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RESEARCH ARTICLE

GUPPIES AND THEIR LIFE STYLE

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ABSTRACT

Guppies are important model system for the study of sexual selection for colouration which is an especially important component of female mate choice. Guppies own phenotypic variation to diverge natural and sexual selection by evolutionary (internal factors) and environmental factors (external). Internal factors include expression of different opsins with sequential variation along with copy number and influenced by many external factors like water quality, role of light, effect of protein, fat and carotenoid, mate choice and presence of predation. Studying all these factors will enable to predict the colour development with sequence variations in guppies.

KEY WORDS:

INTRODUCTION

The guppy is named after the Rev. J. L. Guppy of Trinidad, an early collector of the species from the late 1800's. Guppies belong to kingdom Animalia, Phylum: Chordata, Genus: *Poecilia*, and Species: *Poecilia reticulata* (Guppy).Guppies (*Poecilia reticulata*) are placed in the family as mollies and mosquito fish. Guppy native to fresh and brackish waters of north-eastern South American and adjacent islands of Caribbean is one of the most popular ornamental fish in the world. Two species from Poeciliidae family (*Gambusia affinis* and *Poecilia reticulata*) are using as control agent against mosquito larvae. In 1901 *Poecilia reticulata* (guppies) was introduced in India for practice to eradication mosquito larvae which acts as a biological malaria control agent. Concepts have not changed and now we are using this fish in fish culturing. In the fishing industry researchers are focussing on the food value and the colour pattern of fishes as like other domesticated animals e.g., dog, cat, parrot, horses and farm animals (sheep's and cow's). It is fruitful to keep guppy as a hobby as well as relax therapy in houses, schools, collages, hospitals and other places where human being find themselves busy. The colour pattern in fishes can be obtained by doing certain changes in environmental conditions. Guppies are small size and can be maintained in small spaces (aquarium tanks) and easy to rear. So it is very easy to get colourful guppies in short period of time with limited resources to culture and reproduces quickly with prolifically. Guppies can be easily identified accordingly to their body shape, body colour, and fin shape and colour pattern. Guppies are live-bearing fish with internal fertilization. Female guppies are much larger than males (sexual dimorphism), and they have dull coloured bodies with brighter colours on their tails. Male guppies are brilliantly coloured, and colour pattern possibilities are endless. The word "reticulate" refers to the overlapping scales that form a lace-like pattern on the body of the guppy. Guppy's beautiful hues develop from very tiny spots of colour known as melanophores.

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The amount and location of the melanophores determines the varying patternof colours in guppy. Different tail shapes include: Delta tail, fan tail, double sword tail, top sword tail, bottom sword tail, pin tail, round tail, veil tail, lyre tail, crown tail, coffer tail and scarf tail. Different tail pattern include (but are not limited to): Solid colour, small spots, irregular colour pattern and large spots. The front half of wild guppy's body is usually gold, grey or silver but it could also be other colour variations depending on the individual. An ideal temperature for adult guppies is 22.22 to 24.44 ºC. Fry are often raised in warmer water for the first 2 or 3 months (25 – 26.6 ºC). The guppy is live bearer, with an average gestation period of 28 days. The female guppy has drops of between 2 – 200 fry, normally about 30 to 60. After mating just once with a male guppy, the female guppy is able to give birth numerous times and produce after every three to four weeks after last birth. The number of fry produced mainly depends on size of the fish, health condition, and water quality parameters.

The female matures at 3 months and the males earlier (6 weeks) depending on genetical and environmental factors (Reznick, 1997). The life span for a well-cared-for guppy is 1.5 to 3 years on average and maximum longevity of guppies is 5 years. The environmental conditions are measured by quality and quantity of water and light, availability of carotenoid, ornamentation of mate and presence of predation. Wild guppies possess limited colour pattern under natural environmental conditions. Clear water is able to transmit all ranges of wavelength of light which is able to develop all opsins with shift in cone frequency and turbid water hinders in absorption of all wavelengths of light which will hinder in opsin development. Proportional measures indicate large effects of light on SWS1 expression, whereas relative measures indicated no such effect. Teleost fishes, with their wide range of natural habitats, have become the model for examining the relationship between ambient light and the spectral sensitivity of visual pigments. It has been shown that species from water bodies with differing spectral irradiance tend to possess visual pigments that are related to the most abundant wavelengths.

These wavelengths are absorbed by photo pigments present in rods and cones of eye retina. There are five opsin classes in guppies, four cone opsin photoreceptors and one rod opsin photoreceptors, showing absorbance peak at 502 nm of the electromagnetic spectrum. The four cones receptors are short wavelength-sensitive 1 (SWS1) pigments with peak sensitivities (λ_{max}) in the UV–violet region of the spectrum showing peak absorbance at 408 nm, short wavelength-sensitive 2 (SWS2) pigments with λ_{max} in the blue region of the spectrum showing peak absorbance at 464 nm, UV-sensitive (UV) pigments with λ_{max} in the ultra-violet region of the spectrum showing peak absorbance at 359 nm of the electromagnetic spectrum, and long wavelength-sensitive (LWS) pigments with λ_{max} in the yellow–red region of the spectrum showing peak absorbance at 533, 548 and 573 nm of the electromagnetic spectrum by Microspectrophotometry method (Bow maker and Hunt, 2006; Yokoyama, 2000).

Directly and indirectly colouration is related to the expression of opsins in a particular environment conditions. Light had large effects on the relative expression of SWS2B, RH2-2, RH2-1 and LWS (Fuller and Claricoates, 2011). Colouration in fishes arises through deposition of carotenoid, melanin or other pigments (structure colours). These pigments can create colour only by absorbing light from a background (usually white) reflective tissue in which they are deposited. Carotenoid colour i.e., orange colour play important role in mate choice and intra and interspecific communications (Needham, 1974).The phylogenetic divergence of all opsins in guppy is shown in Figure1.

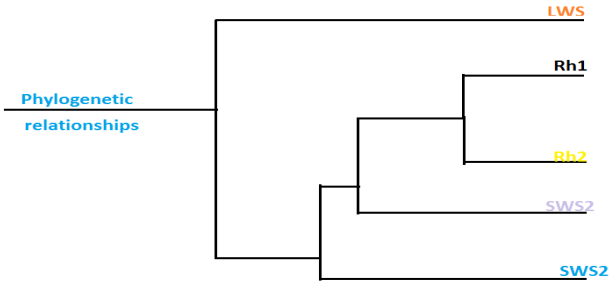

Figure 1. Representing Phylogenetic relationship of opsins in guppies

Within teleost fish, lineage-specific opsin gene duplication and sequence divergence have contributed to class expansion in many species. In case of cichlid fishes, their habitat varied in diverse range of environments and show variation in opsin gene expression, with different species expressing different subsets of cone opsins. Archer *et al*., (1987) have studied cone polymorphism in guppy *Poecilia reticulata* and states that males are highly polymorphic for body colour and is possible that cone polymorphism is related to appreciation of the different yellow, orange and red carotenoid colour spots that are used in sexual display. The most important opsin is LWS opsin which provided guppy a unique identity for lineage-specific opsin duplication and subclass expansion. Species may have up to four LWS opsin genes with the potential to absorb light maximally at three different wavelengths within the green to yellow portion of the light spectrum, which is more than any other teleost studied (Hoffmann *et al*, 2007). Interestingly, it is well established in many species of Poeciliidae that female mate choice is strongly influenced by male red and orange colouration which is developed by the expression of LWS opsin gene. The expansion and divergence of LWS opsin genes in these fish families are of particular interest to study of sexual selection in these species, and suggest a role for LWS opsin genes in facilitating divergence in female mating preference. The guppy visual system has expanded to include one additional LWS cone. The additional LWS cone cell is due to the duplication of LWS opsin gene (gene repertoires) which has resulted in expansion of long wavelength visual capacity determined by Microspectrophotometry. Partial sequencing of LWS opsin gene using polymerase chain reaction (PCR)-based approaches suggest that both LWS opsin gene copy number and sequence diversity is responsible for the presence of three cone cell types in this species (Weadick andChang, 2007). However, it is not clear whether this additional cone type is the result of opsin gene duplication specific to the guppy lineage or simply divergence of opsin loci shared across a broad range of species within Poeciliidae. Many other external factors are there which are responsible for growth, colour development and expression of opsin genes leading to polymorphism like in LWS opsin gene. These factors are water quality, effect of light, role of carotenoid, mate choice and presence of predation. Water quality plays an important role in shaping the life style of aquatic life which has direct impact on guppy fishes. All the physico-chemical parameters of water should be within the normal range so that it will not hinder in fish physiological and morphological activity. Water should be clear enough to absorb light from environment and make light available to aquatic fishes for different morphological processes like growth, colour development and life cycle.

Natural light is composed of different wavelengths of light and due to this different lights are absorbed by aquatic fishes through their photoreceptor cells present in retina of eye and develops different colour pattern on their body. Changes in absorption of light by photoreceptor cells leads to change in colour pattern by having changes in genotype of opsin responsible for that colour pattern. Colouration and growth in fishes depends on diet intake which is influenced by carotenoid as supplement. Higher the protein and fat content in the feed higher is the growth and carotenoid enhances the colouration in guppies. Enhance coloured males is always choice of females for mating. Females prefer to mate with familiar mate whenever population size of guppies is small. Colour enhancement, growth and mate choice is directly influenced by presence of predation in the population. In presence of predation colour development will be less, growth will be reduced and males will spend less time in mating the females.

Effect of light

Animal communication occurs when an animal emits a signal; the signal is transmitted through the environment, and then detected by the sensory system of receiver. In terms of visual communication, the wave-lengths of a given colour pattern must be transmitted through the environment and the colour pattern must differ from the colour pattern of the visual background. The natural light is transmitted to aquatic fishes by water communication and absorbed by the visual pigments of photoreceptor cells present in eye retina of fishes (guppies). Visual pigments in sensory system initiate vision and are characterised by their wave-lengths of maximal absorption

Lambda max (λ_{max}). Modification of the λ_{max} values of visual pigments has allowed organisms to adapt in diverse light environments. There is genetic and environmental variation in vision sensory systems. The magnitude of variation in sensory system and the extent to which that variation is genetic and environmental has important implications. The presence of genetic variation implies that either natural or sexual selection can favour a change in the population's sensory system properties. Guppy exhibits marked intraspecific variation in behaviour and morphology which occurs over a wide range of natural environmental light conditions. Differential light conditions leads to different colour development which directly influences the mate choice. Mate choice allows in forming genetic variation which leads to sexual selection. The genetic basis of this variation is of interest because the elaboration of mating preferences requires additive genetic variation in their traits. Male guppies exhibit high levels of phenotypic and genetic variability for several secondary sexual traits that are important to male fitness (Winge, 1927; Haskins *et al*., 1961).

Light should be so enough to make visual contact at a distance between males and females for effective courting by displaying colours in front of females. More the light available in water for fishes, more is the colour development on fishes. The colour development is also affected by other factors as well, like presence of carotenoid in their diet, predation influence and expression of genes for particular colour. Male guppies court females at exact and predictable distances in a given light level, both in field and laboratory studies (Long and Rosenqvist, 2006). In lower light levels, for example at dawn, dusk, or under heavy canopy, males court females at closer and less variable distances (< 3 cm). At higher light levels, which occur during most of the day and with less canopy cover, males often court from twice or three times further out. Laboratory manipulations of irradiance confirmed that courtship distance depends on illumination. Hence, courtship distances may be set by the effect of lighting on signal efficiency, minimization of energy or time expenditures, or predation risk.

Role of protein, fat and carotenoid in guppies

Feed management in terms of optimization the feeding rate is essential in culture of fishes as feeding rate presents a significant effect on all the growth performance. Higher amount of protein and fat present in feed improve the higher growth rate in fishes. Under natural conditions guppies eat a wide range of organic matter that is available in the water such as algae, bloodworms, white worms, mosquito larvae, and microorganisms that grow on water plants. Artificial fish feed mainly contain protein, fat, fibre, moisture, traces of carotenoid and ash, out of which protein and fat are included in macronutrients. Proteins help fishes for growth, tissue repair, immune function, making essential hormones and enzymes and to preserve lean muscle mass. Fat helps in normal growth development, energy source, absorbing certain vitamins (like vitamins A, D, E, K and carotenoid), providing cushioning for the organs, maintaining cell membrane and provide consistency with stability to foods. Fishes are not able to synthesize carotenoid in vivo, so they take it from their food to develop colours. In absence of carotenoid in diet fishes are not able to produce highly intense colours irrespective of genetical factor expression for colour development. Physiologically carotenoid (Diler and Dilek, 2002) is in attractant for the sperm, fertilization improving agent, resulting in a higher proportion of fertilized eggs, protection against to environmental effects (harmful light, high temperature, low oxygen tension ammonia etc., thus reducing mortality during embroyonic development). Carotenoid present in feed helps to develop colour in fishes association with expression of opsin gene (genetical factor) under influence of light conditions (environmental factor). Differential expression of opsin leads to express different colours in combination with carotenoid present in feed. Under natural conditions guppies are dull in colour, females are grey in body colour and males have splashes spots or stripes that can be any of a wide variety of colours. After providing proper feed along with carotenoid increases the ornamentation in guppies.
Guppies have three kinds of coloured spots: structural, carotenoid, and non-carotenoid pigments; examples are blue, red, and black respectively. Carotenoid pigments are widely used to produce red, orange, and yellow colouration especially in fish, lizards and birds (Evans and Norris, 1996). The carotenoid spots are dependent upon the carotenoid taken in the diet and are brighter when food is very abundant. The structural colours and black spots are independent of food intake. Black spots are good for species recognition and are not as visible to predators as are the other colours. Structural colours are conspicuous like carotenoids, but also very conspicuous to predators. In many instances, these carotenoid-based colours are sexually attractive to prospective mates. Carotenoid pigments also serve a variety of physiological roles like male social status, reproductive success, motivation, physical condition and with one major function as an immune-stimulant and antioxidant. Courting males in guppies develop large black spots, a horizontal stripe along the side of the body, thereby increasing the conspicuousness and complexity of their colour patterns.

Females prefer intensely pigmented males which represents its healthy, unparasitized mates in superior physical condition and presumably of higher genetic, as well as phenotypic quality. Carotenoid colours are produced by the deposition of pigments that interact with light on a molecular level to absorb certain wavelengths of light. For example, carotenoid pigments absorb shorter wavelength of light and allow longer wavelength of light to be transmitted or reflected, depending on the composition of the surrounding material, thereby resulting in red, orange or yellow colours (Fox, 1957). By contrast, melanin pigments exhibit high absorbance across all visible wavelengths of light, with increasing absorbance at shorter wavelength of light, resulting in black or brown colours. Structural colours are produced by the physical interaction between light and nanometre-scale variation in the integumentary tissues of some animals.

Familiarity for Mate choice

Mate choice or intersexual selection, is an evolutionary process in which selection of a mate depends on attractiveness of its traits, male-male competition, presence of predator and intra-sexual selection. Darwin first introduced his ideas on sexual selection in 1871 but advances in genetic and molecular techniques have led to major progress in this field recently (Moller and Jennions, 2001). In systems where mate choice exists, one sex is competitive with same-sex members and the other sex is choosy (selective when it comes to picking individuals to mate with). In most species, females are the

choosy sex that discriminates amongst competitive males but there are several examples of reverse roles. Mate choice is affected by previous mating ie, mating history, familiarity and presence of predation which results guppies to perform two types of mating tactics. Males use mating history with familiarity to mate with preference female. Sigmoidal display ie, normal courtship sequence performed by males in front of females and sneaky mating tactics, in which they perform gonopodial thrusts by males in front of females without displaying first.

For many years it has been suggested that sexual isolation are caused by differences in mating behaviour is a precursor for reproductive isolation (lack of gene flow), and consequently speciation, in nature. Mate choice behaviours are thought to be important forces that result in speciation events because the strength of selection for attractive traits is often very strong. Speciation by sexual selection is gaining popularity in the literature with increasing theoretical and empirical studies. In guppies the driving for mate choice is influenced by presence of orange colour on male's body. Endler and Houde (1995) studied that in guppy populations the receptive females show a clear preference for courting males with large areas of orange colour. Guppies are located across several isolated streams in Trinidad and male colour patterns differ geographically. Female guppy's preference for these colour patterns vary across locations. This preference could result in reproductive isolation if two populations came into contact again. There is evidence of early speciation through mate preference in guppies. Familiarity and mating experience influence female mating preferences and hence alter the strength of sexual selection on male ornamentations. Female guppies choose mates on the basis of complex and highly variable colours patterns comprising orange, iridescent and black spots as well as on the basis on morphological traits such as tail fin size. A male's most intense courtship display is the sigmoid displays, which is characterized by the male orientating himself in front of a female and vibrating his body in an S-shaped posture. A measure of female sexual responsiveness for a particular male can be estimated by the percentage of sigmoid to which female responds in a positive fashion (Houde, 1988).

Presence of predation effect

Predation is an important selection pressure that can affect prey individuals, populations and communities which contributes significantly to mortality in many ecological systems. Prey species have evolved means for avoiding encounters with predators for surviving attacks. Anti-predator defences have been shown to have a strong genetic basis across a wide range to taxa (Huntingford and Wright, 1993). However, the development of defences can be costly and so when predation risk varies temporally or spatially it may be adaptive for prey organisms to phenotypically respond to changes in the environment to avoid incurring such costs. Different populations of a species may experience varying intensities or types of predation, leading to differences in their anti-predator behaviour. It is obvious which colour patterns are more adaptive in the presence of visually hunting predators. The colour pattern in a particular place represents a balance between selection for crypsis by predators and selection for conspicuousness by sexual selection. Predation risk affects male mating behaviour as well as male colouration. Colour patterns of natural populations of guppies show marked changes with predation intensity and appear to fulfil the predictions. Males cannot have colour patterns which are too conspicuous, or they will be consumed by predators, but they cannot be too inconspicuous or females will choose other males (Fisher, 1930). In areas of high predation, the background match should be better than in areas with weak predation. On the other hand, sexual selection favours colour patterns which deviate from the background. If both sexual selection and predation occur together, then a compromise must be made. Male guppies under predation risk often switch from their normal courtship sequence, which begins with the conspicuous sigmoid display, to a "sneaky" mating tactics, in which they perform gonopodial thrusts without displaying first. It is probably less conspicuous to predators than sigmoid displays. Moreover, females are also exposed to predation risk during mating activities and sometimes respond to risk by moving away from males (Godin and Briggs, 1996). Well-developed colouration is observed in males that are reared under no predation effect. Bright colouration and mating effect in males is decreasing as the effect of predation is increasing.

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