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Chapter

Biomonitoring Ecosystem: Modelling Relationship with Arthropods

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Abstract

Arthropods community structure and composition provides multiscale information about an environment health. Their reproduction and growth model are effective to assess the impact on ecosystem in response to stress such as anthropogenic activities (climate change) or natural (drought). Terrestrial and aquatic insects are potential bio-indicators. Terrestrial insects are an excellent model to assess the quality of terrestrial ecosystem. These insect species are assayed to detect metallic pollution and forest abundance. Soil and litter arthropods are used for examining soil quality. Honey bee mortality rates and the residues such as heavy metals, fungicides and herbicides presence in honey are good indicator of environmental pollution. The specificity of food and habitat selection by wasp population make it suitable for assessing habitat quality. Similarly butterflies habitat itself signifies a healthy ecosystem because of their sensitivity to even slightest change. Different arthropods act as keystone species and these keystone interactions also reveal many facets of an ecosystem quality. Similarly fly population such as *Drosophila subobscura* and their shift in the genetic composition indicate the global climate warming. The arthropods are explored as screening platform to understand the ecosystem resilience to disturbances. These underscores arthropods potential for evaluation of environmental impact and global climate change.

Keywords: arthropods, ecosystem, climate change, environmental pollution, biodiversity conservation

1. Introduction

The main objective of this chapter is to monitor and explore the ecosystem and biodiversity by understanding the surrounding environment and public health surveillance. By monitoring the ecosystem and biodiversity, one can assess the proven significance of ecological indicators over terrestrial and geographical scales to discover emerging changes in the structure, function, and composition of ecological system with respect to natural and man-made influences. The extent to which the ecological indicators are used in monitoring the whole ecosystem and the selection procedure followed identifying the symbiotic indicators. There have been numerous articles, books, journals, videos, and manuscripts that relate to the field

of monitoring ecosystem and biodiversity. Although former researchers, educationists, and many others have contributed to this area of study with different perspectives, there are still numerous common sections untouched which seem to link most of the articles collectively.

Moreover, it has been observed that several monitoring programs have been conducted to complete the ecological indicator selection process of which arthropod ecological indicators stand stringent. The whole arthropod community structure contributes to the well-being of environment health. Arthropods reproductive system, growth, and development aids the ecologists in assessing the impact of man-made activities which stand responsible for climate change, drought and other environment- effecting disasters. Different types of arthropods are explored which helps to evaluate environmental impact and design strategies for a successful healthy ecosystem and biodiversity. Thus, the current chapter highlights on key aspects of healthy ecosystem which include arthropods, relationship between arthropods and ecosystem, concept of biomonitoring, anthropogenic factors effecting ecosystem, and analyzing biodiversity.

Arthropods are invertebrate animals with an exoskeleton, a segmented body and jointed legs. High functional, biological diversity and sensitiveness to environment, of arthropods make them suitable to be considered for utility as ecological indicators of sustainable ecosystem. The potential bioindicators groups of arthropoda include Acari, Collembola, Coleoptera, Hymenoptera and Araneae.

2. Biodiversity

In this whole universe, diversity exists at all levels of biological organization irrespective of the species ranging from macromolecules to ecosystems. The term biodiversity refers to the degree of biological variations within the ecosystem. In other words, biodiversity is the combination or blend of all biological organizations. As a whole, biodiversity refers to various forms of life existing on earth. The different forms of life on earth can be categorized into animals, plants, genes, microorganisms and the ecosystem itself. Biological resources such as species, genes, ecosystems and organisms and ecological processes of the above said resources can be manifested as biodiversity [1]. Therefore, Biodiversity is analyzed and understood at 3 major levels namely: Genetic diversity, Species Diversity, and Ecosystem Diversity.

Genetic diversity provides the genetic information of all plants, animals, species, and microorganisms with respect to the population of species. It simply deals with variety of genes within the specie and population. Species diversity is nothing but diversity at specific levels. It includes variety of species such as species richness, which refers to total number of species identified in the target area; species abundance, which refers to the relative number among the species; and taxonomic diversity, which takes into account the genetic relationship between various species. Ecosystem diversity refers to variety of habitats, ecosystems, ecological communities, and ecological processes in the environment.

2.1 Importance of biodiversity

Every single form of life on earth seems to be rare and has its own value regardless of the species under which that living organism is considered. Just like human beings all other forms of life has its own place and value. This is the right of every organism in the ecosystem. Every organism which is the part of this ecosystem has an innate right to exist in the universe regardless of its value, respect and honor.

However, human beings seem to be the integral part of the natural world and hence the world value the human life more than all other living species. The environment preserves human heritage as humans are considered essential to the world. For this reason, the well-being of the coming human generations is wholly invested in the hands of existing generation. Sustaining the diversity becomes the key social responsibility of the anthropogony. Therefore, only by conserving the resources and organisms the future generation's existence can be determined. Hence, these values become ethical or moral values for preserving biodiversity.

The nature in which human beings live, grow and develop turns out to be a great enjoyment to the whole humanity. Natural environment in which human beings live plays an essential role in shaping and structuring the culture, stimulate the senses of human beings and eventually enrich our social culture. Hence, biodiversity is vested in human culture which is popularly preserved, valued, and protected. For instance, colossal amounts of money is paid by organizations in order to preserve, conserve and yield wild life as it becomes the vital part of human nature. The environment is protected, appreciated, and enjoyed only when the wild species are kept preserved. In fact, wild species enhance mankind's way of living by providing enjoyment through different types of activities such as bird watching, trekking, spotting activities, watching wildlife and so forth. The above said activities attribute aesthetic value to biodiversity.

Besides, biodiversity comes with utilitarian values that contribute to the very existence and material well-being of living organisms. Apart from emotions and feelings of human race, there are several other materialist things which provide ultimate satisfaction to a human life. This includes conservation of materials from biodiversity such as agricultural materials, source of food, clothing, medicinal values, industry materials, educational values, scientific understanding and materialistic yearnings. Thus, a rich biodiversity is essential for healthy ecosystem and stands imperative for the survival of human race.

2.2 Ecology and biodiversity

Ecology and Biodiversity are two interrelated terms that seeks to maintain, preserve, and sustain the integrity of the ecological system thorough different ways such as maintaining carbon dioxide (CO_2) and oxygen balance (O_2), regulating biochemical cycles, decomposing waste materials, regulating natural world climate, identifying indicators that change the environment, and provide protection services to the ecosystem. Maintaining carbon dioxide and oxygen levels in the atmosphere can be made possible only through biodiversity. Carbon dioxide accumulation in the atmosphere results in greenhouse effect which eventually leads to ozone layer depletion. Ozone layer depletion makes the earth warmer and liable to natural disasters.

Preserving biochemical cycles is another important way to maintain biodiversity levels in this ecosystem. Regulating biochemical cycles is equally important in maintaining ecological values of biodiversity. Decomposing waste materials thorough absorption and breakdown of pollutants will lead to food webs and food chains to other forms of biodiversity. Production of waste would be zero as the waste id decomposed and transformed as food to other forms of biodiversity. Thus, pollutants are broken down and absorbed naturally. The other ecological values of biodiversity include controlling and determining the natural world climate irrespective of their regions by means of influencing factors such as precipitation, temperature, and air turbulence; act as indicators of environmental change, for instance, global warming changes in ecosystem and affects crops; and protect humans from harmful weather conditions.

2.3 Threats to biodiversity

Generally, threat is defined as a natural or human-made process or event responsible for causing adverse effects on the sustainable use of biodiversity components at large. The biological diversity and wealth of our ecosystem has been rapidly decreasing due to the clearly pointed anthropogenic activities. Several studies have discussed the disappearance of large number of species along with the possible threats to the species as well as ecosystems. In the recent times, highest number of threats to ecosystems has been recorded. The reason for the failure of ecosystem is identified as human mismanagement of biological resources often stimulated by misguided policies which results in loss of biodiversity. Loss of biodiversity can further lead to decline in ecosystem process, decline in plant production, and lowered resistance to environmental pollutant such as physical, chemical and biological. The quicker rates of species extinctions that the world is facing now are largely due to human activities. Given below are the major threats to biodiversity:

2.3.1 Habitat destruction

Increased voracious demand for resources results to use of land species which eventually acts as cause to loss of genetic diversity, changes in ecosystem such as disease outcrops, population increase or decrease, habitat fragmentation, and reduction in the number of species of ecosystem. The above mentioned reasons lead to heavy biodiversity loses. Habitat destruction, therefore, becomes a threat to biodiversity.

2.3.2 Overexploitation of biological resources

When individuals of particular species which can be sustained for a longer period of time with its reproductive capacity are decomposed at higher rate, population is said to be harvest or exploited at higher rate. For instance, human-induced activities such as fishing, hunting, food gathering, trade and so forth are responsible for overexploitation of higher sustainable biological resources. Over exploitation leads to extinction of biological resources and thereby reduces the number of species in the ecosystem. Exploitation of resources with the consent of law is termed as cropping. While exploitation of species even after providing protection is termed as poaching. Thus, overexploitation of resources or biological resources will turn out to be a major threat to biodiversity.

2.3.3 Pollution

Any kind of pollution, be it physical, chemical, biological or thermal is a hazard to biodiversity. Majority of the species living in their habitats are prone to harmful industrial activities, pollution, and excessive use of chemicals. This kind of pollution eventually harms the ecosystem.

2.3.4 Biological invasions

Biological Invasion can be intentional or accidental. Changes within the ecosystem are mainly due to the biological invasion of new species. The newly introduced classes are organisms that arise from habitats in which they were not found. These new introduced species from new habitats are generally termed to as biological pollutants. The ecological impacts of biological invasion include disorder of food webs, out competition, hybridization, disorder of ecosystem, disease transmission,

plant pathogenic influences, and extinction of species in peculiar situations. The new species may be introduced intentionally for different types of reasons such as ornamental concerns; agriculture; hunting and spotting activities; biotechnology for scientific research; and trade.

2.3.5 Climatic changes

Climate change is one of the greatest concern especially when global carbon dioxide increases in the atmosphere resulting to global warming. Economic stability of an ecosystem is tolerated when most species originate within a narrow physiological limit. Hence, changes may be gradual or abrupt and hence result in species extinction.

2.3.6 Population

With increasing human population, vigorous demand for raw materials also increases which results in changes in biodiversity. Hence, controlling human population will be the only solution to conserve biodiversity for the coming generations.

2.4 Biodiversity conversation

Biodiversity Conversation embodies maintenance, preservation, conservation, and enhancement of crucial biological diversity components. Conservation is referred to as the sustainable use of biological resources with the aim of protecting them for the coming generation and at the same time protect them exploitation. Preservation is keeping the materials in a safe manner without altering it. Biodiversity Conservation and Sustainable Development are interlinked to meet the needs of current generation without undermining the thought of preserving for the coming generations to meet their basic needs. In other words, it establishes a balance between the ecosystem and living organisms which ensures biodiversity.

The narrow practical arguments for biodiversity conservation are several. For instance, human being spring multiple benefits from nature such as pulses, cereals, firewood, fruits, construction material, fiber, industrial products such as dyes, lubricants, tannins, perfumes, and resins; and medical products. More than twenty five of the drugs sold in the market are derived from plants and twenty five thousand species of plants are used to prepare traditional medicines that are used by human beings around the world. Hence, all the species in the ecosystem depend on each other.

The broad practical argument claims that biodiversity plays a major role in ecosystem services. Through photosynthesis, Amazon forest produces twenty percent of the whole oxygen in the earth's atmosphere. While the ethical argument for conserving biodiversity to plant, animal and microorganisms living in this planet. Philosophically or spiritually, every species has an intrinsic value. Hence their well-being should be taken care and pass on biological inheritance to the coming generations.

2.5 Concept of biomonitoring

The concept of monitoring can be defined as the process of observing and measuring the state of key indicators such as physical, chemical and biological with respect to the element of environment or the medium. Physical monitoring is usually carried out considering the physical parameters such as temperature, climate, and other variables. Chemical monitoring monitors the chemical variables

responsible for environmental pollution. However, these two types of monitoring failed to come up with the long-term effects of pollution on the environment. Assessing the ecosystem by taking into account the physical and chemical monitoring seems to be unreliable. Hence, the concept of biomonitoring has been introduced to assess the long-term effects of identified pollutants on ecosystem and produce reliable results. Biomonitoring or Biological monitoring is introducing biological variables to assess the structural, functional and compositional aspects of an ecosystem. These biological variables play an important role in controlling environmental alterations.

Biomonitoring is a systematic use of symbiotic organisms to assess the quality of environment. It enables to check for the additive effects of pollutants and monitors the overall health condition of ecosystem [2]. Hence, biomonitoring acts as a supplement to physical and chemical monitoring techniques that are commonly applied. Biomonitoring is defined as an act of observing, noticing, and assessing the changes within the ecosystem, structure of ecosystem, composition of biodiversity, and functions of ecosystem and biodiversity including different types of natural habitats, keystone species and population [2]. The advantages of biomonitoring are rich than those of physical and chemical monitoring which include: (1) it reflects the overall environmental integrity comprising of physical, chemical and biological monitoring; (2) it imparts an integrated and holistic measure of ecological condition by uniting stresses over a period of time; and (3) it provides a better understanding of healthy environment to the public surveillance than others.

Biomonitoring can be achieved by bringing about a change in the structural, functional and compositional aspects of biodiversity and ecosystem that are affected due to the adverse anthropogenic activities. Different parts of the world are conducting programs with the aim of spreading awareness on pollutants to the public. Several approaches, methods and strategies are identified to monitor the ecological pollutant out of which four of them have been marked approval. First approach is to monitor the effects of pollution depending on the absence or presence of taxa, changes in its composition or any other drastic changes. In other words, the first step is to monitor the adverse effects of pollutant within the community. After this, concentration of pollutants in indicators should be measured. Later, effects of identified pollutants on organisms should be assessed and classify them to abiotic and biotic indicators. Lastly, identify different strains of species which develop resistance in response to a pollutant.

Several micro-organisms are used as bioindicators to assess the impact of pollutants on the whole ecological system. Some of the bioindicators include protozoa, fishes, algae, macroinvertebrates and microinvertebrates [3]. According to Nesemann [4], arthropods is one of the macroinvertebrates that seems to be dominating seabed groups found in the seafloor [4]. Of all the other macroinvertebrates, arthropods are found to be more dominant bioindicator with respect to ecological pollution tolerant, followed by molluscs and annelids.

According to Holt and Scott [5], bioindicators are the species, communities and processes that are used to assess the environmental quality and record the changes happening in the ecosystem over a period of time [5]. Generally, environmental changes are often interconnected and interlinked with man-made disturbances such as pollution, droughts, climatic changes, and so forth. These bioindicators expanded their arena to all types of environments such as aquatic and terrestrial. Past studies claimed that bioindicators successfully indicates the condition of the environment along with the rate of tolerance to environmental variability. It is also observed that species or indicators with low or narrow tolerance act sensitive to the changes occurring in the ecosystem. In contrast, indicators or species with high or

broad tolerance act less sensitive to the changes occurring in the environment which disturb the community.

To conclude, biomonitoring and bioindicators are more or less the same and hence can be interchangeable within the science community with slight difference. While bioindicators assesses the impact of environmental pollutants qualitatively, biomonitors determine the responses of pollutants quantitatively. Therefore, the main functions of bioindicators or biomonitoring include: (a) monitor or assess the environment; (b) monitor or assess ecological process; and (c) monitor or assess biodiversity. Thus, biomonitoring lies at the core of ecosystem and has become the essential and effective tool to study environmental exposure to chemicals, pollutants, and other hazardous materials. Biomonitoring studies measures the responses and recoveries of water communities from the ecological disturbances, environmental pollution, and evaluate the relationship between physical, chemical and biological components.

3. Arthropods as ecological indicators

The important components of the ecosystem that occupy vital positions in food webs, changing population, and communities are called as Arthropods. Arthropods play multiple roles in this ecosystem such as going about as herbivores, decomposers, predators, parasites, seed dispersers, and pollinators [6]. The peculiar characteristics of arthropods such as small body size, high diversity, increased reproductive capacity, easy sampling, and less sensitive to environmental changes make them suitable for environmental biomonitoring. For these reasons, arthropods are used as biological indicators to monitor and assess the impact of pollutants on the ecosystem.

Usually, arthropods are used as bioindicators for the following reasons: (a) the most frequently polyphagous predators that play a crucial role in biological control; (b) groups are made easily with danger traps; (c) allow elevated statistical analysis. According Da Rocha [7], environmental indicators such as physical, chemical, human, and biological shows changes in the ecosystem. These indicators should be analyzed in the complex dynamics of the environment.

Biological indicators give insight of biological systems. These indicators provide significant information for prioritizing conservation areas and come up with better ecosystem management plans. Arthropods possess explicit spatial and temporal scales that distinguishes high patch sizes, patch dynamics, quick turnover, geographic distributions, larger population size when compared with birds and vertebrates. Thus, arthropods could be used reliably to infer ecosystem function and habitat condition.

Arthropods occupy the widest diversity of microhabitats and niches, and play more ecological roles, than any other group of animals. They have diverse body sizes, agilities, and growth rates. Arthropods have been recognized as efficient indicators of ecosystem function and recommended for use in conservation planning and many researchers have assessed habitat quality and measured habitat differences using arthropods [7]. Important biondicator groups include Coleoptera (Carabidae, Curculionidae, Staphylinidae), Collembolla (Springtails), Diplura, and Hymenoptera (Formicidae). *Parallelomorphus laevigatus* is good indicator of toxic elements. Arthropod groups have been used to track global health of ecosystem in many contexts. Major arthropods and their taxonomic classification are represented in the **Figure 1**. Ecological indicators such as arthropods help to identify the impacts of natural and anthropogenic disturbances on biota. Among the arthropods, it
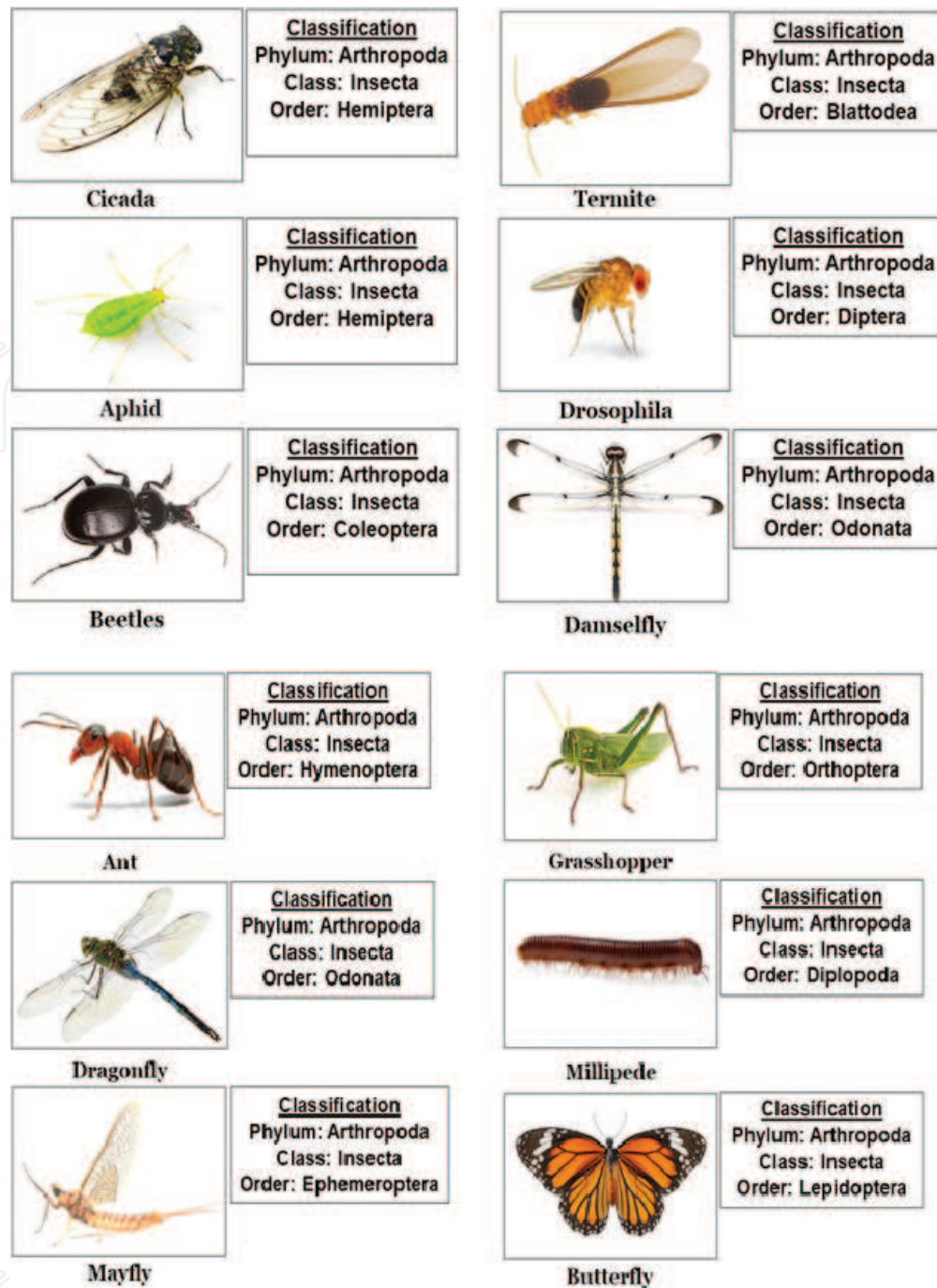
Figure 1.
Major arthropods and their taxonomic classification.

is indicated that insects becomes useful as they represent half of the species and allows to assess different habitats in a refined manner.

3.1 Arthropod characteristics as good indicator

The attributes that make Arthropod biomonitoring acceptable because of the following attributes (1) cost-effective (2) their easy, reliable identification (3) respond differently to disturbance regimes [8]. Arthropods are commonly sampled from different habitats Spiller et al. [9]. Soil Arthropods are biological indicators of farm and plantation ecosystem processes because their existence regulate nutrient dynamics, soil quality, and are useful to reveal ecosystem condition [10, 11]. Some arthropod bioindicator groups live, feed and reproduce in the soil. They are highly sensitive to soil quality alterations [12, 13]. Moreover the high functional and

biological diversity of arthropods provide evidence for their utility as ecological indicators of sustainable forest [14].

3.2 Arthropod characteristics as bad indicator

Studies reported the disadvantages of Diptera species (flies) such as great taxonomic difficulty, especially in their larval stage is an important barrier to its use as environmental bioindicators [15]. Challenges such as sampling methods and the proper identification of soil and litter arthropod diversity up to species level demands further research to overcome the disadvantages for utility of soil arthropods while assessing soil quality. An investigation to the most suitable methods for sampling soil and litter arthropods will be beneficial to strive arthropod potential for biomonitoring [16].

3.3 Cicadas

Cicadas are large hemipteran insects characterized by unique life-history traits. Their interesting attributes are follows (1) extraordinarily long life cycles (2) a subterranean/terrestrial habitat transition (3) xylem sap-feeding (4) melodious sound production.

Cicada fauna is known for community responses to climate change. Different studies taken up this model to understand its ecophysiological consequences to climate change. The cicadas are promising candidates for use as bioindicator species to monitor ecological impacts of climate change. Recently cicada nymphs have been studied in response to emerging novel environmental stress such as construction and demolition (C&D) waste. Studies carried out in uncontaminated and contaminated habitats by C&D waste where the cumulative effects on fitness and community structure of cicada nymphs such as biodiversity, community structure, population dynamics and morphology were investigated. A significant negative response was reported in *Cryptotympana atrata* and *Platypleura kaempferi* including higher ratio of malformed nymphs [17]. Findings also identified soil compaction due to urbanization as a key reason to cicada diversity loss. The response of cicada nymphs to C&D waste have significant implications for the habitat destruction. Cicada nymphs may be suitable bioindicators for underground-habitat-quality monitoring. However further research is required to reveal the association between the magnitude of C&D waste contamination with the fitness and population dynamics of cicada nymphs.

3.4 Aphids

Aphids are known for their feeding style and close association with host plants. Due to various environmental stresses, developmental instability in morphological characters such as fluctuating asymmetry can occur in aphids. Heavy metal accumulation, pesticide application, other pollutants and anthropogenic disturbances posses (**Figure 1**).

3.5 Beetles

Beetles form a large group of organisms which differ taxonomically and ecologically. The attribute that makes beetles distinguishable from insects are presence of hardened fore wings which provides protection to membranous hind wings. They feed on animal waste, rotten wood, animal carcasses and make soil suitable for vegetation. Beetles are very sensitive to environmental modifications and can be

cost effectively sampled by employing different methods and these criteria makes beetles an excellent model for monitoring terrestrial ecosystem [18].

Beetles are used to detect environmental contaminants including biomonitoring of metal in the field studies. Biomonitoring programs include measurements of metal in these invertebrates. *Carabus lefebvrei*, is considered suitable for evaluation of As and Hg in the environment because of high bioaccumulation factor. Similarly a positive correlation is reported between body mass and Pb in *Notiophilus biguttatus*, and *Notiophilus rufipes* and *Calathus melanocephalus*. Sex specific variation in the content of Zn has been reported in carabids including *Poecilus cupreus*, *Pterostichus melanarius*, *Pterostichus niger*, *Pseudophonus rufipes*, *Carabus nemoralis* and *C. granulatus*.

Carabid beetles diversity is suitable for studying ecological impacts of anthropogenic activities. They are extremely sensitive to increasing human disturbances. Their abundance in grasslands and boreal forest was studied in relevance to habitat disturbance gradient. Staphylinid beetles biotopes have been considered for various land management practices.

According to Spector [19], dung beetles are found in different types of landforms such as forests, grasslands, deserts and grasslands [19]. In addition to, dung beetles feed on fungi, fruits, decomposing leaves. Taking these characteristics into account, dung beetles are considered as an ideal indicator to monitor biodiversity. Out of all bioindicators, dung beetles are utilized for clear-cutting, fragmentation, forest modification, fragmentation, and logging in the tropical regions [20]. Several aquatic insects groups or arthropods are identified as aquatic environment bioindicators. Hydrophilid beetles such as *Cercyon unipunctatus* are important indicators of aquatic pollution.

Beetles from order Coleoptera and Family Carabidae are important predators. They participate in biological control, biological monitoring of pollution from oil, sulfur, herbicides, CO2, insecticides and radioactive phosphorus [7]. Predatory aquatic beetles are good indicator of trace elements. These are good candidates to monitor the trend of metal accumulation in aquatic invertebrates thereby making it suitable for distinguishing an impacted or non-impacted environments [21].

Dragonflies or Odonata species act sensitive to changes occurring within their habitat especially flooded areas, lakes and drainage areas. Several other species of the families such as Coleoptera, Heteroptera, Gyrinidae, Dytiscidae, Notonectidae, Plecoptera and Ephemeroptera have high adaptive capacity, dominating capacity, reflect ecological and geographical changes, and their biodiversity conservation. Thus, the tolerance of aquatic organisms to metals are found to be less, however, tolerates toxic agents responsible for environmental stress.

3.6 Termites

The termites are detritivores and feed on dead and decaying organic matter. Hence they are efficient nutrient recyclers which colonize dead and decaying organic matter. Termite mounds are considered as 'hotspots of fertility' or 'nutrient patches'. These increases plant and animal diversity in the ecosystem. The population dynamics and species richness in termites can be used as an environmental bio indicator to detect habitat disturbance.

Termites possess several characteristics that make them appropriate to use as bioindicators of habitat quality. The richness, abundance and composition of termite communities analyzed in vegetations with different levels of anthropogenic disturbances [22]. The ecological behavior of termites is affected by land use change and disturbance level. According to the land use types and disturbance level, a variation in termite species' richness and evenness, relative abundance, and biomass of

termite were reported. Hence a major factor for declining termite diversity is found to be habitat disturbance [23]. The conformity between environmental variables and ecological data can effectively model termite communities as potential tools for ecological monitoring.

India's Coffee forests are considered as self-sustaining ecosystem and inter linked with various biotic partners including termites' community. Termite mounds act as important bioindicator that reveals ecology of the region. Their distribution and abundance may provide vital clues with respect to nutrient recycling and soil dynamics inside the coffee ecosystem.

3.7 Flies

The ecology of *Drosophila* species Drosophilid (Diptera) and their assemblage has the potential as bioindicator in open environments. Family Syrphidae is widely known for its well-known taxonomy and the larvae require different environmental condition and these characteristics makes these flies a potential bioindicator. Similarly Sarcophagidae flies are considered as good bioindicator of environmental pollution by heavy metal, fibre asbestos and waste chemicals.

3.8 Damselflies

Damselflies (Zygoptera) are insects belonging to the order Odonata and their nypmhs spend most of their lives as aquatic nymphs. Damselfly larvae are sensitive to water depth, water movement, and pH. Fluctuating asymmetry in damselflies has been used widely to investigate the effects of environmental pollution. They are considered moderately sensitive to pollution. Damselflies together with other macroinvertebrates considered as common bioindicators of stream and wetland health.

3.9 Ants

Ants are eusocial insects from Formicidae family and their communities headed by queen or queens. Worker ants are wingless females which carry out activities such as foraging, take care of queens offspring, they live in structured nest underground.

Studies suggest, ants are extensively used as effective bioindicators that hold responsible for ecosystem management and biodiversity restoration [24]. Ants seem to have high sensitivity to environmental disturbances such as grazing, forest fires, forest conversion, forest thinning, forest fragmentation, species invasion, and other forms of disturbance [25].

They are considered as important part of soil macro fauna because of their ability to restore soil quality. These bioindicators are required to monitor adverse changes in soil quality and can provide warning. Ants-soil quality model can be explored to identify sustainability of soil resource [26].

The biogeography of ants community structure has been used for validation. Ants are used to check habitat disturbance. Their composition have been used to identify ecological change in different habitats around the world including rainforests of Australia, Brazilian Savanna, Shivalik Mountains of Himalayas [27, 28]. They have been used as representatives of ecological trend in the mining site [29].

3.10 Dragonflies (Anisoptera)

Land used intensification can be studied by evaluating Odonata species richness, body size and individual species' response. An Odonates body size variable

found to better variable than richness to tract integrity of original vegetation [30]. Methylmercury (MeHg) levels in dragonfly larvae and water were measured. In aquatic systems dissolved MeHg concentrations levels in dragonfly larvae are useful indicators [31]. Their sensitivity to habitat quality and the amphibious life cycle make Dragonflies (Anisoptera) an efficient environmental tool to track micro changes within the confines of coffee ecosystem. Similarly these Dragonflies are best suited for evaluating water quality and any environmental changes in a coffee ecosystem.

3.11 Mayflies

Mayflies are found in a wide variety of habitats and are very sensitive to pollution. They are considered as valuable indicator of water pollution [32]. Ephemeroptera larvae are recognized as bioindicators and used in many monitoring programmes for their sensitivity to oxygen depletion in running waters [33, 34]. They are considered as keystone species. Different mayfly genera such as *Tricorythopsis* (Leptohyphidae) and *Camelobaetidius* (Baetidae), are considered as potential bioindicators of different anthropogenic activities [35]. Along with caddisflies and stoneflies, mayflies are one of the three most commonly used indices to understand aquatic ecosystem health [32]. The quantitative biological information for conserving and managing freshwater ecosystems.

3.12 Grasshoppers

Grasshoppers are a dominant group of herbivorous insects and their diversity, sensitivity to disturbances and ease of sampling make them quality bioindicators for land management. Grasshopper assemblage dynamics is considered reflective to human land use.

They are sensitive to disturbances and their ease of sampling makes it a good model for land management studies. The accumulation of metal such as accumulation patterns for Cd, Ni, Cr, Zn, and Cu as result of industrial effluents, agricultural runoff, vehicular smoke, domestic and sewage wastes, and use of fertilizers studied in acridid grasshopper (*Oxya hyla hyla*) [36]. Studies also suggest *Serpusia opacula as useful indicator for anthropogenic activities* [37].

3.13 *Millipedes*

Millipedes are involved in breakdown of organic matter and because of their sensitivity to habitat change considered as important bioindicator taxa. Biodiversity conservation efforts should consider these invertebrates. The content of some elements such as Ca, P, K, Mg, Na, Fe, Cu and B in adult bodies of *Glomeris hexasticha* millipedes reflect the intensity of environmental pollution.

3.14 Butterflies

Butterflies with a lifespan ranging from 15 to 30 days, are considered to be most potential bioindicator group because (1) easily identifiable by DNA barcoding (2) require little labour to collect (3) maintain symbiosis with definite host plant. They respond extremely quickly to environmental changes and acts as early warning system of biodiversity reduction. A decline in butterflies can suggest the richness of other British species, in particular birds such as blue tits, jays and sparrows.

According to Halder [38], **butterflies** are used as bioindicators of robust ecosystems as they have firm connections with habitat variants such as meadows, hilly

regions, and edges of woodlands, flower-filled fields, sunny conditions, and plenty of herbaceous plants [38]. Monitoring butterfly abundance indicates the presence of seminatural conditions. These seminatural conditions such as, flower abundance, understory herb cover, and vegetation diversity promotes butterfly diversity in an ecosystem [38–40]. Kitahara [40] claimed that richness of butterfly species is associated with nectar plant species richness, vascular plant species richness, and herbaceous plant species richness [40]. The results of the study claimed that even in conifer plantations, butterfly conversation should be maintained in forestry practices [38, 40].

Butterfly often live in close association with specific larval host plants and carry out different pollinating activities. This attributes makes butterflies a strong indicators of the presence of particular plant taxa. The composition of different butterfly communities in a specific habitat suggest environment quality and its ability to support a diverse arthropod community [41]. The rare butterfly *Tomares nesimachus* (Lycaenidae) serve as umbrella species and their abundance is dependent on different ecological factors [42]. Its population dynamics is suggested to be good indicator of ecosystem functioning.

In addition to, moths are the bioindicators widely used during vegetation recovery as a result of environmental disturbance. Moth families such as Arctiinae, Catocalinae, Heliothinae, Noctuinae, Hermeniidae, and Phycitinae respond positively to the environmental disturbances, while others such as Ennominae, Geometrinae, Epipaschiinae, Lymantriidae, and Anthelidae respond negatively. For the above reasons, moths are considered as effective bioindicators. These different responses to environmental changes make them suitable bioindicators.

4. Conclusion

From the study it can be claimed that appropriate use of biological indicators is fundamental for biomonitoring or environmental monitoring. The primary features of bioindicators include species richness and diversity, indicators can be handled easily, showcase high faithfulness towards ecology, more sensitive and fragile to ecological changes. It is observed that some of the environment species in the ecosystem tend to respond in better ways to the changes in the environment. Odonata species are observed to be highly sensitive to environmental changes occuring in the water. While some other species such as Plecoptera, Heteroptera, Coleoptera, and Ephemeroptera are highly adaptive in nature. With respect to land insects, Coleoptera Order has several bioindicators. Different types of bees are used to monitor trace metals in pesticides, herbicide effects, ecological conditions, and radioactivity. Therefore, this study concludes that arthropods are environmental bioindicators which monitors, assesses and maintains a healthy biodiversity conservation with a healthy ecosystem.

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References

[1] Mutia TM. Biodiversity conservation. *Short Course IV on Exploration for Geothermal*. Resources. 2009:1-22

[2] Derocles SA et al. *Advances in ecological research* Vol. In: 58 1-62. 2018

[3] Sharma K, Chowdhary S. Macroinvertebrate assemblages as biological indicators of pollution in a Central Himalayan River, Tawi (JK). International Journal of Biodiversity and Conservation. 2011;**3**:167-174

[4] Nesemann H, Sharma G, Sinha R. Benthic macro-invertebrate fauna and" marine elements" sensu Annandale (1922) Highlight the valuable dolphin habitat of river Ganga in Bihar-India. *TAPROBANICA*: *The Journal of Asian Biodiversity*; 2011

[5] Holt, E. & Miller, S. (2011) Bioindicators: Using Organisms to Measure.

[6] Maleque MA, Ishii HT, Maeto K. The use of arthropods as indicators of ecosystem integrity in forest management. Journal of Forestry. 2006:113-117

[7] da Rocha JRM, De Almeida JR, Lins GA, Durval A. Insects as indicators of environmental changing and pollution: a review of appropriate species and their monitoring. Holos environment. 2010;**10**:250-262

[8] Pearce JL, Venier LA. The use of ground beetles (Coleoptera: Carabidae) and spiders (Araneae) as bioindicators of sustainable forest management: a review. Ecological Indicators. 2006;**6**:780-793

[9] Spiller MS, Spiller C, Garlet J. Arthropod bioindicators of environmental quality. Revista Agro@mbiente On-line. 2017;**12**:41-57

[10] Suheriyanto, D., Zuhro, Z., Farah, I. & Maulidiyah A. in *Journal of Physics: Conference Series.* 012180 (IOP Publishing). 2019

[11] Walker JT, Suckling DM, Wearing CH. Past, present, and future of integrated control of apple pests: the New Zealand experience. Annual Review of Entomology. 2017;**62**:231-248

[12] Parisi V, Menta C, Gardi C, Jacomini C, Mozzanica E. Microarthropod communities as a tool to assess soil quality and biodiversity: a new approach in Italy. Agriculture, Ecosystems & Environment. 2005;**105**:323-333

[13] Parisi V, Menta C. Microarthropods of the soil: convergence phenomena and evaluation of soil quality using QBS-ar and QBS-c. Fresenius Environmental Bulletin. 2008;**17**:1170-1174

[14] Langor DW, Spence JR. Arthropods as ecological indicators of sustainability in Canadian forests. The Forestry Chronicle. 2006;**82**:344-350

[15] Frouz J. Use of soil dwelling Diptera (Insecta, Diptera) as bioindicators: a review of ecological requirements and response to disturbance. Agriculture, Ecosystems & Environment. 1999;**74**:167-186

[16] Nsengimana, V. Use of soil and litter arthropods as biological indicators of soil quality in forest plantations and agricultural lands: A Review. (2018).

[17] Hou Z, Liu Y, Wei C. Influence of construction and demolition waste on fitness and community structure of cicada nymphs: New bioindicators of soil pollution. PLoS One. 2018;**13**:e0203744

[18] Ghannem S, Touaylia S, Boumaiza M. Beetles (Insecta: Coleoptera) as bioindicators of

the assessment of environmental pollution. Human and Ecological Risk Assessment: An International Journal. 2018;**24**:456-464

[19] Spector S. Scarabaeine dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae): an invertebrate focal taxon for biodiversity research and conservation. The Coleopterists Bulletin. 2006;**60**:71-83

[20] Nichols E, Larsenb T, Spectora S, Davise AL, Escobarc F, Favilad M, et al. Global dung beetle response to tropical forest modification and fragmentation: a quantitative literature review and meta-analysis. Biological Conservation. 2007;**137**:1-19

[21] Burghelea CI, Zaharescu DG, Hooda PS, Palanca-Soler A. Predatory aquatic beetles, suitable trace elements bioindicators. Journal of Environmental Monitoring. 2011;**13**:1308-1315

[22] Viana-Junior AB, Reis YT, Costa APM, Souza VB. Termite assemblages in dry tropical forests of Northeastern Brazil: Are termites bioindicators of environmental disturbances? Sociobiology. 2014;**61**:324-331

[23] Pribadi T, Raffiudin R, HARAHAP IS. Termites community as environmental bioindicators in highlands: a case study in eastern slopes of Mount Slamet, Central Java. Biodiversitas Journal of Biological Diversity. 2011;**12**

[24] Underwood EC, Fisher BL. The role of ants in conservation monitoring: if, when, and how. Biological Conservation. 2006;**132**:166-182

[25] Sinclair J, New T. Pine plantations in south eastern Australia support highly impoverished ant assemblages (Hymenoptera: Formicidae). Journal of Insect Conservation. 2004;**8**:277-286

[26] De Bruyn LL. *Invertebrate Biodiversity as Bioindicators of Sustainable Landscapes*. Elsevier; 1999. pp. 425-441

[27] Lawes MJ, Moore AM, Andersen AN, Preece ND, Franklin DC. Ants as ecological indicators of rainforest restoration: Community convergence and the development of an Ant Forest Indicator Index in the Australian wet tropics. Ecology and Evolution. 2017;*7*(20):8442-8455

[28] Ribas CR, Campos RB, Schmidt FA, Solar RR. Ants as indicators in Brazil: a review with suggestions to improve the use of ants in environmental monitoring programs. Psyche. 2012;*2012*

[29] Cooper C. *Simplifying the use of ants as bioindicators on mine sites*. University of York; 2018

[30] Rocha-Ortega M, Rodríguez P, Córdoba-Aguilar A. Can dragonfly and damselfly communities be used as bioindicators of land use intensification? Ecological Indicators. 2019;**107**:105553

[31] Jeremiason JD, Reiser T, Weitz R, Berndt M, Aiken GR. Aeshnid dragonfly larvae as bioindicators of methylmercury contamination in aquatic systems impacted by elevated sulfate loading. Ecotoxicology. 2016;**25**:456-468

[32] Voshell, J. R. (2002). *A guide to common freshwater invertebrates of North America* (No. Sirsi) i9780939923878.

[33] Menetrey, N., Oertli, B., Sartori, M., Wagner, A. & Lachavanne, J. (2007). *Pond Conservation in Europe* 125-135 .

[34] Zedkova B, Rádková V, Bojková J, Soldán T, Zahrádková S. Mayflies (Ephemeroptera) as indicators of environmental changes in the past five decades: a case study from the Morava and Odra River Basins (Czech

Republic). Aquatic Conservation: Marine and Freshwater Ecosystems. 2015;*25*(5):622-638

[35] Firmiano KR, Ligeiro R, Macedo DR, Juen L, Hughes RM, Callisto M. Mayfly bioindicator thresholds for several anthropogenic disturbances in neotropical savanna streams. Ecological Indicators. 2017;*74*:276-284

[36] Azam I, Afsheen S, Zia A, Javed M, Saeed R, Sarwar MK, et al. Evaluating insects as bioindicators of heavy metal contamination and accumulation near industrial area of Gujrat, Pakistan. BioMed research international. 2015

[37] AGRIPPINE Y-FJ, DIDIER MA, XU S-Q. Diversity, abundance and distribution of grasshopper species (Orthoptera: Acrididea) in three different types of vegetation with different levels of anthropogenic disturbances in the Littoral Region of Cameroon. Journal of Insect Biodiversity. 2020;**14**:16-33

[38] Halder I, Barbaro L, Corcket E, Jactel H. Importance of semi-natural habitats for the conservation of butterfly communities in landscapes dominated by pine plantations. Biodiversity and Conservation. 2008;(**5**):1149-1169

[39] Bergman K-O, Ask L, Askling J, Ignell H, Wahlman H, Milberg P. Importance of boreal grasslands in Sweden for butterfly diversity and effects of local and landscape habitat factors. Biodiversity and Conservation. 2008;**17**:139-153

[40] Kitahara M, Yumoto M, Kobayashi T. Relationship of butterfly diversity with nectar plant species richness in and around the Aokigahara primary woodland of Mount Fuji, central Japan. Biodiversity and Conservation. 2008;**17**:2713-2734

[41] Miller DG III, Lane J, Senock R. Butterflies as potential bioindicators of primary rainforest and oil palm plantation habitats on New Britain, Papua New Guinea. Pacific Conservation Biology. 2011;**17**:149-159

[42] PE'ER G, Settele J. The rare butterfly Tomares nesimachus (Lycaenidae) as a bioindicator for pollination services and ecosystem functioning in northern Israel. Israel Journal of Ecology and Evolution. 2008;**54**:111-136