

Evaluating Insects as Bio-Indicators of Environmental Pollution : A Review

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Abstract

In recent decades of environmental degradation, bio-indicators have been generating great interest in environmental pollution research. Actually the main goal of research on bio-indicators is to identify and know about the species that would successfully indicate environmental stress, not only that but they show the effects of disturbances on other species & the overall biodiversity. Insects are truly beneficial to determinate the effects of anthropogenic activities on the terrestrial and aquatic ecosystem and atmosphere, because insects are in close contact with toxic elements present in soil, water and air. In this article we have highlighted the importance of the insects in monitoring of environmental pollution and assessment of pollutants. We have mainly focused on various insect groups as bio-indicators of change in air, water and soil quality. Some specific insects like Odonates, honeybees, ants & butterflies are used as bio-indicators in this study because they are very sensitive to even a slight change in environment and also they are used in monitoring of various environmental pollutants.

There was a growing change of natural environment around the world, as a result of the growth of human population in recent decades. The economic potential of biodiversity and advanced destruction process of land ecosystem especially in tropical regions led to the search for an extinction rate estimation of plant and animal species which are around 27000 per year⁴. Invertebrates are more severely and quickly affected than other taxes by changes in the landscape. The insects are responsible for many process in the ecosystem and its laws can have negative effects on entire communities. Thus a strong sensitivity of insect responses to human activity to support policy implications for conservation

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& to evaluate functional consequences of human disturbance on ecosystem²⁰. Studies about biodiversity preservation can provide information about maintenance of environmental resources and sustainable development. In almost all ecosystem, insects are the most abundant animal groups and can be used to evaluate the environmental stress. Through population and behavioral studies and the taxonomy of species its possible to estimate what the current degradation rate is and its future consequences. Bio-indicator species are used to monitor and identify the health of an environment and the qualitative status of environment¹³. A good bio-indicator provides information about pollutants and intensity of exposure and there is no better technique for environment monitoring than the bio monitoring agent¹⁰. As insects are of sensitive nature, in respect to pollution because of these they help us to identify the changes in environment and serves as good biotic indicator of alteration in quality of environment¹². This paper aims to analyse the major groups of insect indicates on the aquatic and terrestrial environment.

Bioindicator :

Bio-indicators are mainly the living organisms such as plants, animals, planktons or microbes which are used to determinate the health of the natural ecosystem in the environment²³. Another definition of Bio-indicator is any species or group of species whose population, function or status can reveal the qualitative status of the environment. Living organisms and environmental conditions of their habitat, that can be examined without any

difficulty, can be regarded as indicator species¹⁴. The numerous benefits of bio-indicators have spurred legislative mandates for their use in countries around the world and their inclusion in several international accords. Some times, we cannot discriminate slight natural changes but some specific insect groups can easily sense it. Finally, the overall objective of bio-indicators is to use a single species or a small group of species, to assess the quality of an environment and it's changes over time.

Insects as Bioindicator :

The use of indicator species as ecological indicators is important for environmental monitoring. The main features and characteristics of a bio-indicator are: reliability, ecological faithfulness and fragility to small environment changes, easy handling, cost effective, richness and diversity species and easy to assess the changes in environment and insects have all of them. Because of this insect act as an important indicator of changes in soil quality, air quality and water quality. These changes leads to the alternation of the abundance, physiological aspects of different species though it is quite challenging to select a specific indicator and then identify it as well as the relation among the indicators and their particular applications. We can use insects to determine pollution in air, water as well as in soil and by this process in the future we can control pollution and prevent the habitat and biodiversity loss. Insect groups used as environmental indicators should have the characteristics shown in the Table-1.

Table-1. Insect groups characteristics used as environmental bio-indicators

Characteristics	Description
Richness and species diversity	Four in five species of animals are insects
Easy handling	Most species require few efforts for their capture, except toxic species. Small size of samples help to their capture & transport.
Fragility to small changes	It allows to select demographical or behavioral variables that can be measured or observed in the field, and have a close correlation with the pre-selected abiotic variables.
Organism's responses	To identify levels of environmental change.
Ecological faithfulness	Many species may have low tolerance to abiotic factors, which allows to link certain insect groups with certain habitats.

Insect Groups as Pollution Indicator :

A. Aquatic insects as water pollution

indicator : Aquatic insects have been used as bio-indicators and are among the most frequently used groups in biological assessment of water quality worldwide². Aquatic insects offer a spectrum of responses to different degrees of environmental stress change over time. Some studies reported that aquatic insects are very good in detecting anthropogenic disturbance and habitat quality due to their sensitivity toward factors, responsible for changing water quality²⁷. Metallothioneins, a measurement of metal tolerance of aquatic insects can provide clues about the possible toxic agents responsible for environmental stress. Generally, aquatic insects from the Orders Ephemeroptera (mayflies), Plecoptera (stone flies), Trichoptera (caddis flies) are bio-indicators for good water quality, while Diptera (midges) are excellent in detecting bad

water quality conditions¹⁹ (Fig. 1). Water quality is evaluated by comparing the number of tolerant species to the number of intolerant insect species¹¹. Several insects can be used as aquatic bio-indicator, which are as follows :

- ❖ **Dragonflies and damselflies as bio-indicator :** Dragonflies and damselflies (Order Odonata) are considered as best ecological indicator in water and riparian systems. They give a rapid and sensitive response to accumulation of heavy metals and habitat disturbance²⁷. Their presence in any water body indicates its pollution-free status⁶.
- ❖ **Mayflies as bio-indicator :** Mayfly larvae are one of the most important bio-indicator of water pollution and they are frequently used in monitoring programs as bio-indicator for their sensitivity to oxygen depletion in running water.

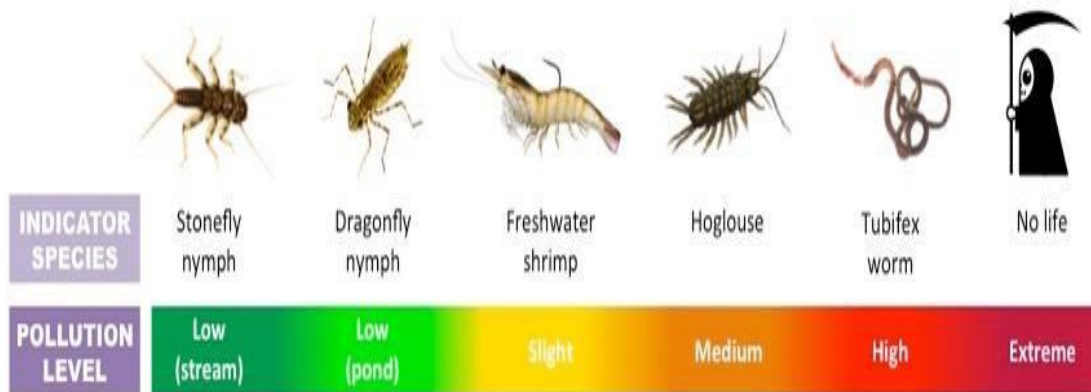


Fig. 1. Indicator insect groups in different water pollution level

- ❖ **Stone flies as bio-indicator** : Stone fly (Order Plecoptera) larvae can live only in the clear, unpolluted and highly oxygenated aquatic environment. Presence of these flies indicate high oxygen level in the water.
 - ❖ **Caddis flies as bio-indicator** : Caddis flies (Order Trichoptera) larvae occurs in freshwater. Only for several species are sensitive to water pollution and they are also used as bio-indicators for the purity of water.
 - ❖ **Sea-skaters as bio-indicator** : Sea-skaters or *Halobates* (Order Gerridae) are suitable bio-indicator for cadmium and mercury distribution in oceanic surface waters⁸. Cadmium accumulation occurs in their tissues and high concentrations have been measured in sea-skaters from tropical oceans⁷.
 - ❖ **Chironomids as bio-indicator** : Chironomids (Order Diptera) are the best bio-indicators of spring water quality because they typically dominate spring fauna in terms of abundance and species number¹⁶. They are also the useful indicators of the quality of surface water and the upper layer of ground water because the larvae are affected by organic content and trace metal load in the sediments.
- B. Insect as terrestrial pollution indicator:** Terrestrial insects are good bio-indicators, and it is used for several types of environmental change including the indication of habitat alteration, destruction, vegetation succession, contamination and rehabilitation, climate change, species diversity, soil fertility and pollutant⁹. Presence of excess acidic or alkaline substances, agricultural or industrial waste kills the larvae, nymphs and adults of these insects. Several insects can be used as terrestrial bio-indicator, which are as follows :
- ❖ **Termites as bio-indicator** : Termites (Order Isoptera) play a major role in nitrogen fixation, methanogenesis, nutrient recycling, movement & transportation of

soil material and acts as bio indicator of soil fertility. They are ecological engineers in building mounds which enhances the content of organic carbon, clay and nutrients²². Termite's gut is adapted for rising of pH, and oxygen level which are important for soil compositional modifications¹⁵.

❖ ***Ants flies as bio-indicator*** : Ants are essential for ecosystem health and providing services in pollination, seed distribution, litter decomposition, nutrient cycling, drainage *etc.*¹⁷ and have strong resistance to radioactive & industrial pollutants. Some ants are a good biological indicators of crop management, soil atmosphere and assessment systems for plantation in agro-ecosystem¹⁸. Ants act as effective bio-indicators for their sensitivity toward ecosystem disturbances caused by forest-thinning, grazing, species invasion, forest conversion, forest fragmentation *etc.*²⁶. Ants have been successfully used as bio-indicators in Australia where ants richness is correlated with microbial activity in rehabilitated mine sites³ and as indicators of forest health, rangeland condition and pollution.

❖ ***Butterflies and moths as bio-indicator*** : Butterflies (Order Lepidoptera) are considered to be a potential ecological indicator of forest condition for their behavioral aspects toward light, temperature, and habitat requirements²⁹. In Gir national park, Nymphalidae and Danaidae butterflies were abundantly observed while Hesperidae butterflies were recorded the least dominant. Butterfly diversity has been

observed higher in disturbed forests in comparison to the natural dense forests as they interact the most in disturbances. They are considered one of the good ecological indicator of climate change²⁸. Their habitat signals a healthy ecosystem because they have strong associations with habitat variables such as sunny conditions, meadows, hilly regions, edges of woodlands, and an abundance of herbaceous plants²¹. Butterflies have been successfully used as bio-indicators for environmental pollution and heavy metals contamination near industrial states and even within urban areas²⁶. On the other hand, moths have also been used as bio-indicators during vegetation recovery after environmental disturbance¹³. Some moth belongs to the family Noctuidae, Arctiidae, Helioidae, Catocalinae and Phycitidae) respond positively to disturbances while moths under Geometridae, Ennomidae, Epipaschiidae and Anthelidae family respond negatively to disturbance¹⁰.

❖ ***Beetles as bio-indicator*** : The bioaccumulation of heavy metals by beetles (Order Coleoptera) has been the subject of several studies. Simon *et al.*³⁰ showed that Carabid beetles are frequently used for Eco toxicological analyses due to the fact that they are easily found in all types of terrestrial environments and they have received considerable attention as potential bioindicators. He found high Bioaccumulation factor values for Cu and Zn with a study of *P. oblongopunctatus* which indicated that this species is preferable in metal pollution assessment. Cerambycidae: The diversity of cerambycid beetles is influenced by many factors, such as canopy cover,

composition of tree species, litter and decayed trees. Consequently, a change in land use, such as logging and timber extraction in the forest can affect their abundance and disturbance. Dung beetles are also sensitive to forest fragmentation and the abundance and species richness of dung beetles was positively correlated with fragment area²⁵.

- ❖ ***Syrphid flies as bio-indicator*** : Wide distribution and requirements of variable environmental factors for larval stages make syrphid flies potentially good bioindicators. Sueyoshi *et al.*³¹ found different syrphid fly responses among young secondary forests, mixed forests, and old-growth forests, recognizing their potential bioindicator value in comparing the biodiversity of various forested habitats. On a local scale, these are indicators of habitat structural features because species richness and the diversity of syrphid flies are positively correlated with vertical stand structural complexity and ground layer vegetation.
- ❖ ***Collembola as bio-indicator*** : Apterygote insects that are influencing the soil fertility and stimulation of microbial activity. The inhibition of diseases causing plant-like such as bacteria and fungi. These insects are sensitive to changes in the soil, and reduction in the number of insects to the pollution by heavy metals, usage of pesticides in agricultural soils and soil water acidification by organic pollutants and wastes.
- C. Insect as light pollution indicator** : In recent decades, advances in lighting technology have precipitated exponential

in creases in night sky brightness worldwide, raising concerns in the scientific community about the impact of artificial light at night on crepuscular and nocturnal biodiversity. Excess exposure to light disturbs the developmental cycle of many insects.

- ❖ ***Fireflies as bio-indicator*** : Fireflies are good bio-indicators for light pollution for their sensitivity²⁴. Laboratory and field studies demonstrate that artificial light at night can inhibit the courtship flashing of several firefly species. As a result, bioluminescent fireflies shows the unique vulnerability of terrestrial light based communication systems to artificial illumination.
- D. Insect as air pollution indicator** : Monitoring of air pollution using insect bio-indicators is a potentially effective process of direct air quality measurements. Air pollution has been associated with both direct and indirect toxic effects on insect populations. Some specific insects can be used as bio-indicator of air pollution, which are as follows :
 - ❖ ***Butterflies and moths as bio-indicator*** : Some specific species of butterflies and moths (Order Lepidoptera) are used as environmental indicators of heavy metals and carbon dioxide concentration in locations close to industrial and even within urban areas. Presence of iron, copper, nickel, cadmium and other substances used in fertilizers were studied with pupae of different moth species (Family Noctuidae, Geometridae and Eriocraniidae) population. Duration of life cycle and newly hatched larval mortality rate of butterfly (Family

Nymphalidae) which feed on plants subjected to high carbon dioxide concentration were also observed²⁶. For an example, pepper moth (*Biston betularia*) occurs in two basic colour phases, black and white. Once the dark form was thought to be a separate species and known as *Biston carbonaria* but now it is proved that it is similar species with mutation at a single locus of a dominant allele. It was rare to find the black form in mid-1800s but with the onset of the industrial revolution in 1830, unregulated smoke and air pollution leads to the increase of *carbonaria* forms.

- ❖ **Syrphidfly as bio-indicator** : Syrphidfly (Order Diptera) some times act as bio-indicator. Actually these flies are used to evaluate impact of different agriculture practices e.g. integrated management¹.
- ❖ **Honeybee as bio-indicator** : Honeybee act as bio-indicator of environmental pollution in two ways. It shows high mortality rate in the presence of toxic molecules and also signals via residues of heavy metals in honey and pollen. As a consequence of atmospheric nuclear testing, honeybees have been monitored as an indicator of radio-nuclide strontium 90 in the environment⁵.

This study concluded that the insect groups has many potential representatives that can be used as environmental bio-indicators, among which are some species from the Coleoptera, Isoptera, Diptera, Hymenoptera, Lepidoptera, Hemiptera etc. Orders. In this review article we have mainly focused in the insect indicators as insects are the most abundant and widely distributed species found

in all types of ecosystem viz. terrestrial, aquatic and aerial habitats. In future usefulness we can use this insects to determine pollution in air, water as well as in soil and by this we can control pollution and prevent habitat loss.

Author contributions :

Dr. Dipanwita Sarkar (Paria) developed the study concept. Both authors contributed to the study design. Data collection, data analysis and interpretation were performed by Nibedita Maji under the supervision of Dr. Dipanwita Sarkar (Paria). Nibedita Maji drafted the manuscript, and Dipanwita Sarkar provided critical revisions. All authors approved the final version of the manuscript for submission.

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