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A Brief Review on Asexual Reproduction in Indian Squamate Reptiles

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Abstract: **Although sexual reproduction is the most common reproductive strategy in most vertebrates but there is asexual mode of reproductions also being reported in several squamate reptiles. It is perhaps an evolutionary reproductive strategy to avoid immediate extinction where population size is drastically low during colonization in newly formed habitats. Most of the asexual populations are perhaps hybrids gradually originated from their sexual parents due to intense ecological resource competition.**

Keywords: **Sexual reproduction, asexual reproduction, parthenogenesis, automictic reproduction, squamates.**

1. INTRODUCTION

Evolutionary and ecological hypothesis such as the **Red Queen model** predicts that species has to constantly adapt in the changing climate or else to face extinction because simultaneously competing species are continually getting better adapted alongside. However, the **Red Queen** hypothesis is largely contradicted by **Court Jester model**, suggesting abiotic factors such as climatic fluctuations or environmental changes due to geophysical activities (earthquakes, volcanic eruptions, plate tectonics, mega-tsunami and emergence of new land masses) or extra-terrestrial intervention on earth such as asteroid impacts are among the most significant causes of large scale species extinctions as well as important driving forces for rapid species evolution through adaptive radiation. Whereas the **Neutral Theory of Biodiversity** model predicts that comparatively more recently evolved species might have higher extinction pressures because they generally fail to successfully adapt in the rapidly changing environments and also to tackle biotic pressures; the concept may be actually relevant for endemic species as endemism in several squamate taxa has been recently evolved. Hence, it is hypothesised that many newly described species are either morphoclinal variants or may be hybrid taxa; their initial population size may be small enough to be considered viable and future survival as well as taxonomic validity assumed to be largely depended on favourable adaptive trait evolution (Benton, 2009; Fujita et al. 2020; Saulsbury, 2023). All these hypothesises particularly both the red queen and neutral model of biodiversity are equally significant to address ecological speciation within the framework of most recent evolutionary time scale. The constant species turnovers in nature resulting from abiotic and biotic interactions might have offered several species a magnitude of multiple opportunities to acquire various novel survival strategies. where **Natural Selection** largely worked to allow the fittest to become selected in their immediate environment to successfully reproduce and the rest were eliminated. Reproduction is the only way to keep progenies thrive to the next generation (Fujita et al. 2020).

In squamate reptiles both sexual and asexual modes of reproduction have been reported; the asexual or **Automictic reproduction** generally known as **Parthenogenesis** a Greek word derived from “perthenos” means virgin and “genes” means born and the hatchlings are often named **Parthenogens** formed through meiosis and the subsequent fusion of cells restoring the maternal chromosomal number. In a more common sense where females may partially clone themselves without any contribution from males (Maslin, 1971; Oliver, 1971; Fujita et al. 2020). In contrast, the true parthenogenesis

or **Apomictic reproduction** lacks meiosis and are largely reported in some plants and invertebrates. Overall, automictic reproduction in squamate reptiles perhaps evolved in isolated populations at higher altitudes in harsh and dry climatic conditions or largely in small island populations, in the disturbed habitats or species in captivity and this strategy also been reported in introduced invasive species (Maslin, 1971; Oliver, 1971; Fujita et al. 2020). It is obviously an adaptive reproductive strategy to breed where mates are scarce in the stressed environmental conditions. However, it has an immediate advantage to avoid extinction during colonization in the newly formed habitats where intense environmental pressure generates critical ecological limitations for reproduction (Fujita et al. 2020). Apart from Automictic, other modes of related vertebrate asexual reproduction are reported in some fishes, salamanders and frogs but in such cases, sperm is required to fertilize eggs which includes Gynogenesis, Hybridogenesis and Kleptogenesis (Avise 2008). Squamate reptiles such as some lizards & snakes are the only known amniotic vertebrates that reproduce via Automictic reproduction by largely maintaining a Thelytokous population of all females. Most asexual populations of squamate reptiles capable of Automictic reproduction might have comparatively recently and gradually evolved from their sexual parental population through hybridization where complete potential niche overlap and complex sexual selection happens in sympatry and then later to reduce resource competition hybrid populations occupy new distinct habitats through niche shifts and gradually achieve asexual mode of reproduction (Fujita et al. 2020).

Mayr (1963) once stated that the most formidable and fundamental obstacle to apply **Biological Species Concept** is to allot species rank in uniparentally reproducing organisms but what should an evolutionist consider the unit of evolution in such organisms? from our perspective we propose to consider them as just genetic variants or may be hybrid taxa depending on viability of their population.

Although asexual reproduction overcomes the costs of mate finding but sexual reproduction has several advantages such as both parents have equal reproductive investments as a result genetic diversity is maintained in population, increased evolutionary and adaptive fitness is achieved due to purging of deleterious variants (Muller 1964; Maynard-Smith, 1978; Haig, 2002; Fujita et al. 2020) and sexual reproduction also facilitates accelerated adaptive evolution which is beneficial when environmental changes happens rapidly as predicted by Red Queen model (Bell, 1982).

However, asexual populations may initially go through several potential challenges such as lack of sexual selection, reduction in selection efficiency due to reduced population size known as Hill-Robertson interference (Hill & Robertson, 1966; Fujita et al. 2020), gradual accumulation of deleterious mutations leading to decreased fitness over time known as Muller's ratchet (Muller 1964; Fujita et al. 2020) the increased hybrid loads in a population known as Dobzhansky-Muller incompatibilities may cost a lot on individual fitness by lacking accumulation of novel adaptive characters these all may simultaneously lead to maladaptive genetic extinction which is an evolutionary dead end (Fujita et al. 2020). But there are possible evolutionary trajectories to get rid of mutational loads which might be achieved through heterosis or hybrid Vigor where two similar parental genomes may be capable enough to produce fertile and viable hybrids known as **Balance hypothesis** and in cases of polyploidy an extra set of chromosomes is usually found while the unique genetic variation may be achieved through hybridization and polyploidization (Avise, 2008; Murphy et.al.2000; Murakami & Hayashi, 2019; Fujita et al. 2020).

The phylogeographic studies hypothesized that the Pleistocene climatic cycle along with the arrival of ice age (lasted from 2.6 million to 11,700 years ago) provided secondary contact between divergent sexual species resulting in hybridization and eventually gave rise to multiple asexual lineages and their terrestrial expansion largely happened during interglacial when new habitats started to expose (Kearney 2005; Schön et. al. 2009; Fujita et al. 2020). The Frozen niche variation (FNV) hypothesis suggested that higher or complete niche overlap among newly formed clonal lineages along with the sexual species may eventually go extinct due to complex spatial and trophic resource competition whereas the most specialist clones may gradually get adapted in more distinct and specified niches (Vrijenhoek, 1979; Schön et. al. 2009; Fujita et al. 2020).

Automictic reproduction in squamates may be obligatory or facultative however facultative Automictic reproduction has been recently reported in a female American crocodile *Crocodylus acutus* in a Costa Rican zoological park. After 16 years in isolation the female American crocodile laid a clutch of 14 eggs although most eggs failed to hatch but one unfertilized egg hatched and developed female hatchling genetically identical to its mother which perhaps indicates that asexual reproduction might have been independently evolved in different oviparous reptilian lineages. Laying unfertilized eggs in

a clutch perhaps a reproductive strategy to confuse ovophagus predators and protect viable eggs (Crocodile's 'Virgin Birth' Is a First for Science's History Books by Louise Gentle & The Conversation US; June 9, 2023).

Although detailed information on asexual reproduction in Indian squamates are scanty but in certain extreme cases facultative asexual reproduction has been reported in captive females devoid of mates such as in the Gekkonid genus *Eublepharis*, Indian rock python *Python molurus* and King cobra *Ophiophagus hannah* in all instances females produced few viable eggs which all hatched into females. However, the obligatory asexual reproduction in natural population is rare but has been reported in Gekkonid *Lepidodactylus lugubris* largely distributed in South Asia and also found in Andaman and Nicobar Islands. Whereas blind snake (*Indotyphlops braminus*) another obligatory asexual uniparental population native to South Asia but has been accidentally introduced to almost all tropical parts is now considered as invasive and automictic (Das, 2002).

It is reported that the mainland *Lepidodactylus lugubris* population is sexual but the island populations are largely asexual and mostly female dominant. In case of *Indotyphlops braminus* the asexual population perhaps derived from bisexual ancestors later dispersal and accidental invasion in new niches along with ecological pressures such as lack of mates perhaps gradually forced them to establish a uniparental female biased population. As blind snakes are subterranean, they largely inhabit in subsoil niches. After analysing their wide geographic distribution and unique obligate asexual mode of reproduction Wallach (2020) proposed to erect a new generic rank *Virgotyphlops braminus*.

In this scenario we encourage evolutionary biologists to revise Indian taxa particularly Gekkonid genera such as *Cyrtodactylus*, *Cyrtopodion* and *Cnemaspis* which are largely considered taxonomically cryptic and still evolving; here we propose that many of the cryptic taxa are hybrids from two bisexual species have complete niche overlap with respect to spatial and trophic resource use. As **neutral model of biodiversity** predicts the newly evolving species may have higher extinction rate due to lack of adaptability by augmenting this view, we propose that hybrids are nothing but evolutionary byproducts or biological artifacts may fail to avoid ecological resource competition in the frequently changing climate and eventually go extinct (Fujita et al. 2020; Saulsbury, 2023; Mukherjee et al. 2023). However, it may also be hypothesized that few of the hybrids may be able to outcompete their ancestral sexual as well as recent asexual rivals and finally may occupy specialized microhabitats through niche conservatism and gradually get adapted in the new environments to establish future asexual progenies. Another reproductive strategy known as communal egg dumping by females may further enhance a chance of higher survival by reducing predation pressure, *Lepidodactylus lugubris* has opted to acquire quite similar survival strategies by occupying narrow niches inside rock crevices besides rocky outcrops in the hilly semievergreen and evergreen island forests.

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