
Citizen Science: A Significant Contribution to Biodiversity Monitoring and Conservation

Muzafar Riyaz

Division of Taxonomy & Biodiversity, Entomology Research Institute, Loyola College, Chennai, India

Email address:

bhatmuzaffar471@gmail.com

To cite this article:

Muzafar Riyaz. Citizen Science: A Significant Contribution to Biodiversity Monitoring and Conservation. *Computational Biology and Bioinformatics*. Vol. 10, No. 2, 2022, pp. 60-67. doi: 10.11648/j.cbb.20221002.12

Received: July 15, 2022; **Accepted:** July 29, 2022; **Published:** August 24, 2022

Abstract: The term "biodiversity" refers to the diverse variety of living things that exist in our natural environment including not just plants and animals, but also fungi and even microscopic organisms such as bacteria. Since there are still millions of species that have not been identified, the overall biodiversity of our world is immense. The biodiversity of our planet plays a significant role in ensuring the health of our ecosystems. Because of habitat destruction, industrialization, urbanization, and the ever-increasing population of humans, many animal and plant species are classified as being either vulnerable, endangered, or in imminent danger of becoming extinct. In addition, there is a high risk of extinction for a large number of species in the event that management and conservation strategies are not immediately put into effect. The goal of the initiative known as "citizen science" is to increase scientific understanding by encouraging collaboration and participation from the general public in scientific research. Individual people have the opportunity to nurture their scientific temperament in the field through involvement in citizen science, which also allows communities an ability to study nature and protect it through collective efforts. In order to monitor and conserve biodiversity together with professionals in the scientific and academic communities to develop solutions to environmental problems, it is important to establish additional citizen science projects for citizen scientists.

Keywords: Citizen Science, Biodiversity, Monitoring, Conservation, Species

1. Introduction

Millions of plant and animal species have coexisted with humans since the dawn of humankind. It is termed as an ecosystem when all kinds of plants coexist in the same habitat. An assortment of various plant and animal species is referred to as biodiversity, and it differs in many ecosystems like tundra, grasslands, savannas, woodlands, deep ocean zones, urban and rural regions, etc. The abundance of living forms that make up the variety of the globe may appear like enduring organisms, yet they are actually vulnerable to collapse. Even without cataclysmic events like eruptions of volcanoes or collisions with asteroids, forests can turn into deserts and reefs into dead rocks. What causes one ecosystem to be robust while another is visibly weak?

If there is a resilient intertwining between species, ecosystem and genetic diversity, the denser and more robust the weave becomes in an ecosystem, which is reflected by taking an example of a rain forest [1]. The rainforests are one of the megadiverse hotspots on the earth, which can be

perceived due to the complex ecological niche, a gigantic mix of species, and the genetic variety among those species. In a rainforest, trees play a major role by providing the seeds, fruits, and leaves to the herbivores, and in turn, the herbivores disperse the seeds throughout the forest, resulting in the growth of much larger vegetation. Millions of land-dwelling insects and other decomposers decompose leftovers of food from the flora, which marks the further engenderment of soil fertility [2]. A rainforest or any other ecosystem is a diverse organization of interconnectivity that is occupied by many other smaller systems, each crammed with interconnected species [3]. Stability is maintained by the mutual consideration between the links in an ecosystem, therefore providing further strength to the weave of biodiversity. This is further reinforced by the changes managed by individuals, permitted by the genetic diversity within the species.

Genetic diversity plays a very crucial role in maintaining the higher chance of long-term survival [4]. However, if the species lack genetic diversity due to a low population or

isolation, they are prone to a vulnerability that may result in fluctuations among the populations caused by climate change, habitat fragmentation, or diseases [5].

Humans have been dependent on biodiversity since the dawn of their evolution, and they have utilized everything in biodiversity. Humans have lived in forests for thousands of years, and in the present era of technology, they still use them for timber, medicinal plants, blocking carbon and therefore keeping the climate stable. Our planet's biodiversity has been providing humans with its resources free for ages [6].

However, at present, biodiversity has been vanishing, and in the last 50 years, man-made activities have dramatically reduced biodiversity across the globe to a greater extent. Biodiversity is an important and vital part of our environment and the interconnectivity of the species living in it. With 8 billion people on the face of the planet, the natural world is experiencing a decline [7]. Biodiversity is declining rapidly, and the nature of this impact that human beings are now having on the planet has led to the extinction of many animal and plant species (Figure 1).



Figure 1. Three major levels/types of Biodiversity.

A collective effort of scientists, researchers, and the public that can serve as natural volunteers can solve a number of environmental issues. Citizen science (CS) is a knowledge-sharing initiative in which the public assists

researchers in informing them and, in turn, the researchers can help inform the public. Citizen science also has the capacity to resolve environmental justice issues and empower communities to change and adopt natural laws [8].

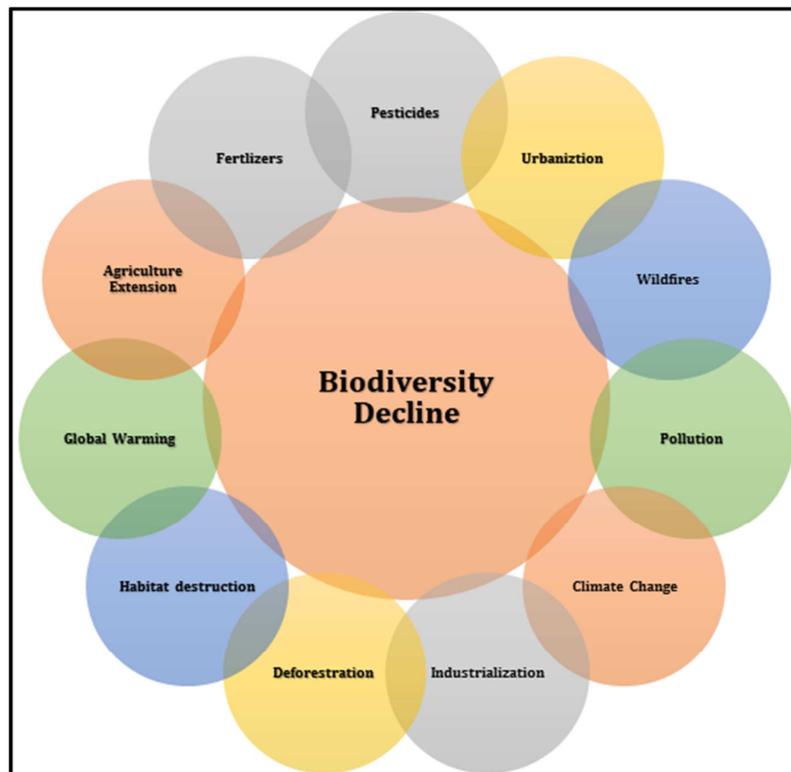


Figure 2. Drivers of Biodiversity decline.

2. Citizen Science and Biodiversity Conservation

Biodiversity decline is factual and accurate, and the rate of decline among species is higher as compared to the decline in the late 19th century [9-11]. The conservation and

management of biodiversity is the need of the hour. Across the globe, governments, non-government organisations, research organizations, colleges, and universities are all tapping all means for collective effort towards biodiversity monitoring and conservation. Citizen science (CS) is a joint initiative between professional researchers, scientists, and CS volunteers, including hobbyists, wildlife photographers, and the general public [12-15]. The aim of this initiative is to

monitor biodiversity across the globe and to spread knowledge among citizen science volunteers. Among the floral and faunal species, butterflies and moths (Lepidoptera), birds, and plants are monitored on a large scale. Across the globe, most of the citizen science projects are active in North

America, Europe, South America, India, and Australia [16]. The participation of the common public, including volunteers, in environmental assessments is conducted by uploading the collection of casual observations of the species in online data depositories (Table 1).

Table 1. List of Citizen Science (CS) projects for Biodiversity monitoring and conservation across the globe.

S. No.	Project Name	Areas	Sponsoring Organizations	Range	Started
1	Anecdata	Air Quality, Botany, Entomology, Ecology, Lepidopterology, Ornithology, Phenology, Water Quality, Zoology	MDI Biological Laboratory	Worldwide	2013
2	Amphibian Migrations and Road Crossings	Herpetology, Ecology	Department of Environmental Conservation, NY, USA	New York, USA	
3	Artportalen (Swedish Species Observation System)	Biology, biodiversity, species distribution. Mapping.	Swedish Species Information Centre / Swedish Environmental Protection Agency	Sweden	1999
4	Artsobservasjoner	Botany, Mycology, Phenology, Species distribution, Zoology	Norwegian Directorate for Nature Management, Norway	Norway	2008
5	Atlas of Australian Birds	Ornithology	BirdLife Australia	Australia	1973
6	Audubon Christmas Bird Count	Ornithology	National Audubon Society	Western Hemisphere	1900
7	Aussie Backyard Bird Count	Ornithology	BirdLife Australia	Australia	2014
8	B. C. Cetacean Sightings Network	Cetology	Vancouver Aquarium, Fisheries and Oceans Canada	Canada (British Columbia)	1999
9	Backyard Bark Beetles	Entomology, Invasive Species	Forest Entomology lab at the University of Florida, Gainesville, FL	USA	2014
10	BeeSpotter	Entomology	University of Illinois at Urbana– Champaign GrowVeg, University of York, Biotechnology and Biological Sciences Research Council, Innovate UK	USA (IL, IN, MO, OH)	2007
11	Big Bug Hunt	Entomology	Butterfly Conservation	USA, UK	2016
12	Big Butterfly Count	Lepidopterology, Entomology	Butterfly Conservation	UK	2010
13	Big Garden Birdwatch	Ornithology, Conservation, Ecology	Royal Society for the Protection of Birds	UK	1979
14	Big Moss Map	Botany, Climatology, Peatlands	Moors for the Future	UK	2015
15	BioDiversity Heritage Library Flickr Image Tagging	Taxonomy, Ornithology, Entomology, Zoology, Botany	Biodiversity Heritage Library	Worldwide	
16	BioNote	Biology, Botany, Zoology, Biogeography, Taxonomy	BioNote, University of Gothenburg, Climate-KIC, European Research Council	Worldwide	2016
17	Biosphere Expeditions	Biology, Conservation	Citizen scientists & local community partners	Worldwide	1999
18	Birdcount India	Ornithology, Biology, Ecology, Conservation	Bird Count India partnership	India	2019
19	BirdSleuth K-12	Ornithology	Cornell Lab of Ornithology	USA	2004
20	Birds and Windows Project	Ornithology, Conservation, Ecology	University of Alberta	Canada	2013
21	Birds-Windows Collisions Project Costa Rica	Ornithology, Conservation, Ecology	Costa Rica Distance Learning University UNED	Costa Rica	2013
22	Project BudBurst	Plant Phenology	Chicago Botanic Garden, National Science Foundation	USA	2007
23	Budworm Tracker Program	Insect Research	John Hughs Forestry Center	Fredericton NB, Maine USA	2015
24	BugGuide	Entomology, Arthropods	Iowa State University	USA, Canada	2003
25	Bumble Bee Watch	Entomology	Xerces Society, University of Ottawa, Wildlife Preservation Canada, Natural History Museum, London, BeeSpotter, Montréal Insectarium	Canada, USA	2014
26	Brushsturkeys - Birds of Suburbia	Ornithology, City Ecology	University of Sydney, SPOTTERON Collaboration	Australia	2018
27	Canadian National Wildlife Disease Surveillance	Wildlife, Health	Canadian Wildlife Health Cooperative	Canada	1992
28	Canberra Nature Map	Wildlife	NatureMapr	Australia	2013
29	Cape Citizen Science	Biology, Botany, Plant Disease	University of Pretoria	South Africa	2015
30	Celebrate Urban Birds	Ornithology	Cornell Lab of Ornithology	USA	
31	Cicada Watch: Brood II	Entomology	National Geographic Society	Northeastern America	2013
32	Clumpy	Biology, Botany	University of Exeter	Worldwide	2012
33	Condor Watch	Ornithology, Conservation	Zooniverse collaboration	California	2014
34	CyanoTracker	Algal Bloom, Water Quality	University of Georgia	Worldwide	2014

S. No.	Project Name	Areas	Sponsoring Organizations	Range	Started
35	DigiVol	Entomology, Malacology, Minerals, Archives	Australian Museum and Atlas of Living Australia	Australia	2011
36	DrugsFromDirt	Ecology, Biology, Genetics	Laboratory of Genetically Encoded Small Molecules, The Rockefeller University	USA	2017
37	eBird	Ornithology	Cornell Lab of Ornithology, National Audubon Society	Worldwide	2002
38	eButterfly	Lepidopterology, Entomology	University of Ottawa, Oregon State University, Vermont Center for Ecostudies	USA, Canada	2010
39	echidnaCSI	Conservation, Ecology, Biology, Genetics	University of Adelaide	Australia	2017
40	EDDMapS	Tracking invasive species, Biology, Botany, Entomology, Wildlife	University of Georgia Center for Invasive Species and Ecosystem Health.	USA, Canada	2005
41	eOceans	Marine Ecology, Marine Debris, Ornithology, Climate Change,	Private	Global	2014
42	eShark	Marine Ecology, Marine Management, Tourism	Crowd-sourced	Global	2005
43	Flying ant survey	Biology, Entomology, Wildlife	Society of Biology, University of Gloucestershire,	UK	2012
44	Foldit	Biology, protein	University of Washington	Worldwide	2008
45	Fossil Atmospheres	Biology, Paleontology, Climate change	Smithsonian Institution	Worldwide	2016
46	Golden Gate Raptor Observatory	Ornithology, Migration, Phenology, Population Change	Golden Gate National Parks Conservancy	Pacific States	1984
47	Great Backyard Bird Count	Ornithology	National Audubon Society, Cornell Lab of Ornithology	Worldwide	
48	Great Cocky Count	Ornithology	Birdlife Australia	Western Australia	2009
49	Habitat Network	Conservation, Ornithology, Wildlife	The Nature Conservancy and the Cornell Lab of Ornithology	North America	2012
50	Hare Survey	Biology, Wildlife	Moors for the Future Partnership	UK	2015
51	Hazelnut Project	Botany, Agronomy	Hybrid Hazelnut Consortium (Arbor Day Foundation, University of Nebraska–Lincoln, Rutgers and Oregon State)	USA	2000
52	Herbarium@home	Botany	Botanical Society of Britain and Ireland	UK	2006
53	Herbonauten (Pilot)	Botany, Natural History	Verein der Freunde des Botanischen Gartens und Botanischen Museums Berlin-Dahlem	Worldwide (Germany)	2016
54	Herpetological Education and Research Project	Herpetology	HERP Board of Trustees	North America	2007
55	HerpMapper	Herpetology, Ecology, Citizen Science, Conservation, Phenology, Research	HerpMapper Advisory Committee	Global	2013
56	Hidden World of Bacteria	Microbiology, Taxonomy	Sparkling Science, University of Innsbruck	Austria	2017
57	Hummingbirds at Home	Ornithology	National Audubon Society	USA	2013
58	Hummingbird Migration Tracker	Ornithology	Birdfeeders.com	USA	2010
59	Hunt for a New Raindrop Treehopper	Biology, Entomology	Murray State University	USA	2021
60	iNaturalist	Botany, Entomology, Ecology, Lepidopterology, Ornithology, Phenology, Zoology	California Academy of Sciences	Global	2008
61	India Biodiversity Portal	Computer Science, Biology, Environmental Science	Prabhakar / Thomas Vattakaven	India	2008
62	Instant Wild	Wildlife, Ecology, Species diversity, Conservation, Zoology	Zoological Society of London	Global	2011
63	iSeahorse	Ichthyology, Ecology, Marine Biology, Marine Conservation, Zoology	Project Seahorse, Guylian Belgian Chocolate, iNaturalist, John G. Shedd Aquarium, The University of British Columbia, Zoological Society of London	Global	2013
64	iSpot	Nature	The Open University	Global	2009
65	iTech Explorers	Psychology, Biology, Evidence based medicine, Health	Community	Worldwide	2019
66	Kelab Alami	Ecology, Mangroves, Biodiversity	Community	Malaysia	2009
67	Koala Count	Wildlife	NatureMapr	Australia	2014
68	Massachusetts Herpetological Atlas	Herpetology	University of Massachusetts Amherst	USA	1992

S. No.	Project Name	Areas	Sponsoring Organizations	Range	Started
69	MammalMAP	Mammal Conservation	Animal Demography Unit, Marine Research Institute	Africa	2012
70	Manta Matcher - The Wildbook for Manta Rays	Marine Ecology, Conservation Biology, Ecology	Wild Me, Marine Megafauna Foundation	Worldwide	2012
71	Marine Metres Squared	Marine Ecology, Conservation Biology	New Zealand Marine Studies Centre	New Zealand	
72	Michigan Herp Atlas Project	Herpetology	Michigan Department of Natural Resources	USA (MI)	2004
73	Mitten Crab Recording Project	Marine Biology, Invasive Species	Marine Biological Association of the United Kingdom	UK	
74	Monarch Health	Entomology, Lepidopterology	University of Georgia	Canada, USA	
75	Monarch Larva Monitoring Project	Entomology, Lepidopterology	University of Minnesota	Canada, USA	
76	Monarch Watch	Entomology, Lepidopterology	University of Kansas	Canada, USA	1992
77	Mosquito Alert	Entomology, Ecology, Public Health	Center for Ecological Research and	Spain	2013
78	Mozak	Neuroscience	Center for Game Science	Worldwide	2016
79	National Moth Week (NMW)	Entomology	Friends of the East Brunswick Environmental Commission	Worldwide	2012
80	Nature's Calendar	Phenology	Woodland Trust	UK	
81	Nature's Calendar	Phenology	Zentralanstalt für Meteorologie und Geodynamik (ZAMG), SPOTTERON Collaboration	Europe	2018
82	Nature's Notebook NatureWatch	Phenology	USA National Phenology Network	USA	2009
83	*FrogWatch *IceWatch *PlantWatch *WormWatch	Ecology, Phenology, Herpetology	Nature Canada	Canada	2003
84	NatureWatch NZ	Botany, Entomology, Ecology, Ornithology, Phenology, Zoology	New Zealand Bio-Diversity Recording Network Trust	New Zealand	2006 (as NZBRN)
85	Natusfera	Biodiversity	Spanish GBIF node, Center for Ecological Research and Forestry Applications (CREAF), Institute of Marine Sciences (ICM-CSIC), FECyT	Europe	2016
86	Neighborhood Nestwatch	Ornithology	Migratory Bird Center, National Zoological Park, SI	USA	
87	NestWatch	Ornithology	Cornell Lab of Ornithology	Americas	2008
88	North American Field Herping Association	Herpetology	North American field herping community	North America	2007
89	North American Bird Phenology Program	Ornithology	United States Geological Survey	North America	2008
90	Notes from Nature	Botany, Entomology, Ornithology, Mycology	Zooniverse collaboration	Worldwide	
91	SeasonWatch	Botany, Ecology	Nature Conservation Foundation	India	2014
92	Odonata Central	Odonata		North America	2004
93	Old Weather	Climatology	Zooniverse collaboration	Worldwide	
94	Ontario BioBlitz	Botany, Ecology, Entomology, Herpetology, Ichthyology, Lepidopterology, Ornithology	Royal Ontario Museum, Canadian Wildlife Federation, Nature Conservancy of Canada, Ontario Nature, Toronto Zoo, Toronto and Region Conservation Authority	Canada (Ontario)	2012
95	Ontario Butterfly Atlas Online	Lepidopterology, Entomology	Toronto Entomologists' Association	Canada (Ontario)	1969
96	Ontario Reptile and Amphibian Atlas	Herpetology	Ontario Nature, Ministry of Natural Resources' Natural Heritage Information Centre (NHIC)	Canada (Ontario)	
97	Operation Wallacea	Biodiversity	Worldwide	UK	1996
98	Orca Game	Bioacoustics	Orchive	Worldwide	2013
99	Orchids: Terrestrial Spiranthes in an Urban Environment	Urban Conservation	Hoyt Arboretum	Portland, OR	2014
100	Ornitho Deutschland	Ornithology	Dachverband Deutscher Avifaunisten	Austria, France (part), Germany, Italy, Luxemburg, Poland, Spain (part), Switzerland	October 2011
101	Painted Lady Migration Project	Lepidopterology	Institut de Biologia Evolutiva, National Geographic, Marie Skłodowska-Curie Actions, British Ecological Society, Barcelona zoo, Harvard University, Zerynthia Association	Worldwide	

S. No.	Project Name	Areas	Sponsoring Organizations	Range	Started
102	PARS (Pennsylvania Amphibian and Reptile Survey)	Biology, Marine biology, Environmental protection	MACHAC	Pennsylvania, US	2013
103	Penguin Watch	Ornithology	Zooniverse collaboration	Worldwide	
104	Pieris Project	Lepidopterology, Entomology	theryanlab.com	Worldwide	2014
105	Pl@ntNet	Botany	Inra Inria	Global	2008
106	Pilzfinder	Mycology	Austrian Mycology Society, University of Vienna, SPOTTERON collaboration	Europe	2019
107	Plankton Portal	Marine biology, Zoology	Zooniverse collaboration	Worldwide	2013
108	Portland Urban Coyote Project	Ecology, Geography, Zoology, Human Dimensions of Wildlife, Mapping	Portland State University	Portland, Oregon	2011
109	Project Roadkill	Ecology, Road Safety	University of Natural Resources and Life Sciences, Vienna	Worldwide	2014
110	Project Splatter	Ecology, Conservation	Cardiff University	UK	2013
111	Reef Check Med	Marine Biology and Ecology, Environmental Science	Reef Check Italia, Reef Check Deutschland, Reef Check France, Reef Check Worldwide Foundation	Mediterranean Sea	2006
112	Reef Environmental Education Foundation (REEF)	Marine conservation, Marine biology	Non-profit organization	Key Largo, FL (worldwide)	1990
113	Report-a-weed	Biodiversity	British Columbia government	Canada	
114	Roadkill	Biodiversity, Transportation	University of Natural Resources and Life Sciences, Vienna, SPOTTERON Collaboration	Worldwide	2015
115	SABAP2 (Southern African Bird Atlas Project 2)	Ornithology	Animal Demography Unit, BirdLife South Africa and the South African National Biodiversity Institute (SANBI)	Southern Africa	2007
116	SeagrassSpotter	Seagrass	Project Seagrass	Worldwide - Marine	2016
117	Secchi Disk	Phytoplankton	Secchi Disk Project	Worldwide - Marine	2013
118	The Shore Thing Project	Biology, Marine Biology, Invasive Species, Climate Change	Marine Biological Association of the United Kingdom	UK	2006
119	Smithsonian Transcription Center	Astronomy, Botany, Entomology	Smithsonian Institution	USA	2014
120	Species Observations System	Botany, Entomology, Ecology, Ornithology, Phenology, Zoology	Norwegian Biodiversity Information Centre, Norwegian Biodiversity Network	Norway	2008
121	Striped AmbASSadors	Fisheries, Conservation, Ecology	Striped Bass Research Team, Acadia University	NS, Canada	2010
122	Taiwan Breeding Bird Survey	Biology, Life Science, Ecology	The Bird Breeding Survey of Taiwan	Taiwan	2019
123	Taxon expeditions	Biodiversity, Ecology	Taxon Expeditions	Borneo, Montenegro	2017
124	Teatime4Science	Botany, Climate change, Ecology, Pedology	The TBI team, Utrecht University	Worldwide	2016
125	Track a Tree	Botany, Ecology, Phenology	University of Edinburgh and the Woodland Trust	UK	2014
126	Track My Fish	Fisheries, Ecology, Tagging	Striped Bass Research Team, Acadia University	Canada	2012
127	TreeSnap	Forestry, Invasive Species, Botany	University of Kentucky, University of Tennessee	USA	2017
128	Turtle Survey and Analysis Tools (TurtleSAT)	Herpetology	University of Sydney, University of Western Sydney	Australia	2014
129	Whistler Biodiversity Project	Biodiversity	Whistler Biodiversity Project	Canada	2004
130	Wikispecies	Biodiversity	Wikimedia Foundation	Worldwide	2004
131	Wildbook	Wildlife, Population ecology, Mark-recapture	Wild Me	Worldwide	2001
132	WildlifeLog.org	Wildlife	WildlifeLog Community Interest Company	Worldwide	2014
133	Wildsense Tigers	Wildlife	The Wildsense Project, University of Surrey	Worldwide	2015
134	WildWatcher (Vadonleső)	Wildlife observation	Hungarian Ministry of Agriculture & Herman Otto Institute Nonprofit Ltd.	Hungary	2009
135	Wisconsin Odonata Survey	Odonata, Biology	Wisconsin Department of Natural Resources	Wisconsin, USA	
136	Wombat Survey and Analysis Tools (WomSAT)	Mammalogy	WomSAT.org.au	Australia	2015
137	Stardust@Home	Astronomy	University of California, Berkeley	Worldwide	2006
138	Yellowhammer Dialects	Ornithology	Charles University in Prague	UK, New Zealand	2013
139	Wakame Watch	Marine Biology, Invasive Species	Marine Biological Association of the United Kingdom	UK	2014
140	Wildlife Spotter	Ecology	National Science Week Australia, Australian Broadcasting Corporation	Australia	2016

Citizen Science (CS) is the practice of public participation and collaboration in scientific research to increase scientific knowledge. Volunteers, members of the public, collect and analyze data relating to the natural world. Volunteers can contribute in a quiet number of ways, like a group of bird watchers whose sightings are used to track migratory patterns of birds, or it could be people who count insects as a part of a pollinator conservation effort [17]. This method of collaboration allows scientists to obtain a large

amount of data in a scope that would otherwise be impossible due to time, geographic, or resource constraints. As biodiversity declines, conservation strategies must be implemented immediately since the health of our ecosystems is deteriorating [18]. Scientists cannot solve these problems alone. A single individual or a whole community in any region of the globe can participate in or initiate CS activities, which can have a compounding effect on monitoring and safeguarding biodiversity worldwide. (Figure 3).

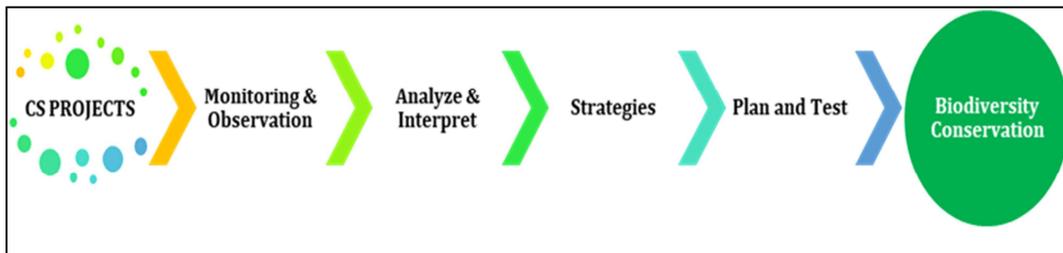


Figure 3. An overview of a working CS project.

3. Conclusion

Citizen science aims at increasing scientific knowledge through collaboration and public participation in scientific research. With this initiative, people from different parts of the world take part in such activities and share and contribute to data monitoring and collection programmes. Citizen science allows people to enhance their scientific temperament in the field and empowers communities to observe nature and with collective efforts to conserve as well. Across the globe, the majority of people, including nature volunteers, wildlife photographers, retired professionals, amateur scientists, teachers, and the public, are taking part in such activities, and people are very enthusiastic about sharing and collaborating on scientific research. More citizen science projects must be initiated in the future as well, so that more discoveries of species can be made and, together with the public, scientists and researchers will be able to solve the environmental problems and biodiversity can be saved collectively.

Acknowledgements

The author wishes to thank Entomology Research Institute, Loyola College, Chennai, Tamil Nadu, India for extended support and guidance.

References

- [1] Shubham, D. (2021). The importance of wildlife and biodiversity. *JOJ Wildlife and Biodiversity*, 4 (1), 01–03.
- [2] Noriega, J. A., Hortal, J., Azcárate, F. M., Berg, M. P., Bonada, N., Briones, M. J.,... & Santos, A. M. (2018). Research trends in ecosystem services provided by insects. *Basic and Applied Ecology*, 26, 8–23.
- [3] Ewers, R. M., Boyle, M. J., Gleave, R. A., Plowman, N. S., Benedick, S., Bernard, H., Bishop, T. R., Bakhtiar, E. Y., Chey, V. K., Chung, A. Y., & Davies, R. G. (2015). Logging cuts the functional importance of invertebrates in tropical rainforest. *Nature Communications*, 13 (6 (1)), 1–7. <https://doi.org/10.1038/ncomms7836>
- [4] Ellegren, H., & Galtier, N. (2016). Determinants of genetic diversity. *Nature Reviews Genetics*, 17 (7), 422–433.
- [5] Booy, G., Hendriks, R. J. J., Smulders, M. J. M., Van Groenendael, J. M., & Vosman, B. (2000). Genetic diversity and the survival of populations. *Plant Biology*, 2 (4), 379–395. <https://doi.org/10.1055/s-2000-5958>
- [6] Duffy, J. E. (2009). Why biodiversity is important to the functioning of real-world ecosystems. *Frontiers in Ecology and the Environment*, 7 (8), 437–444. <https://doi.org/10.1890/070195>
- [7] Dietz, S., & Adger, W. N. (2003). Economic growth, biodiversity loss and conservation effort. *Journal of Environmental Management*, 68 (1), 23–35. [https://doi.org/10.1016/s0301-4797\(02\)00231-1](https://doi.org/10.1016/s0301-4797(02)00231-1)
- [8] de Sherbinin, A., Bowser, A., Chuang, T. R., Cooper, C., Danielsen, F., Edmunds, R., Elias, P., Faustman, E., Hultquist, C., Mondardini, R., Popescu, I., Shonowo, A., & Sivakumar, K. (2021). The critical importance of citizen science data. *Frontiers in Climate*, 3 (3: 20). <https://doi.org/10.3389/fclim.2021.650760>
- [9] Abdi, A. M., Carrié, R., Sidemo-Holm, W., Cai, Z., Boke-Olén, N., Smith, H. G.,... & Ekroos, J. (2021). Biodiversity decline with increasing crop productivity in agricultural fields revealed by satellite remote sensing. *Ecological Indicators*, 130, 108098.
- [10] Lanz, B., Dietz, S., & Swanson, T. (2018). The expansion of modern agriculture and global biodiversity decline: an integrated assessment. *Ecological Economics*, 144, 260–277.
- [11] Capdevila, P., Noviello, N., McRae, L., Freeman, R., & Clements, C. F. (2022). Global patterns of resilience decline in vertebrate populations. *Ecology Letters*, 25 (1), 240–251.

- [12] Groom, Q., Weatherdon, L., & Geijzendorffer, I. R. (2017). Is citizen science an open science in the case of biodiversity observations? *Journal of Applied Ecology*, 54 (2), 612–617. <https://doi.org/10.1111/1365-2664.12767>
- [13] Haklay, M. M., Dörler, D., Heigl, F., Manzoni, M., Hecker, S., & Vohland, K. (2021). What is citizen science? The challenges of definition. *The science of citizen science*, 13.
- [14] Land-Zandstra, A., Agnello, G., & Gültekin, Y. S. (2021). Participants in citizen science. *The science of citizen science*, 243.
- [15] Rosas, L. G., Espinosa, P. R., Jimenez, F. M., & King, A. C. (2022). The Role of Citizen Science in Promoting Health Equity. *Annual review of public health*, 43, 215.
- [16] Pocock, M. J. O., Chandler, M., Bonney, R., Thornhill, I., Albin, A., August, T., Bachman, S., Brown, P. M. J., Cunha, D. G. F., Grez, A., Jackson, C., Peters, M., Rabarijaon, N. R., Roy, H. E., Zaviero, T., & Danielsen, F. (2018). A vision for global biodiversity monitoring with citizen science. *Advances in Ecological Research*, 1 (59), 169–223. <https://doi.org/10.1016/bs.aecr.2018.06.003>
- [17] Kawahara, A. Y., Reeves, L. E., Barber, J. R., & Black, S. H. (2021). Eight simple actions that individuals can take to save insects from global declines. *Proceedings of the National Academy of Sciences*, 118 (2), e2002547117.
- [18] Soley, F. G., & Perfecto, I. (2021). A way forward for biodiversity conservation: high-quality landscapes. *Trends in Ecology & Evolution*, 36 (9), 770-773.