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Research Article

THE ATRI HOT SPRING IN ODISHA - A NATURAL ECOSYSTEM FOR GLOBAL WARMING RESEARCH

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ABSTRACT
Global warming has been a challenging environmental problem in the recent decades. For managing and surviving the negative impacts of high temperature stress, specific preventive measures need to be developed. The organisms constantly exposed to high temperature stress, like fishes inhabiting the hot-spring runoffs might be able to provide insights and clues to develop strategies to cope with the climate extremes like high-temperature stress. The Atri hot spring located in eastern India appears to be a natural ecosystem for global warming research. The hot spring runoff joins to a nearby rivulet thereby providing connectivity to the hot spring water. A variety of aquatic flora and fauna including fish are found to inhabit this place and these organisms could be useful for understanding the mechanism of thermal acclimation and thermotolerance. Fishes present in the hot spring runoff can be utilized for investigating physical, biochemical and metabolomic responses to the adaptation pressure and the prevailing high temperature stress as observed in our preliminary investigations. The rivulet is relatively free from pollution as anthropogenic activities are less and it is not receiving effluents; thus temperature is the major abiotic stress. All these factors make the Atri hot spring an ideal, natural ecosystem for global warming research and it could perhaps be developed as a 'hot spring research laboratory'.

***Keywords**: Atri, Hot Spring, Climate Change and Global Warming, Fish, Thermal Acclimation, Thermal Adaptation*

INTRODUCTION
Global warming refers to the increase in the average temperature of the earths near surface air and oceans since the mid-twentieth century and its projected continuation, and implies an anthropogenic influence (Doran and Zimmerman, 2009; Chen *et al.*, 2013). It has become a challenging environmental problem in recent decades (IPCC, 2007; Mohanty and Mohanty, 2009; Mohanty *et al.*, 2010). Increase in global temperatures has been projected to lead to broader changes, including glacial retreat, arctic shrinkage, and worldwide sea level rise. There has been undeniable evidence on how changing climate and global warming together have had profound effects on our planet as well as the ecosystem as a whole. Climate change has been implicated in rapid pole ward shifts in distributions of fish and plankton in regions such as North East Atlantic, where temperature change has been rapid and there have been mass mortalities of several aquatic species including plants, fishes, corals and mammals (Harvell *et al.*, 1999; Brander, 2007). Because many disease pathogens and carriers are strongly influenced by temperature, humidity and other climate variables, climate change may also influence the spread of infectious diseases or the intensity of disease outbreaks. Many plants and animals have already begun to respond to the changing climate but are struggling to adapt to the climate change.

Organisms have adapted to low temperature extremes in the Antartics

Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, by lessening the harmfulness or by exploiting the beneficial opportunities. For survival in a changing environment, animals and plants must be able to fit or adapt to the changing environment occurring in their habitat. The Antarctic animals have adapted well to the harsh

Antarctic environment which made it possible for them to survive in an environment where the temperature is perennially low and during winter falls to -8 to -12 ^{o}C. Studies on the physiological, biochemical and molecular basis of adaptations in these animals have contributed to the mechanistic understanding of 'how they cope with such extreme climatic conditions', and 'what makes them different from their temperate counterparts'. The presence of blood-borne anti-freeze proteins (AFPs) in Winter flounder and other Antarctic organisms provide them the capability to survive in the frigid marine environment (Marshall *et al.,* 2004; Marshall *et al.,* 2005; Patel and Graether, 2011). The AFPs prevent freezing of the body fluids by binding with ice crystals resulting in freezing point depression or 'thermal hystereses. Other than AFPs, in response to low temperature stress, the up-regulation of stress proteins (heat shock proteins, HSPs) such as HSP70 has been demonstrated in several species of Antarctic notothenoid fishes (Clark *et al.,* 2008). Another important feature of the Antarctic notothenoids is the high degree of cold stability of their constituent eye lens proteins which prevents development of cold-cataract and hence, the lens transparency is maintained even at the perennially freezing subzero temperature, as low as -12 ^{o}C (Kiss *et al.,* 2004). The lens proteins (crystallins) possess high protein density-constrained mobility thus reducing the propensity of the cold-induced structural rearrangement. Thus, starting from the regulation of membrane proteins by altering the lipid composition of the membranes to increasing the mitochondrial density and capillaries in skeletal muscles, the mechanism of adaptation varies in all aspects in animals acclimatized to cold temperatures.

Surviving the high temperature stress under projected climate change regime

In contrast to the temperature extremes faced by the Antarctic organisms, the animals inhabiting the tropical environment face high temperature stress, which is projected to go up under the climate change regime. To prevent the ill effects of high temperature stress, including sudden shock and death upon exposure to heat stress, specific preventive measures need to be found out. The organisms constantly exposed to high temperature stress, like fishes inhabiting the hot-spring run-offs, might provide clues on 'how to cope with high-temperature stresses. The acquired thermo tolerance mechanisms operating in these lower vertebrates living in stressful environment might provide the insights to develop strategies to cope with the climate extremes, especially the high-temperature stress and global warming.

Hot springs

Hot springs are sites that discharge hot ground water, the temperature of which is notably higher than the ground water. The springs usually emerged along the deep faults or fissure of earth along which the ground water comes out. The high temperature of hot spring water is because of the geothermal energy, exothermic recations and disintegration of radioactive elements (Mahala *et al.,* 2013). Usually, hot spring water contains a wide range of minerals like alkali, alkaliline metals, sulphates, carbonates and trace elements (Reddy *et al.,* 2013). The dissolved minerals are found because of the water-rock interaction. Therefore, the water of hot springs is thought to have medicinal properties and is used in folklore medicine. It also contains gases like hydeogen sulphide (H_2S), carbon dioxide (CO_2) and low amount of oxygen (Mahala *et al.,* 2013) and the sulphorus odor of the hot spring water may be because of such gases.

There are about 340 hot spring in India out of which 8 are present in the state of Odisha. These hot springs are located within the Eastern Ghat mobile belt, North Odisha craton and Western Odisha proterozoic sedimentary basins. The water temperature of these hot springs range from 32 - 67 ^{o}C (Bisht *et al.*, 2011).

The Atri hot spring- An ideal ecosystem for global warming research

We surveyed many hot springs in eastern India, especially in West Bengal and Odisha, with the objective of identifying a natural system for investigating acclimation and adaptation to thermal stress in eukaryotes. Out of the springs surveyed, the Atri hot spring appeared to be an ideal ecosystem for this purpose.

Atri hot spring is located in the Khurda district of Odisha (20^{o}09'N 85^{o} 18'E) in eastern India. The hot spring takes its name from the village Atri where it is located and as per the revenue records it exists for many centuries. As this area is a low seismic zone, there has been no change in its flow and existence. The hot spring has a religious dimension also; its water is considered pious and there are some temples located nearby. It is a place of tourists' attraction and is justifiably maintained by the state-run tourism development corporation. The main source of the spring at Atri has a circular tank (Fig. 1), the temperature of which has been recorded to be at 57-58 ^{o}C, except the rainy season. The water from this tank is then channelized in to cemented tanks outlets to prevent stagnation where it is used for bathing. The outlet which carries the hot-spring run-off water, temperature of which is about 38 ^{o}C connects to a nearby rivulet, a branch of river Rananadi; the temperature of the confluence and immediate periphery remains about 36-38 ^{o}C.

Figure 1: Atri Hot spring, Odisha: Atri hot spring located in a small village called Atri is about 42 km from Bhubaneswar, is famed for its hot sulphur water spring (A). The temperature of the spring water is 58 ^{o}C which always remains steady (B), is believed to have medicinal properties for curing skin diseases. The bathing complex, located close to the spring provides steam bathing facilities for the tourists. For this, water of the hot spring is collected in a reservoir with a depth of around 15 feet and a circumference

of 10 feet (C) and it is provided to the tourist with outlets to prevent stagnation (D). This outlet which carries the hot-spring run-off water temperature of which is about 38 ^oC connects to a nearby rivulet (E) branch of river Rananadi, the temperature of the confluence and immediate periphery remains at about 36-38^oC and fishes are present in this hot water (F).

Table 1: Physico chemical parameters of soil and water samples collected from Atri hot spring and the confluence point of hot spring runoff water and river Rananadi (samplings were done during May 2013)

S. No.	Analysis Parameters	Main Tank (Water)	Confluence (Water)	Confluence (Soil)
1	Color	Clear Transparent	Clear Transparent	-
2	Odour	Sulphorous	Odorless	-
3	Temperature (^oC)	56	36	
4	Total dissolved solids (ppm)	309	312	-
5	Turbidity (NTU)	1.0-1.5	1.2-1.7	5.5
6	pH (units)	8.4	7.7	7.85
7	Salinity	1.2%	1.2%	1.2%
8	EC ((mS/cm))	0.618	0.609	0.615
9	Nitrite- Nitrogen (µg/ml)	0.0129	0.09	0.38
10	Nitrate- Nitrogen (µg/ml)	6.71	5.56	3.02
11	Ammonia (mg/l)	0.2	0.45	0.76
12	Inorganic phosphate (mg/l)	0.16	0.17	0.48

Physicochemical studies of the water of the main tank as well as the confluence point was carried out following standard methods as prescribed by APHA (2005). The pH of the water of the main tank was found to be 8.8 while the electrical conductivity and nitrate content was 618 µS/cm and 6.71 mg/ml, respectively, similar to that of the previously reported values by Das et al. (2013). The physico chemical properties of the main tank water have been studied by earlier workers (Das *et al.*, 2012 and 2013). However, no such data were available for the confluence point. The pH of water at the confluence zone was 7.7 (Table 1), which according to the Central Pollution Control Board, falls under the category D and can be used for propagation of wild life and fisheries (CPCB 2007). Dissolved oxygen (DO) is an important indicator of water quality. The average DO of the main tank water has been reported to be 6.095 which gradually changed to 6.23 - 7.17 as the water flows down towards the canal connecting the rivulet making it suitable for growth of phytoplanktons and zooplanktons (Das *et al.*, 2013, 2012). Inorganic phosphate is a limiting factor for survival of various aquatic organisms. The inorganic phosphate concentration of the main tank water was found to be 0.16 mg/ml (Table 1), which is higher than the value reported earlier (0.015 mg/ml) by Das et al. (2013). The phosphate concentration of the confluence zone water was also found to be 0.17 mg/ml (Table 1), which is within the range prescribed for fisheries and aquaculture (Stone and Thomforde, 2004).The average chloride concentarion of the main tank has been reported to be 263.5 mg/ml which showed positive correlation with water temperature which decreased from the main tank to the subsequent overflows (Das *et al.*, 2013). The electrical conductivity and nitrate content was found to be 609 µS/cm and 5.56 mg/ml, respectively (Table 1).

The main tank water has sulphorus smell which could be because of the formation of hydrogen sulphide due to interaction between the water and sulphide mineral bearing rocks (Mahala *et al.*, 2012). However, the confluence point water was found to be odorless which might be due to the dilution with the river water. The Atri hot spring water is known to have minerals like calcium, magnesium, nitrate, sulphate, fluorine and chlorine (Das *et al.*, 2013). It also harbors a wide range of zooplanktons like Copepod spp., Diatoms, Rotifers, Cladospora (Das *et al.*, 2012) and phytoplanktons like Chlorophycea, Cyanophycea, Bacilarophycea and Euglenophycea in the overflow tanks (Das *et al.*, 2012).

Hot springs have long been of interest to geologists and biologists. However, biological research in hot springs is so far confined to microbiological and metagenomic investigations. Atri hot spring distinguishes itself from others in having existence of higher life forms like fish (lower vertebrates) at its confluence with the rivulet, thus making it unique as an ideal ecosystem that offers a scope to carry out investigations on fishes constantly exposed to thermal stress. Experimental fishing at the confluence zone showed presence of miscellaneous fish and shellfish species including the minor carps *Puntius sophore* and *Cirrhinus reba* (occasionally), the murrel *Channa striatus* and prawns (Yadav, 2012). Investigations on the heat shock (stress) protein (Hsp) gene expression profile, muscle proteome profile, amino acid composition and GC-MS fingerprinting of fatty acids in *Puntius sophore* and *Channa striatus* collected from the hot spring runoff has been carried out, using fish of same species collected from aquaculture ponds from nearby areas as control. Preliminary findings look exciting (Yadav, 2012; Mahanty *et al.*, 2013a, b, c). *Puntius sophore*, belongs to the same family (Cyprinidae) as Zebrafish *Danio rerio*, one of the most well studied animal models, and is available almost round the year in Atri. The complete blueprint of the genome of *Danio rerio* available would facilitate for molecular studies on its cousin *Puntius sophore* for understanding thermal acclimation and adaptation to high temperature.

Epilogue

The Antarctic animals have adapted to the harsh Antarctic environments because of the blood-borne anti-freeze proteins and other adaptation mechanisms. Synonymous with AFPs, the organisms (fishes) constantly exposed to high temperature in the hot spring runoffs, can be ideal candidates for searching for novel heat tolerance proteins (HTPs), which could be helpful in thermal stress management in humans and animals. *Puntius sophore* and *Channa striatus* appear to be ideal candidates for such studies (Mahanty *et al.*, 2013c). Keeping in view, the attention it is getting of late, from experts and investigators from different fields, like geologists, environmentalists and biologists, the Atri hot spring perhaps can be developed in to a class 'Hot Spring Research Laboratory'.

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