Invasive Species – A Threat to Endemics and Biodiversity?

Vinod Khanna

An "invasive species" is defined as a species that is
1) *non-native (or alien) to the ecosystem* and
2) *whose introduction causes or is likely to cause economic or environmental harm or harm to human health.*

Human actions are the primary means of invasive species introductions. Invasive species generally have a dramatic and negative effect on other species and even on theentire ecosystem to the extent that it includes the extinction of species or sometimes even changes the hydrology and nutrition cycles of entire ecosystems. The impact of invasive species is second only to that of human population growth and associated activities as a cause of loss of biodiversity throughout the world. The invasions of non-native plants, animals and microbes are thought to be responsible for the decline of native species now listed as endangered or threatened. Pests, weeds and pathogens, introduced deliberately or accidentally, reduce crop and stock yields, besides degrading terrestrial, marine and freshwater ecosystems. After habitual loss, this biological invasion constitutes the greatest threat to biodiversity, and it has already had devastating consequences on the planet. Several plant species, in North America, have been eliminated by invasion of pathogens from other continents.

The invasions initially lead to an increase in species richness, as invasive species are added to the existing species pool, but eventually the invasive species also lead to extinction, resulting in decrease of species richness. The negative interactions in these cases will primarily be competition, which may allow coexistence or lead to extinction more gradually than predation. The rate at which the invasions are occurring globally has been increasing exponentially over the course of human history. Ecology of invasion requires addressing of three criteria.

1. The rate and mechanism of transport or movement of organisms.
2. The characteristics of the organanisms that allow them to be successful invaders and
3. The properties of ecosystems that make them susceptible or resident to the invaders.

1. Transport as a mechanism: The transport of the organisms and their introduction into regions where they did not previously occur, has tremendously increased as a result of human activities and continues to increase exponentially, at present. Natural invasions occur at a very slow rate.

The basic patterns of invasions and invisibility are : 1. the high susceptibility of island communities to invasion by mainland species, with subsequent extinction of island endemics and replacement by mainland species. 2. The dominance of the earth's largest land mass, Eurasia, as a primary source of successful invaders throughout the rest of the world and 3. Relatively low proportion of successful invaders in Eurasia in comparison with the rest of the world.

2. Organisms in relation to invasions: While introduction or invasion of a species in alien area is a first step yet it is not necessarily the most critical. All the species introduced are not successful invaders. There should be some relationship between the biological properties of the invading species and the properties of ecosystem that it invades. We do not have much studies available on the patterns of invasions nor have an idea on the failure of when a potential invasion has failed, let alone the reasons for failure. Nonetheless, the patterns that emerge from many invasions that have occurred may provide insights into the biological process underlying successful invasions. Some of the successful cases have been discussed in the forthcoming paragraphs of the present communication. **Those species have been nominated as among 100 of the "World's Worst" invaders.**

3. Relationship between land area and competitive ability: It seems difficult to separate the biological properties of Eurasian species from the fact that they have had far greater opportunities to disperse throughout because of the pre-eminence of Europe as a center of exploration and trade. However, trade and transport are a two way process, with the return of trade goods, raw material and agriculture products, probably containing as much invaders from other regions as have been dispersed out of Europe. The interpretation that Eurasian species tend to be better competitors than other organisms from other continents is consistent with both prehistoric and historical patterns of extinction and invasion.

Scientists have, however, propounded the theory of poor competitive ability of island species compared to mainland species. Because the islands have fewer potentially competitive species than mainlands and because the islands generally have a smaller variety and total amount of resources (e.g., plant seeds, insects) than do the mainlands, the island species may tend to be generalized to use a broader range of resources than mainland species and thus are unlikely to have the high efficacy that results from specialization on particular resources. The low ecological resistance to biological invasion of islands in comparison to mainlands is reflected in relative proportion of insect pests that have invaded successfully on islands in relation to mainlands. In Hawaii, 29 % of the total insect fauna is composed of introduced species in contrast to North America where the proportion of introduced insect species is just 1.7 %. Apparently lower resistance of island faunas to invasion is attributed to both weaker competitive ability and lower resistance to predators and pathogens.

The communities that have successfully invaded are not a random selection but represent specific environmental conditions. Vast majority of invaders are weeds associated with agriculture, cultivation or grazing. Not all invading species are weeds and not all weeds are invaders, since many species become agricultural problem within their original range. In spite of general resistance to invasion of

*** Zoological Survey of India, Northern Regional Station, 218 Kaulagarh Road, Dehra Dun 248 195, Uttarnchal (drvkhanna@sancharnet.in)**

Eurasian plant and animal communities, there have been some notably successful invasions, including Prickly Pear Cactus (*Opuntia*), the nitrogen fixing legume Black Locust (*Robinia pseudoacacia*) and Fall Web Worm (*Hypanthia cunea*) from North America. Within Eurasia, there have been many notable invasions of Europe from Far East and Middle East, including the Black Rat (*Rattus rattus*) and the House Mouse (*Mus musculus*). However, the properties of successful invading animal species are more difficult to generalize, and the probability of success of any animal is more difficult to predict. The International introduction of insects or pathogens to control agricultural pests has provided a large number of test cases for theories of invasion, although the details of most releases, particularly those failed, are poorly documented.

Ecosystem properties related to Invasibility: Not all types of ecosystem are equally susceptible for invasion. Part of the resistance of some ecosystems to invasion is clearly a function of the competitive ability and other ecological properties of the species already present. In addition to the species attributes that influence invasibility there seems to be some systems particularly susceptible to invasion. Undoubtedly these environmental conditions interact with the properties of the species already present in the environment and the invading species to determine whether any particular invasion will succeed.

Role of Invasive species : - a preview of the known case studies:

1.Anoplolepis gracilipes **(Land Invertebrate):**
Taxonomic name: *Anoplolepis gracilipes* Smith
Synonyms: *Anoplolepis longipes* Emery 1925, *Formica longipes* Jerdon1851, *Plagiolepis longipes* Emery1887
Common Names: *Ashinaga-ki-ari,* Crazy Ant, Gramang Ant, Long-legged Ant, Maldive Ant, Yellow Crazy Ant.

Ecological Category: Anoplolepis gracilipes, *the Yellow Crazy Ant, has been introduced across the tropics as a byproduct of human commerce. It invades urban, agricultural and native ecosystems where it can have large, catastrophic impacts. These impacts include decimation of endemic species, rapid degradation of native communities, and altered ecosystem processes.*
Description: Member of the subfamily Formicinae. *Anoplolepis gracilipes* is notable for its remarkably long legs and antennae (hence the common name, Long-legged Ant) as well as its frenetic behavior when disturbed (hence the name, Crazy Ant). Workers have a long slender (i.e. gracile) body, approximately 4-5 mm long. The gaster is usually darker than the head and thorax. Lacks a sting but subdues and kills prey by spraying formic acid.
General Impacts: *Anoplolepis gracilipes* is a major environmental and secondary agricultural pest, as well as a human nuisance, in the tropics and subtropics. Where densities are high, direct impacts can occur on native 'keystone' species and on species of special conservation value (including endemic reptiles, birds, and mammals). This can alter community structure and species composition, and affect ecosystem processes including litter decomposition. Deletion of native keystone species by *A. gracilipes* can cause rapid state changes in native communities. Mutualism between *A. gracilipes* and honey dew-secreting Homoptera can cause population outbreaks of these generalist herbivores and lead to canopy dieback. On Christmas Island, Indian Ocean, secondary invasions of Giant African land snails and shade-intolerant woody weeds can follow invasión by *A. gracilipes*, further degrading native forests. In agricultural systems, impacts are primarily indirect, through increased populations of Homoptera on crops, although some believe that this ant benefits crop plants by deterring plant pests. *A. gracilipes* commonly nests at the base of plants, sometimes undermining crops such as sugarcane and coffee. In some instances, *A. gracilipes* is a household and village pest. Formic acid sprayed by the ants can cause skin burns and irritate the eyes of fieldworkers.
Notes: Because *A. gracilipes* is highly predatory, agriculturalists have explored its use as a potential biological control agent in control of insect pests of crops such as coconuts and cocoa. This generalist consumer has even been actively introduced into plantations in efforts to control plant pests. *A. gracilipes* forages three-dimensionally throughout the day and night, and over a wide range of temperatures. High temperatures associated with mid-day often prevent workers from foraging on ground surfaces hotter than 44° C and activity of foragers declines from 25° C. Foraging can be limited by rain. Nesting requirements are generalized; they nest under leaf litter, in cracks and crevices in the soil, usurp land crab burrows, and readily colonize bamboo sections when placed on the forest floor. They also nest in canopy tree hollows. In coconut plantations, *A. gracilipes* nests at the base of trees and in the crowns of coconut palms and feeds on nectar secreted from male flowers and from honeydew-producing scale insects.
Geographical Range: The native range of *A. gracilipes* is not known explicitly, although authors have speculated its origin as West Africa, India, or China. The canter of diversity for the genus is Africa and *A. gracilipes* is the only species distributed beyond that continent. It has been widely introduced across the subtropics and tropics, including East Africa, South and Southeast Asia, and the Indo-Pacific Islands. Recent incursions have been reported in tropical and subtropical Australia. *A. gracilipes* is reported to have

an elevational limit of 1000-1200 m. It is capable of invading both disturbed and undisturbed habitats, including tropical urban areas, plantations, grassland, savanna, woodland, and rainforest.
Invasion Pathways: *Agriculture*: Translocated in soil, produce and timber.
Aircraft: Transported in packaging material, timber.
Military: Transported in road vehicles, machinery, boats, and aircraft.
Nursery trade: Transported in soil and produce.
Other: Deliberate introductions for biological control of plant pests on coconut, coffee and cocoa plantations.
Road vehicles (long distance): Transported in soil, packaging materials, pallets.
Sea freight (container/bulk): Transported in goods, packaging, and pallets in container. *Anoplolepis gracilipes* has entered Australian ports in sea cargo containers in Cairns and Brisbane, Queensland, Australia and has been intercepted in Fremantle, Western Australia.
Local Dispersal Methods: *Boat*: Translocated in packaging material, timber, produce, soil, and plants. *Other (local)*: Redistribution for biological control on coconut, coffee, and cocoa plantations. *Road vehicles*: Translocated in packaging material, timber, produce, soil, plants. *Wind*: Movement of winged queens.
Management Informations: Control and management of Yellow Crazy Ants has primarily involved the broadcast of toxic chemical baits. Current programs use a fishmeal attractant laced with an invertebrate intoxicant, e.g., Fipronil. Concentration of the intoxicant is low so that foragers will live long enough to return the bait to the colony and disperse the intoxicant among other workers, larvae, and queens. On Christmas Island, an initial island wide survey was used to identify locations of infestations of *A. gracilipes*. These infestations are mapped at a finer scale and baits are then broadcast on parallel transects through each infestation. Aerial baiting using helicopters is being explored as an alternative, more efficient control methodology.
Nutrition: *Anoplolepis gracilipes* has a broad diet. Initially described as a scavenger, it has been called subsequently a "scavenging predator". It preys on a variety of litter and canopy fauna, from small isopods, myriapods, molluscs, arachnids, and insects to large land crabs, birds, mammals, and reptiles. In addition to these protein-rich foods, *A. gracilipes* obtains carbohydrates and amino acids from plant nectaries and especially from honeydew excreted by Homoptera, which it tends on stems and leaves of a wide variety of tree and shrub species.
Reproductive Mode: *Anoplolepis gracilipes* is a well-known tramp ant species. It is polygynous (multi-queened) and intraspecific aggression among workers is not reported. It can form diffuse supercolonies, sometimes extending continuously over large areas (10-150 ha). Most dispersal and colony foundation appear to occur through colony budding. Although mating flights have not been reported in the literature, many winged queens and males have been captured in canopy malaise traps and at lights on Christmas Island, Indian Ocean. Worker production is continuous, though fluctuating, throughout the year. Sexual stages can be present year round, but in most instances, initiation of brood follows the onset of the wet season. Researchers have reported an increase in nest size and foraging activity in the dry season.
Reproductive Output: Single nests of *A. gracilipes* can contain upwards of 300 queens and 2500-36000 workers.
Life-cycle Stages: The life cycle of *A. gracilipes* has been estimated to take 76-84 days. Eggs hatch in 18-20 days, and worker larvae develop in 16-20 days. Pupae of workers require around 20 days to develop while those of queens develop in 30-34 days.
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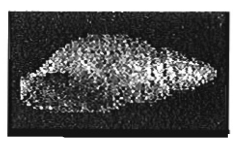
2. *Euglandina rosea* (Land invertebrate)
Taxonomic Name: *Euglandina rosea* (Ferussac, 1818)
Common Names: Cannibal Snail, Rosy Wolf Snail



Ecological Category: *The predatory "Rosy Wolf Snail" (also known as the "Cannibal Snail") is native to the southeastern United States, especially Florida. It has been introduced to the islands in the Pacific and Indian Oceans, also to Bermuda and the Bahamas, as a putative biological control agent for another alien species, the Giant African snail* (Achatina fulica). *There is no good evidence that control of* A. fulica *has been affected, but* E. rosea *has caused the extinction of numerous endemic partulid tree snails in French Polynesia and has been heavily implicated in the extinction or at least decline of other species of snails wherever it has been introduced, notably inHawaii.*
Description: Adult shell tall and slender, height up to about 6 cm, width to about 2 cm.
General Impacts: *Euglandina rosea* is the most widely introduced of the numerous species that have been used in attempts to control populations of *Achatina fulica*. However, there is no rigorous scientific evidence that *E. rosea* effectively controls *A. fulica* populations. It is now widely recognized that the *A. fulica* populations decline for other reasons. It is further widely recognized that *E. rosea* has been a major scourge of vulnerable native snail populations, to the extent of the extinction of a

large number of endemic species. The most widely publicised impacts have been on the slow-reproducing endemic tree snails of the islands of the Pacific (Partulidae and Achatinellinae). Statements that *E. rosea* is entirely ground dwelling are not true; it is frequently seen in trees. It will also go under water in search of its prey. Most governments and other authorities appear to be aware of the potential threat posed to native faunas by *E. rosea*. However, under pressure from voters to "do something" about *Achatina fulica*, they often at least consider the introduction of *E. rosea* (and other snail predators like the flatworm *Platydemus manokwari*). Many island people are not aware of their unique native faunas, or do not understand their precarious existence, but have heard that *E. rosea* can solve the *Achatina fulica* problem. The pressure to introduce *E. rosea* may then become intense, or people may resort to introducing it unofficially. The IUCN has formally condemned the deliberate introduction of *E. rosea* and other carnivorous snails. Nevertheless, with the continuing spread of *Achatina fulica*, the threat posed by the continued introduction of *E. rosea* is serious.

Geographical Range: Native range: Southeastern USA, especially Florida.

Introduced range: Hawaii, Kiribati, French Polynesia, American Samoa, New Caledonia, Vanuatu, Solomon Islands, Palau, Guam, Northern Mariana Islands, Papua New Guinea, Japan, Hong Kong, Taiwan, N. Borneo, Madagascar, Seychelles, Mauritius, India, Andaman Islands, Sri Lanka, Bahamas, Bermuda.

Invasion pathways: Failed biological control agent.

Local dispersal methods: *Agriculture (local)*: Deliberate spread by agricultural officials. *Self-propelled (local)*: Probably once established, natural spread is the main means of spread.

Management informations: Small enclosures have been built in Hawaii and on Moorea (French Polynesia) to protect native tree snails from attack by *Euglandina rosea*. These are somewhat successful, but require constant vigilant monitoring and maintenance. Baiting techniques are being tested in Hawaii.

Nutrition: A predator of other snails. It appears to prefer smaller individuals, which it swallows whole, but will attack large snails by entering through the shell aperture. It finds its prey by following their slime trails.

Reproductive Mode: Cross-fertilizing hermaphrodite; lays eggs.

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3. The exotic fishes like **Brown Trout** (*Salmo truta fario*) and Rainbow Trout (*Salmo gairdnerii*) were introduced by the British administrators for sports in the cold-water streams of Himalaya. Realizing their potential as a food fish, these trouts are now being cultured in large scale in the parts of Kashmir, Himachal Pradesh, Garhwal and Kumaon hills. Since these trout are carnivorous they adversely affect the natural population of endemic Mahaseer (*Tor* sp.), wherever cultured.

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4. Chromolaena odorata **(Land plant)**

Taxonomic Name: *Chromolaena odorata* (L.) King & Robinson

Synonyms: *Eupatorium odoratum* L., *Osmia odorata* (L.) Schultz-Bip.

Common Names: *Agonol*, Bitter Bush, Hagonoy, *Herbe Du Laos, Huluhagonoi*, Jack in the Bush, *Kesengesil, Mahsrihsrihk, Masigsig, Otuot,* Siam Weed, Triffid Weed,

Ecological Category: *A fast-growing perennial shrub produces abundant wind-blown seeds, occurs in open, well-drained sites. A weed of pasture and plantation crops in tropical Africa and Asia. Encourages fire*

Description: Thrives in Open areas.

Reproductive Mode: Sexual reproduction. It is not known to reproduce vegetatively, although the plant may resprout from the root crown following fire or death of old stems.

Reproductive Output: Seed production is prolific with up to 87,000 seeds per mature plant or 400,000/m^2 having been recorded. Seeds germinate readily.

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5. *Lantana camara* (Land plant)

Taxonomic Name: *Lantana camara* L.1753

Synonyms: *Camara vulgaris, Lantana scabrida*

Common Names: *Ach Man, Ayam, Bunga Tayi, Cambara De Espinto, Cuasquito,* Flowered Sage, Large Leaf Lantana, *Latora Moa, Pha-ka-krong,* White Sage.

Ecological Category: *Widely grown as an ornamental shrub throughout the tropics, subtropics and temperate zones, it is established there as a weed of pastures and the environment in ca 50 countries.*

Description: Much branched, thicket-forming shrub normally 2-4 m but capable of becoming a liana up to 15 m tall. Flowers from white to red with variations in between, including purple.

General Impacts: Decreased productivity in pastures. Poisons cattle. Invades disturbed natural ecosystems establishing in open situation creek banks and roadsides. Excludes understorey species. Changes faunal makeup by providing perch sites and cover. Understorey competitor for forestry.
Invasion pathways: Nursery trade
Local dispersal methods: Digestion/ excretion, garden escape/ garden waste
Management Informations: Control must be integrated, including manual removal, burning, shading, chemical control and revegetation. In many cases natural restoration is difficult after removal of thickets, due to reduced seed banks of native species. Long history of international biological control, however few are effective to date.
Nutrition: Concentrates nitrogen in the soil. Produces allopathic compounds.
Reproductive Mode: Year round flowering. Self and cross-pollination. Large fruit and seed set. Fruit a small drupe with 1 seed. Lantana does not sucker from damaged or broken roots but will regrow from the base of the stem and from rooted horizontal stems in contact with moist soil.
Reproductive Output: 24 fruits per inflorescence, 511 inflorescences per plant, 12265 fruits per plant.
This species has been nominated as among 100 of the "World's Worst" Invaders.

Conclusion: Aside from the fact that we identify invading species as being indigenous to some regions other than the area being invaded, there is essentially no biological difference between the process of invasion and the process of colonisation or recolonisation of areas by native plants. Colonisation of new substrate or of areas partially or wholly denuded of vegetation by disturbance is a fundamental process of plant succession. Interspecific competition and other interactions ultimately regulate community structure and species diversity in natural communities. They also regulate the success and failure of invading species. The life histories of the invaders are strongly constrained by the frequency of disturbance. Vast majority of successful invasions into productive environments are associated with agricultural activities and other disturbances such as road building, urban constructions and lawns. Herbivorous insects tend to invade much more successfully than the insects at higher trophic levels. Most serious effects of invading plants occur when they alter the environment they invade. However, most dramatic changes produced by invading species occur when they alter the disturbance regime of the ecosystem, particularly the fire cycle, specially in arid and semi-arid environments where natural fires are relatively infrequent and the indigenous vegetation is not well adopted to fire. Endemism and Invasions represent ecological phenomena at extremes of several contexts of evolutionary and ecological process. The environmental conditions that allow the evolution and survival of endemic species, namely low rates of competitive displacement and low frequency of major disturbances, also allow high diversity plant communities with many endemic species to be easily invaded by exotic species. Fortunately the same conditions also prevent the invading species from dominating the community and reducing species diversity unless the invasion is accompanied by a change in the disturbance regime of the community. Ecosystems in productive environments are quite resistant to invasion under natural conditions of low disturbance frequencies. The properties of the species that influence their ability to resist invasion or survive in the presence of exotic species of competitors or predators are largely the result of their evolutionary history. The vulnerability of island species to extinction caused by competition or by predation by introduced predators is responsible for most of the extinctions that have occurred as a result of phenomenal increase in the transport and dispersal of species by human activities.

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References

Civeyrel, L. and D. Simberloff (1996). A tale of two snails: is the cure worse than the disease? *Biodiversity and Conservation* 5: 1231–1252.
Cowie, R.H. (2001). Can snails ever be effective and safe biocontrol agents? *International Journal of Pest Management* 47(1): 23-40.
Griffiths, O., A. Cook and S.M. Wells (1993). The diet of the carnivorous snail *Euglandina rosea* in Mauritius and its implications for threatened island gastropod faunas. *Journal of Zoology* 229: 79–89.
Hadfield, M.G., S.E. Miller and A.H. Carwile (1993). The decimation of endemic Hawai'ian [sic] tree snails by alien predators. *American Zoologist*, 33: 610–622.
Huston, A. M. (1994). *Biological Diversity-The coexistence of Species on changing landscapes.* Cambridge University Press.
Murray, J., E. Murray, M.S. Johnson and B. Clarke (1988). The extinction of Partula on Moorea. *Pacific Science* 42: 150-153.