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Causes And Consequences of Sex Ratio Distortion

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***Abstract*: Populations of sexually reproducing organisms are always affected by various evolutionary forces and dynamic atmospheric conditions that lead to variation in their behaviour and life-history traits. In order to adapt themselves according to the changing environment, animals favour producing those types of progeny that are favorable to them for increasing the fitness of the species. Numerous factors support the selection of those traits that function in the alteration of sex ratios for the survival of a species. There are substantial reports regarding a number of species of animals that when a particular sex starts posing threat to parental generations by increasing the competition for mating, feeding or habitat or producing them is not gaining any benefit for the fitness of the mother then parents use to suppress the production of that particular sex and favour the production of the other sex. Some evolutionary models explain as to how uneven sex ratios are created in a population in one condition and in other, again made equal and stable. The present review article deals with the precise role of parents in shaping the sex ratio of their offspring to have a sustainable existence of the species.**

Key words: Local Mate Competition, Meiotic Drive, Sex Allocation, Sex Ratio Distortion, Sexual Conflict.

I. Introduction

Our planet is the abode of millions of species of microorganisms, plants and animals that have evolved during the long span of biological evolution. The diversification in life forms has been accomplished due to a number of evolutionary forces like mutation, genetic drift, gene flow and natural selection. The various genetical processes lead to variation in the genotype and phenotype of organisms and such variations among the individuals of a population are essential for the evolutionary forces to act upon to create new species. The chromosomal complements of a large number of animal species provide evidence for the XX and XY system of sex determination that should produce equal number of males and femalesin a population. However, the sex ratio distortion may be one of the ubiquitously occurring events in many species of animals, whether invertebrates or vertebrates. Fisher (1930) stated that in most sexually reproducing species of animals; the sex ratio tends to be 1:1 however, for various reasons, species deviate from an even sex ratio, either periodically or permanently. The deviation from 1:1 sex ratio can be observed in many species across animal kingdom and a number of evolutionary forces produce unequal number of males and females by influencing the survival and propagation of a specific sex (Charnov 1982).

In various animal species, the role of parents opting to produce offspring of a specific sex in more number depending on the environmental condition that increases the fitness of the population has been ascertained (Trivers and Willard 1973, Cameron 2004, Lynch et al 2018), while in certain hermaphroditic species of animals, individuals change sex to increase their fitness (Trivers and Willard 1973). Animal domestication started long back for the purpose of their use in food, transport, agriculture, and conveyance and since then preference towards one sex came in practice just because of the higher economic significance of that sex. Conventionally, farmers prefer female cattle for dairy and due to this their apathy for male calves results into their larger mortality.

Here, we are addressing the issue of uneven sex ratios that occurs in various species of organisms. Sex ratio distortion occurs due to many factors that range from environmental and behavioural factors to microorganisms and sex chromosomes responsible for favoring a particular sex. Sometimes, parents prefer the production of a particular sex in their progeny that increases the possibilities of survival for that species, by assisting them in reproduction or decreasing the competition for mates, habitats and resources. Besides these factors, sometimes the sex of the offspring also depends upon the health of the mother (Trivers and Willard 1973). It had been reported by Kahn et al (2015) that in normal atmospheric condition, mothers produce more sons than daughters, if each male has lower survival and therefore, they will not occupy resources for long time. But when the mother is in poor condition, then they will produce more daughters because they will have limiting resources to rely upon. Apart from that, certain genetic factors are also responsible for favoring a particular sex which is termed as sex chromosome drive (Jaenike 2001; Vaz and Carvalho 2004).

Sex ratio distortion causes adverse effects on the survival of the species by creating sexual conflict in mating and parental behavior that lead to selection of certain physical and physiological traits in both the sexes. The distorted sex ratio may cause inbreeding (breeding between close relatives), as a consequence of it there is decrease in the heterozygosity which ultimately can lead to the extinction of the species.

It can be broadly explained in two categories: causative agents and consequences of sex ratio distortion.

A. Causative agents behind uneven sex ratio

Factors that lead to uneven sex ratios in nature across many phyla can be broadly classified into two major elements. They are Sex Allocation and Sex Chromosome Drive.

1) Sex Allocation

The practice of favoring the sex in progeny as to be either male or female by parents which will benefit in the survival of the species in the prevailing environment is called sex ratio adjustment (West et al 2002). The sex of the progeny to be favored depends upon the cooperation and interaction of relatives and these types of sex ratio adjustment is called sex allocation (West et al 2005). Sex allocation can also be defined as the allocation of resources to male versus female reproduction in sexually reproducing species (Charnov 1982).*Nasoniavitripennis*is a parasitoid wasp in which females on the basis of previous experience of high parasitism use to lay more unfertilized eggs leading to higher male than to female ratio (Wylie 1966).

The sex ratio occurring at birth is mostly even (Fisher 1930, West 2009, Kahn et al 2015) which is considered as equal sex allocation (1:1). However, due to one or other reasons this ratio may get highly skewed in several species of animals (Hewison and Gaillard 1995, Abe et al 2002, West et al 2005, Silk and Brown 2008). There are certain hypotheses addressing the reasons of why uneven sex ratios occur in natural populations of animals. These are being discussed below:

a) Local Resource Competition (LRC)

This theory advocates that whenever, there is competition for resources such as food and space among the members of the group, then in such situation, fostering females favor that sex that doesn't increases competition for the resources and leaves the group at an early age. This theory was given by Clark (1978) who also asserted the example of *Otolemurcrassicaudatus,* a nocturnal primate, whose cases studied at worldwide level revealed sex ratios asymmetry favoring males. In all cases, there was no evidence of differential mortality of any sex. Among the offspring, both males and females interact equally with their siblings so the reason behind male-biased sex ratios can't be in favoring the helping sex. Males are not restricted from entering the high productivity areas and neither have they competed with their siblings for resources. Males leave their groups at an early age so they are not affected by the sex ratio of their siblings, while females reside with their mother, sisters and create competition for food, mates, and habitat. Thus, females giving births to sons are unlikely to face competition as compared to females that give birth to daughters.

Similarly in passerines, daughter biased dispersal is more and in anseriformes, son biased dispersal is more. So according to LRC, it was observed that in passerines, female-biased sex ratios are observed and in anseriformes, male-biased sex ratios are observed in the progeny (Gowaty 1993). Herre (1985) analyzed female-biased sex ratios that used to occur in some insects where males don't disperse thus creating competition for female mates.

In Roe dear (*Capreolus capreolus*), sex ratios used to skew towards a particular sex that does not cause competition for mothers (Hewison and Gaillard 1995). Silk (1983) studied the parental behavior of higher primates and gave an idea that poorer than average females in apes choose to give birth to the sex that is more dispersing to avoid competition for her in the future (Silk and Brown 2008).

b) Local Mate Competition (LMC)

Local mate competition theory was given by Hamilton (1967) by considering the example of fig wasps. In fig wasp, female maximizes the number of grand-children she produces if, she is the only foundress laying eggs in figs. This hypothesis is mainly based on conditions where reproductive females in the founder population are less in number. Therefore, if there is a competition between her sons, then it becomes advantageous for her to make a female sex-ratio adjustment and produce more daughters than sons. Griffiths and Godfray (1988) have advocated local mate competition, sex ratio and clutch size in bethylid wasps. Abe et al (2002) worked on an ectoparasitoid, *Mellitobiaaustralica*and found that the sex ratio of offspring was highly female-biased irrespective of infection from sex ratio distorter, *Wolbachia*. The female in such conditions prefers to produce more female progeny because, if they would produce males, then it will adversely affect their fitness, as all males will not get the chance to mate. But an increase in the number of females in the progeny will maximize female fitness, as more of its genes will pass on and it would lead to more offspring (West and Herre 1998). This hypothesis is also applicable to ants (Hasegawa and Yamaguchi 1995). In beetles and termites, haplodiploidy occurs which is mainly due to mating among siblings (Hamilton 1967). It is hypothesized that haplodiploidy is maintained and spreads due to LMC (Alexander and Sherman 1977).

c) Local Resource Enhancement (LRE)

Among the offspring, the gender that improves the reproductive success or fitness of the parents is favoured by the parents during reproduction e.g. *Seychelles warbler* (Komdeur et al 1997). According to this theory, female favors the helping sex among its offspring, which in fact helps the mother in raising more number of her descendants. Individuals in low-quality territories (which are measured by food availability) reduce their parent's reproductive success while, those in high-quality territories, increase their parent's fitness. In the socially organized animal communities, helpers are mostly females and parents adjust the sex ratio of its offspring depending on the territorial quality. The helper progeny decrease the fitness of their parents in low-quality territories and increase their fitness in high-quality territories. Extremely male-biased sex ratios were obtained in low-quality territories where no help was obtained whereas, in high-quality territories and without any help, female-biased sex ratios were obtained. This pattern of biased sex ratios that depends on the quality of territory and helpers indicates that breeding pairs favour the sex which increases the fitness of them by providing help in the reproduction of new offspring (Komdeur et al 1997). This theory was found to be applicable in African wild dogs where females disburse more than males and thus sons accompany mother to help her in raising new offspring and females living in small packs create more male-biased sex ratios as compared to females in larger packs because, in small groups, there is more need of help for raising offspring (Mc Nutt and Silk 2008). Evidence for LRE leading to sex ratios biasness in the favour of helpers has also been found in several vertebrates (Silk and Brown 2008, West et al 2005).

d) Trivers-Willard Hypothesis

Trivers and Willard (1973) gave the hypothesis that male's reproductive success strongly depends on the condition of the mother. A female in good condition will tend to produce offspring of a good condition and should therefore preferentially produce males. Parents decide to produce several male or female depending upon the cost incurred on each production, the number of prey available, food availability, maternal condition, and mate attractiveness. According to the hypothesis, parental investment in reproduction can be predicted and therefore, parents can affect the survival of male and female offspring differently (Trivers and Willard 1973). This occurs in conditions where variance in reproductive success among male and female sex exists. In cases, where males have higher mating success than females, then females in good condition produce more sons to increase their fitness. This hypothesis holds well in Red Deer, *Cervus elaphus*, where mothers in good condition produce more sons and such mothers in poor condition produce more daughters. In polyandrous species, where sex role is reversed and single female mates with multiple males and males mate with single or few females, parents in good condition in such cases give birth to more daughters than sons. However, in poor condition, females produce more sons and few daughters. The condition of parents can be assessed to multiple parameters such as body size, parasite load, and dominance. In *Macaca sylvanus*, the dominant female used to produce more sons and non- dominant females more daughters (Paul et al 1993). Larson et al (2001) worked on sexual dimorphism in bovine embryos and reported that when high glucose content is present in embryonic culture, it gives rise to more male blastocysts than females.

According to Trivers and Willard theory, there are following factors on which sex allocation depends:

Food availability

Appleby et al (1997) worked on tawny owls, *Strixaluco* and found that adult females used to produce more female-biased chicks in seasons that are likely to have more prey and male-biased sex ratio in seasons that have less prey. Wiebe and Bortolotti (1992) reported that in American krestels, *Falco sparverius*, whenever, food resources are unlimited, high numbers of female progeny are produced.

Maternal quality

Clutton-Brock et al (1984) found that in Red deer (*Cervus elaphus*), females that are dominant in the herd give birth to more sons than daughter and subordinate mothers give birth to more daughters. A dominant female can raise a healthy and strong male adult deer which is relied on to protect the harem as well as to increase his reproductive success.

Mate attractiveness

According to Weatherhead and Robertson (1979), females produce more sons when they are mated with attractive males. There are scientific reports that females tend to choose those attractive males that are indicative of good genes which help them to produce more attractive sons (Fisher1930, Burley 1981). This behavioral liking of females will increase the reproductive success of their male offspring due to their attractiveness (Fisher1930, Burley 1981). This is termed as 'sexy son' hypotheses formulated by Fisher (1930). Burley (1986) worked on zebra finches and found that male birds with attractive leg-band colors tend to produce more sons as compared to female progeny.

2) *Sex chromosome drive*

Sex chromosome drive is also referred to as 'meiotic drive' (Morgan et al 1925; Sandler and Novitski 1957). Sex chromosome drive was first reported by Morgan et al (1925) in *Drosophila affinis* where it leads to female-biased sex ratios and was later known to occur by a meiotic driver and therefore, also referred to as 'meiotic drive'. Gershenson (1928) also showed that males in *D. obscura* have an X- linked element called SR (sex ratio) element that used to kill Y- bearing gametes and cause progeny to become female-biased. The phenomenon of segregation distortion or meiotic drive is well reported in *D. melanogaster* and *D.ananassae* (Stadler and Novitski, 1957; Stadler et al 1959; Mukherjee and Das, 1971, Singh,2000). According to Jaenike (2001) sex chromosome drive occurs when the transmission of one chromosome is favored more than the other. Sex chromosome drive or meiotic drive (Lyttle 1991) that leads to female-biased sex ratios are called 'sex ratio' trait and was reported to occur in nine species of *Drosophila* (Gershenson 1928,Jaenike 2001). It occurs in polymorphic forms in nature but after fixation, causes the population to exert by favouring female production and depriving males (Hamilton 1967). This factor is present in polymorphic forms in many species of *Drosophila* like *D. simulans* (Atlan et al 1997), *D. quinaria* (Jaenike 1999), *D. subobscura* (Jungen 1990) and *D. paramelanica* (Stalker 1961). The 'SR' trait can be fixed, subjected to stable polymorphism or extinction which depends on the fitness of 'SR' males (Vaz and Carvalho 2004). This condition is prevented in nature by the selection of autosomal or Y- linked modifier genes that are antagonists of the meiotic drive (Stalker 1961, Carvalho and Klaczko 1994). The genes responsible for sex chromosome drive are autosomal as well as Y- linked and are reported to be polymorphic in *D. simulans* (Atlan et al 1997, Moreau and Cazemajor 2002). Also, in mice, there is gene (MSYq) present on the long arm of Y chromosome in males that tend to suppress sex ratio distortion and deletion of which causes skewed sex ratio toward females (Conway 1994).It had been reported that there is a mutation linked with a Y chromosome that leads to very high male: female ratio in subsequent generations and thus sex ratio distortion (Hamilton 1964). There are also cases of X-linked drive for sex ratio distortion but their rate of propagation is one-third faster as that of the Y chromosome, and due to polygamy the transmission throughout generations decreases further (Novitski 1947).

Sandler and Novitski (1957) coded the term 'meiotic drive'. According to them, certain genes get increased in frequency and it owes to meiotic drive. Novitski (1947) found out that in *Drosophila affinis*, there is a recessive gene that causes sex ratio distortion by causing the overproduction of mostly Y- bearing sperm. There would also be the possibility for the selection of certain genes that would eventually eliminate or bring down the effect of meiotic drive. Mukherjee and Das (1970) reported segregation distortion (SD) in the lab strain (px pc) of *Drosophila ananassae* where SD was observed in both sexes males and females with greater distortion reported in males than females. They advised that occurrence of high frequency of spontaneous male recombination and its relation to segregation distortion must be looked upon. According to (Sandler and Novitski 1957; Sandler et. al. 1959; Singh 2000) segregation distortion (or meiotic drive) causes unequal segregation of two alleles in a heterozygote due to meiosis which was widely studied in *Drosophila melanogaster*.

In cases where sib- mating takes place in a small population then, there is more chance of accumulation of the Y-mutant allele for giving rise to more sons than daughters (Hamilton 1967). Therefore, in nature both types of gene expression favouring male and female-biased sex ratios are present and both are involved in controlling the other's expression and maintaining balance in the number of males and females present in any species. In extreme cases of sex-biased distribution of members of a species, the phenomenon of gynogenesis is most relevant example where, all individuals belong to single sex that is female. The cases of gynogenesis in nature have been mainly reported in fishes and amphibians (Avise 2015).

There are also roles of symbionts in sex ratio distortion. It had been reported by Engelstadter and Hurst (2009) that *Wolbachia* mostly infects Arthopods where they reside as cytoplasmically inherited symbionts. They increase their proliferation by changing the sex ratio of the host population by killing the male hosts and improving the viability and fertility of the female host. Microorganisms such as *Wolbachia* and *Cardinium* (Zchori-Fein et al. 2001; Weeks et al. 2001; Hunter et al. 2003) that reside as symbionts in many species of arthropods, manipulate them in a variety of pathways. Some of the methods of manipulation are feminization of host from male to female in Hemiptera and Lepidoptera (Hiroki et al. 2002; Negri et al. 2006), parthenogenesis induction in mites, thrips and Hymenoptera (Huigens and Stouthamer 2003), Early male killing in Diptera, Lepidoptera, Coleoptera, Hemiptera and Hymenoptera (Hurst et al. 2003; Zeh and Zeh 2006), late male killing in mosquitoes and Lepidoptera (Hurst et al. 2003; Nakanishi et al. 2008) and through cytoplasmic incompatibility in mites and insects (Bourtzis et al. 2003).

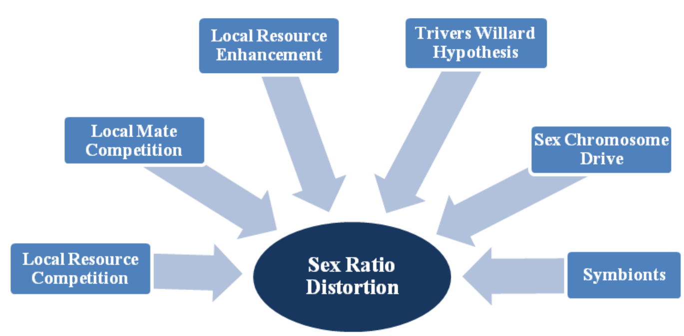

Fig.1. Causative agents behind sex ratio distortion

B. Repercussions of Sex Ratio Distortion

Evolutionary scientists believe that operational sex ratio is the major driving force in shaping sexual selection due to enforcement of mate competition in the more common sex (Trivers 1972, Emlen and Oring 1977). It affects parental care (Liker et al 2013) and in male biased sex ratio, a decrease in parental care by male isobserved (Jennions and Fromhage 2017). Cases where female biased ratios are created, sex role reversal occurs in the form of competition among females for resources provided by males (Jiggins et al 2000). Females obtained from female biased selection regime experiment were faster in courtship displays, mating and decrease in copulation latency (Fritzsche et al 2016). According to Liker et al (2014), in female biased ratio, breaking of pair bonds increases as compared to in male biased ratios. It can be concluded by their studies that duration for which pair bond remains depends largely on the adult sex ratio (ASR).

Sex ratio in a mating pool effects many other behavioural patterns, e.g., inbreeding system evolution in shorebirds and sex differences in parental care (Liker et al 2013). It had been reported that sex ratio affects mating propensity in *Drosophila biarmipes* (Singh and Pandey 1994) and *D. pseudoobscura* (Kaul and Parsons 1966) while in case of *D. bipectinata* no such effect of sex ratio was reported (Singh and Sisodia 1999). Uneven sex ratio leads to sexual conflict that causes males to manipulate their mating behaviour in order to increase fitness and females to evolve counter adaptations in response. In male as well as female-biased sex ratios, both the life history and reproductive traits of males and females are affected (Pitnick et al 2001, Chapman et al 2003, Arnqvist and Rowe 2005). The sex-biased ratio is expected to increase competition and variability between individuals of the more abundant sex and increase mate selectivity in the rarer sex.

According to Hamilton (1967) one of the best methods to control pests is by creating an extreme male-biased sex ratio in their population. In *Aedes aegypti,* there are genes located on the chromosome Y that when get mutated lead to an increase in the number of male progeny. In such mutated strain, there are X chromosomes that constrain the effect of the mutated chromosome to varying degrees. Male sterilization techniques have been employed as one of the measures to control mosquito population hence; these types of male-biased sex ratios in a population are very beneficial for biological control strategies (Hickey and Craig 1966). Galizi et al. (2014) inserted I-PoI endonuclease that cleaved gene sequences on the X-chromosome in the malaria vector *Anopheles gambiae*. This prevents the production of female offspring due to inactive X-chromosome while creating a male- biased sex ratio thus eventually declining the whole population. Similarly, Maccariello et al (2021) performed the same approach of creating male- biased sex ratios in the pest *Ceratitis capitata* by X- shredding that involves the introduction of multiple DNA-double strand breaks during male-meiosis. Y- chromosome is transmitted more in subsequent generations leading to male-biased sex ratios. These examples explain how sex ratio distortion can limit the production of disease vectors and pests.

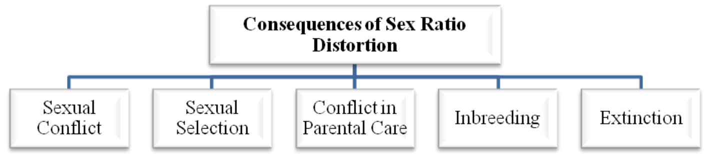

Fig.2. Consequences of sex ratio distortion in nature

II. Evolutionary stable strategy

Owing to sex ratio variation in the population of a species, its members develop different ways to deal such situation. There are many processes through which the occurrence of uneven sex ratios in nature are dealt with. For instance, if there is more number of females in a population than males, then a male would mate with more partners than single female and hence male increases its fitness by multiple mating (Parker 2006, Bonduriansky 2013). Parents producing male offspring would have a fitness advantage over those who had produced females. This would increase the number of males in the population, thus eliminating the advantage of males of being in high number and leading to a 1:1 ratio in the population. This equal ratio is termed as an evolutionarily stable strategy (ESS). This term was first coined by Smith (1972) who along with Price (Smith and Price 1973) first proposed ESS theory. Stabilization of ESS is done by following two strategies; Nash equilibrium (Suzuki and Iwasa 1980) and Stackelberg equilibrium (Abe et al 2003). The type of strategy to be applied to an evolutionary model depends upon the habitat condition and on the adaptation abilities of the organisms. In Nash equilibrium, which involves two or more players, any player enacts accordingly in order to bring equilibrium, while being unknown of the other player’s future action plan but its own action neither benefits nor harms any individual player but to affect the stability of the system. According to Stackelberg equilibrium, an actor leads the actions by taking initiative while the other one acts according to the leader’s action. These types of equilibrium models are applied for fixation of ESS in population to prevent any other evolutionary force to change the traits present that had become fixed in that population.

III. Discussion

The origin of life could be accomplished due to a macromolecule having the ability to replicate. The genetic macromolecule which is now well established genetic material as DNA has characteristics to replicate, mutate and recombine to produce its varied altered forms. Sexual reproduction accelerates the chances of genetic variation among the individuals of a species. Due to this reason, distinctly male and female sexes originated and evolved during the course of biological evolution. The existence of XX and XY system in several forms of organisms resulted in the formation of two sexes with phenotypic variations and also to ensure equal availability of the two sexes in nature. With all such natural phenomena to create variation, what benefits the animal populations gain due to sex-biased ratio is an important aspect to envisage.

In nature, there are many animals that create a biased sex ratio among its offspring due to many different reasons and thus male or female-biased sex ratio is found in the wild. This affects the life history traits of both males and females. Organisms change their mating behavior to survive in adverse conditions when a biased sex ratio arises. This affects their efficiency of gender roles in both males and females which they modify in order to achieve fitness in adverse conditions. It had been reported that morphology of many reproductive organs in *Drosophila melanogaster* in both the sexes change due to the prevailing sexual conflict for many generations (Reuter et al 2008). So, it can be inferred that due to the continuous exposure of evolutionary pressure, parents adapting towards it by bringing change in their mating pattern eventually change their morphology after few generations and that become incorporated in their genes that may result in the change in sexual dimorphism. Sex ratio distortion is well observed phenomenon in insects particularly in wasps, bees and their closely related species (Pereira and Prado 2005, Wang et al 2015). Although, there exists a distinct skewed male to female sex ratio in Hymenoptera (bees and wasps), however, the entire society has evolved in such a way that a larger chunk of individuals, being sterile dedicate their life for the betterment of the colony. Therefore, the perusal of sex ratio evolution in these insects is one of the important aspects of studying their sex allocation (Charnov 1982) and the effect of kin selection on social behavior (Trivers 1985). Trivers and Hare (1976) looked into the sex ratio theory of Fisher's (1930) and kin selection theory of Hamilton (1964) and then, regarding hymenopterans opined that the stable ratio from the queen’s viewpoint is 1:1, because queens are equally related to daughters and sons. However, the stable ratio from the worker’s viewpoint is 3:1, i.e., female to male ratio. This is because haplodiploidy (i.e., the production of males from haploid eggs) causes workers to be three times more closely related to sisters than to their brothers. Trivers and Hare (1976) therefore, deduced that workers should usually control sex allocation because they typically outnumber queens and rear the brood. In many species of Hymenoptera, that depict social behavior, there is a female-biased sex ratio (Bourke and Franks 1995, Crozier and Pamilo 1996).

D. melanogaster has also been reported to allocate specific sex to its offspring depending on the age of its mate (Long and Pischedda 2005). In animal kingdom, a number of species opt to cannibalism and infanticide owing to competition for food, shelter, and mates. In some taxa of primates and rodents, adult male kills the young male in order to increase the access to fertilizable females thus increasing its reproductive fitness along with reducing the competition among males, while females evolve counter adaptations to escape such incidents (Palombit 2015). Sex ratio distortion had been evolved as a behavioral adaptation towards eliminating the sex that increases competition and favoring the gender that increases the chances of survival of the species in adverse atmospheric conditions. For example, if a population is started from low founder population, then the sex ratio is skewed towards more number of females as reported in *D. melanogaster* (Dubey and Singh 2018) that can be associated to local mate competition which may be an adaptation towards increasing population and variation and that would increase the stability of the population. It had been reported that mitochondrial transmission by the female parent in many arthropods causes sex ratio distortion (Perlman et al 2015). There are chances of fixation of any mutation that causes sex ratio (SR) distortion (Vaz and Carvalho 2004) and also suppressors of this SR trait that are present on Y chromosome in mice (Conway 1994) which increases the number of males in various species. Organisms have gender roles and their efficiencies increase or decrease in them for e.g. mating behaviour, reproduction, foraging and escape from predators for adaptation towards the changing environment. When they are not able to further modulate sexual behaviour then killing of the members of one particular sex starts occurring as a strategy for adaptation. These sorts of behaviour that aim to create uneven sex ratios in a particular population would have evolved with changing environments for generations and resulted in the selection of certain biochemical and genetic traits that will create uneven sex ratios that are found in various species (Schino 2004, Kappeler 2017).

Population with biased sex ratio is shifted to even sex ratios when strategies like Nash equilibrium or Stackelberg equilibrium starts operating there and the population is shifted to an evolutionarily stable state. In case, any kind of major evolutionary disturbance occurs, it may again lead to gender breakdown (Suzuki and Iwasa 1980, Abe et al 2003).

IV. Conclusion and Future Perspectives

Although, a large number of animal species are destined to produce both sexes in equal proportion, however, due to one or other reasons, there occurs significant difference in their sex ratio, in later part of their life that leads to intra and intersexual conflict among them. Sex ratio distortion helps us to address the conditions where sexual conflict causes harm to females while also affecting males adversely. The outcome of sex ratio distortion on ecology is also a matter of concern that should be looked upon. The phenomenon of sex ratio distortion helps us to analyze the causes behind the extinction of a species. If the reduction in the number of individuals of a population is due to mere cause of sex ratio distortion, then this aspect may be tackled by equalizing the number of both sexes so that the species could be sustained. There is immense need to focus research on the pros and cons of uneven sex ratios in the survival and genetic variation of a species to design future perspective for their conservation and propagation.

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Authors' contributions

PD wrote the major aspect of this review as she had worked during her research work on the impact of skewed sex ratio on various life history traits of *Drosophila melanogaster*. AKS helped in suggesting the contents and writing the manuscript.

Conflicts of interest

The authors declare that there is no conflict of interest between them.

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