E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2017; 5(2): 112-117

www.fisheriesjournal.com
Received: 18-01-2017
Accepted: 19-02-2017

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Background adaptation in the *Trichogaster trichopterus*, blue gourami

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Abstract
The observations on the fascinating aspect of animal behaviour dealing with physiological colour change in the fish as a result of adaptation to a lighter and a darker background has been taken up to understand the mechanisms relating to this aspect in a *Trichogaster trichopterus*, blue gourami.
As a result of background response, the rate of colour change by exposure to a light (white) and dark (black) background under constant illumination has been described. For the measurement of response, Munsell Colour Index including (figs.3 and 4). The various grades representing body shade, was utilized. These grades were matched to the changes in body shade during adaptation to specific background by necked eye and it represents a subjective method. The results, obtained clearly indicate that the responses are biphasic where initial response is faster followed by a slow, gradual and prolonged colour change.
The data recorded clearly indicate the participation of both the nerves and hormone(s) during background responses. It appears that the responses are initiated neurally and cover a large part of colour change which at a later stage is supplemented by hormonal means. The fish requires 30 min for initial faster change in both the backgrounds and then it takes a time of about 5 hr to nearly complete the response. However, on leaving the fish overnight in the appropriate background, same more change in terms of Munsell grades has also been recorded. The maximum paling the fish attains on a white background is 8 Munsell Colour Index. While the maximum darkening equals the grade 2.5.Thus these grades represents the range to which the fish is capable of changing its colour.
The rate of colour changes as a result of adaptation to different backgrounds i.e., white and black do point for a biphasic control, where they appear to be initiated by neural control and completed by simultaneous and synergetic hormonal control in the fish.

Keywords: *Trichogaster trichopterus, Octopus, Chameleon*

1. Introduction
Fish color patterns are shaped by a variety of selective pressures imposed by their predators and prey, their competitors, and their prospective mates. Some of these interactions favor reduced conspicuousness, or crypsis, while others promote the opposite. Plasticity in pigment-based color patterns, or in associated display behaviors, appears to be a common solution to balancing opposing pressures. While the following sections will catalog many striking examples of elaborate color patterns, it is important to note that most fish species have fairly inconspicuous coloration that matches the background in their natural habitat.
Aristotle who is often referred to as the "Father of Natural History" described the colour changes of an *Octopus* and *Chameleon* in his famous book "History of Animal". Although the most perfect physiological colour change is shown by *chameleon*, it cannot be matched with some teleost fishes to change colours and pattern to match their environment.
Considerable number of examples among the higher animals ranging from cephalopods, crustaceans to the poikilothermic vertebrates displays the excellent background-related chromatic adaptations (Parker, 1948; Waring, 1963; Fingerman, 1963; Bagnara and Hadley, 1973) [40, 50, 15, 2]. Among the poikilothermic vertebrates, teleost is the most widely studied group of animals with regard to mechanism of adaptation to a particular background (Fujii, 1969, 1993a, b, 2000; Fujii and Oshima 1986, 1994) [16, 17, 18, 19, 20, 21]. The chromatic systems evolved in fishes are quite complex; many fish species display variable colours and colour patterns (Bhargava and Jain, 1974; Lanzing and Bower, 1974; Kohda and Watanabe, 1982) [5, 34, 30]. These chromatic phenomena have great importance in social communication besides providing protection and assistance in the survival of species in their habitats.

Lot of attention has been paid by many ethologists for examining this aspect of pigmentation as reviewed (Baerends and Bearends, 1950) [4] and some of them are further trying to explain the formation and disappearance of those patterns in terms of differential neuronal control of chromatophores in a restricted area of the skin (De Groot *et al*., 1969; Lanzing, 1977; Bauer and Demski, 1980; Burton, 1980; Douglas and Lanzing 1981; Kohda and Watanabe, 1982; Naitoh *et al*., 1985) [12, 13, 3, 10, 35, 31, 37].

The teleost fishes have the ability to adapt to different backgrounds and likewise they become pale on a lighter background and dark over a dark or black background depending upon the shade of the surrounding (Parker, 1948; Waring, 1963; Bagnara and Hadley, 1973) [40, 50, 2]. This change in the shade of the fish is brought about by rearrangement of pigment granules within various pigment cell types and may take place within few seconds to several hours or days varying form species to species. The importance of time relation in the study of colour changes in teleosts has been realized from the work of Hogben (1924) [26]. On screening the literature on this aspect, it was found that some fishes undergo paling at a faster rate than darkening and some others undergo darkening at a faster rate than paling, for instance, in *Crenilabrus* (von Frisch, 1912) [49] which can change colour chiefly in the reds and yellows, these changes are accomplished in a few seconds only. In *Holocentrus* as reported by Smith and Smith (1935) changes from red to white occur in 5 seconds and the reverse changes from white to red take 10 seconds. *Ameiurus* takes 36 hrs to blanch and 19 hrs to darken completely (Parker, 1934) [39]. *Fundulus heteroclitus* requires 2 min for paling and only 1 min for darkening (Parker and Brower, 1937) [41]. *Salmo salar* (Neill, 1940) [38] attains maximum paling in 10 hrs but maximum darkening in only 30 min. *Mollienesia latipinna* (Pierce, 1941) [42] becomes completely pale in 20-50 seconds and completely dark in 10-25 seconds. *Rasbora daniconius* (Dwivedi, 1972) [14] requires 48 hrs for paling and only 5 hrs for darkening. *Nandus nandus* (Jain, 1975) [27] takes 3 hrs to attain maximum paling and 5 hrs for maximum darkening. *Clarias batrachus* (Jain and Bhargava, 1978) [6] takes 10 hrs for paling and 20 hrs for darkening. *Heteropneustes fossilis* (Bhargava and Jain, 1978) [6] takes 60 hrs for paling and 100 hrs for darkening. *Labeo rohita* and *Cyprinus carpio (*Bhatnagar, 1985) [9] take 5 hrs and 3 hrs respectively to attain paling or darkening in them. *Labeo gonius* (Prabhakar, 1988) [43] however, takes 7 hrs to achieve paling or darkening. *Trichogaster fasciatus* (Bhargava *et al.,* 1991a, b) [7, 8] and *Trichogaster trichopterus* (Handa, 2007) takes only 20 and 30 min for complete paling or darkening. *Nuria danrica* (Bhargava *et al.,* 1991a, b) [7, 8] takes 15 min and 40 min for attaining full paling and darkening respectively.

Nervous mechanism seems to dominate in species eg. *Fundulus heteroclitus (*Kleinholz, 1938) [33]*, Macropodus opercularis,* (Umrath and Walcher, 1951) [48] and *Oryzias latipes* (Ando, 1960) [1], where the melanophores are controlled exclusively by nerves and the mechanism appears to have evolved for the rapid background adaptation of animal. The chromatic responses due mainly to endocrine systems are usually slower as reported in species eg. *Anguilla anguilla* (Neill, 1940) [6]. For a gradual and sustained adaptation, the latter kind of co-ordination may be efficient. As a further variation in *eg. Ameiurus nebulosus*, the colour change has been shown to be controlled by the effect of both nerves and hypophyseal hormones. Neopterygii are a highly diversified group of fishes, morphologically, ecologically and behaviourally. The variety of colour change mechanisms that have been identified within various members of the group (Fujii, 1969, 1993a, b, 2000; Fujii and Oshima, 1986, 1994) [16, 17, 18, 19, 20, 21], MSH and MCH receptors and ANS innervation provides many opportunities for comparing adaptational significance of the various regulatory mechanisms.

2. Material and Methods

2.1 Fish Used

There are 16 general and 50 species of *Trichogaster* distributed over Asia, Either sex were used for this study having body length between 7 to10 cm. It inhabits thickly vegetated areas of rivers, canals, ditches, lakes and swamps. The fish were originally obtained from a commercial source and maintained in the laboratory *Trichogaster trichopterus* is bluish white above, dirty white below with 16 dark colored oblique, vertical bands that descends downwards and backwards from back of abdomen. Its dorsal, caudal and anal fins are spotted. *Trichogaster trichopterus* reaches maximum maturity at 12 to 14 weeks of age.

Fig 1: Trichogaster trichopterus

Male *Trichogaster, s* dorsal fin is longer than females and reaches back to caudal peduncle. The three-spot or Blue gourami, *Trichogaster trichopterus*, is a member of the anabantoidei group of air-breathing fishes. It has a very small, dorsally directed mouth, with a vertical, somewhat protractile upper jaw and prominent lower jaw. The species has scales that are moderate in size and irregularly arranged with a curved, irregular lateral line. The dorsal fin is small and the anal fin is elongate, while the caudal fin is slightly emarginated or truncate. The paired ventral pelvic fins are filamentous in which the first ray is elongated and the remainder are vestigial. The fins have a sensory function; they are well endowed with tactile and chemo-receptors and play a role in feeding, courtship and mating, and aggressive activities. In the wild, the three-spot gourami occurs in two main colour morphs: brown and blue, with several variants, many produced through commercial selective breeding. The blue-coloured gourami occurs in two morphs: the "Sumatran" form (present in northern Queensland) which is a relatively uniform blue with two characteristic dark spots of varying intensity on the mid lateral flank and on the caudal peduncle; and the "Cosby" form with a distinct dark shading pattern on the dorsal flank region which tend to obscure the pair of dark "eyespots".

2.2 Care and Maintenance

Fishes collected from the commercial source were brought to laboratory and were stocked in sized transparent glass aquarium (60 x 30 x 30 cm), containing fresh aerated water. As these fishes are omnivorous, they were fed with commercial fish diet, chopped earthworms and planktons. During the experiments feeding was avoided. Water in aquaria was changed by siphoning process that also helps in removal of faecal material and uneaten food. This was done on every third day. Before the experiments the animals were acclimatized to laboratory conditions for at least 15 days. No attempt was made to control the photoperiod and temperature (ranged from 25 to 32°C).

2.3 Background related colour response or chromo motor colour change

To study the colour changes of skin to background tones in light, the healthy fish from the stock tank placed in natural light condition, were taken out and placed in white/black background with overhead illumination. Five fish as experimental groups were placed for a period of 24 hrs in troughs (30x10x10 cm) painted black/white on outside wall and covered with black/white cotton net on the open surface of trough so as to serve as the black/white background respectively.

To study the rate of paling these black adapted fish from the aquarium were gently transferred to white painted glass troughs. The pre-experimental shade was recorded using Munsell grey series colour standards. The colour changes were recorded at regular intervals of time until no further change was noticed for a considerable time period. To study the rate of darkening, white-adapted fish were gently transferred to a black trough and the same procedures as mentioned above were followed.

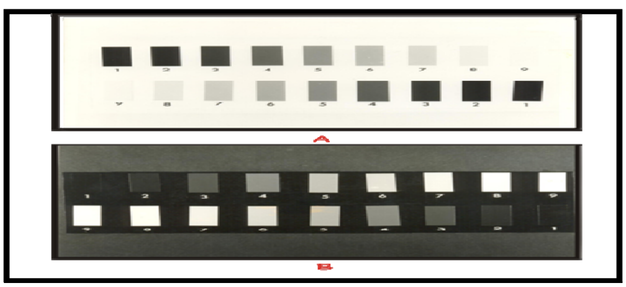

Fig 2: The Munsell Colour Index (MCI) scale as used in measuring the melanophore responses of the fish over two contrasting backgrounds.
(A)White background (B) Black background.

3. Observations and Results

3.1 Rate of paling

When white-or black-adapted *Trichogaster trichopterus* were kept had previously on these respective backgrounds for 24 hours been subjected to background reversal, they showed a quick response by changing their body shade according to their background (fig.3).

Black-adapted fish having pre-experimental shade i.e. grade 2.5 of M.C.I, when placed to adapt on an illuminated white-background attained a grade of 4.8 in first five minutes. In 30 minutes they attained the grade of 6.3. They paled further slowly to attain a grade of 7.8 at 5 hours stage. Subsequently they attained the maximum grade of 8.0 when observed the day next at a stage of 24 hours.

3.2 Rate of darkening

White-adapted fish having the experimental shade i.e., grade 8.0 when transferred to black-background reached to a grade of 6.0 in first 5 minutes. In 30 minutes they attained the grade of 4.1. The fish darkened further slowly and gradually to attain a grade of 2.6 at 5 hours stage. The maximum darkening i.e., grade 2.5 was attained by them when observed at a stage of 24 hours. Thus, the grade within which the fish changes its shade ranges from 8.0 to 2.5 when subjected to adapt to a white- and a black-background. (fig.4).

Fig 3: white adapted fish in a white background.

Fig 4: Black adapted fish in a black background.

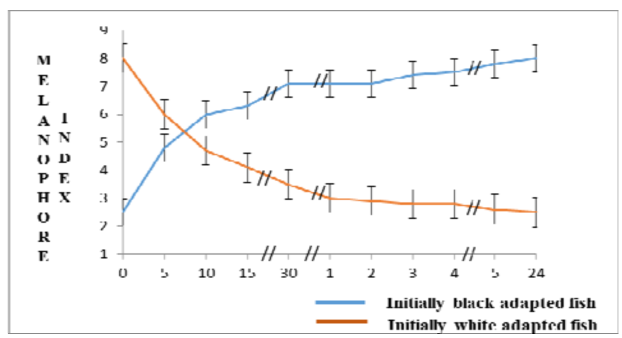

Fig 5: Change in body shade of black and white-adapted fish as a result of adaptation to white and black background with overhead illumination. The values are expressed as mean (5 animals) ±SD (vertical lines) of the mean.

4. Discussion

Majority of teleostean fishes display colour change as a result of background response giving evidence that in them both the hormonal and neural mechanisms are involved and the physiological mechanisms associated with the change of colour is the result of combined effects of hormones and neurotransmitters operating synergistically in these animals.

In the background reversal experiments, a biphasic chromatic response was found. In the first phase the response was rapid covering a larger part of colour change exhibited by the fish. This was followed by the second phase of slow and gradual colour change.

The initial faster background response over the two contrasting backgrounds; the pale and the dark one, as has been recorded in this study in species of the *Trichogaster trichopterus,* clearly appear to implicate a predominant neural co-ordination responsible for initiation and regulation of early phase of background-related chromatic response in the fish. Thus on comparison with other species, the time relations for these background adaptations as recorded here, points clearly that the responses are slower than reported for predominantly nervous reaction of fishes like, *Phoxinus* (Healey, 1951) [24], but faster than reported for the predominantly hormonal reaction of *Anguilla* (Neill, 1940) [6]. As pointed by Collis (1979) [11], it is inadvisable to draw conclusions regarding the relative degree of nervous co-ordination or hormonal influence in such comparisons, since the time period of response may not always be an accurate indication of the mechanism involved.

From a general survey of time relations during adaptation to a light and a dark background in variety of teleosts (Parker, 1948; Waring, 1963) [40, 50], it becomes apparent that the colour changes in teleost are co-ordinated variously where relative influences of neural and endocrine mechanisms operate to regulate these chromatic responses. Parker as early as 1934 segregated the animals into three groups depending on the degree to which neural and endocrine control of melanophores appear to exist. Control entirely independent of neural activity (aneuronic) had been reported in certain forms eg., *Anguilla anguilla,* (Neill, 1940) [6] in which the chromatic responses are very slow that take days or weeks to complete and thus are regulated solely by the activity of blood-borne hormones. On the other hand, mononeuronic melanophores are innervated by a single set of motor nerves, the excitation of which always results in aggregation of pigment and dineuronic ones are innervated by separate aggregating and dispersing fibres. The possibility in many forms, of a combination of neural and hormonal influences, the two systems usually acting synergistically but under some circumstances, one may act independently (Kavaliers and Abbott, 1977) [29].

The *Trichogaster trichopterus* is considerably sensitive in their background (secondary) responses as can be seen by initial phase of the response (15 min stage) which is quite rapid. However, thereafter the colour change as a result of background response becomes slow and gradual and in 5 hrs of time the fish adapt to either of the backgrounds almost fully.

The fishes show a rapid colour change during first 15 min. which suggests a nervous co-ordination. This initial phase in both the experiments *i.e.,* the paling as well as the darkening is fast. In later phase, the rates become greatly subdued and the colour change process continues at slow rate to attain almost the full response in about 5 hrs. However, on being left in the appropriate backgrounds overnight, the fishes on a white background and those on a black background, paled and darkened a little further, respectively.

The results pertaining to this study of transitory or physiological colour change in the fish as a result of background response do suggest that co-ordination of colour change process seems to be not only nervous (to initiate the responses) but also humoral (to supplement the responses) working synergistically.

On comparing the background responses of the fish *Trichogaster trichopterus* with other fish species (Neill, 1940; Waring, 1963; Healey, 1967; Khokhar, 1971; Jain, 1975; Jain and Bhargava, 1978; Bhatnagar, 1985; Prabhakar, 1988; Sharma, 1990; Handa, 2007; Gulzar, 2014; Yaqoob, 2012) [6, 50, 24, 27, 6, 9, 43, 46, 23, 22, 32, 51] it becomes apparent that the colour change in the fish are initiated neurally, and it controls relatively a larger change as reported earlier for *Phoxinus* (Healey, 1951; Pye, 1964) [24, 44], *Lebistes reticulatus, Gasterosteus aculeatus,* and prolonged phase is taken care of by hormonal means.

5. Conclusion

As a result of background response, the rate of colour change by exposure to a light (white) and dark (black) background under constant illumination has been described. For the measurement of response, Munsell Colour Index including (fig.2) the various grades representing body shade was utilized. These grades were matched to the changes in body shade during adaptation to specific background by naked eye and it represents a subjective method. The results (fig.3-4), obtained clearly indicate that the response are biphasic where initial response is faster followed by a slow, gradual and prolonged colour change. The data recorded clearly indicate the participation of both the nerves and hormone(s) during background responses. It appears that the responses are initiated neurally and cover a large part of colour change which at a later stage are supplemented by hormonal means. The fish requires 30 min for initial faster change in both the backgrounds and then it takes a time of about 5 hr to nearly complete the response. However, on leaving the fish over night in the appropriate background, same more change in terms of Munsell grades has also been recorded. The maximum paling the fish attains on a white background is 8 M.C.I. while the maximum darkening equals the grade 2.5.Thus these grades represents the range to which the fish is capable of changing its colour.

6. Acknowledgements

Foremost, I would like to express my sincere gratitude to my Supervisor Prof A. K. Jain, School of Studies in Zoology, Jiwaji University, Gwalior, for the constant encouragement, critical guidance throughout the period of study and making valuable suggestions in order to give this report its present shape. My thanks are due to the U.G.C, New Delhi for various laboratory and physical facilities extended to this department by awarding DRS I & II (SAP) Programmes.

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