APPENDIX
Abstracts: XXXI Annual Conference of Indian Academy of Neurosciences, October 23 - 27, 2013, Allahabad, India

**Methods:** Briefly four groups of rats were exposed to CHR for 11 days assigned as Control-VEH, Control-DRUG, CHR-VEH and CHR-DRUG. On the last day, behavioral assessment was done and immediately brain sample were isolated for histology and biochemical parameters. The morphology of microglia was evaluated by using immunohistochemical binding of actin molecule 1 and tau-1 which is a marker of active microglia. ELISA & western blot were also used to assess the inflammatory status in hippocampus. Results: Our results show that CHR exposure caused morphological changes in microglia. The balance between four subtypes of microglia during its activation process get alter in DG, CA1 and CA3 region of hippocampus along with increased neurodegeneration. L-NAM administration modulates this balance and reduces neurodegeneration as well as improves the behaviour of rats. L-NAM also reduced the level of nitrite oxide & proinflammatory cytokines in brain samples. Western blot analysis also showed the decrease expression of various other markers like IAP-1 receptor, NF-κB, NOS and cox-2 and annexin. Conclusion: From the above study it can be concluded that L-NAM treatment improves functional outcomes of rats during CHR exposure. Inhibiting NO with L-NAM modulates the microglia activation and improves behaviour by regulating neurodegeneration in hippocampus.

**Ethical Statement:** The ethical committee of the Institute approved the experimental protocol and adequate measures were taken to minimize pain or discomfort and the experiments were conducted in accordance with international standard animal welfare as well as being compliant with local and national regulations. Compliance to ICAR Regulations: Yes, Funding Source: The study was supported by Defence Research and Development organisation, Ministry of Defence, Government of India. We are also thankful to Council of Scientific and Industrial Research, New Delhi for providing fellowship for conduct of the study. Competing Interests: The authors declare there is no actual or potential conflict of interest regarding this study.

**EFFECT OF HYPOXIA AND METABOLIC ADJUSTMENTS IN AN AIR-BREATHING INDIAN CATFISH CLARIS BATRACHUS**

**Ajay Kumar, Anit Gopesh**

Department of Zoology, University of Allahabad, Allahabad, INDIA

**Background:** Stress in fishes has been studied quite intensively in a tropical country like India. Hypoxia is one of the major stresses, frequently experienced by fishes. A number of typical responses to stress induced by a variety of factors have been revealed. The effect of hypoxia is manifested at all the three levels, namely, behavioral, morphological and physiological. At biochemical level the effect have been seen in terms of increase in aminotransferases, cortisol and glucose, changes in enzyme activities and blood constituents etc.

**Purpose:** To assess the effect of hypoxia at physiological level change in LDH and Acetylcholinesterase enzyme activity was studied in selected tissues of an air-breathing catfish, Claris batrachus. Methods: Fishes were exposed to experimentally provoked hypoxia for different durations and were sacrificed to study its effect on the LDH and Acetylcholinesterase enzyme activity in heart, liver, brain and muscle, using UV-VIS spectrophotometer. Results: Significant changes were observed in LDH and LDH activity after exposure of Claris batrachus to different period of hypoxia. LDH activity increased in all the tissues after varying periods of hypoxia while AChE activity observed to decrease in same condition. After 48 hours of hypoxia LDH activity go down at almost normal respiratory condition due to aquatic surface respiration (ASR). Conclusion: The observation indicates that different tissues respond differently to the stress of hypoxia and the enzyme activities respond in a tissue specific manner. It is not uniformly distributed across the metabolic pathway.

**Ethical Statement:** No requirement of ethical statement in case of fishes. Compliance to ICAR Regulations: Yes, Funding Source: Defence Research and Development Organisation, Ministry of Defence, Government of India. We are also thankful to Council of Scientific and Industrial Research, New Delhi for providing fellowship for conduct of the study. Competing Interests: The authors declare there is no actual or potential conflict of interest regarding this study.

**EFFECT OF HYPOXIA ON UNPREDICTABLE CHRONIC MILD STRESS INDUCED DEPRESSION IN RATS**

**Neetukushwaha, Satayavarayan Deep, Vishal Jain, Nilofar Khan, Diptri Prasad, Shashi Bala Singh**

Neurobiology Division, Defence Institute of Physiology and Allied Sciences (DIPAS), Delhi, India

**Background:** Role of intermittent hypoxia (IH) as an antidepressant in Unpredictable Chronic Mild Stress (UCMS) which has long been accepted as a model for depression in rats. It refers to periodic exposures to hypoxic conditions interrupted by return to normoxia of less hypoxic conditions. **Purpose:** The present study was designed to find out the neuroprotective role of IH in UCMS induced depression in rats. Methods: Male Sprague Dawley rats were screened out using open field, elevated plus maze and force swim testing and were subjected to UCMS (3 weeks). We found that there is depressive-like behavior in open field, increased anxiety levels is elevated plus maze, and increased the immobility time in force swim test. UCMS was followed by the exposure of hypoxic (1000min, 4hrs/day for 2 weeks) again all behavior tests were performed. Results: It was observed that IH had an antidepressant effect in depressed rats if returned to the behavioral parameters with values almost next to the control. Also morphologically there was increase in the number of pyknotic cells in the UCMS exposed rats which was less in the IH exposed rats. Further, expression levels of BDNF protein were also found to be elevated after giving IH which was otherwise earlier decreased in depressed rats. Conclusion: Results obtained from various behavioral, morphological, and histochemical and biochemical studies support the hypothesis that the intermittent hypoxia has an antidepressant role in animal model of depression and it can be used as a therapy for treating these disorders.

**Ethical Statement:** The project entitled "Neuroprotective role of intermittent hypoxia in Unpredictable Chronic Mild Stress induced depression in rats" has been approved by the Institutional Animal Ethical Committee of DIPAS, Shimla, Delhi-110054. Compliance to ICAR Regulations: Yes, Funding Source: DIPAS, DRDO, DELHI. Competing Interests: None.
Celebrating 100 Years

Indian Science Congress Association

National Seminar

On

Exciting Frontiers of Research in Science and Technology

ABSTRACT

Organized by

Allahabad Chapter of

The Indian Science Congress Association

Department of Chemistry

University of Allahabad, Allahabad
efficient and fast computational methodology which facilitates in understanding the brain connectivity and the effects of neural diseases such as brain tumor through diffusion images. The software can read raw data formats from a variety of MR scanners. The program is developed on a Windows platform using Visual C++ and MFC. As the importance of DT-MRI technology in clinical practice is expected to grow in the near future, the need for resource programs that researchers and clinicians can use to rapidly process DTI data, obtain fiber tracts, and view images in 3D with user-friendly interfaces.

64.

Effect of hypoxia on malate dehydrogenase (MDH) enzyme activity in catfish *Clarias batrachus*

A. Kumar and A. Gopesh
Department of Zoology, University of Allahabad,
Allahabad, 211002(U.P.) India.
E mail: ajay.kumar16july@gmail.com

Hypoxia is one of the major stresses, frequently experienced by the aquatic organism in a tropical country like India. Aquatic organisms which are frequently exposed to hypoxia show adaptations at behavioral, morphological and physiological levels. Among these the air-breathing catfishes are of special interest, as these have special capacity to tolerate the longer periods of hypoxia and drought. To assess the effect of hypoxia at physiological level, change in MDH enzyme activity in selected tissues of an air-breathing catfish *Clarias batrachus* was undertaken. Fish were exposed to experimentally provoked hypoxia for different duration and were sacrificed to study the effect on the MDH enzyme activity in heart, liver, brain and muscle. The MDH enzyme activity has been measured using UV-VIS spectrophotometer. Significant changes were recorded. The observations indicate that different tissues respond differently to the stress of hypoxia and the enzyme activity respond in a tissue specific manner.

65.

Heavy Metal Chromium Disrupts Endocrine Physiology of Fish: Assessment of Hormonal Profiles of a Freshwater Teleost, *Channa punctatus* (Bloch)

Ashish K. Mishra and Banalata Mohanty
The National Academy of Sciences, India
(The Oldest Science Academy of India)

82nd Annual Session and National Symposium on "Nano-science & Technology for Mankind"
November 29-December 01, 2012

Organized by
Banaras Hindu University (BHU), Varanasi (U.P.)

Section of Biological Sciences
ABSTRACTS OF PAPERS
dorsolateral corticoid area (CDL). Dorsolateral corticoid area (CDL) has shown very strong connection with hippocampal formation, in birds is a thin superficial part of tectcephalic pallium. The hippocampal formation is a component of the avian limbic system, and the CDL has been considered as a part of limbic system ill birds. The limbic system plays an important role in emotion, cognition, and memory processes. Spires a membranous profusion present on dendrites function as primary postsynaptic structure. They enhance dendritic surface area for making synaptic contacts and helps in transmitting signals to neurons cell body.

Multipolar, pyramidal and unipolar neurons were identified. In both the region i.e. CDL, multipolar neurons exhibit higher spine density indicating more contribution of multipolar neurons towards the functioning of corticoid complex. Unipolar neurons possess minimum spine density, in CI region and in CDL region pyramidal has low ext spine density.

On comparing between the region CI and CDL, CI seems to be more efficien; than CDL since it posses higher spine density for all types of neurons.

150. Seasonal dynamics in neurons in hyperpallium apicale of male Baye Weaver bird, *Ploceus philippinus* (Linnaeus, 1766)

PARUL GAUR and U.C. SRIVASTAVA

*Department of Zoology, University of Allahabad, Allahabad 211002.*

The cellular organization of Hyperpallium apicale (HA) of Wulst of a seasonally breeding male Baye Weaver bird, *Ploceus philippinus* (Linnaeus, 1766) was studied in Nissl and Golgi-stained brain sections principally to identify various neurons present and also to assess seasonal variations (during breeding and non-breeding period) in them. Various lesion studies indicate the importance of wulst ill learning processes such as some reversal learning and navigational behavior or sun-compass associative learning. In Nissl study, HA, the most superficial lamina or the wulst, was found bordered ventrally by the interstitial nucleus of the hyperpallium apicale (IHA) followed by hyperpallium intercalatum (HI) and hyperpallium densocellulare (HD). Three types of neurons viz. multipolar, pyramidal and stelate were identified using Golgi method in HA according to their various morphological parameters, such as soma shape, size, dendritic branching pattern and extent etc. Quantitative study of Golgi-impregnated dendrites from various neuronal types revealed appreciable cyclic fluctuations ill dendritic thickness and spine density. Significant increase during breeding as compared to non-breeding period in these attributes were noticed (P<0.05) suggesting that hormonal variations and increased activeness during breeding season may result ill behavioral charges accounting for enhanced neuronal parameters as reported in this study.

151. Lactate dehydrogenase (LDH) enzyme activity in experimentally provoked hypoxic fish species *Clarias batrachus*

A. KUMAR and A. GOPESI

*Department of Zoology, University of Allahabad, Allahabad, 211 002 (U.P.)*

Hypoxia is one of the major stresses frequently experienced by the aquatic organism in a tropical country like India. Aquatic organisms which are frequently exposed to hypoxia, show
adaptations at behavioral, morphological and physiological levels. Among these the air-breathing catfishes are of special interest, as these have special capacity to tolerate the longer periods of hypoxia and even the long duration of drought. The effect of hypoxia is manifested at all the three levels namely behavioral, morphological and physiological. To assess the effect of hypoxia at physiological leve, change in LDH enzyme activity in selected tissues of an air-breathing Indian catfish *Clarias batrachus* was undertaken. Fish were exposed to experimentally provoked hypoxia for different duration and were sacrificed to study the effect on the LDH enzyme activity in heart, liver, brain and muscle. The LDH enzyme activity has been measured using UV-VIS spectrophotometer. Significant changes were recorded. The observations indicate that different tissues respond differently to the stress of hypoxia and the enzyme activities respond in a tissue specific manner. It is not uniformly distributed across the metabolic pathway. The results are discussed in the light of tissue specificity.

152. Electrospinning - A paradigm in nano/fiber technology for biomedical application

ABHIJEET SINGH MEHTA, KIRTI SNIGDHA and R.P. TEWARI

*Department of Applied Mechanics (Biomedical Engineering), Motilal Nehru National Institute of Technology, Allahabad-21 1004 U.P.*

The process of creating nanofibers through an electrically charged jet of polymer solution or melt is electrospinning. This technique applicable to virtually every soluble or fusible polymer is capable of spinning fibers in a variety of shapes and sizes with a wide range of properties to be used in a broad range of biomedical and industrial applications. Requiring a very simple and economical setup, it is an involute process that depends on several molecular, processing, and technical parameters. A brief look in the evolution of electrospinning suggests a lot of work being reported and published after the year 2000 by many researchers. This review article presents the work done in last twenty years on various natural polymers, co-polymers and polymer mixtures used for fabrication of scaffolds using electrospinning technology in the field of biomedical engineering.

153. Perspectives of chitin, chitosan and silk fibroin electrospun nano/nofibrous scaffolds and its application in tissue engineering

ABHIJEET SINGH MEHTA and KIRTI SNIGDHA

*Department of Applied Mechanics (Biomedical Engineering), Motilal Nehru National Institute of Technology, Allahabad-21 1004, U.P.*

Intensive studies of a wide range of polymeric scaffolds have been done for use as implantable and temporal devices in tissue engineering. Biodegradable and biocompatible scaffolds having a highly open porous structure and good mechanical strength are needed to provide an optimal microenvironment for cell proliferation, migration, and differentiation, and guidance for cellular in-growth from host tissue. Bopolymer chitin and its deacetylated derivative, chitosan, are non-toxic & biodegradable. They have shown potential in biomedical applications such as tissue engineering scaffolds, wound dressings, separation membranes, antibacterial coatings, stent coatings, and sensors. Recent studies indicate use of electrospun chitin and chitosan nanofibrous scaffolds to produce tissue engineering scaffolds with
The National Academy of Sciences, India
(The Oldest Science Academy of India)

81st Annual Session and National Symposium on
"Sustainable Management of Biodiversity using Science & Technology"

November 24-26, 2011

Organized by
University of Kerala, Kariavattom-695 581
(Thiruvananthapuram)

Section of Biological Sciences
ABSTRACTS OF PAPERS
Fish appear to be good indicators of the status of aquatic communities and river environments and fish are often key elements in environmental planning. *Cyprinus carpio* is an alien fish species in the India. Present investigation was carried out during January 2008 to December 2009 at Sadiaput fish landing centre on the bank of the Yamuna river at Allahabad. Studies were undertaken to assess the age composition, growth rate and age pyramid of *C. carpio* var. *communis*. Age composition varied from 0 to 13+ age groups. The maximum growth was recorded at 1 ± year (26 cm) and minimum at the 9+ year (3.01 cm) of the life cycle. Growth of *C. carpio* was higher than that of *C. carpio* in Europe and Australia. According to percentage, 0 age group shared 75.5% only. Age group 1+ was dominant (24.60%), which was observed to be nearly one fourth of the total collected samples. The difference was very high in 0 to 1+ age groups (17.16%). The age groups 0, 2+, 3+, 4+, 5+, 6+, 7+, 8+, 9+10+11+, contributed 7.5%, 18.38%, 15.48%, 9.84%, 5.35%, 3.90%, 3.19%, 3.04%, 2.74%, 2.60% and 1.59%, respectively. The remaining age groups (12+ to 13+) contributed below 3% of the sample.

140. Effect of experimentally provoked hypoxia on the Acetylcholinesterase (AChE) enzyme activity in selected tissues of an air-breathing fish, *Clarias batrachus*

A. KUMAR, A. GOPESH and SUSHMA

Department of Zoology, University of Allahabad, Allahabad-211002(U.P.)

Hypoxia is one of the major stresses which is frequently experienced by the aquatic organism in a tropical country like India. Aquatic organisms which are frequently exposed to hypoxia, show adaptations at behavioral, morphological and physiological levels. Air-breathing catfishes are a group of teleosts which have special capacity of withstanding the long periods of hypoxia and even the long drought condition. The effect of hypoxia is manifested at all the three levels namely behavioral, morphological and physiological. To assess the effect of hypoxia at physiological level, change in AChE activity in selected tissues of an air-breathing Indian catfish *Clarias batrachus* was undertaken. Fish were exposed to experimentally provoked hypoxia and were sacrificed at different stages of it to study the effect on the AChE enzyme activity in brain and muscle of the fish. The AChE activity has been measured using UV-VIS spectrophotometer. The result obtained in experimental fishes has been compared with those of controlled ones. The observation indicates that different tissues respond differently to the stress of hypoxia and the enzyme activities respond in a tissue specific manner. It is no uniformly distributed across the metabolic pathway. The results are discussed in the light of tissue specificity.

141. Influence of leaf powder of *Melia azedarach*, *Eucalyptus* and *Caesalpinia roscus* on oviposition of *Tribolium castaneum* (herbst)

SUDHAKAR GUPTA¹ and MONIKA GUPTA²

¹Department of Life Science, Lovely Professional University, Phagwara, Punjab
²Department of Chemistry, Lovely Professional University, Phagwara, Punjab

The egg laying in untreated adults of *Tribolium castaneum* started on the fourth day (6.66 eggs per female) after emergence of adults. Subsequently, the mean total number of eggs laid per female in 20 days were 196.6 (100%). At 1 and 2% treatments with *Melia azedarach* leaf
Dear Author,

Here are the proofs of your article.

- You can submit your corrections **online**, via **e-mail** or by **fax**.
- For **online** submission please insert your corrections in the online correction form. Always indicate the line number to which the correction refers.
- You can also insert your corrections in the proof PDF and **email** the annotated PDF.
- For fax submission, please ensure that your corrections are clearly legible. Use a fine black pen and write the correction in the margin, not too close to the edge of the page.
- Remember to note the **journal title**, **article number**, and **your name** when sending your response via e-mail or fax.
- **Check** the metadata sheet to make sure that the header information, especially author names and the corresponding affiliations are correctly shown.
- **Check** the questions that may have arisen during copy editing and insert your answers/corrections.
- **Check** that the text is complete and that all figures, tables and their legends are included. Also check the accuracy of special characters, equations, and electronic supplementary material if applicable. If necessary refer to the *Edited manuscript*.
- The publication of inaccurate data such as dosages and units can have serious consequences. Please take particular care that all such details are correct.
- Please **do not** make changes that involve only matters of style. We have generally introduced forms that follow the journal’s style. Substantial changes in content, e.g., new results, corrected values, title and authorship are not allowed without the approval of the responsible editor. In such a case, please contact the Editorial Office and return his/her consent together with the proof.
- If we do not receive your corrections **within 48 hours**, we will send you a reminder.
- Your article will be published **Online First** approximately one week after receipt of your corrected proofs. This is the **official first publication** citable with the DOI. **Further changes are, therefore, not possible.**
- The **printed version** will follow in a forthcoming issue.

**Please note**

After online publication, subscribers (personal/institutional) to this journal will have access to the complete article via the DOI using the URL: http://dx.doi.org/[DOI]. If you would like to know when your article has been published online, take advantage of our free alert service. For registration and further information go to: [http://www.link.springer.com](http://www.link.springer.com).

Due to the electronic nature of the procedure, the manuscript and the original figures will only be returned to you on special request. When you return your corrections, please inform us if you would like to have these documents returned.
Effect of Hypoxia and Energy Conservation Strategies in the Air-Breathing Indian Catfish, *Clarias batrachus*

Fish in a tropical country like India are frequently exposed to different duration of hypoxia. The effect of hypoxia on the physiology of fish, air-breathing catfish *Clarias batrachus* were exposed to different duration of hypoxia and its effect on activities of lactate dehydrogenase (LDH) and malate dehydrogenase (MDH) were studied in four tissues (heart, liver, brain and muscle). The specific activity of LDH increases in all tissues, which reflects towards onset of anaerobic respiration and decrease in energy demand in all these tissues. In contrast, MDH specific activities were decreased significantly in heart, suggesting involvement of strong aerobic respiration in heart during hypoxia. The present investigation revealed that during hypoxia enzyme activities responded in a tissue-specific manner in the fish *C. batrachus* reflecting the balance of energetic demands, metabolic role and oxygen supply of particular tissues.
Effect of Hypoxia and Energy Conservation Strategies in the Air-Breathing Indian Catfish, *Clarias batrachus*

A. Kumar · A. Gopesh

Received: 6 November 2013/Revised: 7 May 2014/Accepted: 18 December 2014

© The National Academy of Sciences, India 2014

**Abstract** Fish in a tropical country like India are frequently exposed to different duration of hypoxia. The effect of hypoxia on the physiology of fish, air-breathing catfish *Clarias batrachus* were exposed to different duration of hypoxia and its effect on activities of lactate dehydrogenase (LDH) and malate dehydrogenase (MDH) were studied in four tissues (heart, liver, brain and muscle). The specific activity of LDH increases in all tissues, which reflects towards onset of anaerobic respiration and decrease in energy demand in all these tissues. In contrast, MDH specific activities were decreased significantly in heart, suggesting involvement of strong aerobic respiration in heart during hypoxia. The present investigation revealed that during hypoxia enzyme activities responded in a tissue-specific manner in the fish *C. batrachus* reflecting the balance of energetic demands, metabolic role and oxygen supply of particular tissues.

**Keywords** Catfish · Hypoxia · Surfacing behaviour · LDH · MDH

Hypoxia is an environmental stressor, caused by normally large temporal and spatial variations in oxygen content of water [1]. Animals are known to adopt different mechanisms to tolerate hypoxia. Many of these responses are behavioural, including surface breathing, reduced activity, and/or increased ventilation rate [2]. Maintenance of low levels of activity is fuelled by anaerobic metabolism and decrease in metabolism accomplished by decreasing enzyme activity and consuming processes [3, 4]. In addition to these responses, some species have evolved additional physiological or molecular mechanisms and the capacity to undergo sustained metabolic depression or to up-regulate anaerobic glycolysis [5].

Lactate dehydrogenase (LDH, lactate; NAD-oxidoreductase, EC 1.1.1.27) and malate dehydrogenase (MDH, L-malate: NADH oxidoreductase, EC 1.1.1.37) are among the most extensively studied enzymes [6–17]. LDH is a glycolytic enzyme [6–12] whereas MDH is an enzyme involved in gluconeogenesis and lipogenesis and in the malate–aspartate shuttle during aerobic glycolysis [13–16]. With an aim to investigate the effect of hypoxia on the metabolism of LDH, an enzyme of anaerobic respiration and MDH, an enzyme of oxidative respiration was undertaken on an air-breathing catfish *Clarias batrachus*.

Experiments were set for determination of enzyme activity at different duration of hypoxia on normal healthy specimens of *C. batrachus*. Each fish (52.00 ± 2.3 g, 19.2 ± 0.2 cm) was introduced in 5 L glass jar and the lid was then sealed with melted wax. Fish were allowed to stay in the jar undisturbed and constantly observed for behaviour pattern. The fish were taken out at 24, 48 and 72 h of hypoxia and were dissected quickly to take out muscle, heart, brain and liver from it and processed for different observation specifically.

LDH activity in cell free extracts of muscle, liver, heart and brain was measured by a NADH linked optical assay following the method of Horecker and Kornberg [18]. MDH activity was determined by conversion of oxaloacetate to malate. Enzyme activity was expressed in μmole min⁻¹ mg protein⁻¹. The molar extinction coefficient of
NADH at 340 nm (6.22 × 10³ M⁻¹ cm⁻¹) was used for calculating the enzyme activity.

The data were expressed as mean ± SE values and analyzed using one-way ANOVA followed by Tukey’s post hoc test to determine homogenous subsets. In all cases, α level of 5% (p ≤ 0.05) was selected to signify differences.

Experiments performed on specimens of *Clarias batrachus* exposed to hypoxia showed significant differences in enzyme activity from the fishes in normoxia at 25 °C. A marked pattern of behaviour was observed in accordance with the physiological changes observed during different periods of hypoxia. Another significant observation from present investigation has been the recording of tissue-specific response to hypoxia.

LDH activity was observed to be increased in the heart after 24 h and was recorded to go down up to nearly normal condition after 48 h of hypoxia. No pronounced change was observed in LDH activity in liver and brain during different periods of hypoxia. In muscle, activities were almost 50% higher than in heart. Significant changes in LDH activities were observed between normoxia and 72 h of hypoxia in muscle and heart when the fish were found in moribund condition (Fig. 1).

After 24 h of hypoxia MDH activity was observed to be decreased in heart and liver while it remained unchanged in brain and muscle. It was observed to be increased slightly as compared to normal condition in heart and liver after 48 h exposure of hypoxia. Further decrease was observed in MDH activity between 72 h of hypoxia and normoxia in heart and liver. The enzyme activities remained unaffected in brain and muscle tissues at this stage also (Fig. 2).

In the present investigation undertaken on catfish *C. batrachus* significant changes in the activities of two selected enzymes LDH and MDH were observed in response to experimentally provoked hypoxia. The level of LDH, a glycolytic enzyme showed increase in muscles at the initial stages of hypoxia. This fluctuation seems to be related with the onset of anaerobic pathways. It may also be correlated with up and down movement of fish in experiment at the onset of hypoxia. The high LDH accumulation in the muscle is in accordance with the behavioural response observed after which the fish resumes “surfacing behaviour” utilising the residual air present at the surface. Specific activities of glycolytic enzyme in muscle have been correlated with the burst swimming activity of fish in response to various stresses in Atlantic Cod *Gadus morhua* [17, 19]. Close to normal levels of LDH recorded in brain, liver and heart indicated towards tendencies of these aerobic tissues to avoid anaerobic respiration [16]. These tissues are known to regulate LDH level according to available environmental oxygen, so that less of lactate accumulates in these tissues.

Higher levels of MDH have been recorded in heart and liver in *C. batrachus*. The role of this enzyme in the metabolism is to supply intermediary metabolites (oxaloacetate) for the Kreb’s cycle used as source of carbon in oxidative metabolism [20]. Thus, the higher levels of MDH observed in heart reflects the role of this enzyme for cardiac tissues after 48 h of hypoxia. This pattern is similar for liver which shows role of MDH in gluconeogenesis [13, 20].

Present investigations clearly support the earlier observation undertaken on other teleosts [6–16] and air-breathing fish *C. batrachus* [21]. *C. batrachus* was observed to undergo a series of coordinated metabolic adjustments which aims at balancing an overall suppression of system metabolic ATP demand along with proportionate increase in fractions of remaining metabolism that is supported by anaerobic glycolysis alone [6, 10]. One of the major responses to hypoxia has been recorded to be an increase in anaerobic ATP production via glycolysis [17, 19]. Number of
observations are on record which revealed that exposure to hypoxia increase the activities of glycolytic enzymes that presumably augment the capacity of fish tissues for anaerobic energy production [9, 20]. Although there is an extensive background of work in general and specific properties of LDH [6, 9] a single answer for enzyme responses has not been reached [10, 12] which needs to be addressed with more in depth targeted investigations.

Acknowledgment Authors express their gratefulness to the Head, Department of Zoology, University of Allahabad, for providing all the facilities needed. The award of BSR fellowship to one of the authors under RFSMS of U.G.C. SAP-FIST programme is also thankfully acknowledged.

References