schol-

ars from the University of Calcutta to investigate the relative efficiencies of various vetiver genotypes for remediating iron ore mine overburden. They tested four specific genotypes available at CIMAP Lucknow: S2 (diploid variety), S4 (tetraploid derivative of S2), TH (from Thailand) and BL (broad leaf).

Image: Deepugn via Wikimedia Commons

The researchers obtained soils from the Joda East Iron mine in Odisha. They observed that the mine soil was more acidic than garden soil. There were high concentrations of iron, chromium, zinc, manganese and copper in the soil.

The team planted vetiver in small pots with either mine overburden or garden soil. For each set, they used one vetiver genotype. The researchers maintained the plants under natural conditions for a year. Though plants on mine overburden soil initially grew less well than those in garden soils, by the end of the year they showed normal healthy growth.

The team observed decreased shoot and root length and lower biomass production in plants grown on overburden soil. Except for copper, roots accumulated higher concentrations of heavy metals than shoots in all genotypes. Copper concentrations were more in the shoots of S2 and S4 genotypes. There was minor iron deposition in leaves, mostly localized in the hypodermal and vascular bundles.

The researchers noticed a decrease in chlorophyll content and an increase in carotenoids in plants grown on mine soil. They presume that this helps the plant combat heavy metal stress.

Enzymatic and non-enzymatic antioxidant activities associated with metal stress were higher in plants grown on mine soil.

'Heavy metal accumulation in plant tissues causes oxidative damage. Antioxidant activities increased to offset this', says Anita Mukherjee, University of Calcutta.

The team also noted a high concentration of phytochelatins in the leaves of plants grown on mine soil.

'Phytochelatins help in metal chelation, protecting plants from toxicity', explains Seshu Lavania, University of Lucknow.

BL and S4 were the most effective genotypes for phytoremediation. Large scale testing on mine overburden sites needs to be undertaken now, says Umesh Lavania.

Natural Plant Extracts
Microalgae harvesting

Microalgae are photosynthetic microorganisms. They grow five to ten times faster than conventional food crops. So, microalgae may offer potential as feedstock. Not only as food, but also as fuel.

However, the small cell size of microalgae and low cell concentration makes harvesting expensive. Adding chemical coagulants such as alum can flocculate algal cells for easy harvesting. But this causes aquatic pollution in the long run.

Bunushree Behera and P. Balasubramanian from the NIT Rourkela decided to try plant extracts as coagulants. They collected a native microalgal consortium consisting of species of *Chlorella*, *Scenedesmus*, *Synechocystis* and *Spirulina* from open ponds in the institute. After an exponential phase of growth in media under controlled experimental conditions, the cultures were used for flocculation studies with different coagulants.

Based on previous studies, the team selected leaves of *Azadirachta indica*, pods of *Ficus indica*, seeds of *Moringa oleifera*, peels of *Citrus sinensis*, *Punica granatum* and *Musa acuminata*, collected locally, to test their use as coagulants for microalgal harvesting.

They found that maximum biomass removal efficiency under physiological pH was between 40% to 60% for all the natural coagulants – except in the case of *Moringa oleifera*, which showed a removal efficiency of 75% at a dosage of eight milligrams per millilitre.

The researchers performed flocculation studies under acidic and basic pH even though the physiological pH of algae is between 7.5 and 7.8. They found that flocculation efficiency was highest at pH 9.5 for all the natural coagulants.

The researchers checked the biomass removal efficiency of the different coagulants using alum, a synthetic inorganic coagulant, and chitosan, an organic coagulant, for comparison. They found that energy consumption and greenhouse gas emission were maximum for chitosan followed by alum.

Then the team tried using a combination of natural and synthetic coagulants. They found that a mixture of *Moringa oleifera* and chitosan, showed a microalgal harvesting efficiency of 96% at physiological pH.

The scientists say that a combination of natural and synthetic coagulants can effectively and economically increase algal biomass harvesting efficiency.

Adaptive Unmanned Aerial Vehicle
Progress in defining guidance law

Unmanned aerial vehicles are being used in surveillance, for monitoring floods and disasters, in agricultural management, in aerial photography and for entertainment. These aerial vehicles are self-guided and chart their own way in space. But the vehicle experiences changes in the planned path due to wind and other parameters. Since external disturbances cannot be predefined, the guidance laws of the vehicle has to be adaptive to changing circumstances. Defining such path following guidance laws has been a challenge.

Recently, Mangal Kothari from IIT Kanpur and his Indian colleagues working in the US and Japan took up the task of finding ways of defining the logic that an unmanned aerial vehicle needs to follow for a safe journey to its destination. Their approach is to project a three dimensional feasible path to two corresponding two dimensional planes perpendicular to each other. This reduces the complexity and yet can help generate acceleration commands to counter any deviation from the paths in their respective planes to gain reasonable control on the flight path in real world situations.

However, this creates a complexity of its own. The control signals from the two 2D planes will overwhelm the system. So they developed a nested guidance law to limit the saturation of the control system.

The researchers first established the stability of this law using numerical simulations. A comparison with the existing guidance law showed superior performance of the guidance laws proposed by Mangal Kothari and his team.

Then they tested their ideas in a real world system, a fixed wing unmanned aerial vehicle, Talon. The autopilot system had an extended Kalman filter to estimate the state using the global positioning system signal, an inertial measurement unit, differential and absolute pressure sensors, and a magnetometer to calculate the position, orientation, heading and flight path angle of the vehicle. The researchers modified the code to suit their new guidance law. They found that the aircraft was able to follow the path with a reasonable level of accuracy.

The guidance law proposed by the team will help improve the reliability of unmanned aerial vehicles. Many more changes are expected in the technology and national policies may need revisions to accommodate the many possible applications. See also an article in this issue that discusses the need for revisions in UAV policy in India.

Reports by: **Pavithra P. Nayak, Ravi Mishra, Sudhir Verma, Archana Singh, Prabitha Mohan, Ravindra Jadav, Sileesh Mullasseri, K. Greeshma** and **Sushmitha Baskar**