Role of digital technology in freshwater biodiversity monitoring through citizen science during COVID-19 pandemic

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Abstract
Citizen Science plays a vital role in monitoring biodiversity. However, it has been challenging for scientists to interact with citizens involved in biodiversity monitoring during the COVID-19 pandemic. In such circumstances, digital technology can serve as a tool for biodiversity monitoring through the cooperation between citizens and scientists. Trained volunteers can share ecological data, photographs, and videos of the species, and disturbances within ecosystems, due to anthropological activities through various digital platforms, such as Email, WhatsApp, Facebook, Twitter, and mobile apps designed for this purpose. The Wildlife Institute of India has taken the initiative by launching an android app “Ganga Data Collector” and Facebook pages “Glimpses of Ganga” and “Ganga Rejuvenation” as part of the “Biodiversity Conservation and Ganga Rejuvenation” project with an objective to monitor the biodiversity of the Ganga River involving the local community known as “Guardians of the Ganga” or “Ganga Prahari.” These trained volunteers can share photos and videos of recorded species, their mortality and rescue operations along with water quality data and prohibited activities like illegal fishing and habitat degradation due to pollution and mining. Professionals around the world employed in freshwater biodiversity monitoring could follow the same strategy to overcome the present COVID-19 pandemic crisis and prepare to monitor biodiversity during future lock-downs.

KEYWORDS
citizen science, COVID-19, digital technology, freshwater biodiversity monitoring

1 CITIZEN SCIENCE FOR FRESHWATER BIODIVERSITY MONITORING

Biodiversity and water quality monitoring are important aspects of ecosystem health assessment and measuring change in Essential Biodiversity Variables (Turek et al., 2016. With exponential anthropogenic population growth, increasing demand for water resources, especially rivers for irrigation, hydro-power generation, urbanization, and industrialization has led to various forms of habitat degradation and hydrological alteration (Ghosh & Ponniah, 2008; Pinder et al., 2019). These detrimental changes are affecting freshwater biodiversity (Collen et al., 2014). Therefore, effective action is needed to measure change in freshwater biodiversity. Various approaches have been suggested for global biodiversity monitoring, one of which is through a complementary mode of Citizen Science (CS; Dickinson et al., 2012; Pocock et al., 2018). The participation of nonprofessionals in scientific research is defined as CS. CS has the potential to support global needs for biodiversity monitoring and therefore should be considered as a mainstream approach for collecting ecological and biodiversity data (Chandler et al., 2017; Pocock et al., 2018). In addition, CS is cost-effective and more useful in rapidly reporting abrupt changes and rare activities occurring within ecosystems. However, to fulfill the potential, CS needs motivation of the local community for voluntary participation in biodiversity monitoring. Reliability of the data, especially related to species identification, is a matter of concern in biodiversity monitoring through CS (Chandler et al., 2017). Issues
related to communication with the local community and geographical, economical, and social circumstances of the local citizens also need to be considered in CS (Gupta et al., 2020). Therefore, successful biodiversity monitoring through CS also depends on proper bonding between citizens and scientists. Hence, the selection of local volunteer participants involving both men and women based on their personal interest is a significant factor for achieving the goal (Everard et al., 2019). Proper training for the participants regarding species identification, threats to biodiversity, photography and data entry in the desired format, use and misuse of social media platforms, and use of mobile applications designed for submitting the data directly from the field are essential for successful biodiversity monitoring using CS.

2 | IMPACT OF COVID-19 ON FRESHWATER BIODIVERSITY MONITORING THROUGH CS

As indicated in the name COVID-19, “CO” stands for “corona,” “VI” for “virus,” “D” for disease, and 19 represents the year it was first recognized. It has been categorized as a pandemic by the World Health Organization (2020). The contagious nature of this virus has been well established and is now considered an indicator of social recession (Chakraborty & Maiti, 2020). Mass gatherings are likely to exaggerate the outbreak of COVID-19. The only solution to avoid community transmission is to maintain social distancing, and hence every country experience expanding cases is under lockdown for long periods of time. This situation has impacted scientists responsible for coordinating motivated individuals involved in CS projects focused on monitoring freshwater biodiversity and especially threatened species which are more prone to indiscriminate and destructive fishing methods (Gupta et al., 2020; Pinder, Raghavan, Britton, & Cooke, 2020). The pandemic has influenced freshwater fish biodiversity in various ways (Cooke et al., 2021). Unemployment during the crisis is resulting in pressure on aquatic wildlife, especially freshwater fishes, for livelihood security in local communities (Pinder et al., 2020). In such circumstances, the responsibility of local citizens involved in biodiversity monitoring is to be more vigilant of anthropogenic activities in and around the river ecosystems and report to local administrators any suspicious or unwanted activities.

3 | DIGITAL TECHNOLOGY AS A LINK BETWEEN SCIENTISTS AND CITIZENS INVOLVED IN FRESHWATER BIODIVERSITY MONITORING

Nonspecialists engaged in biodiversity monitoring may struggle with accurate species identification, especially with genera lacking simple differentiating characteristics among species (Chandler et al., 2017). Digital technology may act as a link between the scientists and the citizens involved in biodiversity monitoring under such circumstances (Gupta et al., 2020). Citizens can share information and photographs of specimens through social media platforms like Twitter and Facebook or can use internet sites such as iNaturalist (www.inaturalist.org) and the Global Biodiversity Information Facility (GBIF) (www.gbif.org) due to their broad outreach and rapid circulation of content. Unfortunately, there are also cases of poachers using the information available on social media (van Uhm, 2016). To avoid this situation, information can be sent to experts via Email, WhatsApp, or other specialized mobile apps. Mobile apps like FishVerify (https://fishverify.com/launch/#about), Frog Find 1.0 (https://gubbilabs.in/launch-Frog-Find-1.0), Outsmart Invasive Species (http://masswoods.net/outsmart), I'veGot1 (http://www.eddmaps.org/florida/report/index.cfm), and Invasive Tracers (http://www.InvasiveTracers.com) provide the opportunity for citizens to submit data directly from the field (Herlekar & Prakash, 2014; Chandler et al., 2017). If recorded following protocols, the potential role that photographs of a species could play in monitoring the diversity is well known in the scientific community (Chen, Bart Jr, & Teng, 2005; Dwivedi, 2019; Dwivedi, Verma, Dewan, & Verma, 2020; Gupta, Dwivedi, & Tripathi, 2018).

Though, disadvantages of taxonomic identification through photographs cannot be denied (Ceríaco, Gutiérrez, & Dubois, 2016). However, with the help of photographs, experts could reach a possible conclusion on the inclusion of any doubtful species in biodiversity monitoring. Citizens can also send ecological data, photos, and videos of illegal fishing, pollution, mining, and other rare events like records of mortality and rescue operations directly from the field. This process could help in developing communication between the experts and the responsible citizens engaged in biodiversity monitoring during the COVID-19 pandemic and motivate them to work together in the future. Otherwise, after such a long time interval, experts have to restart recruiting nonprofessional participants and train them how to monitor biodiversity, which will be a time- and resource-consuming process.

4 | A CASE STUDY OF MONITORING FISH DIVERSITY OF THE GANGA RIVER THROUGH DIGITAL TECHNOLOGY

Fish are the most diverse group of vertebrates (Moyle & Cech, 1996). Fish can be used as an indicator of aquatic ecosystem health and development of environmental policy (Blossom, 2012). Fish are potentially most impacted by anthropogenic stressors, which can have a direct influence on the food resources, distribution, diversity, and biological behavior of both resident and migratory species (Whitfield & Michael, 2005). Major threats to freshwater fish diversity are habitat alteration and destruction, pollution, invasive species and exploitation (Cooke et al., 2021; Reid, Contreras, & MacBeath., & Csataindi, K., 2013).

The Ganges basin is the largest river basin in India in terms of the catchment area, which drains an area of approximately 1,087,300 km² in India and Nepal, constituting 20% of the country’s land mass and supporting about 43% of its population. The basin lies between 21°6′–31°21′N and 73°2′–89°6′E (Figure 1). The basin covers...
**FIGURE 1** Map of the Ganges River Basin

**TABLE 1** Topography of various sections of the Ganga River

| Section no. | Section name                     | Stretch               | Length (km) | Topography                                                                                                                                 |
|-------------|----------------------------------|-----------------------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| (i)         | Upper reaches                    | Gaumukh to Rishikesh  | 290         | Mountainous nature of river habitat with torrential water flow and deep gorges and steeped gradients. River flow is altered by human interventions as Tehri dam. |
| (ii)        | Upper middle reaches             | Rishikesh to Narora   | 255         | The river is wide and flows in flood plains on bed of fine sand, and altered through diversion/abstraction by barrages and subjected to high degree of pollution loads from household, industrial and agricultural activities. |
| (iii)       | Middle stretch                   | Narora to Kanpur      | 320         | This section of the river experience considerable changes in the sedimentation with high siltation causing wide spread flooding and also undergoes frequent changes in channel path. In many places dumping of solid wastes washing of clothes, wallowing of animals, throwing un-burnt/partially burnt dead bodies adversely affect aesthetics, water quality and aquatic life. |
| (iv)        | Lower middle stretch             | Kanpur to Varanasi    | 445         |                                                                                                                                              |
| (v)         | Lower stretch                     | Varanasi to Farakka   | 685         | This section is the estuarine zone with massive loads of sediment is deposited in the stretch between Kolkata city and Gangasagar and tidal variation dominates river hydrology. In many places house hold and industrial effluents affect water quality and aquatic life. |
| (vi)        | Lower stretch with tidal influence| Farakka to Gangasagar | 530         |                                                                                                                                              |
FIGURE 2  Photographs of selected fish species of the Ganga River (a): Bangana dero; (b) Schizothorax richardsonii; (c) Tor putitora; (d): Labeo rohita; (e) Gibelion catla; (f) Cirrhinus mirgala; (g) Clarias magur; (h) Chitala chitala; (i) Wallago attu; (j) Sperata aor; (k) Bagarius bagarius; (l) Tenualosa ilisha; (m) Anguilla bengalensis [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 2  Information on section wise availability of selected fish species (IUCN status are EN, Endangered; LC, Least Concern; NT, Near Threatened; VU, Vulnerable)

| Sl. no. | Fish species              | Common name                        | Vernacular name                  | IUCN status | Section wise availability | Photo according to Figure 1 |
|--------|---------------------------|------------------------------------|----------------------------------|-------------|--------------------------|-----------------------------|
| 1.     | *Bangana dero* (Hamilton, 1822) | Kalabans                           | Katalkusi, Bongsa, Bangan        | LC          | (i)–(vi)                 | a                           |
| 2.     | *Schizothorax richardsonii* (Gray, 1832) | Snow trout                        | Asela                            | VU          | (i)                      | b                           |
| 3.     | *Tor putitora* (Hamilton, 1822) | Golden Mahseer                      | Mahseer                          | EN          | (i), (ii)                | c                           |
| 4.     | *Labeo rohita* (Hamilton, 1822) | Roho labeo                          | Rahu                             | LC          | (ii)–(vi)                | d                           |
| 5.     | *Gibelion catla* (Hamilton, 1822) | Catla                              | Catla, Bhakur                    | LC          | (ii)–(vi)                | e                           |
| 6.     | *Cirrhinus mirgala* (Hamilton, 1822) | Mrigal carp                         | Nain                             | LC          | (ii)–(vi)                | f                           |
| 7.     | *Clarias magur* (Hamilton, 1822) | Mangur                             | Magur                            | EN          | (ii)–(vi)                | g                           |
| 8.     | *Chitala chitala* (Hamilton, 1822) | Clown knifefish, feather back       | Chital, Moya                     | NT          | (ii)–(vi)                | h                           |
| 9.     | *Wallago attu* (Bloch & Schneider, 1801) | Wallago                           | Padhin, Elanchi                   | NT          | (ii)–(vi)                | i                           |
| 10.    | *Sperata aor* (Hamilton, 1822) | Long-whiskered catfish              | Singara, Tengra                   | LC          | (ii)–(vi)                | j                           |
| 11.    | *Bagarius bagarius* (Hamilton, 1822) | Goonch                            | Bagarius                         | NT          | (ii)–(vi)                | k                           |
| 12.    | *Tenualosa ilisha* (Hamilton, 1822) | Hilsa shad                         | Hilsa, Ilish                      | LC          | (vi)                     | l                           |
| 13.    | *Anguilla bengalensis* (Gray, 1831) | Indian mottled eel                  | Bambauch                          | NT          | (iv)–(vi)                | m                           |
11 states, namely, Uttarakhand, Uttar Pradesh, Madhya Pradesh, Rajasthan, Haryana, Himachal Pradesh, Chhattisgarh, Jharkhand, Bihar, West Bengal, and Delhi.

The main stem of the Ganga River originates from ice-cave “Gaumukh” (30°55’N and 70°7’E) in the Garhwal Himalaya at an altitude of 4,100 m and flows through five states of India, namely Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal and finally flow into the Bay of Bengal, covering a total length of about 2,550 km. Because of its high cultural and religious values, the Ganga River was declared the “National River” of India in 2008 (Sanghi, 2014). Based on topography, geography, and ecology, the Ganga River has been divided into six sections for monitoring aquatic organisms (Dwivedi, Rana, Shukla, Sivakumar, & Johnson, 2019). Detailed information on section wise topography of the Ganga River is given in Table 1.

The Ganga River is home to a large number of economically important fish species, and its fisheries contribute substantially to the nutritional and financial demands of people of the Gangetic plains (Dwivedi et al., 2019; Sarkar et al., 2012). Detailed information about the section wise important fish species (Figure 2) of the Ganga River is presented in Table 2. The ICAR-Central Inland Fisheries Research Institute (2019) recorded 190 species, of which around 80% can be correctly identified on the basis of their photographs (Das et al., 2010).

Over recent years, fish diversity of the Ganga River has experienced an alarming decline due to anthropogenic activities such as habitat degradation by mining, construction of dams for power generation, diversion of water for irrigation purposes, pollution, indiscriminate fishing and the introduction of exotic species (Figure 3; Vass, Mondal, Samanta, Suresh, & Katiha, 2010). Appropriate monitoring of fish diversity is essential for sustainable utilization of the fisheries resources of the Ganga River so that the local communities reliant on the fisheries may be able to maintain their stake in the fisheries resource and its possible benefits.

The National Mission for Clean Ganga (NMCG), launched by the Department of Water Resources, River Development and Ganga

![Figure 3](Color figure can be viewed at wileyonlinelibrary.com)
Rejuvenation, under the Ministry of Jal Shakti, the Government of India has implemented the project “Biodiversity Conservation and Ganga Rejuvenation” with the Wildlife Institute of India. One of the main objectives of the project is long-term monitoring of the biodiversity including the fishes involving the local community of 11 Ganga states known as “Guardians of the Ganga” or “Ganga Prahari” (https://nmcg.nic.in/wii/prgbggp.aspx). The Ganga Prahari selected are the youth of local villages who are interested in biodiversity conservation. The Ganga Prahari are trained about various aspects of fish biodiversity monitoring, like fish identification, the proper understanding of ecological conditions, illegal fishing practices and pollution, through field workshops. (https://wii.gov.in/images/images/documents/trg18Dtl31.pdf). Trained Ganga Prahari also assists researchers in the biodiversity and ecological data collection from the field. Around 600 volunteers from the local communities are working for biodiversity conservation and cleanliness of the Ganga River (https://nmcg.nic.in/pravasigangaprahari.html#).

All 11 Ganga states are under high risk of the COVID-19 contagious stage and have therefore been kept under complete or partial lockdown for the past few months with strict norms of social distancing, especially avoiding mass gathering. Training of the local community, “Guardians of the Ganga” about fish biodiversity monitoring through field workshops will be considered a mass gathering activity. In such circumstances, conducting online training sessions and workshops and motivating local communities toward biodiversity monitoring of the Ganga River is required immediately. Therefore, the experts from the Wildlife Institute of India, through the NMCG project, are training local communities involved in fish biodiversity monitoring about fish diversity, habitat features, hydrology, threats, and conservation measures through Zoom, Google Meet, and live sessions on Facebook. The institute has also created Facebook pages such as “Glimpses of Ganga” and “Ganga Rejuvenation”, where all the activities related to biodiversity monitoring, especially efforts of the “Ganga Prahari” and updates regarding online training sessions and workshops are posted. The institute has launched a specialized android mobile app, “Ganga Data Collector” (https://wii.gov.in/Ganga_knowledge_product; https://indianexpress.com/article/india/an-app-to-map-ganga-water-aquatic-life/). Trained volunteers can share photos and videos, along with other information related to biodiversity monitoring through this app. The app provides a real-time complete data entry solution related to water quality and aquatic life of the Ganga River and fast transmission of data directly from the field to monitor the population of aquatic species. The app is also beneficial from a security perspective given that poachers will not be able to misuse the information.

5 | CONCLUSION

There are reported cases of successful biodiversity monitoring through CS. Therefore the involvement of the local citizens is essential for the success of biodiversity monitoring through established links between citizens and scientists. However, during the COVID-19 pandemic, it has been difficult for the experts involved in biodiversity monitoring to interact with the local citizens openly. The present situation gives the impression that the impact of the COVID-19 pandemic will last for a long period of time, and the social distancing norm will be required for much longer duration. In such circumstances, digital technology may be a better choice for biodiversity monitoring through CS. However, internet connectivity, electricity, access to smart phones and laptops, and limited participants in poverty-driven remote areas are issues which influence digital training. Conducting training through digital platforms also has some downsides, especially in handling sophisticated instruments like water quality multi-parameter meters (measure variety of environmental attributes such as pH, dissolved oxygen, conductivity, turbidity, temperature, and salinity), flow meter, depth finder and in identifying complex groups/cryptic species based on digital images. Though, hands on training is more important for handling of instruments, by sharing photographs with the experts through Email or WhatsApp or specialized apps, taxonomic ambiguity can be largely resolved. Professionals across the world employed in biodiversity monitoring may adopt the useful approach initiated by the NMCG project for biodiversity monitoring of the Ganga River through digital technology involving CS in view of the present COVID-19 pandemic and other future lockdowns. This procedure will also keep the local citizens engaged in biodiversity monitoring and motivated during and after the current crisis period of the COVID-19 pandemic.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were generated in this study.

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