Why are some species found everywhere, and why does it matter?

Insights from 25 years of ATREE's work on invasive alien species

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***Lantana camara* native to South America**

Introduction

In nature, each species functions in certain environmental conditions and plays a unique role in the ecosystem. This environmental and functional space within which a species operates is known as its ecological niche; the spatial extent of that niche defines its range. Changes in ecosystem structure or climatic conditions can alter a species' range. Suitable conditions expand the range while unfavorable conditions shrink it.

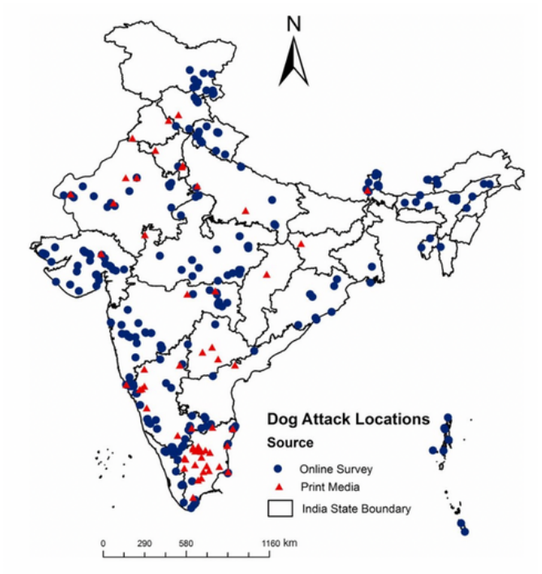
Human activities have played an important role in altering these ranges as people moved species accidentally or intentionally, shaping ecological communities worldwide. For millennia, intentional species introductions were often driven by concerns for aesthetics, food, fiber, or recreation. Yet, the dramatic increase in the post-industrial-revolution volume of shipping and trade has transferred hundreds of species at unprecedented rates and to unprecedented distances. Global interconnectedness has also unintentionally resulted in some species expanding their ranges in ship ballast and transport containers.

When a species travels to a new location, it encounters new climatic and biogeographic conditions. The response of the species to these new conditions determines its fate in the landscape. Many species that are brought remain in human-managed systems as crop plants (e.g., maize and tomato), garden ornamentals (e.g., marigold), or plantation trees (e.g., tamarind). One in ten, however, goes on to become invasive by escaping cultivation, displacing neighbors, and becoming abundant and widespread, earning them the epithet of invasive alien species (IAS).

For a species to turn invasive and form a “home away from home,” as Aravind Madhyastha, G. Ravikanth, and others term invasion, it must overcome many abiotic and biotic barriers. For instance, the species must be introduced to a climate similar to its native range or undergo rapid adaptation or evolution to deal with the novel climate. Many introduced species turn invasive if there are no native competitors, consumers, or predators. Others may secrete chemicals that are toxic to their competitors (i.e., a phenomenon called allelopathy) and are thus able to outcompete them. Native species can also become invasive if provided additional resource subsidies to help them overcome competition in the landscape (see Box 1). However, the impact of exotic invasive species is relatively more widespread than native invasive species.

Box 1: Native Invasive Species

Native species can also become invasive given a suitable opportunity. Humans often provide direct (food, water, and shelter) or indirect (through landscape change) additional resource subsidies to free-ranging animals. These subsidies may benefit certain species over others, resulting in increasing their numbers and range. These species can have deleterious impacts on other species in the community. Such species are termed native invasive species. Free-ranging dogs in natural habitats are a prime example of such native invaders. A nationwide survey by Chandrima Home revealed that around 80 wildlife species, of which 31 are categorised as threatened, are frequently attacked by free-ranging dogs.



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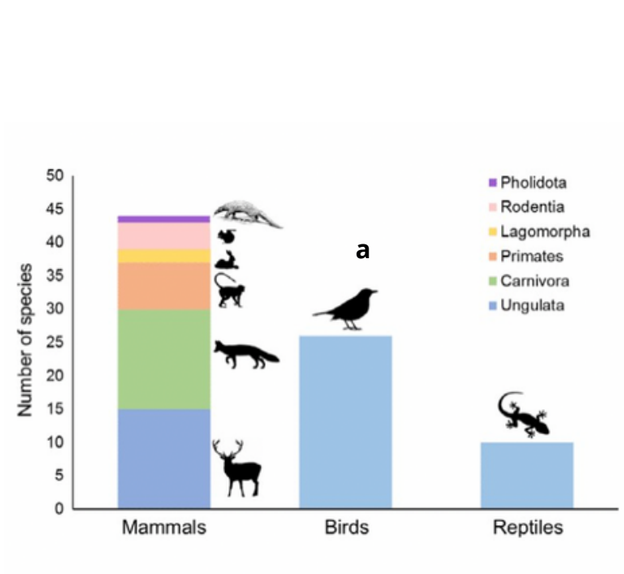

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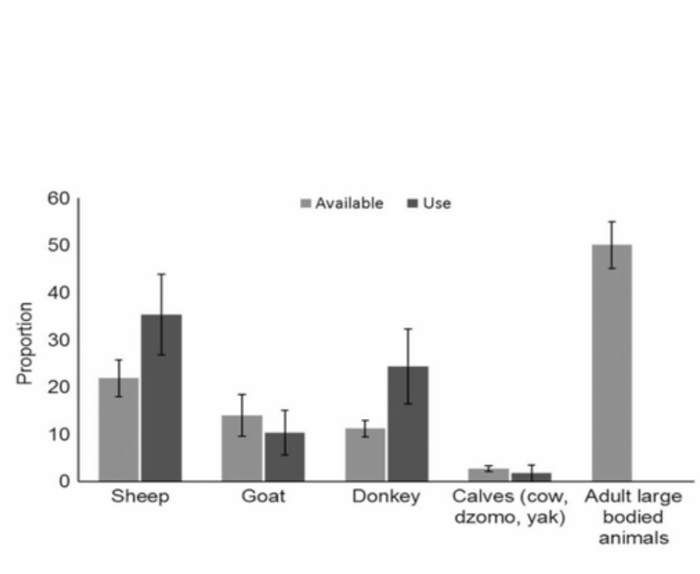

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A) A map of India showing the spatial locations of domestic dog attacks on native wildlife reported through an online survey and newspaper reports. B) The numbers of vertebrate species observed to be negatively impacted by domestic dogs. C) The figure shows the proportion of different livestock available and the proportion of depredation by dogs in the Upper Spiti Landscape. Chandrima Home’s study shows that dogs are responsible for more livestock depredation than snow leopard in the Upper Spiti valley (Data from Home et al 2016 & 2017)

Why bother about invasive species?

Although only a few introduced species turn invasive, those that do have negative impacts on native biodiversity, local livelihoods, ecosystem services, human health, and crop and forestry production. The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) reports that IAS records have increased by 40% in just the past four decades worldwide, reflecting one of the threats of a globalized economy (IPBES 2019). The impact of IAS on the Indian economy has been estimated to be around INR 8.3 trillion in the last 60 years. Yet India lags behind developing (e.g., South Africa) and developed economies (e.g., Europe and Australia) in addressing the threat of IAS. More than half of the research on IAS in India has only been conducted in the last 20 years, as Ankila Hiremath and Bharath Sundaram observe. Worse still, public awareness about IAS in India is negligible, with little impact on policy and management strategy. A considerable gap exists in the knowledge of many IAS introduction processes, pathways, and long-term ecological invasion trends, which hampers management efforts.

Over the last 25 years, ATREE's work on IAS has endeavored to address these gaps by investigating a) pathways of IAS introduction; b) trends in IAS spread; c) drivers of IAS spread; c) impacts of IAS and d) IAS management strategies using formal and informal knowledge systems.

Lissachatina fulica, commonly known as Giant African snail, native to East Africa

Euphorbia heterophylla, commonly known as painted euphorbia, native to Mexico

How did they get here, and how fast have they spread?

India's struggle with IAS curiously mirrors its history as a British colony with an innocuous introduction of an ornamental hedge plant called *Lantana camara* (a likely hybrid of several Lantana species native to South America) in 1809. The late Ramesh Kannan traced the introduction of Lantana to what was then known as the Royal Botanic Garden, Calcutta. From there, it was planted in cantonment towns and botanical gardens across India and eventually escaped cultivation by 1874. Lantana is ubiquitous now—it grows along roadsides, is a serious weed in croplands and pastures, and forms dense thickets in forest understories, altering wildlife habitat and suppressing native plants.

Nearly 50 years after Lantana was introduced, a British malacologist brought a pair of giant African snails *Lissachatina fulica* into a garden in Kolkata, in 1847. The snail spread across Kolkata within a decade and now occupies large stretches of peninsular and eastern India, affecting crop yields in invaded areas (see Box 2). Another 30 years later, *Prosopis juliflora* was introduced between 1879 and 1909 (Pasiecznik et al., 2001). Prosopis was initially brought to control desertification and has since taken over most of India's open natural ecosystems (ONEs) in these landscapes.

Tragically, India's independence brought little relief from these introductions. Nobin Raja and G. Ravikanth list 14 species of freshwater invasive alien fishes in Indian lakes and rivers impacting native biodiversity and local livelihoods. Among these, the mosquitofish (*Gambusia spp.*) was introduced 70 years ago as part of independent India's malaria control program. Today, its negative effects on fish farms are clearer than its efficacy in controlling mosquito populations. Regrettably, it continues to be introduced across Indian lakes, rivers, and ponds. Several species of armoured catfish, native to the Amazonian rivers, were introduced as aquaculture species in India. However, they quickly escaped into natural waterways and have been displacing (and eating) native fish and other aquatic diversity.

Gambusia holbrooki, commonly known as mosquitofish, native to USA

This devastating impact of introduced alien species can also be seen as far as the montane grasslands of the Western Ghats. Black wattle (*Acacia mearnsii*) was first introduced by the British and later systematically planted by the Tamil Nadu Forest Department during the 1950s across the shola sky islands of the Anamalai-Palanis and the Nilgiris.

Over the next 40 years, nearly a quarter (340 sq. km.) of the native grasslands were lost to wattles and other invasive alien timber plantations, as Milind Bunyan and his collaborators' work shows. The weed, commonly known as Congress grass, is assumed to have arrived accidentally as a hitchhiker on wheat imported from the USA in the 1950s. It can cause serious respiratory and skin allergies in humans and is also poisonous to livestock.

The evidence from plant and animal IAS in India is clear and consistent with well-recognized global patterns. After a species is introduced, there is an initial lag period (which varies across taxa), followed by a period of exponential spread.

Understanding how these species are introduced and spread is vital to formulate proactive plans to prevent IAS from reaching the exponential spread phase. This is not a mere academic exercise, as Biswa Mahapatra's research on Purcell's hunter slug (*Laevicaulis haroldi*) shows. Introduced from South Africa between 2010-2012 through agricultural trade, the slug has already become a pest in Maharashtra, although it is rare and endangered in its native range. Worryingly, ecological niche models developed by Biswajit and Aravind suggest that climate change may favour the spread of the slug across western and southern India.

How do invasive species affect our ecosystems and society?

Once an IAS spreads widely across a landscape, it can drive significant change in ecosystems, ecosystem services, and local livelihoods and culture. The loss of the Banni grasslands of Kutch, Gujarat—once the finest dry grassland of India—to *Prosopis juliflora* and the resultant change to the socio-ecological fabric is a case in point. Ramya Ravi notes that Prosopis was widely planted across the Banni during the 1960s to fight desertification and salinity ingression.

Farmer collecting giant African snails in an infested spinach field.

Chetan Misher and Abi Vanak's research from the Banni shows that the conversion to Prosopis woodland is shrinking suitable habitat for the desert fox and Indian desert jird. These changes trigger further alterations in native species assemblage by mediating interspecific interactions. Prosopis expands the distribution of generalist predators such as the golden jackal, resulting in increased competition for smaller specialists such as foxes.

Prosopis is locally called *Ganda Bawar* or *Bawaliya* (literally translated as a mad tree) because of its copious regeneration and ability to coppice. Ramya Ravi's research shows that communities use these properties to their advantage by manufacturing charcoal and collecting resin. The charcoal economy is important to local livelihoods and contributes substantially to community wellbeing. Ironically, an eco-hydrological assessment by Ankila Hiremath and her collaborator Sonali Saha shows that Prosopis transpires more water than native species, drawing in saline groundwater from below and potentially increasing the salinity it was introduced to combat.

Asclepias curassavica, commonly known as blood flower, native to Tropical America

Moving from arid grasslands to higher elevations and moister regimes, Lantana suppresses the production of important NTFPs (Non-Timber Forest Produce) such as *Amla* or Indian gooseberry. This directly affects people's livelihoods, as shown by Tamara Ticktin, Rengaian Ganesan, Mallegowda Paramesha, and Siddappa Setty's work. Unpalatable Lantana increases crop depredation by wildlife, thus increasing human-wildlife interactions, and has forced people to change cropping patterns (Sundaram et al. 2012, Mundoli et al. 2016). ATREE's insights about Lantana have emerged from one of India's few long-term monitoring initiatives (spanning 20 years) for IAS (Murali and Setty 2001, Sundaram and Hiremath 2011). Bharath Sundaram and Ankila Hiremath's research also suggests that fire suppression aids the spread of Lantana. On the other hand, local knowledge in the Biligiri Rangaswamy Temple (BRT) Tiger Reserve suggests that Lantana can be controlled by using cool season litter fires or *taragu benki* in the savanna woodlands. This local knowledge corroborates current scientific research but sharply contrasts the colonial forestry view of suppressing fires inherited by most state forest departments.

Even higher up in the shola sky islands, ATREE's work with FERAL found that the loss of grasslands to black wattle plantations contributes to higher surface runoff during extreme rain events leading to sudden flooding in low areas. The native forest-grassland mosaic, on the other hand, functions as a sponge, holding water when it rains and releasing it slowly into streams and springs, whereas wattle transpires more water than the grasslands they invade, depleting soil moisture and reducing groundwater recharge.

Is a future without invasive alien species possible?

The short answer is probably not. Decades of experience have taught us that complete removal of an IAS once established is not always possible, nor always ecologically or socially desirable. The latter is especially true where people have adapted to having the invader around and use the IAS to improve their wellbeing. Human interventions in these landscapes, often described as novel ecosystems, continue to shape social and ecological processes.

Bidens pilosa, commonly known as black jack, Native to South America

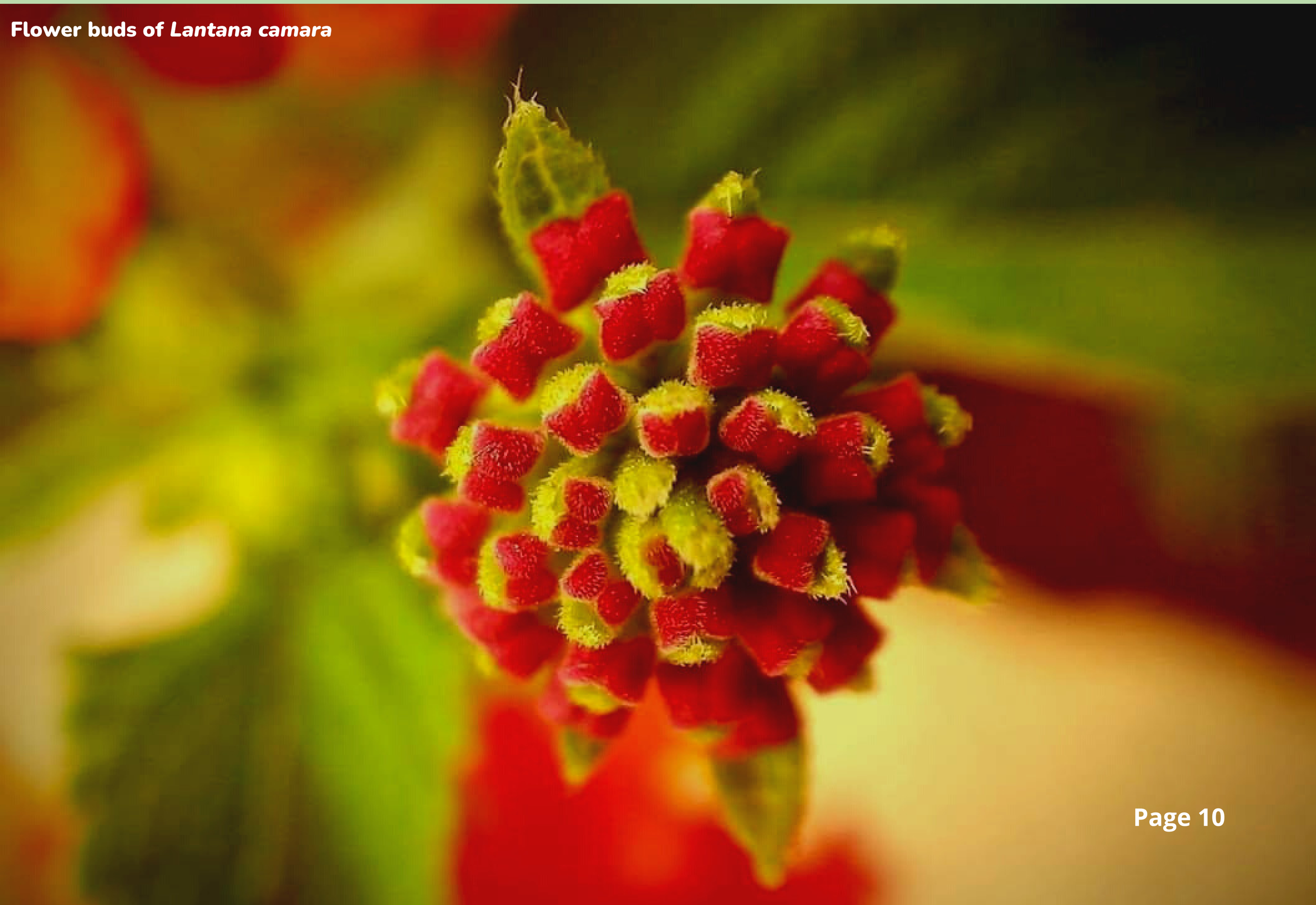
IAS management in novel ecosystems must be multidisciplinary, inclusive, and sensitive to all stakeholders. In the Banni grasslands, for instance, Ashish Nerlekar and other collaborators' research demonstrates that mechanical removal of Prosopis can restore grass cover and provide fodder. Yet, Nirav Mehta and others find that communities are more likely to lop Prosopis, which promotes rapid regrowth, providing them with a renewable resource and dependable livelihood option. To address such complexities, ATREE and DESTA have demonstrated the utility of a system dynamics approach that blends biophysical and socioeconomic components of the system (e.g., Prosopis and grassland area, livestock, biomass for charcoal, livelihoods, and rainfall). Trends, stories, and mental models from the Banni *Maldharis* and researchers were used to build a model and multilingual Android App. These tools provide valuable insights into future 'What-If' management scenarios for the Banni.

In the Male Mahadehwara Hills Tiger Reserve, the late Ramesh Kannan first proposed using Lantana as a substitute for bamboo and cane in furniture making, as Uma Shaanker and Gladwin Joseph note. The underlying idea was to see if creating livelihoods from Lantana could help mitigate the negative impacts of the species on NTFP revenues.

Newer initiatives under ATREE's Centre for Social and Environmental Innovation (CSEI) are exploring the potential to create high-value products from Lantana. A Lantana removal-usage-restoration model is being carefully co-designed with local stakeholders to reduce the costs of responsible restoration while preventing maladaptive outcomes.

Ultimately though, the best hope for limiting the impacts of IAS is to prevent invasions from occurring in the first place. Such pre-emptive management requires sufficient baseline information about the species frequently transported by people and a tool to predict potential future invasion. Kesang Bhutia's PhD research is directed at developing a Weed Risk Assessment (WRA) tool to understand the potential emergence of invasive alien plants in India from species currently cultivated as ornamentals. This WRA tool will categorise 1200 currently traded ornamental species into safe or "Green-listed" species and potentially invasive or "Black-listed" species

Flower buds of *Lantana camara*

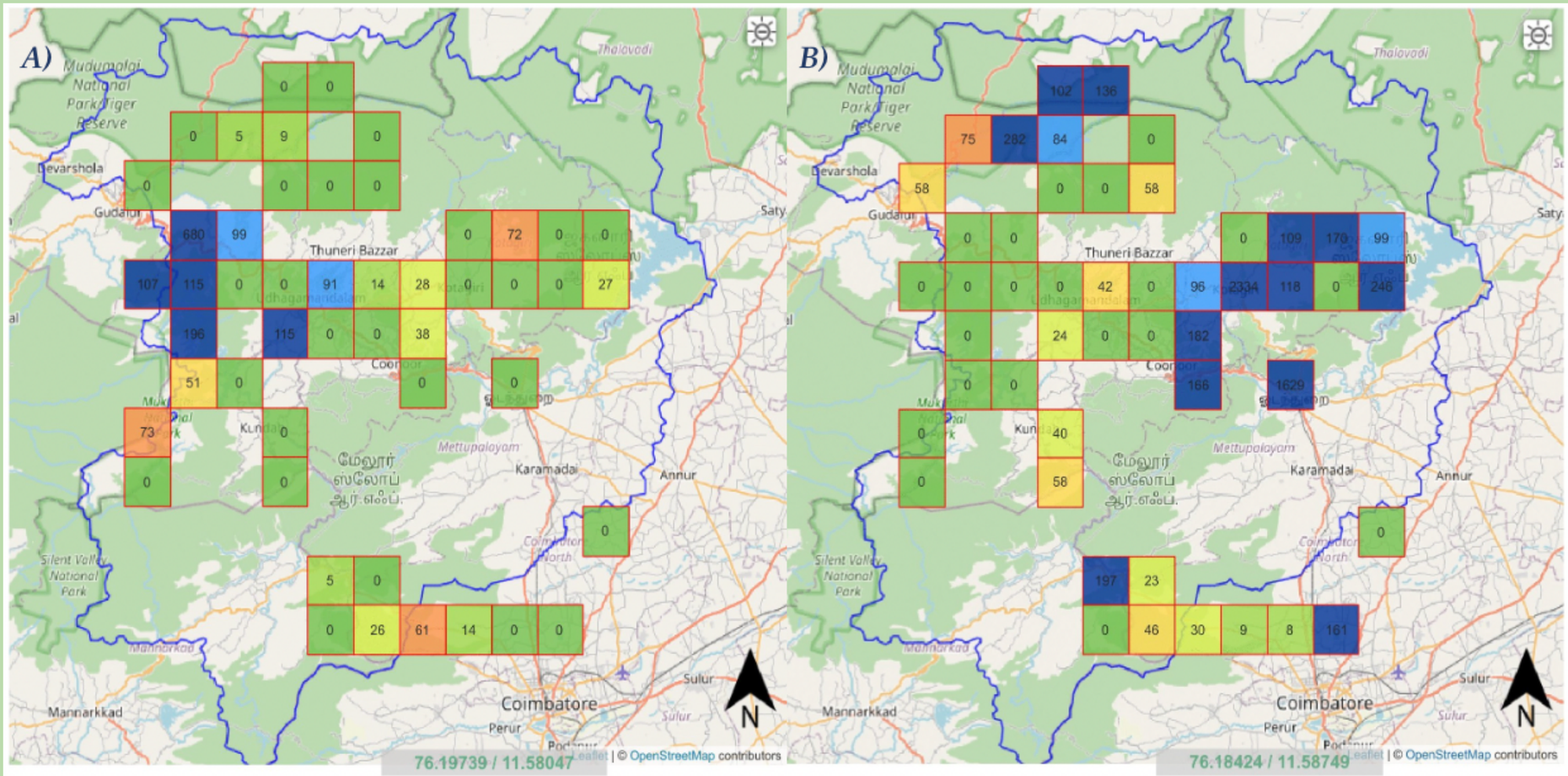


***Parthenium hysterophorus*, commonly known as congress grass, native to Tropical America**

Moving from Knowledge to Synthesis

ATREE's work on IAS is consistent with its institutional mission of producing knowledge that informs sustainability policy and practice. ATREE works with citizen scientists, policymakers, the judiciary, bureaucracy, and frontline staff to address IAS concerns relevant to society and the environment.

Citizen science helps us answer fundamental questions on the number (i.e., how many invasive species are there?), distribution (which sites or land uses are these associated with?) and intensity (how bad is the invasion at these sites?) of IAS. Citizen science helps us collect this information at a scale that cannot be answered by the research community alone. This information can then help prioritise sites, species, and logistics for invasive species management. ATREE has spearheaded citizen science initiatives that collect data on species presence (e.g., Spotting Alien Invasive Species; SPAIS) and invasion intensity (e.g., Mapping Invasive Alien Plants; MIAP). SPAIS has generated 3500 observations across 21 plants, animal, bacterial, and fungal species. MIAP has generated regional gridded distribution maps for 26 invasive alien plants in the Nilgiris.



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Distribution map of invasive A) *Acacia mearnsii* (black wattle) and B) *Lantana camara* in Moyar Bhavani watershed in The Nilgiris generated using citizen science data collected through the MIAP. Colours indicate species' relative prominence, with dark blue denoting grids where the species is most abundant and widespread.

These maps can inform and guide management action and have generated substantial interest from the Tamil Nadu Forest Department.

ATREE also works with state forest departments on IAS removal and forest restoration. Ankila Hiremath, Bharath Sundaram, and Ayesha Prasad found that uprooting Lantana can be counter-productive since the disturbance encourages regeneration from buried seeds (Hiremath et al. 2018), but the cut-rootstock method prevents re-sprouting. Ankila Hiremath and her collaborators also recommend reintroducing a grassy understory to help relieve herbivore pressure and prevent reinvasion by Lantana. Abi Vanak, Ankila Hiremath, Nitin Rai, and their collaborators' work supports restoring the indigenous practice of cool season fires following Lantana removal to suppress Lantana regeneration. In the shola sky islands, Milind Bunyan and his collaborators have prioritised 168 sq. km. for IAS removal and grassland restoration. ATREE has also contributed to ongoing public interest litigation addressing the loss of native habitat to IAS in the landscape. The Madras High Court appointed Jagdish Krishnaswamy as an expert, and ATREE's work was used to change the dominant narrative from forest-to-grassland loss. Ankila Hiremath is also contributing to the ongoing IPBES global IAS assessment as a lead author. This assessment will inform policymakers and governments globally.

Where do we go from here?

ATREE's work on Indian IAS documents their varying impacts across biophysical and socio-ecological conditions. IAS impact ecosystems, native biodiversity, local livelihoods, and wellbeing—albeit asymmetrically and, at times, counterintuitively. Management interventions must account for this complexity by mainstreaming cutting-edge scientific insights with an inclusive, multidisciplinary approach. Addressing Indian IAS with these nuances will contribute to human wellbeing, ecosystem integrity, and planetary health.

Box 2: A Giant Menace: The Giant African Snail

Farms across peninsular India are grappling with an infestation of giant African snails. Collect and kill methods (collecting in the sacks, burning, and drowning them in water) are being used, but these bring additional costs and reduce their profit margin.

Banana Plantations

Agro-forestry

Spinach Farms

Infestation

Control

Burning

Sacking

Drowning

About Authors

Chetan Misher is a wildlife biologist studying dry grasslands and desert ecosystems of India. His research is focused on the impacts of plant and animal invasive species on multispecies interactions in socio-ecological systems.

Ankila Hiremath is a plant ecologist with an interest in the dynamics and resilience of social-ecological systems, and in ecosystem restoration and novel ecosystems. She works in tropical dry forests and savannas on invasive species and their ecological and socio-economic impacts.

Milind Bunyan is a forest ecologist, with research interests in invasive alien species, ecosystem restoration, and the use of technology in studying natural ecosystems. Through his research, Milind promotes using open-source platforms and data, citizen science, and applied research that addresses societal challenges.

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