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INVESTIGATION OF MICROPLASTIC IN PELLETS FROM THE SELECTED PISCIVOROUS BIRD ALONG THE WETLANDS OF COIMBATORE CITY IN TAMIL NADU STATE OF INDIA

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ABSTRACT

The presence of microplastic has reported in the pellets of various water birds across the world but little information were available on plastic ingestion of fresh water birds in India. The Common Kingfisher (*Alcedo atthis*) pellets were collected along the wetlands of Noyyal River. In total, 50 regurgitated pellets were examined between September, 2021 to March, 2022. The putative plastic elements were detected from visual examination followed by μ-FTIR and SEM-EDS. There are two types of polymers namely polyethylene fibers and polypropylene fibers were detected from 13 regurgitated pellets. This was the first reconnaissance study examined the presence of micro plastic fragments in regurgitated pellets of the Common Kingfisher in the Southern India (Fig. 1). This is an important document to understand the impact of microplastic pollution in food web of fresh water ecosystem.

KEY WORDS: Microplastics, Pellets, Kingfisher, Fresh water, Pollution, Hazards

INTRODUCTION

Plastics including microplastic are now ubiquitous in our natural environment and the micro plastics with less than a millimeter in length originates from commercial product development. Since the early 1950s, the production and consumption of plastic items have increased substantially due to global industrialization and modernization (Geyer *et al.*, 2017; MacLeod *et al.*, 2021). Approximately, 8.3 million metric tons of virgin plastic were produced up to 2017, and 12 billion tons of plastic wastes are expected to be found in the natural environment by 2050 (Geyer *et al.*, 2015). An Asian country like India is a home for plastic production used for various domestic and industrial purposes and the large quantities of plastic wastes enter into the environment and mainly into the ocean and fresh water ecosystem and these plastics cause a well-known environmental problem (Bergmann *et al.*, 2017). The presence and occurrence of microplastics has been reported in the freshwater ecosystem worldwide (Dris *et al.*, 2018; Lahens *et al.*, 2018; Mani *et al.*, 2016).These micro-plastic contaminants can originate from both primary sources such as micro-beads in facial cleansers and plastic resin for commercial use (Eriksen *et al.*, 2014; Gregory, 1996), and secondary sources through the breakdown of larger plastic items, common sources of secondary micro-plastics are synthetic fibers from washing clothes mainly made of polyester or acrylic, which are then discharged in high concentration in household effluent (Browne *et al.*, 2007, 2011). These characteristic features of micro plastics can pass through filtration systems and easily accumulated in the pond, rivers and oceans, these microplastics can be ingested by fresh water organisms. Even though microplastics has been discovered in remote areas such as Polar Regions (Bessa *et al.*, 2019), Mount Everest (Napper *et al.*, 2020) and the Mariana Trench (Jamieson *et al.*, 2019). Microplastic can cause a threat to environment (Amelineau *et al.*, 2016; Nabi *et al.*, 2019) and health hazards to various organisms (Cole *et al.*, 2013; Bessa *et al.*, 2018; Nelms *et al.*, 2019)

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and leads to easily enter into the food chain causing potential threats to biodiversity and ecosystems (Karami *et al.,* 2016; Dawson *et al.,* 2018; Zhu *et al.,* 2018). Bio-accumulation of the microplastic wastes was becoming an emerging threat for environmental pollution (Rochman *et al.,* 2014; Wilcox *et al.,* 2015; Zhu *et al.,* 2019). The birds are high mobile vertebrates that are widely distributed in various habitats worldwide, from equator to polar areas, and from oceans and fresh water to high plateau, and considered as eco-indicators and become important members of many ecosystems (Orme *et al.,* 2005) and birds have a high metabolic rate as compared to other animals (McNab, 2009), they have better antioxidant capacity (Costantini, 2008), long life span (Munshi-South and Wilkinson, 2010) efficient digestive system (Caviedes-Vidal *et al.,* 2007). In addition, birds are believed to be highly sensitive to external environmental conditions, and therefore, could be easily used for monitor environmental changes (Carral-Murrieta *et al.,* 2020; Li *et al.,* 2021; Nabi *et al.,* 2021). The study is important to monitor the presence of microplastic in the entire freshwater ecosystem and its food web by selecting fish eating birds as model organism for this study because this might represent a potential problem for continental fresh water bird conservation. Furthermore, the implications of the presence of microplastic on fauna in freshwater system are still little known in India.

Study Area

The Vellalore Lake is situated between Lat 10°58'19.91''N, Long 77°00'24.36''E in Coimbatore (Map. 1). The Lake is spread 95 acres of the wetland water from Noyyal rivers fills up Chitirai Savadi Check Dam, Coimbatore Check Dam, Kuruchi Check Dam and Vellalore Check Dam. Water reaches Vellalore Check Dam only after the above said dams are filled. The Noyyal River flows through Coimbatore, Tirupur, Karur and Trichy districts before joining the Cauvery River at Kodumudi in Erode district. The commercial fishes are Catla, Rohu and Tilapia being reared and cultivated from the Vellalore Lake. Nearly 900 tonnes of city wastes such as vegetable wastes followed by plastic waste, e-waste and meat wastes being generated from Coimbatore city dumped near the Vellalore Lake. This dump yards are located very near to bank of the Noyyal River and wetlands. A proportion of house hold wastes also dumped directly into the wetland by local residents on the river bank. The wetland bird species facing high degree of threats due to anthropological threats and many of the wetland birds are listed as threatened category by International Union for Conservation of Nature (IUCN) in India.

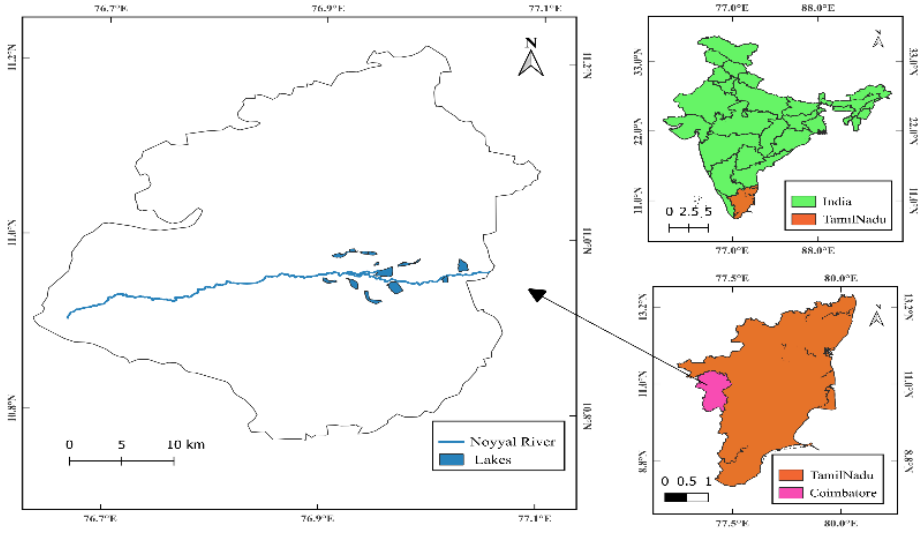
MATERIALS AND METHODS

Sample Collection

The samplings of a total of 50 kingfisher's pellets were collected along roosting places of piscivorous birds along the wetland between September, 2021 to March, 2022

Sample Preparation and Microplastic Extraction

Winkler *et al.,* (2020) method was followed for this



Map. 1. Vellalore Lake

study. The common kingfisher pellets were carefully visually inspected for the presence of potential plastic items under a stereomicroscope (wildM3B Heerbrugg Switcherland, 6.4 x to 40 x) with a detection limit of 40 µm for particle and fragments. Maximum number of fibers had a thickness with ≤ 40 µm and imaging software Fiji was used to capture images from stereo microscope. The putative items were transferred into small glass vials stored until analysis of their polymeric composition by µ-FTIR (Fourier transform infrared spectroscopy). The detection and identification limit with regards to particle size for the applied µ-FTIR instrument was 10 µm. The SEM-EDS (Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS)) an analytical high-resolution technique was used to determine the occurrence of even smaller plastic items. Out of all pellet material, we chose ten pellets from different transects representing in Vellalore Lake. The material was placed in a beaker and underwent a density separation in 100 ml of saturated Sodium Chloride solution for 24 hours to settle parts of the prey such as bone and float microplastic items. Subsequently the supernatant was filtered with an in-house manufacturer's gas filtration apparatus on silver membrane filters (sterlitech, 0.8- µm pore size, 13-mm diameter, filters area of 19.6 mm). The filters were dried for 48 h in glass desiccators and stores until analysis with SEM for SEM-EDS analysis, high resolution images of the filtered material on the silver filter will be taken. Polymer particles of fibers will be identified by their elemental composition signatures.

RESULTS

There are 50 pellets were collected from the Vellalore lake in Coimbatore district of Tamil Nadu. The elemental analysis by SEM-EDS performed on a subset from the pellet material out of 50 samples, 13 samples showed the presence of microplastic revealed two fibers with a C:O ratio corresponding to that of Polyethylene Terephthalate (PET) and 2 fibers with the elemental composition of 100% carbon indicating polyolefin composition from in total 15 different pellets (Fig. 4 and 5). These pellets were carefully examined under the microscope and the suspected putative plastic items were carefully removed from the pellets. Then these collected particles were analyzed with FTIR and derived result. The FTIR values were showed that the presence of two types of polymers such as polyethylene fiber (Graph 2 & Fig. 3) and polypropylene fiber (Graph 1 & Fig. 2). The detected microplastics were mainly fibers of very small size also different size with a mean length of 1.16 ± 1.22-mm standard deviation, ranging from a length of 60 µm to 2.86 mm. While the presence of

Fig. 1. Regurgitated pellets of Common Kingfisher

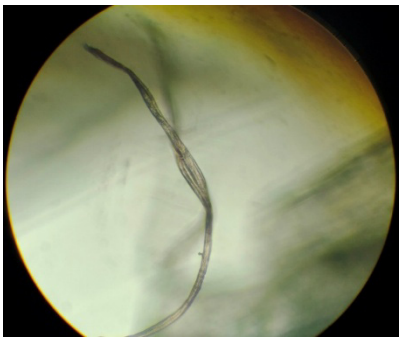
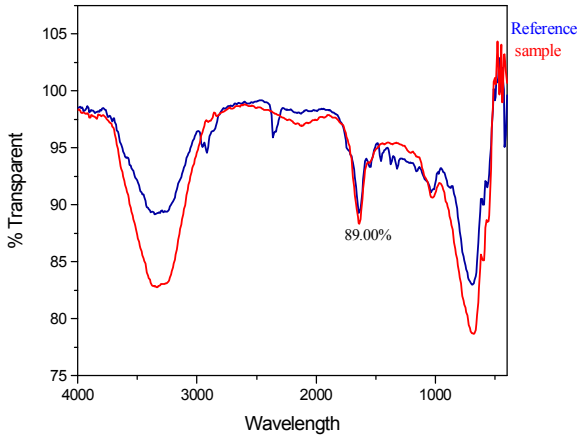
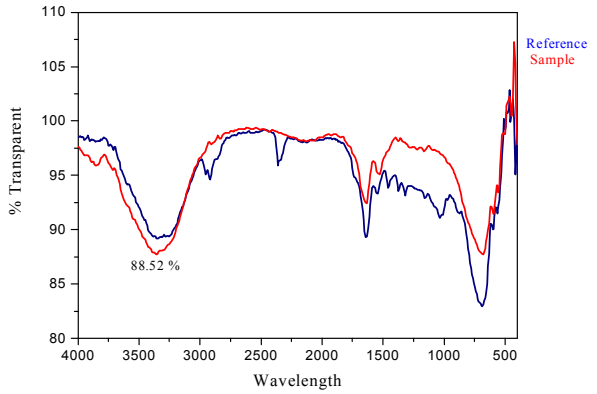


Fig. 2. Microscopic image of visually identified microplastics in pellets of Kingfisher and respective µ-FTIR spectra (red) with matches to reference to polymer from the library (blue).



Graph. 1. Polypropylene with a match of 89%.



Graph. 2. Polyethylene with a match of 88.5%

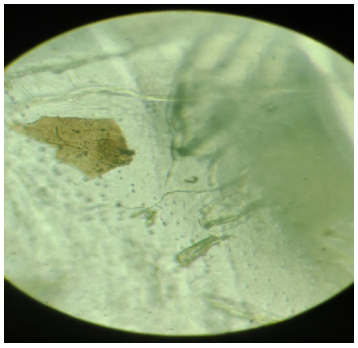


Fig. 3. Microscopic image of visually identified microplastics in pellets of Kingfisher and respective μ-FTIR spectra (red) with matches to reference to polymer from the library (blue).

the kingfisher was confirmed throughout the whole watercourse of the lake (visual observations and response to bird call). Considering the geographical distribution of pellets which included plastic items no strong spatial variation (for example, an increase of microplastic in pellets over the length of the Noyyal River). Following the watercourse, the first occurrence of plastic items in pellets was discovered starting point in the Vellalore Lake of a potential primary input source: a large waste water treatment plant (WWTP) with a population equivalent > 3, 00, 000 that discards its effluent into the Noyyal River. Moreover, microplastic fibers were detected in two procedural blanks analyzed by SEM-EDS hence, airborne contamination during sampling in the field and analysis in the lab was efficiently minimized.

DISCUSSION

There are vast studies available on marine microplastics but few studies investigate on microplastic in fresh water context. Numerous studies are available on the presence of microplastics in the marine biota but little information only is available on investigation of microplastics in freshwater context. Microplastic fibers are often more abundant items in water (Campanale *et al.*, 2019; Kay *et al.*, 2018; Mani *et al.*, 2016) but also in fish (Collard *et al.*, 2015) and reported in surface water of lake (Dris *et al.*, 2018). The fibers of microplastic have been detected in the surface water of the Vellalore Lake in Coimbatore City of Tamil Nadu in India. Among 13 out of 50 pellets (26%) were contaminated by microplastics. The important source of fibers is from the breakdown of textile in

Fig. 4. SEM images and respective EDS spectra with elemental qualitative data of analyzed Polypropylene fibers from filtered extracts of pellets of Common Kingfisher.

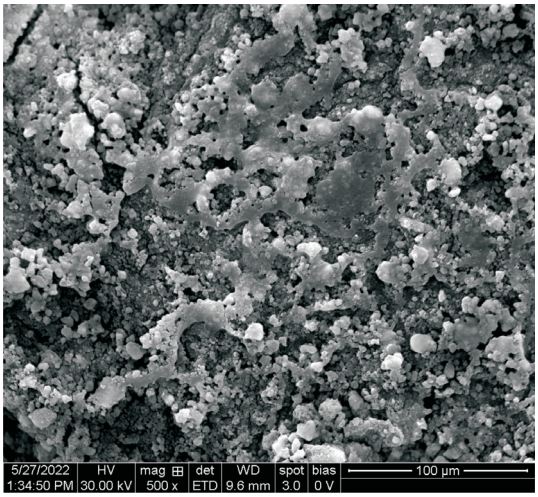


Fig. 5. SEM images and respective EDS spectra with elemental qualitative data of analyzed Polyethylene fibers from filtered extracts of pellets of Common Kingfisher.

washing machines entering the lake through the effluent of waste water treatment plants (Kay *et al.,* 2018). Therefore, fibers predominant form of microplastic found in digestive track of fish (Collard *et al.,* 2015), which one of the main genera of fingerlings composing of the kingfisher from the Vellalore lake. The juvenile stage of Barbus fish species is exposed to fibers as they inhabit shallow areas close to the water surface where fibers are floating stages of the predominant fish species in the diet of the Kingfisher, such as chubs and barbels (Barbus spp.), are exposed to fibers, as they inhabit shallow areas close to the water surface where fibers are floating (Winkler *et al.,* 2020). Therefore, it was assumed that the microplastic load of the lake water increases with its length, has also proven in other studies (Eerkes-Medrano *et al.,* 2015; Mani *et al.,* 2016). Now a days microplastic can be found in all types of habitats all around the world, with most organisms, often almost every individual having consumed them (Erekes-Merdano *et al.,* 2015). However, long-term effects of microplastic ingestion have not been studied in India. There is also a conservation component to consider as the organisms living in the fresh water and birds are exposed to the plastic pollution (Winkler *et al.,* 2020). We recommend that a possible solution should take such as researching plastic substitutes or imposing bans and proper waste management programmes with better equipment to clean microplastics out of our water.

CONCLUSION

A reconnaissance of microplastics in the pellets of the common kingfisher was carried out for the first time in Southern India. Microplastics a new environmental contamination and the occurrence of the microplastic and its impacts on the different organisms are very essential. Despite few studies on large lakes are available but no clear picture on the magnitude of the plastic pollution in surface waters. It is important to generate baseline information on the abundance of fresh water microplastics. The role of microplastics is poorly understood in the fresh water ecosystem. An urgent study is needed to identify hotspot and sinks and quantify loads. It is very difficult to understand the characteristics of microplastics such as size, material and its impact in the biota. A proper study is needed to determine the actual exposure.

REFERENCES

Amelineau, F., Bonnet, D., Heitz, O., Mortreux, V., Harding, A.M.A., Karnovsky, N., Walkusz, W., Fort, J. and Gremillet, D. 2016. Microplastic pollution in the Greenland Sea: background levels and selective contamination of planktivorous diving seabirds. *Environ. Pollut.* 219: 1131-1139. https://doi.org/10.1016/j.envpol.2016.09.017.

Bergmann, M., Wirzberger, V., Krumpen, T., Lorenz, C., Primpke, S., Tekman, M.B. and Gerdts, G 2017. High quantities of microplastic in arctic deep-sea sediments from the Hausgarten Observatory. *Environ. Sci. Technol.* 51(19): 11000-11010. https://doi.org/10.1021/acs.est.7b03331.

Bessa, F., Barría, P., Neto, J.M., Frias, J.P.G.L., Otero, V., Sobral, P. and Marques, J.C. 2018. Occurrence of microplastics in commercial fish from a natural estuarine environment. *Mar. Pollut. Bul.* 128: 575-584. https://doi.org/10.1016/j.marpolbul.2018.01.044.

Bessa, F., Ratcliffe, N., Otero, V., Sobral, P., Marques, J.C., Waluda, C.M. and Trathan, P.N. 2019. Microplastics in gentoo penguins from the Antarctic region. *Sci. Rep.* 9: 14191. https://doi.org/10.1038/s41598-019-50621-2.

Browne, M.A., Galloway, T. and Thompson, R. 2007. Microplastic – an emerging contaminant of potential concern? *Integrated Environ. Assess. Manag.* 3(4): 559-561. https://doi.org/10.1002/ieam.5630030412.

Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T.S. and Thompson, R.C. 2011. Accumulation of microplastic on shorelines worldwide: sources and sinks. *Environ. Sci. Technol.* 45(21): 9175-9179. https://doi.org/10.1021/es201811s.

Campanale, C., Stock, F., Massarelli, C., Kochleus, C., Bagnuolo, G., Reifferscheid, G. and Uricchio, V.F. 2019. Microplastics and their possible sources: the example of Ofanto River in Southeast Italy. *Environ. Pollut.* 258: 113284. https://doi.org/10.1016/j.envpol.2019.113284.

Carral-Murrieta, C.O., García-Arroyo, M., Marin-Gomez, O.H., Sosa-Lopez, J.R. and MacGregor-Fors. I. 2020. Noisy environments: untangling the role of anthropogenic noise on bird species richness in a Neotropical city. *Avi. Res.* 11(32). https://doi.org/10.1186/s40657-020-00218-5.

Caviedes-Vidal, E., McWhorter, T.J., Lavin, S.R., Chediack, J.G., Tracy, C.R. and Karasov, W.H. 2007. The digestive adaptation of flying vertebrates: high intestinal paracellular absorption compensates for smaller guts. *Proc. Natl. Acad. Sci.* 104(48): 19132-19137. https://doi.org/10.1073/pnas.0703159104.

Cole, M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J. and Galloway, T.S. 2013.

Microplastic ingestion by Zooplankton. *Environ. Sci. Technol.* 47: 6646-6655. https://doi.org/10.1021/es400663f.

Collard, F., Gilbert, B., Eppe, G., Permentier, E. and Das, K. 2015. Detection of anthropogenic particles in fish stomachs: an isolation method adapted to identification by Raman spectroscopy. *Arch. Environ. Contam. Toxicol.* 69(3): 331-339. https://doi.org/10.1007/s00244- 015-0221-0.

Costantini, D. 2008. Oxidative stress in ecology and evolution: lessons from avian studies. *Ecol Lett.* 11(11): 1238–1251. https://doi.org/10.1111/j.1461-0248.2008.01246.x.

Dawson, A., Huston, W., Kawaguchi, S., King, C., Cropp, R., Wild, S., Eisemann, P., Townsend, K. and Nash, B.S. 2018. Uptake and Depuration kinetics influence microplastic bioaccumulation and toxicity in Antarctic Krill *Euphausia superba*. *Environ. Sci. Technol.* 52: 3195–3201. https://doi.org/10.1021/acs.est.7b05759.

Dris, R., Gasperi, J. and Tassin, B. 2018. Sources and fate of micro plastic urban areas: a focus on Paris megacity. In: Wagner, M., Lambert, S. (ed) Freshwater micro plastics. *The Handbook of Environmental Chemistry. vol 58. Springer International Publishing*, pp 69–83. https://doi.org/10.1007/978-3-319-61615-5_4.

Eerkes-Medranọ, D., Thompson, R.C. and Aldridge, D.C. 2015. Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. *Wat. Res.* 75: 63-82. https://doi.org/10.1016/j.watres.2015.02.012.

Eriksen, M., Lebreton, L.C., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G. and Reisser, J. 2014. Plastic pollution in the world's oceans: More than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. *Plos One.* 9(12): e111913. https://doi.org/10.1371/journal.pone.0111913.

Geyer, R., Jambeck, J.R. and Law, K.L. 2017. Production, use, and fate of all plastics ever made. *Sci. Adv.* 3(7): e1700782. https://doi.org/10.1126/sciadv.1700782.

Geyer, R., Kuczenski, B., Zink, T. and Henderson, A. 2015. Common Misconceptions about Recycling. *J. Ind. Ecol.* 20(5): 1010–1017. http://dx.doi.org/10.1111/jiec.12355.

Gregory, M.R. 1996. Plastic 'scrubbers' in hand cleansers: a further (and minor) source for marine pollution identified. *Mar. Pollut. Bull.* 32(12): 867-871. https://doi.org/10.1016/s0025-326X(96)00047-1.

Jamieson, A.J., Brooks, L.S.R., Reid, W.D.K., Piertney, S.B., Narayanaswamy, B.E. and Linley, T.D. 2019. Microplastics and synthetic particles ingested by deep-sea amphipods in six of the deepest marine ecosystems on Earth. *R. Soc. Open. Sci.* 6(2): 180667. https://doi.org/10.1098/rsos.180667.

Karami, A., Romano, N., Galloway, T. and Hamzah, H. 2016. Virgin microplastics cause toxicity and modulate the impacts of phenanthrene on biomarker responses in African catfish (*Clarias gariepinus)*. *Environ. Res.* 151: 58–70. https://doi.org/10.1016/j.envres.2016.07.024.

Kay, P., Hiscoe, R., Moberley, I., Bajic, L. and McKenna, N. 2018. Wastewater Treatment Plants as a Source of Microplastics in River Catchments. *Environ. Sci. Pollut. Res.* 25(20): 20264-20267. https://doi.org/10.1007/s11356-018-2070-7.

Lahens, L., Strady, E., Kieu-Le, T., Dris, R., Boukerma, K., Rinnert, E., Gasperi, J. and Tassin, B. 2018. Macroplastic and Microplastic Contamination Assessment of a Tropical River (Saigon River, Vietnam) Transversed by a Developing Megacity. *Environ. Pollut.* 236: 661-671. https://doi.org/10.1016/j.envpol.2018.02.005.

Li, M., Nabi, G., Sun, Y.F., Wang, Y., Wang, L.M., Jiang, C., Cao, P., Wu, Y. and Li, D. 2021. The effect of air pollution on immunological, antioxidative and hematological parameters, and body condition of Eurasian tree sparrows. *Ecotoxicol. Environ. Saf.* 208: 111755. (in Chinese) https://doi.org/10.1016/j.ecoenv.2020.111755.

MacLeod, M., Arp, H.P.H., Tekman, M.B. and Jahnke, A. 2021. The global threat from plastic pollution. *Sci.* 373(6550): 61-65. https://doi.org/10.1126/science.abg5433.

Mani. T., Hauk, A., Walter, U. and Burkhardt-Holm, P. 2016. Microplastics profile along the Rhine River. Sci Rep 5:17988. http://doi.org/10.1038/srep17988.

McGoran, A.R., Clark, P.F. and Morritt, D. 2017. Presence of microplastic in the digestive tracts of European flounder, Platichthys flesus, and European smelt, Osmerus eperlanus, from the River Thames. *Environ. Pollut.* 220: 744-751. https://doi.org/10.1016/j.envpol.2016.09.078.

McNab, B.K. 2009. Ecological factors affect the level and scaling of avian BMR. *Comp. Biochem. Physiol. A. Mol. Integr. Physiol.* 152(1): 22–45. https://doi.org/10.1016/j.cbpa.2008.08.021.

Munshi-South, J. and Wilkinson, G.S. 2010. Bats and birds: exceptional longevity despite high metabolic rates. *Ageing. Res. Rev.* 9(1): 12–9. https://doi.org/10.1016/j.arr.2009.07.006.

Nabi, G., Ali, M., Khan, S. and Kumar, S. 2019. The crisis of water shortage and pollution in Pakistan: risk to public health, biodiversity, and ecosystem. *Environ Sci Pollut Res.* 26: 10443–10445.

Nabi, G., Wang, Y., Lu, L., Jiang, C., Ahmad, S., Wu, Y.F. and Li, D. 2021. Bats and birds as viral reservoirs: a physiological and ecological perspective. *Sci. Total. Environ.* 754: 142372. https://doi.org/10.1016/j.scitotenv.2020.142372.

Napper, I.E., Davies, B.F.R., Clifford, H., Elvin, S., Koldewey, H.J., Mayewski, P.A., Miner, K.R., Potocki, M., Elmore, A.C., Gajurel, A.P. and Thompson, R. 2020. Reaching new heights in plastic pollution - preliminary findings of microplastics on Mount Everest. *One Earth* 3(5): 621-630. https://doi.org/10.1016/j.oneear. 2020. 10.020.

Nelms, S.E., Barnett, J., Brownlow, A., Davison, N.J., Deaville, R., Galloway, T.S., Lindeque, P.K., Santillo, D. and Godley, B.J. 2019. Microplastics in marine mammals stranded around the British coast: ubiquitous but transitory? *Sci. Rep.* 9: 1075. https://doi.org/10.1038/s41598-018-37428-3.

Orme, C.D.L., Davis, R.G., Burgess, M., Eigenbrod, F., Pickup, N., Olson, V.A., Webster, A.J., Ding, T.S., Rasmussen, P.C., Ridgely, R.S., Stattersfield, A.J., Bennett, B.M., Blackburn, T.M., Gaston, K.J. and Owens, I.P.F. 2005. Global hotspots of species richness are not congruent with endemism or threat. *Nat.* 436(7053): 1016–1019. https://doi.org/10.1038/nature03850.

Rochman, C.M., Kurobe, T., Flores, I. and The, S.J. 2014. Early warning signs of endocrine disruption in adult fish from the ingestion of polyethylene with and without sorbed chemical pollutants from the marine environment. *Sci. Total. Environ.* 493: 656-61. https://doi.org/10.1016/j.scitotenv.2014.06.051.

Winkler, A., Nessi, A., Antonioli, D., Laus, M., Santo, N., Parolini, M. and Tremaloda, P. 2020. Occurrence of microplastics in pellets from the common kingfisher (*Alcedo atthis*) along the Ticino River, North Italy. *Environmental Science and Pollution Research*. 27: 41731-41739. https://doi.org/10.1007/s11356-020-10163-x.

Wilcox, C., Van Sebille, E. and Hardesty, B.D. 2015. Threat of plastic pollution to seabirds is global, pervasive, and increasing. *Proc. Natl. Acad. Sci.* USA 112: 11899-11904. https://doi.org/10.1073/pnas.1502108112.

Zhu, D., Bi, Q.F., Xiang, Q., Chen, Q.L., Christie, P., Ke, X., Wu, L.H. and Zhu, Y.G. 2018. Trophic predator-prey relationships promote transport of microplastics compared with the single *Hypoaspis aculeifer* and *Folsomia candida*. *Environ. Pollut.* 235: 150-154. https://doi.org/10.1016/j.envpol. 2017.12.058.

Zhu, Y.G., Zhu, D., Xu, T. and Ma, J. 2019. Impacts of (micro) plastics on soil ecosystem: progress and perspective. *J. Agro-Environ. Sci.* 38: 1-6. http://dx.doi.org/10.11654/jaes.2018-1427.