



Policy analysis



Insights on COVID-19 impacts, challenges and opportunities for India's biodiversity research: From complexity to building adaptations

Ghosh Ramvilas^{a,*}, Shalini Dhyani^{b,c}, Biju Kumar^d, Neha Sinha^e, Rajeev Raghavan^{f,g}, Gayathri Selvaraj^h, Nithin Divakarⁱ, V.K. Anoop^a, Kannan Shalu^a, Alolika Sinha^j, Apoorva Kulkarni^{k,l}, Sandeep Das^m, Sanjay Molurⁿ

^a School of Ocean Science and Technology, Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi, India

^b Critical Zone Research Group, CSIR National Environmental Engineering Research Institute (NEERI), Nehru Marg, Nagpur, India

^c Commission on Ecosystem Management (CEM), International Union for the Conservation of Nature (IUCN), Gland, Switzerland

^d Department of Aquatic Biology and Fisheries, University of Kerala, Thiruvananthapuram, India

^e Bombay Natural History Society (BNHS), Mumbai, Maharashtra, India

^f Department of Fisheries Resource Management, Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi, India

^g South Asia Office, IUCN SSC/WI Freshwater Fish Specialist Group (FFSG)

^h Biodiversity Research and Conservation Society, Munnar, India

ⁱ Conservation Research Group, St. Albert's College, Kochi, India

^j Aaranyak, Guwahati, Assam, India

^k Oxford India Centre for Sustainable Development, Somerville College, Oxford, United Kingdom

^l Edward Grey Institute of Field Ornithology, Department of Zoology, University of Oxford, Oxford, United Kingdom

^m Kerala Forest Research Institute (KFRI), Peechi, India

ⁿ Zoo Outreach Organization (ZOO), Coimbatore, India

ARTICLE INFO

Keywords:

Lockdown

Perceptions

India

Policy

Wildlife

New normal

Early career researchers

ABSTRACT

The COVID-19 pandemic has impacted every sphere of human society. The paradigm shift of focus to COVID-related research and management has significantly affected various scientific domains, including biodiversity conservation. We assessed the perceptions of early-career researchers working for biodiversity conservation across India, to understand the impacts of the ongoing pandemic on their research. We administered an online questionnaire survey to 565 respondents, who identified four key areas that are affected by the pandemic: (1) research, (2) conservation (3) education, and (4) communication and networking. Respondents (89.2%) perceived that their fieldwork, followed by travel for meetings and funding were the most affected due to COVID-19 outbreak and subsequent lockdown. Nonetheless, responses on the impact varied between different professional categories and were disproportionate. Our study highlights that majority of the respondents (80%) advocate for stakeholder-driven policies and management practices as the most effective strategy to promote biodiversity conservation, in the post-COVID-19 world. To this end, as a post-pandemic response, we propose holistic solutions such as optimising research funding and collaborations, and supporting and strengthening them by citizen science and big data analytics. Our findings and recommendations will also serve as a paradigm for post-COVID-19 biodiversity policy, advocacy and implementation of the post 2020 biodiversity action plan that supports eco civilization.

1. Introduction

The ongoing COVID-19 pandemic has impacted all spheres of human society, as governments around the world prepare for the largest economic shock in decades (World Bank, 2020). The viral infection which

emerged from China, and spread across continents is now an unprecedented socio-economic crisis than a health emergency (Harapan et al., 2020; United Nations Organisation, 2020). World economy is projected to fall by 3.5% in 2020 causing measurable shifts in spending patterns, disruptions in the gross domestic product (GDP), plummeting external

* Corresponding author.

E-mail address: ramvilas@kufos.ac.in (G. Ramvilas).

<https://doi.org/10.1016/j.biocon.2021.109003>

Received 15 September 2020; Received in revised form 18 January 2021; Accepted 25 January 2021

Available online 16 February 2021

0006-3207/© 2021 Elsevier Ltd. All rights reserved.

demands, and commodity prices (IMF, 2020). This socio-economic impasse has cascading effects on the scientific community as well, where the nature and magnitude of impact is still unclear (Myers et al., 2020). The global outbreak is nevertheless altering academic dynamics and particularly sabotaging the diversity in science, technology, engineering and mathematics (STEM) related fields (Woolston, 2020).

Disproportionate impacts of the pandemic are particularly visible in biodiversity research and conservation (see Cooke et al., 2020). Evidence from around the world suggests that human lockdown measures during the pandemic resulted in positive effects on the environment (e.g., improved air quality across major cities) (Lal et al., 2020; Mahato et al., 2020; Nakada and Urban, 2020) including a drastic reduction in global and regional carbon footprints (Molintas, 2020). The 'anthropause' has also benefited wildlife and allowed researchers to quantify anthropogenic impacts on biodiversity (Rutz et al., 2020). For instance, reduced human movements and activities near national parks have lowered the stress on wild animals. Most fishing fleets being docked in ports and harbours, fishing pressure in the oceans has drastically reduced (Gianni, 2020). However, ironies such as cleaner environments (e.g., improved water quality, see Yunus et al., 2020) elevating the extinction risk of wild species have also become visible (Pinder et al., 2020).

India is a megadiverse nation of global conservation priority (Bawa, 2006), thus requiring special focus during this abysmal situation. International Union for Conservation of Nature (IUCN) has prioritised South Asia, as a region that requires the greatest conservation attention during COVID-19. The epidemic curve is escalating in India on a daily basis, making it one of the worst-hit countries (WHO, 2020). Mainstream and social media, nevertheless, suggests a brighter side for environment and wildlife, as the lockdown has drastically reduced human mobility and various disturbances in nature. However, reported wildlife poaching cases more than doubled during the lockdown (Badola, 2020). As academic and research-related field work is temporarily discontinued, labs are not fully functional, education, training and other communication have moved online (Corlett et al., 2020), an attempt was made to understand the impacts of COVID-19 on biodiversity research and conservation in India. This paper presents the views and perspectives of early career researchers (ECRs) and conservation professionals on biodiversity research and conservation during, and beyond the post-COVID recovery, particularly highlighting concerns and perspectives regarding career prospects, new models of adaptive learning, and methods of communication and networking forced into existence by the current crisis. We then identify points of disagreement, similarities and overlap between views, and discuss possible solutions to address research progress and policies that will influence conservation actions for immediate, and post-pandemic response.

2. Materials and methods

We organized a webinar on 16th July 2020 to understand the impacts, challenges and opportunities for India's biodiversity research and conservation vis-à-vis COVID-19. An online questionnaire was distributed (Table A) (administered through Google forms) to all registered participants, specifically targeting ECRs and conservation professionals across the country. The questionnaire drew inspiration from Corlett et al. (2020), with modifications to make it simple, short, and easy to comprehend, so as to reduce respondent fatigue (Dillman et al., 2014). Initially, the questionnaire was pretested with ten colleagues and the feedbacks thus received on the coverage of topics, clarity of wordings, and time to answer all questions helped us to further modify and refine the survey structure. The modified questionnaire was then circulated to another group of colleagues for a second round of testing before administering to the target group. Emails were manually sent to target groups comprising a cover letter detailing the importance of the study, and a link to the survey. We also asked participants to distribute the questionnaire among their colleagues; a common convenient sampling

approach used in web-based surveys (Kaye and Johnson, 1999). In addition, we distributed the questionnaire through 'mail-groups', listservs and online discussion platforms such as youth biodiversity network, IUCN species survival commission (SSC) and Commission on Ecosystem Management (CEM) groups, and other conservation networks relevant to biodiversity research, to increase the inclusivity of respondents. No incentives were provided for the respondents, and the survey was completely voluntary.

The questionnaire was strategically divided into four sections, and all questions were mandatory. Respondents were asked to record their demographic details (nationality, gender, age), area of research, and perceptions and opinions on the impacts of COVID-19 on biodiversity research, conservation, education and networking. To understand the effect of the pandemic on their work or profession, ongoing biodiversity and conservation projects/research/activities, respondents were asked to categorise their response on a five-point Likert scale (i.e., 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). Similarly, in case of questions related to post-COVID-19 solutions and recommendations, another five-point Likert scale was used (1 = not at all important to 5 = extremely important). The questionnaire was circulated five days prior (11–15 July 2020) to the webinar (16 July 2020) and continued for ten days beyond, in order to record the largest possible perspective of biodiversity professionals and ECRs. Our study sample adequately represents different demographic profiles and regions in India which reduces the coverage error, providing a sound basis for interpretations (Fig. 1). The number of respondents in terms of educational categories and regions are also comparable with the All-India Survey on Higher Education (AISHE, 2019 www.aishenic.in).

All statistical analyses were carried out in R version 4.0.2. (R Development Core Team, 2020). Non-response bias was measured between late and early response for all variables used for the Chi-square Test, assessed at the 0.05 significance level. Ordinal logistic regression was used to estimate the effect of respondents' demographic categories on the pattern of responses, where responses were measured on a 5-point Likert scale, which are considered to be ordinal categorical variables (Zumbo and Ochieng, 2002). Responses that were not collected on a 5-point Likert scale were treated as unordered categorical independent variables. Multiple linear regression followed by two-way ANOVA on the regression model was used to estimate the predictors' effect on the response variable (Table B). Linear regression techniques were used on independent categorical variables after conversion into dummy variables. Two-way ANOVA performed on the results of the regression estimated the significance of variations that occurred within the model at the 0.05 significance level (West et al., 1996) (see Table B). For the ordinal logistic regression, 'students who did not specify their gender', 'others' (see Table C; 'others' in education category for definition) and 'freshwater ecosystem' were used as the reference categories. Regression models generated for responses in gender, education and primary area of research were compared against the aforementioned reference categories in the respective order.

3. Results

3.1. Response and demographics

We received 612 completed questionnaires from 28 states and eight union territories of India, which represented a major part of the country. Initially, responses were collected from Indian nationals and students currently studying or working in institutions outside India. While COVID-19 is a global pandemic, its impact and subsequent mitigation strategies applied varied across developed and developing countries. Therefore, only those responses (=565) from Indian nationals who are studying, or working in India were analysed. Chi-square test did not reveal a significant difference between the two respondent groups (early, $n = 518$ vs. late, $n = 94$), on any variable. Respondents were mostly young researchers (18–30 years) with equal gender

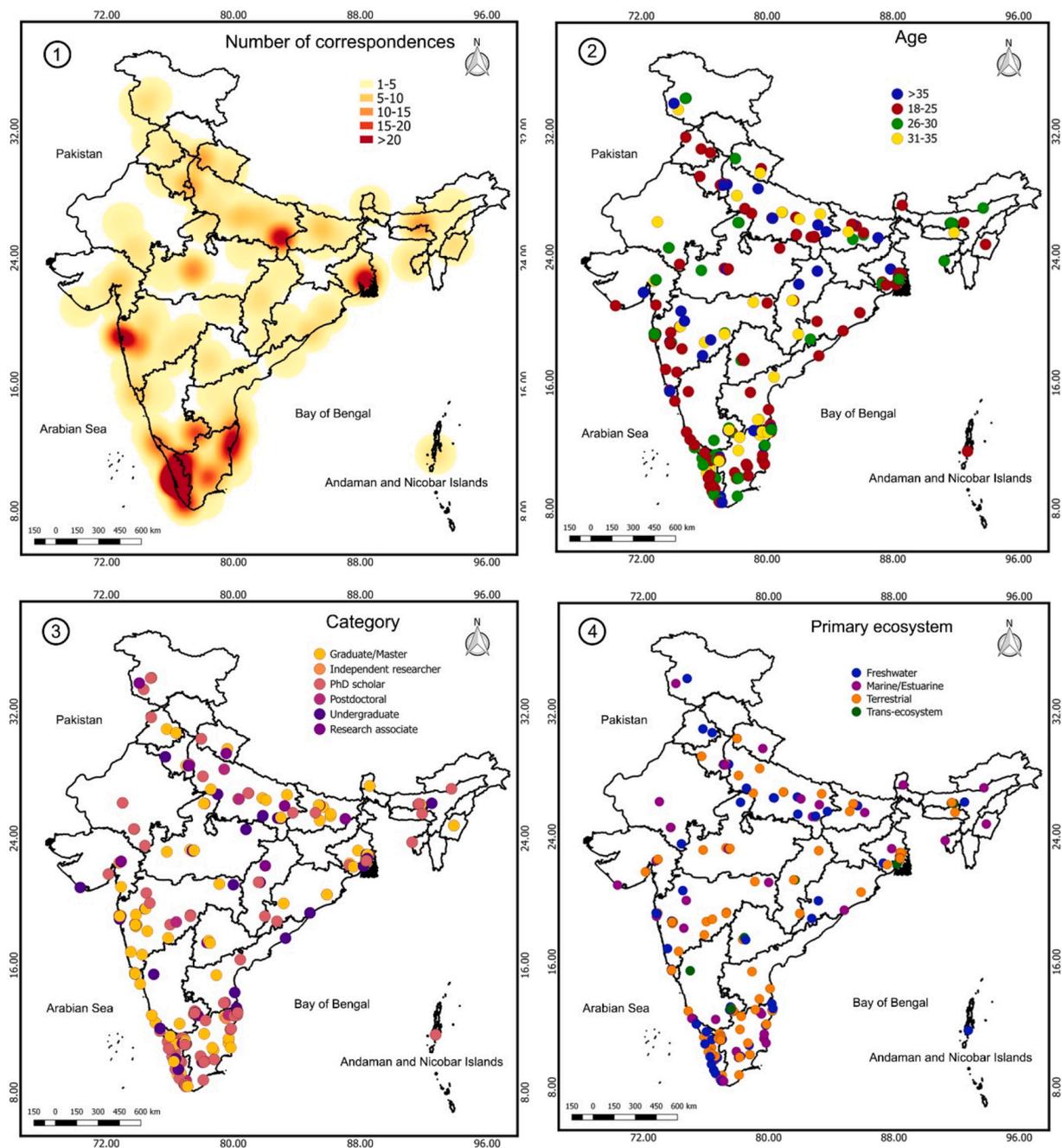


Fig. 1. Maps showing geographical representation of 1) respondents (read early career researchers (ECRs)) in numbers, 2) age groups of respondents, 3) education category of respondents, and 4) respondent's primary area (read ecosystem) of research/conservation activities. Note: For convenience, we eliminated certain groups in the representation of education category (e.g., responses who were unable to identify with any of the given group) and primary ecosystem of research (e.g., those responses which stated 'cannot specify') for convenience and clarity.

representation, a demographic profile comparable to the 2011 Indian population census data (https://censusindia.gov.in/2011-prov-results/prov_rep_tables.html). Thus, responses were weighted so that the results were more representative of the national population.

3.2. Impacts on research and conservation

3.2.1. Gender

Our study found that COVID-19 has strongly impacted both research and conservation (Fig. 2). There was no impact on gender when respondents were asked to scale the impacts of the pandemic on their research activities. From the analysis, only two models showed significant p values (≤ 0.05), indicating the likelihood of gender having a

significant effect on biodiversity-related professional gatherings (e.g., conferences, workshops, seminars), and travel (international and domestic). The odds ratio (OR) of both male and female responses to professional gatherings are more likely to be affected by 10.7 and 9.52 times respectively than those of students who did not specify their gender, and less likely in the case of travel; provided all other variables are held constant.

3.2.2. Education categories

Responses based on education categories towards different problems (e.g., field work, lab experiment, funding etc.) varied. Most respondents were affected in their field work (89.2%), followed by travel (85.13%) and funding (70.97%). However, undergraduates were not affected by

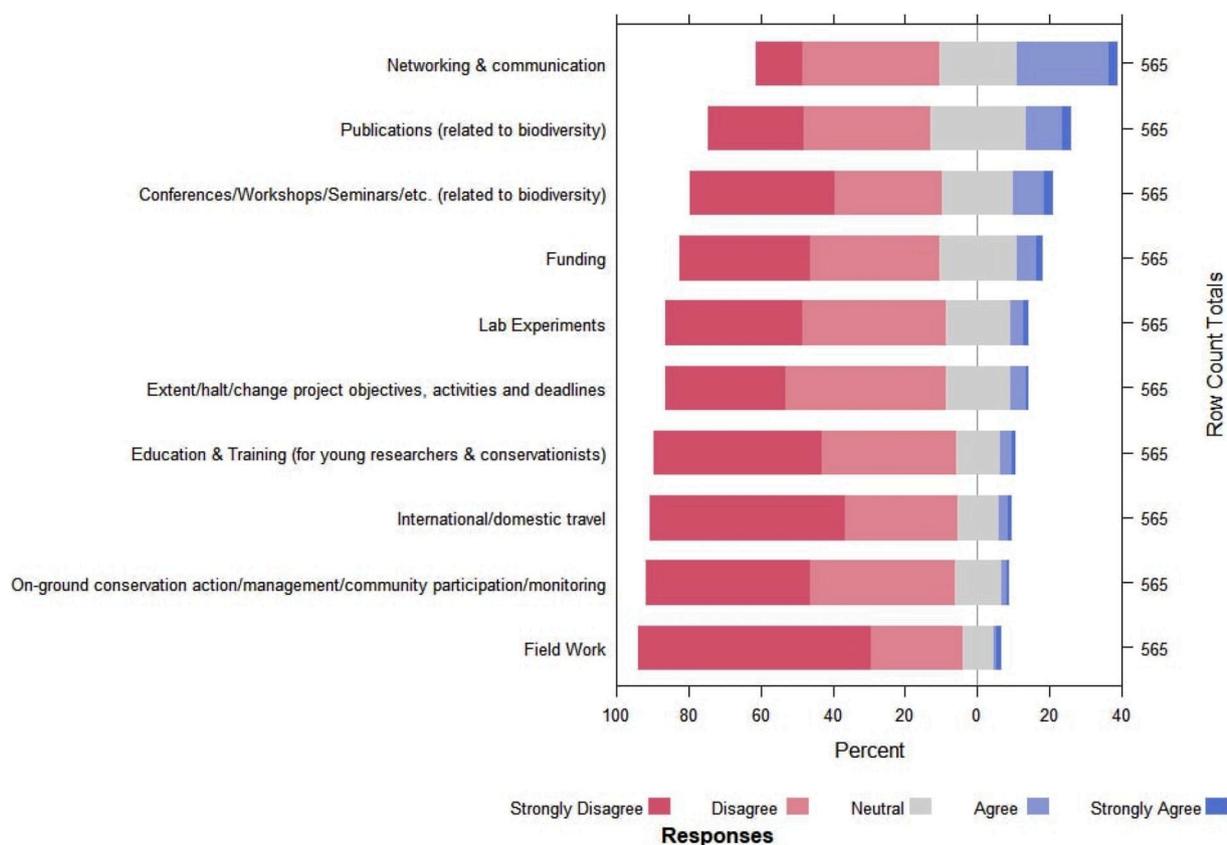


Fig. 2. Perceptions of respondents/early career researchers (ECRs) on effects of COVID-19 on biodiversity research and education in India ($n = 565$).

any of these problems. PhD scholars involved in lab experiments were more likely to be affected by 3.96 times than ‘other’ respondents. At the same time, postdoctoral researchers were more likely to be affected by 7.08 times than ‘other’ respondents in not being able to attend professional gatherings. Postdoctoral researchers were also likely to be more affected by 36.4 times the loss of field work, but their small sample size makes this assumption of less significance, and could probably change if the sample size increases (see [Nature Editorial, 2020](#)).

3.2.3. Primary area of research

Models indicate that the respondents working in terrestrial ecosystems were less likely to be affected by 0.53 times in lab experiments and publications, and more likely to be affected by 1.75 times in their field work than a respondent working in freshwater ecosystems. Respondents working in marine/estuarine ecosystems were less likely to be affected by 0.47–0.54 times in education and training, attending professional gatherings, publications and, networking and communication than a respondent working in freshwater ecosystems. Extent, halt or change in project objectives, activities and deadlines were more likely to be affected by 3.76 times in the case of a respondent working across multiple ecosystems, than a respondent working in freshwater ecosystems. A significant number of respondents ($n = 232$, 41%) felt biodiversity research would receive less attention and funding after COVID-19, while 200 (35%) were unsure of the outcome.

3.3. Impacts on education, training, and networking

When respondents were asked to indicate the effect of pandemic (e.g., a rapid shift in adaptive learning models, online platforms, webinars) in developing research collaborations, it was revealed that only the primary area of work/ecosystem is significantly associated with the variation in response. Examining contrasts of the categorical variable ‘primary area of work/ecosystem’ revealed that respondents working in

marine/estuarine ecosystems are 0.35 times likely to agree that new models of online learning and conferences will affect the nature of research collaborations when compared to respondents working in freshwater ecosystems. Analysis of the effect on career due to COVID-19 revealed that only the primary area of work/ecosystem was significantly associated with the variation in responses about changing career options. On further examination of the contrasts of the categorical variable ‘primary area of work/ecosystem’, respondents working in marine/estuarine and terrestrial ecosystems are 0.28 and 0.22 times more likely to agree to change their career options compared to respondents working in freshwater ecosystems respectively.

3.4. Post-COVID-19: solutions and recommendations to improve biodiversity conservation and research

Effect of education categories on the responses to post COVID-19 biodiversity and conservation strategy suggestions revealed that most respondents were 2.5–3.04 times more likely to consider stakeholder-driven policies and management practices followed by community-level conservation and better research publications (Fig. 3.). Responses on the “primary area of work (read ‘ecosystem’)” and approach (read ‘strategy’) to promote conservation of biodiversity in post-COVID India showed that respondents working in terrestrial, marine and estuarine ecosystems are 0.43–0.59 times less able to consider any of the strategies (e.g., research collaborations, participatory, community-based conservation, and research publications) than respondents working in freshwater. Respondents working in trans-ecosystem studies are 0.28 times less likely to consider stakeholder-driven policies and management practices as the most effective strategy to promote biodiversity conservation, compared to respondents working in freshwater ecosystems. Similarly, respondents were asked to scale the necessary steps towards improving the career paths and prospects for the current batch of senior undergraduate and graduate students and subsequent

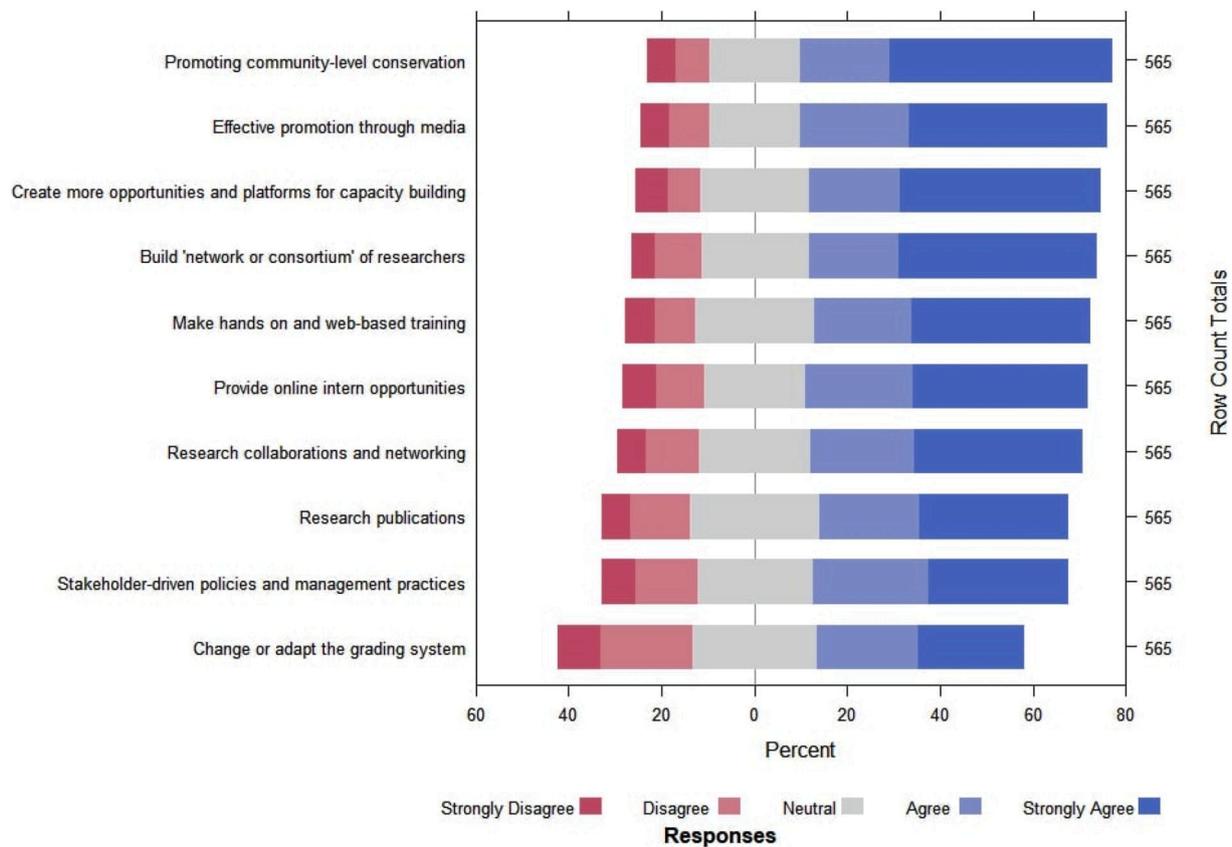


Fig. 3. Perceptions of respondents/early career researchers (ECRs) on post COVID-19 recommendations to improve biodiversity conservation and research in India (n = 565).

cohorts. Results revealed that most education categories were 3.3–4.93 times more likely to consider opportunities for capacity building and training at the school and college level as an effective strategy to improve career prospects of biodiversity research aspirants. But the response based on the primary area of work showed that respondents working in terrestrial and marine/estuarine ecosystems were 0.44–0.63 times less likely to consider any of the strategies mentioned as a necessary step towards improving career prospects in biodiversity research and conservation. Also, respondents working in terrestrial ecosystems were 0.63 times less likely to consider changing or adapting the grading system as the most effective practice/strategy to improve career prospects in India.

4. Discussion

Since all respondents are potentially impacted due to the pandemic in one way or another, our study is poised to convey general trends on issues surrounding this field of research. However, we do not seek to legitimize respondent viewpoints based on the measure of their popularity, but rather provide insights into the intrinsic values and apprehensions held by professionals and researchers sampled. While we acknowledge the limitations in understanding the perceptions of ECRs on the existing issues related to the closure of academic and research institutions, and with regard to the long-term implications, as suggested by Corlett et al. (2020), the concerns of ECRs and students in this field need to be addressed (Pardo et al., 2020).

4.1. Impacts on research and conservation

As expected, the pandemic has affected the ability of researchers and conservationists to continue their regular work. For example, respondents working in terrestrial ecosystems tend to more affected by lost

field days, while it is lab experiments and publications in the case of freshwater. This may be because freshwater biologists require more formal lab infrastructure than terrestrial ecologists where even citizen science-based approaches can largely help. Also, the more advanced the educational qualification, the more the candidate seemed impacted by COVID-19, both in laboratory and field work. For instance, undergraduates were not affected by any problems (e.g., field work, lab experiments, conferences, workshops, etc.) because undergraduate programmes in India rely mostly on classroom lectures over field-based projects. Moreover, the proposed biodiversity-related group projects based on fieldwork in undergraduate programmes have been replaced with 'quick-fix' solutions involving literature review and questionnaire-based surveys. Despite a few initial weeks of discomfort, most universities and colleges reinstated classes using virtual lectures. For PhD and postdoctoral scholars', lab and field components are required to fulfil their study objectives or postdoctoral research projects. At the same time, professional gatherings help develop networks and identify future career opportunities. This has been seriously affected despite several virtual conferences, because of not being able to interact personally. As graduate students and postdoctoral researchers need opportunities for their future experiences, financial worries interact with the problem of missed field or lab research (see Corlett et al., 2020). A rapid decline in biodiversity research funding was also understood and addressed by the respondents (41%), and many researchers feared that funding for biodiversity research would not be a priority (Muenz, 2020).

Our results also correspond to the findings of a leading international conservation donor that COVID-19 and its associated lockdown has severely affected conservation activities and field work with dire consequences on the career prospects and economic health of many researchers and institutions (MBZSCF, 2020). A similar study from Australia suggests that existing financial concerns before, and during the pandemic will push PhD students and ECRs to the point of monetary

stress that they might be forced to quit research (Johnson et al., 2020). Such an exodus of young professionals at this delicate time would adversely impact future research capacity, as well as on-ground conservation. This might be particularly true for biodiversity research, as conservation science and practice are unlikely to be a government priority in post-COVID19 response in many countries. The present condition and impending economic recession will further divert most research funding to COVID-19 related research or there will be greater prioritisation towards topics related to viral diseases, as seen in the case of two major funding agencies for science research in India, Science and Engineering Research Board (SERB) under Department of Science & Technology, Government of India (<http://serb.gov.in/Funding-covid.php>), and Department of Biotechnology (<http://dbtindia.gov.in/>). On a brighter side, international donors such as Rufford Foundation and Mohamed Bin Zayed Species Conservation Fund (MBZSCF) (2020), Conservation Leadership Program, National Geographic, and IUCN have been flexible adaptive in their approach to ensure an uninterrupted flow of funding towards conservation projects. Much to the respondents' anxiety, the shifting priority is also evident in scientific publishing. There is a 'preprint rush' to publish COVID-19 related studies at an increased pace. But on the positive side, efforts such as open publishing, 'Review Commons' and 'pooling of scientists' by several journals to rapidly review COVID-related manuscripts might have a long-standing positive effect on the review-process of journals (rapid publication) (Callaway, 2020).

4.2. Impacts on education, training, and networking

Our results suggest that the impact of pandemic tend to be varying among ECRs working in different primary ecosystems. Respondents working in marine/estuarine ecosystems tend to more apprehensive about new models of online learning and conferences than those working in freshwater ecosystems. This could likely be due to the 'scales' involved. Marine researchers often require collaborations with colleagues based in different countries and even continents, whereas this geographical scale is rather reduced for freshwater researchers. Also, respondents working in marine/estuarine ecosystems were less likely to be affected by education and training, publications and, networking and communication than a respondent working in freshwater ecosystems. Reasons for this variation in responses could not be deduced, but could be because of the overall neglect and data-deficiency encountered with freshwater science, research and conservation (see Darwall et al., 2011).

Many conservation biologists are adapting to the 'new normal' through continuous monitoring of wildlife remotely with the help of citizen scientists, and designing online courses for students, thus inspiring new hope for species conservation amid the uncertainties. (Ghosh, 2020). The gaps in long-running projects can be effectively bridged by involving citizen scientists in data collection (e.g., backyard bird counts, web-based projects) (Young et al., 2019; Boersch-Supan et al., 2019). Ongoing citizen science-based research projects in India (for e.g., India Biodiversity Portal, Hornbill Watch, Wild Canids India, eBird India and other upcoming ones) are expected to strengthen the COVID affected conservation efforts by strengthening participatory approaches to gather field-based data for biodiversity researchers in the 'new normal' (Datta et al., 2018; Malhotra, 2018; Sondhi and Kunte, 2020). This will facilitate and considerably support and contribute to monitoring, regulation and strategic decision-making (Wilthers, 2020; Sharma, 2019; Warrrier, 2017). For academics in teaching and outreach, webinars have become more relevant now than ever. Six months into the pandemic, for a few, 'webinar fatigue' is now becoming more visible. To cater to the younger generation of researchers' needs, the virtual internship has emerged as a good platform. The Indian National Young Academy of Science (INAYAS) organized the very first country-wide virtual internship with science leaders, through which students from school grade seven until PhD were able to find mentors from various national and international laboratories, organisations and universities. Such

efforts will be more common and frequent in the 'new normal' (Bast, 2020). Virtual webinars low in budget and relatively lower carbon footprint provide excellent opportunities to listen and interact with diverse scientists. There has also been a tremendous rise in online skill-building courses, both paid and unpaid, helping to develop new expertise related to taxonomic identification, remote sensing (RS) and geographic information system (GIS), ecological modelling, statistical analysis, project and research paper writing. 'New normal' biodiversity research and researchers will need to equip themselves for more integrative, multifaceted approaches, to provide crucial data (Soltis and Soltis, 2016).

New training approaches, and tools that integrate 'domain knowledge' in biodiversity and data sciences will help streamline research in the 'new normal'. Museums, especially in developing countries, should use this as an opportunity to digitise type collections and start international collaborations. Sharing big data, processing and storage platforms, besides developing better informatics tools for analytics and modelling are required to elevate biodiversity research into a 'cutting edge' science. Despite advancements in biodiversity research, gap between research advancement and policies, vested interest of various stakeholders and insufficient conservation awareness among masses has further widened the gap between the conservation planning and conservation action on ground (Brewer, 2006; Karanth et al., 2008; Misra et al., 2009). This demands purposeful interventions by young researchers, to engage with the public through stories of perceptions about life on earth and its conservation as a way to promote biodiversity education in the informal sector. ECRs may be more involved in public policy consultations by both the government and non-governmental organisations, so as to ensure their participation and engagement in these exercises, besides enhancing their experience in the process. This should enhance public awareness about biodiversity conservation and provide new avenues for public engagement and perceptions for self-employment in the sector for ECRs. This is particularly relevant as Indian environmental legislation, such as the Environment Impact Assessment Notification, is proposed to be changed by the government, which requires a greater bridge between science and policy.

In the times of pandemic artificial intelligence (AI) and citizen science (CS) has emerged as an attractive alternative to manually process vast troves of data, including camera-trap images or audio recordings (Kwok, 2019; Wilthers, 2020) and the capacity of CS, AI, big data and machine learning algorithms can help better inform protected area managers (Palminteri, 2019; Torney et al., 2019). COVID-19 situation has provided the impetus for innovative species assessment strategies from the more inclusive, conventional and robust workshop-based assessments or exclusive independent group assessments. The new normal could be an improved version of the ongoing experiments in species assessments (IUCN Red Listing of South Asian Amphibians; S. Molur pers. comm.). Online, group platforms for maximum participation of experts in evaluating species' conservation status could potentially optimise the efforts, save travel time, receive broader participation, and provide staggering opportunities for a more holistic assessment. Global Biodiversity Information Facility (GBIF) and many strands of social media-based species occurrence data are now being used to model species distribution under changing climate, and will further help the next generation of researchers to address, for example, red listing concerns for species. During the recent pandemic and looking ahead to our expectations for the 'new normal' we believe that the lack of field-based experience and an insufficient number of interactions with species will present major gaps as well.

4.3. Post-COVID-19: solutions and recommendations to improve biodiversity conservation and research

Many respondents preferred and were also well-aware about the need for stakeholder-driven policies to help conservation in the post-pandemic period. Most respondents said promotion of community-

level conservation would be very important. Tied in with importance given to both community involvement and stakeholder-driven policy, this suggests that a local to global approach is favoured by the respondents of our study. However, there needs to be further investigation on the divide between preference towards stakeholder-driven policies among terrestrial, marine and freshwater researchers. Impacts of COVID-19 on higher education organisations involved in biodiversity research may vary, but institutions will have to prepare contingency plans to mitigate this impact. The limitations in funding for basic research pertaining to biodiversity documentation and conservation are evident, and in the post-COVID era, these resource deficiencies can be addressed through the suggested activities: (1) promoting collaborative biodiversity research by shared sample collection and field based monitoring responsibility by the one close to the field followed by lab work, data analysis by other competent institute (2) engage in multi-taxa inventories from a common field site for maximum utilization of resources; (3) develop contingency plans to increase virtual internships by motivating students to prefer field based research closer to their locations, learning and skill development through on-line workshops, expert discussions and promoting virtual laboratories; (4) extend tenure to ECRs with fellowship support; (5) launch support grants for ECRs to work on priority areas that demand special attention in the post-COVID era, specifically focusing on a 'one health approach'. (6) create effective and robust citizen science modules for collecting data, emphasizing value through voluntary participation with relatively less resource load. While the first two and the last recommendation make up to the lost field days and research activities during the pandemic, points 3–5 would ensure uninterrupted financial support, training, education and networking to ECRs in biodiversity research and conservation. Continued efforts will be required to reach out to governments (international, national and local) to understand the importance of the need to biodiversity and conservation research and action. Impact of the pandemic on scientists, especially the next generation of researchers should be a priority for 2020 - 'Year of Biodiversity', and beyond as the world enters the Decade for Ecosystem restoration (2021–2030) and 2030 UN Sustainable Development goals. India is also the current President of the Convention on Migratory Species (CMS), from 2020 to 2022. One of the goals of the CMS is to create a unified approach of ecosystem services, migratory wildlife conservation and health, which has become even more pressing after the COVID-19 pandemic. The emergence of bird flu in India in January 2020 (Ojha, 2021) also underlines the need for biodiversity conservation to further ally with public health, which is likely to develop as a research priority.

5. Concluding remarks

Our study revealed that COVID-19 has significantly affected biodiversity researchers and conservationists' community in India in at least four broad areas, viz. research, education, communication and networking, and on-ground conservation research and community based participatory activities. Our analysis of viewpoints among the respondents suggests that the impact is disproportionate for different professional categories and the underlined conclusions of such impacts seem to be cautionary rather than encouraging. In short, the impacts of the pandemic on ECRs are much layered, specific to area of research or education categories rather than gender. For instance, respondents working in marine/estuarine ecosystems are more apprehensive to new models of online learning and conferences affecting future research collaborations. Similarly, respondents working in marine/estuarine and terrestrial ecosystems are more likely to change their career option compared to respondents working in freshwater ecosystems. Undergraduates were the least affected group while graduates are likely to be affected in a number of issues like lost field days, lab experiments and funding. While the diversity of viewpoints was skewed towards the pandemic's detrimental short-term impacts, long-term impact on biodiversity and conservation is yet to be reflected in the coming

months. Despite acknowledging the apprehensions of ECRs and conservation professionals, we argue that some of the impacts can be reassuring in the longer term as also discussed under the various sub headings of the discussion section, underscoring the importance of understanding ECR perceptions at every stage of the 'new normal'. Since the differential effects are specific to individuals, our results can serve as crucial pointers in identifying constraints, limitations and potential grounds of research progress that will further decide the career prospects of ECRs. The proposed recommendations are holistic as a post-pandemic response or policy, to contribute to the advancement of biodiversity research and conservation in India, by optimising the use of research funding, collaborations and further strengthening them with the support of citizen science and big data analytics. The insights and inputs presented in the paper are expected to serve as a paradigm for strengthening post-COVID-19 biodiversity policy (read post 2020 biodiversity strategy), conservation advocacy and activism, a 'one health' approach to biodiversity conservation and public health, and the setting of 2030 biodiversity targets in megadiverse nations.

Declaration of competing interest

The authors of this manuscript entitled 'Insights on COVID-19 impacts, challenges and opportunities for India's biodiversity research: from complexity to building adaptations' declare no competing or conflicting interest.

Acknowledgements

The authors are thankful to Steve Lockett, Mahseer Trust, for his insightful comments and edits during the preparation, and writing of the manuscript; Payal B Molur for advice and recommendations on the questionnaire and for her editing skills; Suresh Kumar, Director, School of Ocean Science and Technology, KUFOS and Ranjeet K, Head, Department of Aquatic Environment Management, KUFOS, for guidance and logistic support for hosting the webinar, and the subsequent online survey. We are grateful to all the respondents who volunteered to participate in the webinar and provide their perspective and opinions. Useful comments and suggestions from two anonymous reviewers greatly improved the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.biocon.2021.109003>.

References

- Badola, S., 2020. Indian Wildlife Amidst the COVID-19 Crisis: An Analysis of the Status of Poaching and Illegal Wildlife Trade. TRAFFIC, India, New Delhi.
- Bast, F., 2020. How to Organise a Successful Online Conference in a Pandemic. Nature India. <https://www.natureasia.com/en/nindia/article/10.1038/nindia.2020.115>. accessed 10 August 2020.
- Bawa, K.S., 2006. Hurdles for conservation science in India. *Curr. Sci.* 91, 1005.
- Boersch-Supan, P.H., Trask, A.E., Baillie, S.R., 2019. Robustness of simple avian population trend models for semi-structured citizen science data is species-dependent. *Biol. Conserv.* 240, 108286. <https://doi.org/10.1016/j.biocon.2019.108286>.
- Brewer, C., 2006. Translating data into meaning: education in conservation biology. *Conserv. Biol.* 20, 689–691.
- Callaway, E., 2020. Will the pandemic permanently alter scientific publishing? *Nature*. 582, 167–168. <https://doi.org/10.1038/d41586-020-01520-4>.
- Cooke, S.J., Twardek, W.M., Lynch, A.J., Cowx, I.G., Oldene, J.D., Funge-Smith, S., Lorenzen, K., et al., 2020. A global perspective on the influence of the COVID-19 pandemic on freshwater fish biodiversity. *Biol. Conserv.* 253, 108932. <https://doi.org/10.1016/j.biocon.2020.108932>.
- Corlett, R.T., Primack, R.B., Devictor, V., Maas, B., Goswami, V.R., Bates, A.E., Koh, L.P., Regan, T.J., Loyola, R., Pakeman, R.J., Cumming, G.S., Pidgeon, A., Johns, D., Roth, R., 2020. Impacts of the coronavirus pandemic on biodiversity conservation. *Biol. Conserv.* 246, 108571. <https://doi.org/10.1016/j.biocon.2020.108571>.
- Darwall, W.R.T., Holland, R.A., Smith, K.G., Allen, D., Brooks, E.G.E., Kataraya, V., Pollock, C.M., et al., 2011. Implications of bias in conservation research and

- investment for freshwater species. *Conserv. Lett.* 4, 474–482. doi:<https://doi.org/10.1111/j.1755-263X.2011.00202.x>.
- Datta, A., Naniwadekar, R., Rao, M., Sreenivasan, R., Hiresavi, V., 2018. Hornbill watch: a citizen science initiative for Indian hornbills. *Indian BIRDS* 14 (3), 65–70.
- Dillman, D.A., Smyth, J.D., Christian, L.M., 2014. *Internet, Phone, Mail, and Mixed-mode Surveys: The Tailored Design Method*, fourth ed. John Wiley and Sons, Inc., New Jersey.
- Ghosh, S., 2020. Conservation biologists navigate the new normal. <https://india.mongabay.com/2020/04/conservation-biologists-navigate-the-new-normal/> accessed 19 July 2020.
- Gianni, K., 2020. How COVID-19 threatens conservation efforts. <https://www.futurity.org/covid-19-pandemic-conservation-biodiversity-2362612-2/> accessed 19 July 2020.
- Harapan, H., Itoh, N., Yufika, A., Winardi, W., Keam, S., Te, H., Megawati, D., Hayati, Z., Wagner, A.L., Mudatsir, M., 2020. Coronavirus disease 2019 (COVID-19): a literature review. *Int. J. Infect. Control.* 13, 667–673. <https://doi.org/10.1016/j.ijph.2020.03.019>.
- IMF, 2020. World Economic Outlook, April 2020: The Great Lockdown. Washington. <https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020>.
- Johnson, R.L., Coleman, R.A., Batten, N.H., Hallsworth, D., Spencer, E.E., 2020. The quiet crisis of PhDs and COVID-19: reaching the financial tipping point. *Research Square*. <https://doi.org/10.21203/rs.3.rs-36330/v2> [preprint].
- Karanth, K., Kramer, R., Qian, S., Christensen, N., 2008. Examining conservation attitudes, perspectives, and challenges in India. *Biol. Conserv.* 141, 2357–2367. <https://doi.org/10.1016/j.biocon.2008.06.027>.
- Kaye, B.K., Johnson, T.J., 1999. Research methodology: taming the cyber frontier—techniques for improving online surveys. *Soc. Sci. Comput. Rev.* 17, 323–337. <https://doi.org/10.1177/089443939901700307>.
- Kwok, R., 2019. AI empowers conservation biology. *Nature* 567, 133–134. <https://doi.org/10.1038/d41586-019-00746-1>.
- Lal, P., Kumar, A., Kumar, S., Kumari, S., Saikia, P., Dayanandan, A., Adhikari, D., Khan, M.L., 2020. The dark cloud with a silver lining: assessing the impact of the SARS COVID-19 pandemic on the global environment. *Sci. Total Environ.* 732, 139297. <https://doi.org/10.1016/j.scitotenv.2020.139297>.
- Mahato, S., Pal, S., Ghosh, K.G., 2020. Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India. *Sci. Total Environ.* 730, 139086. <https://doi.org/10.1016/j.scitotenv.2020.139086>.
- Malhotra, R., 2018. Citizen Science Projects Take Flight. *Nature India*. <https://www.natureasia.com/en/nindia/article/10.1038/nindia.2018.142>. accessed 10 Aug 2020.
- Misra, S., Maikhuri, R.K., Dhyani, D., Rao, K.S., 2009. Assessment of traditional rights, local interference and natural resource management in Kedarnath Wildlife Sanctuary. *Int J Sust Dev World* 16, 404–416. <https://doi.org/10.1080/13504500903332008>.
- Mohamed Bin Zayed Species Conservation Fund (MBZSCF), 2020. The Impact of the COVID-19 Pandemic on Conservation Activities Worldwide. <https://www.speciesconservation.org/media/mbz-species-conservation-fund-70.pdf> accessed 10 August 2020.
- Molintas, D.T., 2020. Analysis of coronavirus and carbon emissions. MPRA 98858. <https://mpra.ub.uni-muenchen.de/98858/>.
- Muenz, R., 2020. How the COVID-19 Pandemic Could Impact Biodiversity Research. *Clinical Lab Manager*. <https://www.clinicallabmanager.com/news/how-the-covid-19-pandemic-could-impact-biodiversity-research-22806>. accessed 10 August 2020.
- Myers, K.R., Tham, W.Y., Yin, Y., Cohodes, N., Thursby, J.G., Thursby, M.C., Schiffer, P., Walsh, J.T., Lakhani, K.R., Wang, D., 2020. Unequal effects of the COVID-19 pandemic on scientists. *Nat. Hum. Behav.* 4, 880–883. <https://doi.org/10.1038/s41562-020-0921-y>.
- Nakada, L.Y.K., Urban, R.C., 2020. COVID-19 pandemic: impacts on the air quality during the partial lockdown in São Paulo state, Brazil. *Sci. Total Environ.* 730, 139087. <https://doi.org/10.1016/j.scitotenv.2020.139087>.
- Nature Editorial, 2020. Postdocs in crisis: science risks losing the next generation. *Nature*. 585, 160. <https://doi.org/10.1038/d41586-020-02541-9>.
- Ojha, S., 2021. Maharashtra, Delhi Confirm Outbreak of Bird Flu; 9 States Affected so Far. <https://www.livemint.com/news/india/maharashtra-delhi-confirm-an-outbreak-of-bird-flu-9-states-affected-so-far-11610341705316.html> accessed 13 January 2021.
- Palminteri, S., 2019. Combining Artificial Intelligence and Citizen Science to Improve Wildlife Surveys. *Mongabay Environmental News*. <https://news.mongabay.com/2019/03/combining-artificial-intelligence-and-citizen-science-to-improve-wildlife-surveys/>. accessed 10 August 2020.
- Pardo, J.C.F., Ramon, D., Stefanelli-Silva, G., Elegbede, I., Lima, L.S., Principe, S.C., 2020. Advancing through the pandemic from the perspective of marine graduate researchers: challenges, solutions, and opportunities. *Front. Mar. Sci.* 7, 528. <https://doi.org/10.3389/fmars.2020.00528>.
- Pinder, A.C., Raghavan, R., Britton, J.R., Cooke, S.J., 2020. COVID-19 and biodiversity: the paradox of cleaner rivers and elevated extinction risk to iconic fish species. *Aquatic Conserv. Mar. Freshw. Ecosyst.* 30, 1061–1062. <https://doi.org/10.1002/aqc.3416>.
- R Core Team, 2020. R: A Language and Environment for Statistical Computing [Internet]. R Foundation for Statistical Computing. <https://www.R-project.org>.
- Rutz, C., Loretto, M., Bates, A.E., Davidson, S.C., Duarte, C.M., Jetz, W., Johnson, M., Kato, A., Kays, R., Mueller, T., Primack, R.B., Ropert-Coudert, Y., Tucker, M.A., Wikelski, M., Cagnacci, F., 2020. COVID-19 lockdown allows researchers to quantify the effects of human activity on wildlife. *Nat. Ecol. Evol.* <https://doi.org/10.1038/s41559-020-1237-z>.
- Sharma, D.C., 2019. Citizen Science Growing in India: Study. <https://www.downtoearth.org.in/news/science-technology/citizen-science-growing-in-india-study-66375> accessed 10 August 2020.
- Soltis, D.E., Soltis, P.S., 2016. Mobilizing and integrating big data in studies of spatial and phylogenetic patterns of biodiversity. *Plant Divers* 38, 264–270. <https://doi.org/10.1016/j.pld.2016.12.001>.
- Sondhi, S., Kunte, K., 2020. The role of citizen science in studying Lepidoptera biology and conservation in India. *Indian Entomologist*. 1, 14–23.
- Torney, C.J., Lloyd-Jones, D.J., Chevallier, M., Moyer, D.C., Maliti, H.T., Mwitia, M., Kohi, E.M., Hopcraft, G.C., 2019. A comparison of deep learning and citizen science techniques for counting wildlife in aerial survey images. *Methods Ecol. Evol.* doi: <https://doi.org/10.1111/2041-210X.13165>.
- United Nations Organisation, 2020. A UN Framework for the Immediate Socio-economic Response to COVID-19. United Nations, New York. <https://unsdg.un.org/sites/default/files/2020-04/UN-framework-for-the-immediate-socio-economic-response-to-COVID-19.pdf>.
- Warrier, S.G., 2017. Enthusiasts and Experts Document Biodiversity on a Digital Platform. *Mongabay-India*. <https://india.mongabay.com/2017/12/enthusiasts-and-experts-document-biodiversity-on-a-digital-platform/>. accessed 10 August 2020.
- West, S.G., Aiken, L.S., Krull, J.L., 1996. Experimental personality designs: analyzing categorical by continuous variable interactions. *J. Pers.* 64, 1–48. <https://doi.org/10.1111/j.1467-6494.1996.tb00813.x>.
- Wilthers, A., 2020. Covid-19 Can't Stop Citizen Science. *Undark Magazine*. <https://undark.org/2020/04/17/covid-19-citizen-science/>. accessed 10 August 2020.
- Woolston, C., 2020. 'It's like we're going back 30 years': how the coronavirus is gutting diversity in science. *Nature*. <https://doi.org/10.1038/d41586-020-02288-3>.
- World Bank, 2020. Global Economic Prospects. The World Bank Group, Washington, D. C.. <https://elibrary.worldbank.org/doi/abs/10.1596/978-1-4648-1553-9>
- World Health Organisation, 2020. WHO Coronavirus Disease (COVID-19) Dashboard. <https://covid19.who.int/region/searo/country/in/> accessed 29 July 2020.
- Young, B.E., Dodge, N., Hunt, P.D., Ormes, M., Schlesinger, M.D., Shaw, H.Y., 2019. Using citizen science data to support conservation in environmental regulatory contexts. *Biol. Conserv.* 237, 57–62. <https://doi.org/10.1016/j.biocon.2019.06.016>.
- Yunus, A.P., Masago, Y., Hijioka, Y., 2020. COVID-19 and surface water quality: improved lake water quality during the lockdown. *Sci. Total Environ.* 731, 139012. <https://doi.org/10.1016/j.scitotenv.2020.139012>.
- Zumbo, B. D., Ochieng, C.O., 2002. The Effects of Various Configurations of Likert, Ordered Categorical, or Rating Scale Data on the Ordinal Logistic Regression Pseudo R-squared Measure of Fit: The Case of the Cumulative Logit Model. *AERA meeting paper*, 19p.