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Bioecology and management of giant African snail, *Achatina fulica* (Bowdich)

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ABSTRACT

Giant African snail (*Achatina fulica* Bowdich) belongs to the Phylum–Mollusca and Class–Gastropoda. It is known for its destructive nature on cultivated crops wherever it occurs and is one of the world's largest and most damaging land snail pests. The pest is an East African origin, has spread in recent times by travel and trade to many countries. They now widely distributed and no longer limited to their region of origin due to several factors *viz.*, high reproductive capacity, voracious feeding habit, inadequate quarantine management and human aided dispersal. *A. fulica* can cause serious economic damage on different crops and extensive rasping (scrapping), defoliation, slime trials, or ribbon like excrement is signs of infestation. In recent times, severe outbreak of this pest has been noticed due to some desirable agricultural and gardening practices like minimum tillage practices and straw retention techniques which help in survival of snails and make seedlings more susceptible to damage. This review paper aims to enlighten on taxonomy, distribution, extent of damage, morphology, biology, ecology, homing behaviour, seasonal incidence, nature of damage, host plants of *A. fulica* and its ecofriendly management strategies.

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INTRODUCTION

The giant African snail, *Achatina fulica* Bowdich is one of the most extensively studied snails in the world because of its economic, ecological and medical importance (Mead, 1979a). It belongs to the phylum–Mollusca, class–Gastropoda, subclass–Pulmonata, and order–Stylommatophora, family–Achatinidae. These land snails are plentiful in the high rainfall areas of tropical countries. *A. fulica* is a major crop pest species that originated in East Africa but has been spreading across the globe since before the 1800's primarily through human activities (Mead, 1961, 1979b; Raut and Barker, 2002). The World Conservation Union (IUCN) has listed *A. fulica* as one of the world's 100 most invasive species. Besides its adaptability in different ecosystems, *A. fulica* also serves as an intermediate host of rat lungworm, *Angiostrongylus cantonensis* (Alicata, 1966). In India, the giant African snail, *A. Fulica* was reported for the first time causing damage to ornamental and vegetable crops in Bangalore during *Kharif* season 1979 (Veeresh *et al*., 1979) and this snail was supposed to have been brought along with plant material from various parts of India including Calcutta, Kerala and Madras. As of now, *A. fulica* has been established in almost all states of India and there pausing a serious threat to agriculture. Considering the economic importance of this serious pest as well as realizing the paucity of compiled form literature, this review article has been prepared to enlighten many information on distribution, biology, ecology, damage, homing behaviour and different management options of *A. fulica.*

Taxonomy :

FAO (1989) has described *A. fulica* as follows :

Authority	: Bowdich (1822)
Classification Kingdom	: Animalia
Phylum	: Mollusca
Class	: Gastropoda
Order	: Pulmonata
Family	: Achatinidae
Genus	: Achatina
Species	: fulica

Distribution :

The introduction of *A. fulica* outside its native range dates back to the early 1800s, when it was spread to Ethiopia, Somalia, Mozambique and Madagascar. The first occurrence outside Africa was in West Bengal (India) through Mauritius in 1847. In the Asia-Pacific region, the snail is recorded from Bangladesh, China, Fiji, India, Indonesia, Japan, Kiribati, Malaysia, New Zealand, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Sri Lanka, Vanuatu and Vietnam and its range is still expanding. This pest can move a substantial distance under its own power. In the field, *A. fulica* can move 50 m (164 ft) over night (Anonymous, 2012). Under optimal field conditions *A. fulica* can reach high densities and biomass (Raut and Barker, 2002). Tillier (1982) recorded a biomass of up to 780 kg/ha in New Caledonia. Raut and Goshe (1984), Raut and Barker (2002) recorded population densities of up to 46 m^2 in mainland India and up to 56 m^2 in Andaman and Nicobar. Subsequently Muniappan *et al*. (1986) reported that 45 million *A. fulica* were collected and destroyed on 1600 hectares over a seven month period. On Christmas Island, Lake and O'Dowd (1991) recorded a mean of 2 individuals/10m in the heavily infested areas.

Extent of damage :

Mead (1961) listed four categories of plants that are likely to be damaged by *A. fulica*. The first category is garden flowers and ornamentals, which were completely susceptible at any stage of development, the second category is mostly vegetables, the third category represented plants usually not eaten at the mature stage but are damaged earlier in development by bark being completely removed as is the case with breadfruit, cassava and teakwood. The final category includes crops upon which damage is indirectly incurred (Mead, 1961; Muniappan *et al.*, 1986). Moreover, the extent of damage caused by *A. fulica* generally depends on size of the snail and age of the plants which makes it very difficult to estimate the damage of *A. fulica*. Sridhar *et al.* (2012) studied the extent of damage caused by *A. fulica* in six different crops in Kolar district, Karnataka and found that the extent of damage was highest in mulberry leaves *i.e.*, 100 per cent followed by groundnut (40-50%) and papaya (40%) and the cucumber was the least preferred host (20%).

Morphology of *A. fulica* :

The adult snail is around 7cm (2.8 in) in height and 20cm (7.9 in) or more in length. The shell has a conical shape, being about twice as high as it is broad. Shell colouration is highly variable, and dependent on diet. However, typically, brown is the predominant colour and the shell is banded (Skelley *et al*., 2011). The mantle, the fleshy part inside the shell through which the foot protrudes, is a pale yellowish colour. The columella, the smooth inner surface to the opening of the shell is also yellow. The 'head' portion of the foot is light brown but the rest of the foot is paler with markings. They move along on a single foot, driven by waves of muscle contraction in the sole. A gland at the front of the foot produces slime for the foot to slide over. Snails have teeth that cut up food as they eat, but a land snail has a rough tongue which has little hooks on it. These hooks scrape off tiny bits of leaves, fruits and other foods which the snail can then eat. These teeth are called radula. The radula is functionally active when the snail is moving over the food and it will rasp pieces of food and eat. There are two pairs of tentacles on their head where one pair is longer than the other pair. The eyes are located on the longer pair which cannot focus well but they are very sensitive to light but the shorter pair is used for smelling and feeling its way around. The shell of *A. fulica* consists of 7 to 12 whorls, with moderately swollen body whorl and a sharply conical spire, which is distinctly narrowed but scarcely drawn out at the apex. The snail has no gill and operculum, but the mantle cavity serves as a lung. It has two pairs of retractile tentacles, with eyes at the tips of posterior tentacles. Being a herbivore, it feeds on leaves and fruits of different plants and the average litter size is 200 g/day. The average weight of a fully matured snail varies from 200-600g and speed of movement is 0.003 km/hour. The giant African Snail has a protective behaviour by which when it disturbs, it pulls it body back into the shell and then seal the entrance with mucus plug. It can give off a protective coating by secreting a calcium compound that dries on contact with the air.

Biology of *A. fulica* :

Hermaphrodite :

Snails are hermaphrodite, which means they have both male and female parts capable of producing both sperm and eggs; however, they still require another snail to mate for reproduction. Further, any two sexually matured individuals have the capacity for being mutually receptive in cross fertilization (Mead, 1961).

Mating :

Giant African snails are nocturnal, moving around at night to feed on a wide range of plant. With the exception of mating, snails spend much of their time alone. They communicate through giving off scents and through the vibrations they pick up. Courtship can last up to half an hour, pair of snails raise the sole of their feet off the ground and bring them together. At the same time they rock their bodies to and fro and actively caress one another with their greatly extended tentacles. During mating two individual come side by side in such a manner that their genital apertures are opposed. The intermediate organ of one comes out through the genital aperture and pushed into the vagina of other and *vice versa*.

Life stages :

The average fecundity of *A. fulica* is around 200 in the soil. A snail may lay 5-6 clutches of eggs per year with a hatching viability of about 90 per cent. Adult size can be reached in just four months. The whole life cycle was found to completed in 5-5.5 months with an egg stage, 7-10 of juvenile stage and 5 months of adult (Upatham *et al*., 1988). Active adult buried within three inches of soil while the dormant adults found in the surface of soil.

Aestivation and hibernation :

A. fulica undergoes aestivation for a prolonged period without food or water. There is strong evidence that the period of quiescence is closely correlated with temperature. The aestivation period is about 5 to 10 months and hibernation generally occurs in winter season.

Ecology :

Raut and Barker (2002) suggested that *A. fulica* is tolerant of a wide variety of environmental conditions. Smith and Fowler (2003) concluded that temperatures in the southern-border and Pacific coast states were likely to be suitable to the snail. A mild temperature of 15-25°C is best for snail reproduction, though most species can stand a wider range of temperature. The optimal temperature is 21°C for many species. When the temperature falls below 7°C, snails hibernate and under 12°C they become inactive. When the temperature raises much above 27°C or more, snails undergo aestivation. They thrive in damp but not waterlogged environments and thus a well drained soil is required. Eggs are susceptible to all reducing temperature. The water content around 80 per cent of the carrying capacity of the soil and air humidity over 80 per cent (during darkness) is the most favourable conditions. Soil organic matter and other micronutrients like calcium, magnesium, potassium etc. play an important role in increasing the size of the snail. Snails are found in greater abundance at an optimum pH range from 6.3-6.7 and P_2O_5 concentration (0.002-0.004%). The snail hides during the daytime but can be seen at night with the aid of artificial lighting e.g. flashlight, ideally in moist and sheltered places.

Homing behaviour :

Tumiyama (1992) observed that homing ability of *A. fulica* in field by following mark-recapture techniques. During his course of investigation, he observed that young adults dispersed for longer distance than old adults and old adults seldom changed their resting sites, while young adults changed their resting sites almost every day. Further, he also reported that the homing ability of *A. fulica* is age-dependent and old adults have a homing ability, while young adults did not show it clearly.

Seasonal incidence :

Seasonal incidence of *A. fulica* in arecanut ecosystem was investigated by Ravi Kumar *et al.* (2007) and observed that mean population was highest in second fortnight of September than the second fortnight of August but in February the lowest mean population was observed in first fortnight and gradually decreased in the second fortnight. The lowest seasonal incidence was due to low temperature in the month of February and the highest seasonal incidence was in September due to favourable environmental condition.

Nature of damage :

Being a macrophytophagous herbivore, *A. fulica* can damage a wide range of plant material, fruits and vegetables. Sometimes it eats sand, very small stones, bones from carcasses and even concrete as calcium sources for its shell. In rare instances the snails will consume each other. Plant materials showing extensive rasping (scraping), defoliation, slime trials or ribbon-like excrement are signs of *A. fulica.* Giant African snails cause extensive damage on farms as well as in natural ecosystems and pose certain risks to society. The characteristic nature of damage by *A. fulica* in papaya are loss of crop yield, death of papaya plants, increased fruit and stem blight caused by *Phytophthora palmivora* (as the snail spreads the pathogen within and among papaya plants in feces and by contact with its body) (Nelson, 2012).

Apart from direct damage, *A. fulica* is also known to pose problems related to human health, environments and society. They may alter/damage natural or native ecosystems by their herbivory, affect nutrient cycling in different ecosystems, adverse effects on indigenous snails and slugs arise through competition for same resources and also pollute residential places. In many Asian, Pacific, and American communities, it transmits human parasites and pathogens in slime trails or when infested snails are eaten raw or undercooked. One such pathogen is rat lungworm (*Angiostrongylus cantonensis*), which causes meningitis, *Eosinophilic meningoencephalitis* in humans (Alicata, 1966).

Host plants :

A. fulica feeds on more than 500 plant species specially stems, leaves, flowers or fruits of a broad range of agriculturally important plants. In India, some of the preferred host plants are banana (*Musa* spp.), bean (*Phaseolus* spp.), cabbage (*Brassica oleracea*), cassava (*Manihot esculenta*), cotton (*Gossypium hirsutum*), eggplant (*Solanum melongena*), papaya (*Carica papaya*) and pumpkin (*Cucurbita pepo*) etc.

Management strategies :

The effective control of pests involves a combination of measures, including cultural, biological and chemical methods so it is best not to rely on just one method. The different management practices are discussed below:

Cultural control :

Abundant ground cover and vegetation growth provide ideal moisture levels, shelter and harbourage where snails and slugs thrive and can be a problem on growth of the crop with a weedy fence line. Good hygiene, weed control and removal of refuges can reduce the problem over time and these practices also improve baiting. Avoidant of minimum tillage and straw-retention techniques in *A. fulica* endemic areas are effective since these practices not only help the snails to survive but also make the seedlings more susceptible to damage. Soils with more organic matter content are more attractive to the snails. Unnecessary raising of plants between trees and vines can also act as shelter belt for the snails.

Mechanical barriers :

Snails do not like dry surfaces. Continuous lines of sawdust and ashes can be used as barriers but their effectiveness is drastically reduced once they become wet, which is unavoidable with rain and watering of gardens. Instead, lines of lime and copper sulphate are pest repellent and can be used to prevent migration into an area. Superphosphate fertilizer applied in rings around the butts of trees may stop snails reaching the trunks. Copper is repellent to snails, bands of thin copper sheet around tree trunks prevent snails from climbing. This method must be combined with skirt pruning and control of under-canopy vegetation to stop snails getting into the trees by other routes (Peter *et al.*, 2012). Fruits extract of *Thevetia peruviana* also reported to repel *A. fulica* (Raut and Barker, 2002). Use cuttings of alligator apple, *Annona glabra* to construct softwood fences as a snail repellant to protect nursery beds has also been reported by Prasad *et al*. (2004).

Trap technology :

Traps set in and around the orchard or home can be effective in reducing snail populations. Some of the commonly used traps against *A. fulica* are Salt traps, Tangle foot traps, Tangle guard paper tree wrap and pitfall traps.

Biological control :

Since *A. fulica* is an alien pest therefore there are limited natural enemies that control this pest. Some predatory beetles, lizards, birds and rats can feed on them. Ducks and chickens can provide effective, long-term control in orchards and vineyards, if an appropriate breed is chosen and properly cared for. Khaki Campbell or Indian runner ducks are best breed to be used in snail control (Peter *et al.*, 2012). Use of predatory snails and worms in *A. fulica* management has also been implicated in the decline of native snails in many countries. Some of the predatory snails which can predate and feed on *A. fulica* include *Euglandina rosea*, *Gonaxis kibweziensis*, *Gonaxis quadrilateralis*, *Edentulina ovoidea* and *Edentulina affinis*. *Platydemus manokwari*, a turbellarian flat worm, has also been used to control the giant African snail in Guam, Philippines and Maldives.

Legal control :

Since *A. fulica* is an alien species, therefore, their further spread to unaffected areas must be checked through different quarantine measures. Spreading can be controlled by preventing the introduction of plants, equipment, building materials, farm vehicles, or soils from infested areas. Inspect agricultural, horticultural and other commercial products and the containers in which they are shipped for snail or snail eggs. Intentional introduction of this pest to a new area for beatification and consumption purposes should be avoided.

Chemical control :

Some of the chemicals are effective to control this species. However, it should be advisable to use the chemicals judiciously as the species is abundantly thrive in residential areas where they feed on household waste materials. Few chemicals which are effective to control the snails are methiocarb, metaldehyde and EDTA. The bait materials such as dicholorvos bait (Wheat flour- 1kg + Jaggery- 0.2 kg + Dicholorvos 76EC- 250ml) and methomyl bait (Rice bran-1kg + Jaggery 0.2 kg + Methomyl 40 SP- 100 g) are suitable to control the infestation of the species. The bait preparation should be carried out prior to application of molluscicides. The bait should be prepared by heating the jaggery with wheat flour/ rice bran along with the poison. Hand gloves should be used to make small balls and keep it in 10 places in the field. Keep away the poultry and pet animals from the baited field.

Conclusion :

Invasive species are one of the top threats to biodiversity. Once an invasive species establishes its population in a new vulnerable area, it is very difficult to check its growth, spread and damages. In case of giant African snails, several eradication measures have already been found unsuccessful. Some of the management options also have lots of indirect issues related to environment, biodiversity and health hazards. Biological control in the form of introducing the rosy wolf snail proved disastrous and caused even more damage, razing of an entire ecosystem in the pursuit of eradicating only one species. Use of toxic baits targeted for *A. fulica* also victimized indigenous as well as other invasive snails. As regards to chemical control, various molluscicides like metaldehyde are non-selective, thus their use has a chance of endangering the survival of non-target organisms (Prasad *et al.*, 2004). However, some easy techniques like collection and destruction of the snails and their eggs are recommended as a form of physical control. Guarding pathways through which giant African Snails can pass is much cheaper than pursuing them through biological or chemical control. Moreover, to be effective, the molluscicides should be such that it may not get dissolved and washed away by rain because snails are normally active during the rainy season. Therefore, an effective eco-friendly management strategy is needed to keep the pest below economic injury level. Holistic efforts among countries at the regional level are not only needed to prevent further spread of *A. fulica* but also required to formulate an effective and environmentally sustainable management strategy.

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