GENETIC SIGNALS IN CLIMATE CHANGE

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Abstract

Industrialization which has enhanced rapid population increases and better livelihoods has brought about associated consequences also. An accumulation of green house gasses in the world's atmosphere as a result of human activities have triggered ecological changes in the chemical and physical composition and distribution of plants and animals which are occurring in all well-studied marine, freshwater, and terrestrial habitats. These observed changes are heavily tilted in the directions predicted from global warming and have been correlated with climatic and biological variations, through field and laboratory experiments in many cases. The unprecedented rates of climate changes anticipated to occur in the future can be expected to disrupt the interplay of adaptation and migration, likely affecting productivity and threatening the persistence of many species through natural selection.

Key words: Green house gasses, climate change, natural selection.

Introduction

Climate change can be defined as a regional or global long-term shift in average temperatures and precipitation as a result of the accumulation of green house gasses in the atmosphere triggered by either natural or human causes. These green house gasses include principally carbon dioxide emitted from transport and industrial activities, methane emitted from anaerobic fermentation in ruminants, insects, paddies and other industrial processes, and nitrous oxide emitted from some agro inputs. These gasses combine together in the atmosphere to be transparent to incoming solar radiation but opaque to night terrestrial radiation thereby increasing surface temperatures over the globe. What is most surprising is that small shifts in average temperature about a few degrees Celsius, which seems trivial on a temperature scale, are obviously not trivial in terms of causing environmental extremes (Choi, 2006). Again, it is important to note that climate affects every sector of living. For example, Kemp (1994) have pointed out that a 1^0C alteration in heterothermal aquatic environment produces behavioral adjustments in many fishes and that a 4^0C shift can lead to major changes in fish distribution and physiological functions. He further pointed out that when such temperature increases are on a sustained level, one way through which fish species can survive could be through genetic selection.

Although there is sufficient literature linking climate change and genetic changes illustrating how the former drives the latter e.g. Permesan (2006), McLachian *et al*, (2005), Fraser & Hofmann (2003), Johnson & Boerlijst (2002), Webster *et al.,* (2002), etc, the issue has remained obscure in contemporary discussions. Permesan (2006) has in his work concluded that ecological changes in the phenology and distribution of plants and animals are in all well-studied marine, freshwater, and terrestrial groups. These observed changes are heavily biased in the directions predicted from global warming and have been linked to local or regional climate change through correlations between climate and biological variation, field and laboratory experiments, and physiological research.

McLachlan *et al.,* (2005) in their work titled 'molecular indicators of tree migration capacity under rapid climate change' had used chloroplast DNA surveys to show that the geography of postglacial range expansion in two eastern North American tree species differ from that expected from pollen-based reconstructions and from patterns emerging from European molecular studies. They discovered that postglacial migration rates were actually slower than those inferred from fossil pollen. Their estimated specie migration rate was put at >100m/yr which became consistent with model predictions based on life history and dispersal data. This led to the suggestion that past migration rates were substantially slower than the rates that will be needed to track 21st century global warming.

Fraser & Hofmann (2003) in their work aimed at understanding causal links between climate change, ecosystem response and resource monitoring and management in the southern ocean, had used the Antartic krill *Euphausia superba* to establish the variability between sea ice cover and its effect on their demography and other ecosystem components such as apex predators. Amongst other discoveries, the study found that during the last two decades in particular, krill populations have been sustained by strong age classes that emerged periodically every four to five years. This is indicative of deteriorating ice conditions conducive to good krill recruitment due to climate warming.

Measurements/Dating in Climate Change and linkage with genetic changes

There are a number of proxies by which long-term trends of environment and climate change can be measured. This could be done biologically by the use of pollen analysis and other macro fossils, marine diatoms and insect coleoptera. There are other physical proxies which involve geomagnetic measurements of radionuclide concentration in soils and air. There is yet a geochemical principle by which the concentration of metals and salts especially from lake basins, flood plains and soils can serve to indicate the varying levels of climate change (Lowe & Walker, 1997).

These materials so analysed are either radiocarbon (^{14}C) dated, or dated based on the laminated varves in which they had been found in the soil horizon or through optically-stimulated luminescence in order to arrive at a well-established chronology. The above processes all amount to field and laboratory work which requires time and patience. It is therefore possible to correlate climate and genetic changes chronologically such as the work of Lynch & Lande (1993) who used a genetic model to infer rates of environmental change that would allow populations to respond adaptively.

Mutation

Mutation is a sudden and discontinuous change in a gene occurring rarely for any particular gene and capable of producing a change great or small in some parts of the body.

According to Kahn & Singh (2002), mutation used in its broad sense refers to any sudden heritable change in the genotype of an organism not explainable by recombination of pre-existing genetic variability. Such genotypic change includes:

i. Changes in chromosome number (euploidy and anaploidy)
ii. Gross change in the structure of chromosomes (Chromosome abberations)
iii. Change in individual genes.

The change in genetic materials may lead to a corresponding change in the structure of the genetic materials. As such, mutation is an extremely important source of genetic variability in living populations. Mutation involves change within the DNA molecules.

However, change in chromosomes structure and number lead to heritable phenotypic change as well.

Classification according to cause

Mutation may be point mutation (occurring as a result of base pair substitution), spontaneous mutation (occurring without known cause due to mistake during DNA replication or due to mutagenic agents present in the environment) or induced mutation (occurring from exposure to mutagenic agents such as ionizing irradiation ultraviolet light or various DNA or RNA, in RNA virus).

Classification according to phenotype

i. Morphology Mutation:- Is the easiest phenotypic change to see alteration of the morphology, location or perhaps colour of a structure.
ii. Bio-chemical Mutation:- not always observed but can be identified only by chemical analysis e.g sickle cell in haemoglobin.
iii. Condition Mutation:- The phenotype is only expressed under certain conditions. The temperature sensitive or drug resistance mutations are good examples.
iv. Regulatory Mutation:- The expression is detected by the inability to control another gene e.g constitutive mulantei in the lactose operon.
v. Lethal Mutation:- The organism carrying the Mutation cannot survive e.g. albino Mutation in plants.
vi. Somatic Mutation:- Occur in any cell and at any stage in somatic cell. For example, delicious apple and navel orange.
vii. Germinal Mutation:- Occur in cells that will ultimately form gametes and therefore are sexually transmitted e.g dominant germinal mutation in short leg sheep of the ancon breed.
viii. Spontaneous Mutation:- Arise randomly in nature without any readily apparent cause.
ix. Induced Mutation:- Occur in response to externally applied agents e.g X-rays induces mutants in Drosophila (Kahn and Singh, 2002).

Definition of climatic change mutation

This is a sudden heritable change in the structure of genetic materials resulting in a living organism due to direct or indirect effects of the change in nature of gas, moisture, or of climatic condition at a given point in time.

Nature of climatic change mutation

According to Morgan, Muller, Dermera, Emerson, Stardler and their colleagues in Khan and Singh (ed),

(2002).

i. Most climatic change mutations are exceedingly stable.
ii. Different genes have different rates of mutation due to climatic change
iii. Climatic change mutation is change in a gene not a loss of the gene
iv. Climatic change may cause more than one change in a given gene producing multiple alleles.
v. The direction of climate change mutation is however, preferentially occurring more often in some direction than the other.
vi. Climate change mutation might result in loss of specific catalytic action without complete loss of the protein or a more extreme gene change.
vii. Climatic change mutations are harmful to the organism
viii. The two members of the pair of genes are mutable independently just as different genes do.
ix. Climatic change mutation with slight effects is much more common.
x. Climatic change mutation with no visible effect is the most common.
xi. Radiation accompanying climatic change may greatly increase the natural mutation rate.
xii. Spontaneous mutation caused by climate change is recurrent in nature (Kahn and Singh, 2002)

A Climatic change as a mutagenic agent

i. As physical mutagens: Natural reactions emitted from radioactive substances, in rocks, soils, water or atmosphere of the earth, from the body of the organism or from ultra-violet rays arriving from space undergo reasonable change under climate change. Each of these includes mutations through their reaction with DNA.

ii. Climate change produces change in the chemical environment including substances ingested as food.

iii. The resulting increase in temperature due to climate change is known to increase the rate of spontaneous mutation.

iv. The resulting increase in temperature and climate change might occasionally lead to failure of gene to duplicate itself with perfect occurrence during cell division. This leads to mutation or change in the constitution of a gene (Kahn and Singh 2002).

The claim that climate change is a mutagenic agent was further consolidated by Rastogi (2008) who illustrated the induced mutation in tobacco mosaic virus (TMV) by HNO_2 which changes cytosine to uracil. In the laboratory, experiment mutations have been induced by a number of chemicals which either affects the DNA replication or transcription, hence it would be expected that some of the chemicals and gas released due to climatic change could have similar effect.

B. Climatic change as indirect chemical mutagens

The change in the high energy ionizing radiation, and the chemical environment of living organisms emanating from climate change might favour the incorporation of base analog (5bromouracil) into the DNA in place of the natural base.

C. Climate change as environmental mutagens

Climate and climate change contain a vastly suspected array of chemicals that human populations are exposed to that are potentially mutagenic. They include air, water pollutants, food additives and preservation and agricultural chemicals. Cytological study of Brenneke (1937) had suggested that dominant lethal genes induced by irradiation were dominantly due to aberrant cleavage and chromosomal fragmentation. The possible mutagenic effect of the high energy radiation emitted from the climate is not debatable owing to numerous reports of sterile and lethal effects of radiations. According to the experiment of Bieler *et al* (1976), mature female mouse is permanently sterilized by a single dose of 50r or greater. Burdette (1963) reported that the degree and time of sterility resulting from ionizing radiation varies with species, sex, dose, age at exposure and quality of radiation.

D. Climate change as indirect oncogene

One of the most exciting discoveries in recent years are genes that cause cancer. The change in high energy ionizing agents and chemical environment resulting from climate change may favour the production of oncogenes.

E. Climate change as potential cause of *xeroderma pigmentosum*

High temperature due to climate change may cause failure in gene duplication and produce xeroderma pigmentosum. This is an example of the best known inherited deficiency in the repair of radiation damage in humans. It is an autosormal disease called xeroderma pigmentosum. The skin of the individual with such deficiency exhibits extreme sensitivity to sunlight in a highly exposed area such as the face.

G. Climatic change and chromosomal abbreviation

High temperature, high-energy ionizing radiation or new chemical environment all resulting from change in climate may directly or indirectly favour chromosomal aberration (Kahn & Singh, 2002).

Interaction of genotype – environment (climate change)

The effect of climate change on the living organism at a particular time according to Hammond’s proposition could result in a proportional change in the phenotype for the entire array of genotype. If such were true, individuals or living organisms would rank in the same order under different climatic change scenarios.

This is contrary to the true situation according to Legate and Warwick (1990) who posited that individuals change their rank and experience improved performance under different climate change scenarios due to the presence of genotype-err.

Climate change, mutation and selection

Gene frequency expressed by individuals in a population is the result of the equilibrium between selection, climate change mutation, chance and migration (Legate & Warwick 1990). In the search for the explanation of evolutionary changes, considerable progress have been made in expressing relationships among the force in predicting the ultimate equilibrium values of gene frequency for a specific population. Hence some degree of change is expected from effect of climate change due to the instability it causes the equilibrium existing in the gene frequency of a population. Change would be expected in the gene frequency of any given population in the different kinds of climate change scenarios and its consequent mutation on a population. The previous gene in such population and the mutant gene resulting from the changes caused by high temperature, high-energy-ionizing agents and chemical compounds of climate change creates selection pressure and afford a chance of survival and adaptation to any of the genes which find the new climate change most suitable. In other words, mass selection can still increase the frequency of any given population but it will be a time consuming process (Legate & Warwick 1990).

Hereditary variance due to effects of climate change

Legate & Warwick (1990) agree that hereditary and environmental influences due to climate change are responsible for the observed variation in records of performance of living things. The hereditary variation result from the action of the genes and gene combination in response to the environmental conditions due to climate change provided to the individual members of the population. Only genes and chromosomes that find the new environment produced by the climate change can be responsible for variation among individuals. It is therefore only such genes and chromosomes conditioning the hereditary variability that can be transmitted from parents to offspring or selected for use in breeding programmes. This fact was substantiated in the early work of Snell (1935) who reported that some offspring of irradiated males of mice were observed to produce consistently small litters. Litter size was reduced to one-half and one half of the progeny of these litters expressed the trait in the next generation.

Conclusion

The result of this review indicate that climate change is embedded with factors such as temperature, high energy ionizing compounds and chemical environment similar to components of mutagenic compounds. This further indicates that the temperature, high energy ionizing compounds and chemicals produced during climate change can cause hereditary changes in genes and chromosomes of individuals. One major impact of climate change is altering the equilibrium constance existing in the gene and genotype frequency of a population resulting to hereditary variability and selection of the fittest; a phenomenon known as natural selection.

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