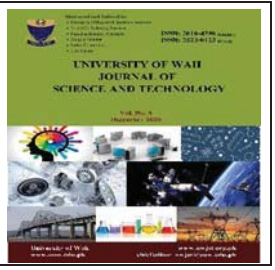
UW Journal of Science and Technology Vol. 4 (2020) 21-25
ISSN: 2523-0123 (Print) 2616-4396 (Online)

University of Wah
Journal of Science and Technology

www.uow.edu.pk



Terrestrial Insects as Bioindicators of Environmental Pollution: A Review

Hareem Sajjad

***Abstract*— Bioindicators are broadly utilized as indicators of natural change, particular biological variables or taxonomic variety. The purpose of this review paper is to give a short-term overview of terrestrial insects orders which are used as biological indicators for environmental change. Three types of bioindicators are present including ecological, environmental and biodiversity indicators. A small amount of taxonomic orders of terrestrial insects is used as bioindicators. But, in spite of the fact that these indicator taxa are thought to questionable as extensive pointers of biodiversity, they may help in recognizing the impacts of habitat management. Coleopterans are the largest group used as bioindicators for soil pollution and metal pollution. Foliage-possessing indicators could include ants, chrysomelid leaf beetles, and arctiid moths. Ants, orthopterans and butterflies possibly proper for use in open living spaces. Utilization of just a small number of taxa might be problematic, and is especially helpless against few intrusive species. These orders ought to be accompanied by other taxa where applicable means and experts are available. This review paper summarizes few taxonomic orders of terrestrial insects, which are used to detect the environmental change.**

***Index Terms*— Bioindicators, Biodiversity, Terrestrial insects, Monitoring, Coleopterans.**

I. Introduction

BIOINDICATORS are taxa or groups which reveals the state of the environment and also act as primary cautioning indicators of any ecological modification to the nearby condition (ecological indicator) and are also used to display a definite biological system pressure or to demonstrate the intensities of taxonomic variety at a place (biodiversity indicator). Employments of bioindicators might be consolidated into a bioindicator system on which site administration choices might be based [1]. Bioindicators may likewise be utilized for preservation prioritization, checking of biological community reaction to administration. Their quality can be checked by their suitability to the question being answered, in addition to the nature of the evaluation [2].

Terrestrial insects as biodiversity bioindicators may imitate tendencies in species productivity and network arrangement more accurate than aquatic insects, as they are more assorted and plentiful in evaluating mine site restoration, proposed that terrestrial insects were preferable biodiversity markers over aquatic insects as they reveals levels of general species fruitfulness and network piece, while likewise being costly to exploit [3,4,5].

Terrestrial insects may often be especially great ecological and environmental pointers because of their little size that makes them delicate to neighborhood environments, although their movement empowers them to travel because of evolving conditions. Thus, short life span end in quick numbering of species, and differences in biological features demonstrate an extensive variety of particular ecological response taxa [5]. Furthermore, these insect invertebrates constitute a generous measure of animal groups biodiversity and are likewise a practically critical part of biodiversity, and although historically ignored in protection and observing systems, they are presently turning into an essential resource in the land biology and preservation tool box [6, 7].

Bioindicators ought to be chosen by figuring out which biological community traits ought to be reflected. They at that point propose posting all taxon groups that fit the traits, where there is some learning of their life histories, as well also known disseminations and ecological resistance stages [8]. Lastly, a subgroup of taxa ought to be chosen which have middle levels of irregularity and are effortlessly noticeable, and also were equally dispersed in the central region [9,10]. As a rule, the required information is missing or to a great degree restricted, particularly the life-history segments. Accordingly, indicators have had a tendency to be chosen from a hardly any gatherings that are accepted to have comparable environmental qualities around the globe, for example, ground scarabs, tiger beetles and dung beetles as markers of disruption and natural surroundings value in the tropics and subtropics [11]. Ants have been

Manuscript received; Feb 21, 2020; accepted July 22, 2020.

H. Sajjad (email: hareemajjad123@gmail.com) is affiliated with University of Gujrat, Pakistan.

Corresponding author e-mail: hareemajjad123@gmail.com

broadly utilized as biodiversity markers, and even a subset of substantial estimated ants have been utilized [12].

In turn, a few examinations have included honey bees (predominantly bumble bees) as gauges of toxin influences on pollinators. A few endeavors have been made to utilize parasitoids or savage arthropods for checking sustainability of agronomic frameworks by showing types assorted variety however as these are to a great extent generalists, their indicator value might be little, as they will probably trail high prey thicknesses than react to the land variety [13]. A review is carried out for some of major taxonomic groups of terrestrial insects used as bioindicators of environmental pollution and habitat fragmentation.

II. MAJOR TAXONOMIC GROUPS USED AS BIOINDICATORS

A. *HYMENOPTERA*

Hymenopterans includes ants, bees and wasps. Ants are generally used to survey landscape disturbance, biological working and species decent variety of habitats [14,15]. So it organizes an essential division of the creature biomass in terrestrial environments and react to weight on a substantially better scale contrasted with vertebrates [16].

A study was conducted in Brazil to check the concentration of heavy metals using two ant species namely *Camponotus atriceps* and *Dorymyrmex brunneus,* which are leading in forest and harvest area. Investigators conclude that ants are good bioindicators of heavy metal contamination because of receiving high inputs of agrochemicals from crops as compared to forests [16,17]. Ants assorted variety and bioindication are the principle issues in myrmecological studies about worldwide for their part in recognition environment qualities and any biological community with delicate finger printing the corresponding changes. Such type of study was conducted in Egypt to check the anthropogenic activities caused by humans using six-study sites adundant with ants [19]. Scientists concluded that species richness, adundance and habitat characteristics of ants had changed due to human activities.

In Asia, Northern-Indian Shivalik mountain range has as of late gone under solid anthropogenic activities. Ants were utilized as bioindicators to survey biological system soundness of the zone. In the study, scientists measured assorted variety, network designs, species structure and the impact of intrusive types of Formicidae at 75 sites in the mountain [20].

Ants are also used as biodiversity indicators. Ground foraging ants are used to check the forests health. Ants insect fauna is firmly related the basic unpredictability of the habit [21-23]. Hence, there must be awesome insect species extravagance in the more established, all the more fundamentally complex fragments [24, 25]. In other studies, a functional group model of ants network organization has been generally utilized as a part of Australia to break down biogeographical examples of ant community and the reactions of ants networks to aggravation. The model has given profitable help to the extensive utilization of these ant populations as bioindicators of natural alteration. The model may consequently assume an essential part in the utilization of ants as bioindicators of environmental change in the World Heritage rainforests of this region [26].

Social wasps are also castoff as pointers for pollution and woodland disturbance. An investigation was directed to check the possible utilization of social wasps as ecological indicators of living space worth in riparian backwoods in Brazil [27, 18]. In other studies, paper wasps are also used as good environmental bioindicators of heavy metal accumulation and forest disturbance [28]. Polistes dominulus has the ability to accumulate lead in the larval feaces through their diet by the process of biomagnification and therefore can be used as bioindicators of heavy meta pollution [29, 30].

Honey bee *Apis mellifera* is also used as bioindicators for checking environmental quality. In a study conducted in Italy, honey bees are used as bioindicators to check the amount and dispersal of insecticides in the agriculture [31, 32, 22].

Despite the fact that ants are broadly utilized as bioindicators, there might be restrictions attributable to their strength and, in a few cases, because of down to earth imperatives. Maximum ant studies have depended on pitfall traps, demanding surveys, which may not generally be favorable [33].

B. *COLEOPTERA*

Insects of this group contains one of the largest taxonomic and ecological diversity. But one problem is that group is too diverse that may create problem during sampling at different sites [34, 35]. In such a diverse order, beetles are mostly used as bioindicators of environmental pollution and habitat degradation. Coleopterans are most widely used in pointing the change in habitat characteristics, or monitoring habitat management and restoration [35, 36, 37]. Different species have particular level of indication e.g tenebrionidae is used as indicator of fire recovery.

Ground beetles are used as bioindicator of heavy metal accumulation. An experiment was done to check the absorption of heavy metals in soil, litter and leaf beetle: *Oulema gallaeciana* [38, 39]. Morphology of beetle is also changed due to heavy metal accumulation. Blaps polycresta is the specie of beetle that shows ultrastructure alteration in ovarian tissues. Most common detected metals found in these ovarian tissues are copper, zinc, cadmium and lead [40]. Carabid beetle; *Parallelomorphus laevigatus*; are used to detect soil metal pollution in the environment. It is present in soil and active at the evening. It is involved in the analysis of ecotoxicological impact of trace metals in this specie of beetle [40, 41]. These beetles are also used as bioindicator of environmental quality by changing there body size. In a study conducted in northern Arizona, these beetles show less distortion in body size where habitat destruction is at its minimum [42].

In another experiment, comparison of bats, butterflies and beetles was conducted to check the sustainability of these bioindicators. Scientists experimented on DNA bar

codes of these three species. According to results, beetles shows more specie richness as compared to other two species and are considered as good bioindicator of environmental quality [43]. Tiger beetles are also used as good bioindicator because of stable taxonomy, easy to monitor and have different species. Moreover, distribution and diversity of these beetles can be correlated with other taxa [44, 45].

Dung beetles are excellent bioindicators of forest disturbance and biodiversity loss. A study was conducted in Tanzania to check the specie diversity, functional diversity and composition of Scarab beetles [45, 46]. Dung beetles are also involved in ecological sustainability of the environment. A case study was conducted in Iran for checking ecological sustainability in rangelands [47]. Fragmentation and habitat distribution are main factors that make them good bioindicators [48].

C. LEPIDOPTERA

Lepidoptera butterflies are widely used as bioindicators because of their conspicuousness and ease of identification. Insects of this group are responsible to detect changes in habitat, forest disturbance and management. Lepidopterans are also good bioindicator of heavy metal pollution and environmental quality [49, 50, 51].

Recently, a study was conducted in Japan on the pale grass blue butterfly, *Zizeeria maha* (Lepidoptera, Lycaenidae), recognizing this species as a good biological indicator to detect variations in human living environment after the nuclear war of Fukushima. It was concluded that specie richness and biodiversity of this butterfly is reduced after this nuclear accident [52, 53].

Moths are also used as good ecological bioindicators of environmental quality [54, 55, 56]. A study was conducted in western Himalayas protected areas for moths assemblage as a potential conservation tool for biodiversity monitoring. Study shows the community structure and distribution pattern of moth in this region [57, 58].

D. DIPTERA

Diptera are also used as bioindicators because of their ecological diversity [60]. However, such insects are less commonly used as bioindicator because of their unstable taxonomy and difficulty in identification [61]. Therefore, diptera are infrequently utilized as bioindicators. Minor amount of families are used as bioindicators e.g chironomidae, Syrphidae, Calliphoridae, Drosophilidae [60].

Drosophila mealnogestar, which is a model organism for genetics and forensic research, can be used as a potential bioindicator in open environments. Dipterans can be used for habitat degradation and forest disturbance [62]. Chironomidae larvae can be used as bioindicators in urban reservoirs of changed trophic levels. These larvae developed deformities in their mouthparts in response to change in environment [63, 64]. Another species of Diptera, *Sarcosaprophagous calyptratae* (Diptera) can be used as bioindicator to detect urbanization in Brazil. It was conducted on sandy Beaches of Brazil to detect the change in the number of this species due to urbanization [65, 66].

E. ORTHOPTERA

Orthopterans includes grasshoppers and crickets, which are also used as ecological indicators to detect change in the environment [2, 44]. These insects are also delicate to environment degradation and climate change as well as they are also used to detect the effect of industrialization and urbanization in different regions. An experiment has been done on *Aiolopus thalassinus* (Orthoptera: Acrididae) by using alkaline comet assay for biomonitoring the toxicity in genes of this species caused by industrial fertilizer pollutants [66].

Orthopterans are also used as indicator of heavy metal accumulation. In a scientific study, *Tetrix tenuicornis* (Tetrigidae, Orthoptera) was collected from polluted and unpolluted areas, and detected the stress on heat shock proteins and studied the cytogenic changes in these species and are also found sensitive to climate change and grassland conditions [66].

III. CONCLUSION

Bioindicators are valuable for recognizing ecological qualities or observing the impacts of territory management, especially in demonstrating progress in reclamation. To create solid outcomes, it is imperative that studies utilize a suite of taxa to cover distinctive viewpoints and to limit danger of an invasive species puzzling outcomes. The taxa to be chosen will rely upon the framework being studied. Foliage-occupying indicators could consolidate ants, chrysomelid leaf bugs, theridiid arachnids and arctiid moths. Open territory bioindicators ought to contain ants, orthopterans and butterflies. For sand ridges, specifically tenebrionidae beetles are the best indicators. Nevertheless, where suitable possessions and taxonomic skill are accessible, it is recommended to add other groups.

REFERENCES

[1] A.A. Anderson, S. Mccormack, A. Helden, H. Sheridan, A. *Kinsella* and G. Purvis. The potential of parasitoid hymenoptera as bioindicators of arthropod diversity in agricultural grasslands, Journal of Applied Ecology, Vol. 48(2), pp. 382-390, 2011.

[2] A. Hiyama, W. Taira, K. Sakauchi and J.M. Otaki. Sampling efficiency of the pale grass blue butterfly zizeeria maha (Lepidoptera: Lycaenidae): A versatile indicator species for environmental risk assessment in Japan, Journal of Asia-Pacific Entomology, Vol. 21(2), pp. 609-615, 2018.

[3] A. Hochkirch. Habitat preferences of grasshoppers (Orthoptera: Acridoidea, Eumastacoidea) in the East Usambara Mountains, NE Tanzania, and their use for bioindication, Ecotropica, Vol. 2, pp. 195-217, 1996.

[4] Loni and A. Lucchi. Hymenoptera parasitoid, a suitable biodiversity resource for vineyard environmental discrimination, Journal of Agricultural Science, Vol. 6(12), pp. 36, 2014.

[5] Urbini, E. Sparvoli and S. Turillazzi. Social paper wasps as bioindicators: a preliminary research with Polistes dominulus (Hymenoptera Vespidae) as a trace metal accumulator, Chemosphere, Vol. 64(5), pp. 697-703, 2006.

[6] A. Siddig, A.M. Ellison, A. Ochs, C. Villar-Leeman and M.K. Lau. How do ecologists select and use indicator species to monitor ecological change, Ecological Indicators, Vol. 60, pp. 223-230, 2016.

[7] A.C. Vermeulen. Elaborating chironomid deformities as bioindicators of toxic sediment stress: the potential application of

mixture toxicity concepts, In Annales Zoologici Fennici, Finnish Zoological and Botanical Publishing Board, pp. 265-285, 1995.

[8] A.M. Ellison. Out of Oz: opportunities and challenges for using ants (Hymenoptera: Formicidae) as biological indicators in north-temperate cold biomes, Myrmecological News, 2012.

[9] C.I. Burghelea, D.G. Zaharescu, P.S. Hooda and A. Palanca-Soler. Predatory aquatic beetles, suitable trace elements bioindicators, Journal of Environmental Monitoring, Vol. 13(5), pp. 1308-1315, 2011.

[10] E. Conti. Ecotoxicological evaluation of parallelomorphus laevigatus (Coleoptera, Carabidae) as a useful bioindicator of soil metal pollution, Advance Technology Biology Medicine, Vol. 5(228), pp. 2379-1764, 2017.

[11] E. Warchałowska-Śliwa, M. Niklińska, A. Görlich, P. Michailova and E. Pyza. Heavy metal accumulation, heat shock protein expression and cytogenetic changes in tetrix tenuicornis (L.)(Tetrigidae, Orthoptera) from polluted areas, Environmental Pollution, Vol. 133(2), pp. 373-381, 2005.

[12] E. A. Abdelfattah., M. Augustyniak and H.A. Yousef. Biomonitoring of genotoxicity of industrial fertilizer pollutants in aiolopus thalassinus (Orthoptera: Acrididae) using alkaline comet assay, Chemosphere, Vol. 182, pp.762-770, 2000.

[13] E. O. Ardali, P. Tahmasebi, D. Bonte, T. Milotic, I.R. Pordanjani and M. Hoffmann. Ecological sustainability in rangelands: The contribution of dung beetles in secondary seed dispersal (Case study: Chaharmahal and Bakhtiari province, Iran), European Journal of Sustainable Development, Vol. 5(3), pp. 133, 2016.

[14] F. Dziock. Life history data in bioindication procedures, using the example of hoverflies (Diptera, Syrphidae) in the elbe floodplain, International Review of Hydrobiology, Vol. 91(4), pp. 341-363, 2006.

[15] F. Löffler and T. Fartmann. Effects of landscape and habitat quality on orthoptera assemblages of pre-alpine calcareous grasslands, Agriculture, Ecosystems & Environment, Vol. 248, pp. 71-81, 2017.

[16] F. Talarico, P. Brandmayr, P.G. Giulianini, F. Ietto, A. Naccarato, E. Perrotta and A. Giglio. Effects of metal pollution on survival and physiological responses in Carabus (Chaetocarabus) lefebvrei (Coleoptera, Carabidae), European Journal of Soil Biology, Vol. 61, pp. 80-89, 2014.

[17] F. O. Arimoro, Y.I. Auta, O.N. Odume, U.N. Keke and A.Z. Mohammed. Mouthpart deformities in Chironomidae (Diptera) as bioindicators of heavy metals pollution in Shiroro Lake, Niger State, Nigeria, Ecotoxicology and Environmental Safety, Vol. 149, pp. 96-100, 2018.

[18] G. Balayiannis and P. Balayiannis. Bee honey as an environmental bioindicator of pesticides' occurrence in six agricultural areas of Greece, Archives of Environmental Contamination and Toxicology, Vol. 55(3), pp. 462, 2008.

[19] G.C. Rabello, J. Dambros, R.I. Andrade and L.D. Battirola. Bioaccumulation of heavy metals in the bodies of workers of Camponotus atriceps and Dorymyrmex brunneus (Hymenoptera, Formicidae): an exploratory study, Revista Colombiana de Entomología, Vol. 43(1), pp. 64-68, 2017.

[20] H. Bharti, M. Bharti and M. Pfeiffer. Ants as bioindicators of ecosystem health in Shivalik Mountains of Himalayas: assessment of species diversity and invasive species, Asian Myrmecology, Vol. 8, 2017.

[21] Del Toro, R.R. Ribbons and S.L. Pelini. The little things that run the world revisited: A review of ant-mediated ecosystem services and disservices (Hymenoptera: Formicidae), Myrmecological News, Vol. 17, pp.133-146, 2012.

[22] I.D. Hodkinson and J.K. Jackson. Terrestrial and aquatic invertebrates as bioindicators for environmental monitoring, with particular reference to mountain ecosystems, Environmental management, Vol. 35(5), pp. 649-666, 2005.

[23] J. Bohac. Staphylinid beetles as bioindicators, Agriculture, Ecosystems & Environment, Vol. 74(1-3), pp. 357-372, 1999.

[24] J. Borowska and E. Pyza. Effects of heavy metals on insect immunocompetent cells, Journal of Insect Physiology, Vol. 57(6), pp. 760-770, 2011.

[25] J. Frouz. Use of soil dwelling Diptera (Insecta, Diptera) as bioindicators: a review of ecological requirements and response to disturbance, Agriculture, ecosystems & environment, Vol. 74(1-3), pp. 167-186, 1999.

[26] J. Gerlach, M. Samways and J. Pryke. Terrestrial invertebrates as bioindicators: an overview of available taxonomic groups, Journal of Insect Conservation, Vol. 17(4), pp. 831-850, 2013.

[27] J. Tylianakis, D. Veddeler, T. Lozada, R.M. Lopez, P. Benítez, A.M. Klein and G. Onore. Biodiversity of land-use systems in coastal Ecuador and bioindication using trap-nesting bees, wasps, and their natural enemies, Lyonia, Vol. 6(2), pp. 7-15, 2004.

[28] J.B. Sifuentes-Winter. Monitoring biodiversity of San Francisco Peninsula grasslands using Lepidoptera as a bioindicator, 2015.

[29] J. D. Majer, G. Orabi and L. Bisevac. Ants (Hymenoptera: Formicidae) pass the bioindicator scorecard, Myrmecological News, Vol. 10, pp. 69-76, 2007.

[30] J.F. Alignan, J.F. Debras and T. Dutoit. Effects of ecological restoration on Orthoptera assemblages in a Mediterranean steppe rangeland, Journal of Insect Conservation, Vol. 18(6), pp. 1073-1085, 2014.

[31] J.G. Carey, S. Brien C.D. Williams and M.J. Gormally. Indicators of Diptera diversity in wet grassland habitats are influenced by environmental variability, scale of observation, and habitat type, Ecological Indicators, Vol. 82, pp. 495-504, 2017.

[32] J.K. Jung, S.K. Lee, S.I. Lee and J.H. Lee. Trait-specific response of ground beetles (Coleoptera: Carabidae) to forest fragmentation in the temperate region in Korea, Biodiversity and Conservation, Vol. 27(1), pp. 53-68, 2018.

[33] J.R. King, A.N. Andersen and A.D. Cutter. Ants as bioindicators of habitat disturbance: validation of the functional group model for Australia's humid tropics, Biodiversity & Conservation, Vol. 7(12), pp. 1627-1638, 1998.

[34] K. Enkhtur, M. Pfeiffer, A. Lkhagva and B. Boldgiv. Response of moths (Lepidoptera: Heterocera) to livestock grazing in Mongolian rangelands, Ecological indicators, Vol. 72, pp. 667-674, 2017.

[35] K. Syaripuddin, K.W. Sing and J.J. Wilson. Comparison of butterflies, bats and beetles as bioindicators based on four key criteria and DNA barcodes. Tropical Conservation Science, Vol. 8(1), pp. 138-149, 2015.

[36] L. Bizzo, M.S. Gottschalk, D.C.D. Toni and P.R. Hofmann. Seasonal dynamics of a drosophilid (Diptera) assemblage and its potencial as bioindicator in open environments, Iheringia, Série Zoologia, Vol. 100(3), pp. 185-191, 2010.

[37] L. A. Nunes, E.D.D. Araújo and L.C. Marchini. Fluctuating asymmetry in Apis mellifera (Hymenoptera: Apidae) as bioindicator of anthropogenic environments, Revista de Biologia Tropical, Vol. 63(3), pp. 673-682, 2015.

[38] L. D Audino, J. Louzada and L. Comita. Dung beetles as indicators of tropical forest restoration success: Is it possible to recover species and functional diversity, Biological Conservation, Vol. 169, pp. 248-257, 2014.

[39] L.M. EL-Samad, E. Mokhamer, W. Osman, A. Ali and M.L. Shonouda. The ground beetle, Blaps polycresta (Coleoptera: Tenebrionidae) as bioindicator of heavy metals soil pollution, Journal of Advance Biology, Vol. 7, pp. 1153-1160, 2015.

[40] M. Shonouda and W. Osman. Ultrastructural alterations in sperm formation of the beetle, Blaps polycresta (Coleoptera: Tenebrionidae) as a biomonitor of heavy metal soil pollution, Environmental Science and Pollution Research, pp. 1-11, 2018.

[41] M.A. Sorensen, D.R. Parker and J.T. Trumble. Effects of pollutant accumulation by the invasive weed saltcedar (Tamarix ramosissima) on the biological control agent Diorhabda elongata (Coleoptera: Chrysomelidae), Environmental Pollution, Vol. 157(2), pp. 384-391, 2009.

[42] M.B. Savage and L.K. Rieske. Coleopteran communities associated with forests invaded by emerald Ash borer, Forests, Vol. 9(2), pp. 69, 2018.

[43] M.J. Koivula. Useful model organisms, indicators, or both? Ground beetles (Coleoptera, Carabidae) reflecting environmental conditions, ZooKeys, Vol. (100), pp. 287, 2011.

[44] M. M. de Souza, J. Louzada, J. Eduardo Serráo and J. Cola Zanuncio. Social wasps (Hymenoptera: Vespidae) as indicators of conservation degree of riparian forests in Southeast Brazil, Sociobiology, Vol. 56(2), pp. 387, 2010.

[45] M. M. El Bokl, F.M. Semida, M.S. Abdel-Dayem and E.I. Surtasi. Ant (Hymenoptera: Formicidae) diversity and bioindicators in the lands with different anthropogenic activities in new Damietta,

EGYPT, International Journal of Entomological Research, Vol. 3(2), pp. 35-46, 2015.
[46] M.S. Coelho, G.W. Fernandes, J.C. Santos and J.H. Charles Delabie. Ants (Hymenoptera: Formicidae) as bioindicators of land restoration in a Brazilian Atlantic Forest fragment, Sociobiology, Vol. 54(1), pp. 51, 2009.
[47] O. Atlegrim, K. Sjöberg and J.P. Ball. Forestry effects on a boreal ground beetle community in spring: selective logging and clear-cutting compared, Entomologica Fennica, Vol. 8(1), pp. 19-26, 1997.
[48] R.M. Moraes, M.D.S. Mendonça Jr and R. Ott. Carabid beetle assemblages in three environments in the Araucaria humid forest of southern Brazil, Revista Brasileira de Entomologia, Vol. 57(1), pp. 67-74, 2013.
[49] R.O. Butovsky. Heavy metals in carabids (Coleoptera, Carabidae), ZooKeys, Vol. (100), p. 215, 2011.
[50] S. Ghannem, S. Touaylia and M. Bejaoui. Assessment of trace metals contamination in soil, leaf litter and leaf beetles (Coleoptera, Chrysomelidae) in the vicinity of a metallurgical factory near Menzel Bourguiba (Tunisia), Human and Ecological Risk Assessment: An International Journal, pp. 1-12, 2018.
[51] S. Ghannem, S. Touaylia and M. Boumaiza. Beetles (Insecta: Coleoptera) as bioindicators of the assessment of environmental pollution, Human and Ecological Risk Assessment: An International Journal, Vol. 24(2), pp. 456-464, 2018.
[52] S. Ghini, M. Fernandez, Y. Pico, Y.R. Marin, F. Fini, J. Manes and S. Girotti. Occurrence and distribution of pesticides in the province of Bologna, Italy, using honeybees as bioindicators, Archives of Environmental Contamination and Toxicology, Vol. 47(4), pp. 479-488, 2004.
[53] S. Saleh, U. Hasanah and E. Elijonnahdi. Effectiveness of dung beetles as bioindicators of environmental changes in land-use gradient in Sulawesi, Indonesia, BIOTROPIA, The Southeast Asian Journal of Tropical Biology, Vol. 21(1), pp. 48-58, 2014.
[54] S. S. Avgın and M.L. Luff. Ground beetles (Coleoptera: Carabidae) as bioindicators of human impact, Munis Entomology and Zoology, Vol. 5(1), pp.209-215, 2010.
[55] S. S. Stephens and M.R. Wagner. Using ground foraging ant (Hymenoptera: Formicidae) functional groups as bioindicators of forest health in northern Arizona ponderosa pine forests, Environmental Entomology, Vol. 35(4), pp. 937-949, 2006.
[56] T. Gardiner, J. Hill and D. Chesmore. Review of the methods frequently used to estimate the abundance of orthoptera in grassland ecosystems, Journal of Insect Conservation, Vol. 9(3), pp. 151-173, 2005.
[57] T. Skalski, R. Kędzior, D. Kolbe and S. Knutelski. Different responses of epigeic beetles to heavy metal contamination depending on functional traits at the family level, Baltic Journal of Coleopterology, Vol. 15(2), 2015.
[58] T.M. Barbosa, R.F.R. Carmo, L.P. Silva, R.G. Sales and S.D. Vasconcelos. Diversity of sarcosaprophagous calyptratae (Diptera) on sandy beaches exposed to increasing levels of urbanization in Brazil, Environmental Entomology, Vol. 46(3), pp. 460-469, 2017.
[59] T.T. Work, M. Koivula, J. Klimaszewski, D. Langor, J. Spence, J. Sweeney and C. Hébert. Evaluation of carabid beetles as indicators of forest change in Canada, The Canadian Entomologist, Vol. 140(4), pp. 393-414, 2008.
[60] Langraf, K. Petrovičová, S. David, M. Ábelová and J. Schlarmannová. Body volume in ground beetles (Carabidae) reflects biotope disturbance, Folia Oecologica, Vol. 44(2), pp. 114-120, 2017.
[61] W. Osman and M. Shonouda. X-ray metal assessment and ovarian ultrastructure alterations of the beetle, Blaps polycresta (Coleoptera, Tenebrionidae), inhabiting polluted soil, Environmental Science and Pollution Research, Vol. 24(17), pp. 14867-14876, 2017.
[62] W. Osman, L.M. El-Samad, E.H. Mokhamer, A. El-Touhamy and M. Shonouda. Ecological, morphological, and histological studies on Blaps polycresta (Coleoptera: Tenebrionidae) as biomonitors of cadmium soil pollution, Environmental Science and Pollution Research, Vol. 22(18), pp. 14104-14115, 2015.
[63] Y.T. Chen, L.W. Yeh, I.M. Tso, H.C. Lin, L.K. Lin and C.P. Lin. Evidence of trait shifts in response to forest disturbance in taiwanese carabus masuzoi (Coleoptera: Carabidae), Annals of the Entomological Society of America, Vol. 111(3), pp. 98-102, 2018.
[64] Z. Aydogan, A. Gurol and U. Incekara. Heavy element accumulation in aquatic beetles of the genus enochrus (Coleoptera: Hydrophilidae) in Erzurum Province, Journal of Environmental Pollutant Control, Vol. 1(1), pp. 101, 2018.
[65] Z. Aydoğan, A. Gürol and U. İncekara. The investigation of heavy element accumulation in some Hydrophilidae (Coleoptera) species, Environmental Monitoring and Assessment, Vol. 188(4), p. 204, 2016.
[66] Z. Aydoğan, T. Şişman, U. İncekara and A. Gürol. Heavy metal accumulation in some aquatic insects (Coleoptera: Hydrophilidae) and tissues of Chondrostoma regium (Heckel, 1843) relevant to their concentration in water and sediments from Karasu River, Erzurum, Turkey, Environmental Science and Pollution Research, Vol. 24(10), pp. 9566-9574, 2017.

Hareem Sajjad completed her M.Phil degree in zoology from University of Gujrat, Pakistan in 2019. Her research work is based on elaborating the impact of pesticides on environment as well as their interaction with living organisms.