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Smart phone-macro lens setup (SPMLS): a low-cost and portable photography device for amateur taxonomists, biodiversity researchers, and citizen enthusiasts

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Abstract

Background In the present era of scientific and technological advancements, the use of smartphones among people has witnessed a large-scale progression. The camera serves as an important tool on smartphones, and the quality of the built-in camera varies with megapixels. The quality of photography and videography can be enhanced by employing macro lenses that can provide precise and high-quality photographs for the documentation and monitoring of macroorganisms, particularly insects. We used a smartphone-macro lens setup (SPMLS), comprising a Redmi Note 8 Pro and Skyvik Signi-20 mm lens, along with Snapseed for image processing. The SPMLS, costing USD 217, was employed in the Hirpora Wildlife Sanctuary, Kashmir, during May to October 2021 for insect diversity documentation. The aim of this study is to introduce and demonstrate the utility of SPMLS as an affordable and portable photography solution for enhancing image quality in biodiversity documentation, making it accessible to a wide range of users.

Results In this study, we report a device that uses a smartphone and macro lens (SPMLS), which is a portable and low-cost photography gear for researchers, photographers, citizen enthusiasts, and the general public who are not able to buy high-end and costly photography equipment for field-based biodiversity studies. The utilization of SPMLS has significantly augmented the image resolution and pixel density, thereby substantially enhancing the overall photographic quality, demonstrating its substantial scientific utility.

Conclusions The SPMLS device presented in this study can be useful for researchers, scientists, students, citizen enthusiasts, and common people that are engaged in the biodiversity monitoring and conservation of animal and plant species across the globe. In addition, the post-photography part of this paper provides users with an outlook on image editing, processing, uploading, and marketing of photographs on different platforms.

Keywords Biodiversity, Monitoring, Conservation, Photography, Smart phone, Macro lens

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Background

Among various scientific methods employed in biodiversity research, photography has always aided in biodiversity, taxonomical, and conservation investigations in the form of captured images or videos of an organism or specimen followed by their processing and publishing (Suprayitno et al. 2017; Mesaglio et al. 2023). With the advancement of technology, the practice of digitalization has increased among researchers in the fields of biodiversity monitoring, systematics, taxonomy, ecology, and allied disciplines all over the world (Hammerle and Hofle 2018; Carreira 2023). The swift accesses to data transfer and collection concerning biodiversity assessment and monitoring research have been empowered by digitalization, which serves as an essential resource for researchers and common people (Yang et al. 2019). In the present age of digitalization, the use of smart phones has surged to an unprecedented scale as they are user-friendly and come at a low cost. The wide range of information that can be accessed anytime from anywhere has been supported through the advancement of mobile phones into smart phones. As the number of users is rapidly increasing, the potential to address many global issues including biodiversity monitoring can be achieved by the use of smart phones and their applications (Hossain and Ahmed 2016; Filazzola et al. 2022).

Despite the fact that smart phone technology has witnessed a sudden expansion of its sales by marketing cheaper android smart phones, individuals, mostly students, who are addicted to watching films and playing games throughout the day, have been affected in the long run (Nayak 2018). However, individuals who are engaged in biodiversity monitoring and allied fields with a deep passion for research have employed smart phones in a far better way by documenting the scientific observations through images and videos of the biological specimens. For studying live biological specimens in the wild or across agricultural habitats, it is difficult to carry the hefty laboratory equipment. While laboratory equipment allows researchers to analyze the minute characteristics of specimens, its acquisition cost and the challenges of transporting it for field studies impose significant financial and logistical burdens on researchers (Madimenos et al. 2022). Studying the minute characteristics of a specimen and its biology such as external morphology, behavior, ecology, and pest nature in different ecosystems is not an easy task, and researchers always find it challenging and problematic (Stephenson 2020; Hughey et al. 2018). The size of the small organisms, typically minute insects like aphids, micro Lepidoptera, flies and bees, ranges from 1 to 100 mm, and they need to be captured alive and taken for laboratory examinations. However, with the SPMLS device, an individual can capture the details of small-sized organisms in the field rather than collect the specimens for laboratory investigations. This method can also avoid the collection of specimens and damage to collected samples, thereby allowing live sampling of the specimens, as collecting specimens is restricted in many protected areas in different parts of the world. This device can transform approaches to studying live biological specimens in natural or agricultural habitats, thereby strengthening monitoring, conservation, and management tactics for the vast biodiversity (Suzuki-Ohno et al. 2017). On the contrary, by replacing expensive photography equipment, this device can save users a lot of money while also allowing them to capture high-resolution images and videos that can be of enormous ecological, systematic, and conservational importance (Mesaglio et al. 2023).

In the present study, we report a novel device, which is the integration of a smart phone with a clipped macro lens, to capture live biological specimens in the form of images and videos that can be of great importance in field-based biodiversity studies. In the methods section of this paper, we describe the design of the device and its cost, followed by a brief outlook of the study area. The working, applications, and novelty of this device as well as the post-photography techniques are also discussed.

Methods

Equipment used and setup of the method

The aim of this study is to introduce and demonstrate the utility of SPMLS as an affordable and portable photography solution for enhancing image quality in biodiversity documentation, making it accessible to a wide range of users. The equipment used in the study is a setup that comprises of a smart phone (Redmi Note 8 Pro) with a handheld macro lens (Skyvik Signi-20 mm). The complete device is referred to as smart phone-macro lens setup (SPMLS). In addition, the application (Snapseed), which is available at no cost on both the Google Play Store and the iPhone App Store, was used for processing the images (Table 1). The macro lens can be easily attached to the main camera of the smart phone since these lenses come with a clip that can be readily adjusted and attached to the smart phone (Fig. 1). In addition to the smart phone used in this study, the macro lens was tested on other low-cost smart phones like the Samsung Galaxy J7 Prime, the Honor 8X (Huawei), and so on. The total cost of this device was USD 217, as of April 20, 2022.

Study area

The area chosen for demonstration of the present device is the Hirpora Wildlife Sanctuary in Shopian, situated at the foothills of the Pir Panjal mountain range, Northwestern Himalayas, Kashmir, India (33° 39′28.6″ N 74° 41′ 15.2″ E). The sanctuary falls in the jurisdiction of District Shopian, which is located on the southern escarpment of the Kashmir Valley at an altitude of 2546 m (Additional file 1: Fig. 1). The area is very rich in both flora and fauna diversity. The area receives approximately 1800 mm of annual precipitation, and the average temperature ranges from 20 to 25 °C during the summer and autumn, while the minimum temperatures range between −15 °C and

Table 1 Equipment and cost involved in SPMLS method and application used in the photograph editing

S. No.	Equipment used	Specifications	Cost (USD)
	Skyvik Signi Macro Lens https://skyvik.in/collections/macro-1/products/skyvik-signi-x-20x-macro-lens	20X (25-mm)	16.07
	Redmi Note 8 Pro (Smart Phone) https://www.mi.com/in/redmi-note-8-pro/	128 GB Storage, 6 GB RAM, 64MP AI Quad rear camera with portrait, 4500 mAH lithium-polymer battery, HDR Display with 2340 × 1080 pixels' resolution and 19.5:9 aspect ratio, Android version 11	201
	Snapseed https://g.co/kgs/pHrpyv	Photograph Editing Smartphone App	Free on Google Play Store and iOS
Total cost			**217.07 USD**

Fig. 1 Equipments used in this method: **A** smartphone, **B** macro lens, **C** ready to use device (SPMLS device)

10 °C during the winter and early spring (Riyaz and Reshi 2021). Random surveys were conducted in the study area from May 2021 to October 2021 to document the insect diversity of the region as the upper Himalayas of the Kashmir valley are yet to be fully explored. In addition, agricultural habitats were also surveyed to document the insect fauna that deliver many ecosystem services like pollination; several pest species were also taken into consideration for the demonstration of this device.

Results

Field demonstration of SPMLS

The field demonstration of this device was conducted on the insect diversity of Hirpora Wildlife Sanctuary, District Shopian, Kashmir, India (33°39′ 28.6″ N 74° 41′ 15.2″ E) and its adjoining areas. This device was employed to observe, monitor, and record the insect diversity of the region by capturing live photographs and videos for documentation of the insect fauna. After capturing the photographs and videos of the insect species, the next step was to identify the species for documentation and uploading to the online data repositories. Based on the morphological characters, the identification of a biological specimen, mainly insects, can be achieved up to the genus level, and for in-depth and detailed photographs of any particular insect, there is a high chance of getting the specimens identified up to the species level using SPMLS.

Working of SPMLS

Attaching a macro lens to a smart phone is quite easy. However, it is very important to get the lens focused over the main camera of the smart phone. After clipping the lens over the main camera of the smart phone, an individual can start taking images or recording live specimens. One can notice that light is becoming a problem after getting up close to a specimen. Getting light in between the subject and the SPMLS can be difficult, as the use of a diffuser can solve this issue. The diffuser can be equipped using a piece of printer paper or tissue paper that must be positioned on the same side of the subject, which will aid in blocking rays of light to improve the details of a photograph. Working distance and magnification are two aspects that are very important in taking sharp and accurate images. In contrast, the working distance is the physical distance between the front of SPMLS (25 mm focal length) and the object. The distance between macro subjects (insects, pollen, larvae) must be very close as compared to the lenses' 50–100 mm focal length. However, working distance also depends on the actual length of a lens (physical construction) and not the focal length (Filazzola et al. 2022).

Magnification, on the other hand, deals with how big the subject is on the camera sensor versus its size in the real world. The simplest case is that, if 1:1 magnification has been set, that means the subject's size on your camera sensor is equal to its size in the real world. For macro subjects and micro characters of a specimen, 1:1, 2:1, and 5:1 magnification suit perfectly for more sharpened and detailed depth photographs (Weiss and Wyman 2022). Depending on the presence of a subject, the SPMLS device can take up to 100 images in 15 min with a focusing distance of 3–5 cm from the front of the lens attached to the smart phone. Usually, a single image can take 5–10 s for the magnification and focus adjustment and 1–2 s for capturing a live specimen. The very good magnification and focal adjustment of the SPMLS can take completely blurred background images (Fig. 2) with sharp and accurate details of a subject, including legs, mouthparts, wing venation, pollen, eggs, and so on. The properties of the images and videos captured using this device are given in Table 2.

Fig. 2 A completely blurred background of the subject (*Sympetrum fonscolombii*) captured and processed using this device

Table 2 Properties of images and videos captured or recorded by SPMLS method

1	Image save format	JPG
2	Video save format	WMV, FLV, SWF
3	Focal length	2–6 mm
4	Resolution	1080×2340^{PX}
5	Pixel density	~395 PPI
6	Minimum focusing distance	3–5 cm
7	ISO	1496
8	Exposure time	1/336
9	Aperture value	1.89

Applications of SPMLS method

Biodiversity researchers from all over the world, particularly entomologists and taxonomists, are making extensive use of the best photography equipment to detect minute organisms, allowing them to publish their findings in prestigious journals (Mesaglio et al. 2023). However, most researchers from developing and poor nations suffer a lot, since there is an unavailability of funding for buying the best photography equipment (Abu-Zidan and Rizk 2005; Akinyemi, 2013). In the present era of scientific advancement, there is everything available that can reduce the work force and financial issues. However, the equipment for photography such as mirrorless cameras, SLR (single-lens reflex camera), and DSLR (digital single-reflex digital camera) can cost researchers thousands of dollars, which most researchers across the world cannot afford.

To overcome these limitations, the SPMLS device can help in examining various aspects of biodiversity and agricultural research, viz. taxonomy, ecology, pest science, pollination, developmental, and conservation biology. With this device, an individual can record live specimens in the wild or in an agricultural field with better precision and exactitude. The setup is fully handy and comes with a clip that is fixed on the main camera of a smart phone within seconds. On the contrary, there is no need to carry power banks, USB cables, or adapters. Although the cameras built-in to today's smart phones are very powerful, they may not be as sharp and accurate as a DSLR or a mirrorless camera. However, we can still use them to create accurate and sharp images by using a macro lens, which is demonstrated in the present study.

The SPMLS device can help in detecting the sharp and accurate body details of a specimen. With this device, actual shape, body details, wing venation, body spots and marks, mouthparts, abdominal segments, head, eyes, and morphology of legs are clearly visible with precision, which can aid in the swift identification of a specimen. Specimens with the accurate detailing of the body parts that are captured using SPMLS are shown in Fig. 3 and (Additional file 2: Video 1). For agricultural researchers, the SPMLS device can help by capturing or recording the pests (larvae and adults), mostly insects that are feeding on vegetable and fruit crops. They can also record and capture insect pollinators, predators, and parasitoids that are pollinating flowers, preying on insect pests, thus attaining the live-action of pollination and predation biology among different sects of insect species (Fig. 4, Additional file 3: Video 2).

Researchers who are engaged in taxonomical investigations of the macroflora and fauna can also make use of this device. After mounting the specimens while the object is in the inactive phase, the SPMLS device can capture detailed body characteristics such as wing venations, body coloration, abdominal, head, and thorax segments, which can be used in detailed taxonomical studies and checklists of the species. In addition, the mounted specimens that are captured using the SPMLS device can achieve fast-track identifications of the species as well. Some of the mounted species captured by the SPMLS method are presented in Fig. 5.

Post-photography: image processing, editing, uploading and distributing

The next step after taking images of specimens in the forest or in an agricultural habitat is to process or edit the photographs using different applications on a smart phone. Most researchers across the globe are finding it

Fig. 3 Field demonstration of some insect species captured with the SPMLS device and processed with Snapseed applications in wild habitat **a** photograph of a Cicada (*Eopycna repanda*) revealing body details, **b** photograph of a cockchafer beetle (*Melolontha furcicuada*) showing seven leaves of antennae that only males possess and other body details in depth, **c** photograph of a male red-veined darter or nomad (*Sympetrum fonscolombii*) showing precise body details like wing venation, scales on legs, and even body hairs in-depth, **d** photograph of a skipper (*Parnara guttatus mangala*) showing detailed antennae segments and translucent spots on wings that help in easy identification of the species

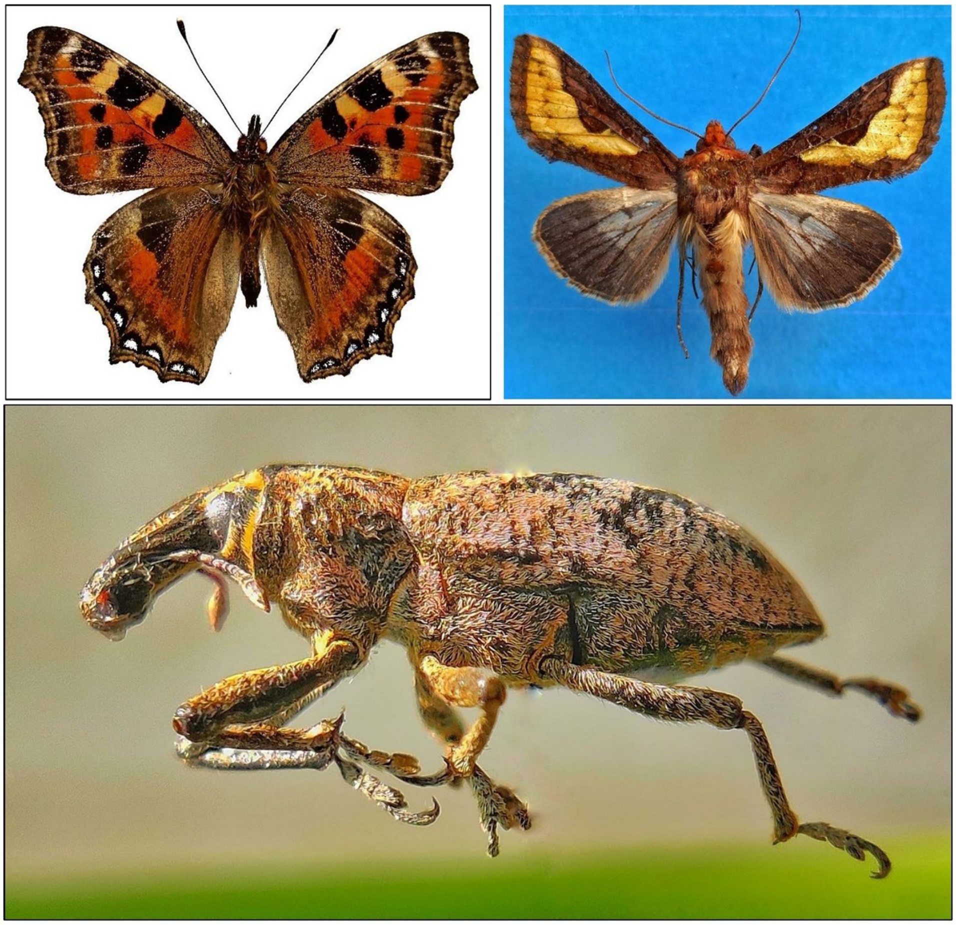
Fig. 4 Field demonstration of some insect species captured with the SPMLS device and processed with Snapseed applications in agricultural habitat **a** Photograph of hoverfly (*Syritta pipiens*) showing detailed body structure (thick legs confirming its common name thick-legged hoverfly) in-depth while foraging on a flower, **b** photograph of a hoverfly (*Eristalinus taeniops*) showing body details (band eyes confirming its common name band-eyed hoverfly, wing venation, and abdominal segments) in-depth, **c** photograph of caterpillar (fifth-stage larva) of *Pieris brassicae* showing body details (body spots, legs and hairs) in detail, **d** photograph of caterpillar (second-stage larva) of *Pieris brassicae* eating voraciously on the leaves of a vegetable crop (Marrow Stem Kale)

difficult to process or edit the images in largely packed software like Adobe Photoshop (Berthouzoz et al. 2011). However, to ease such difficulties, we have used a free mobile application for editing and processing the images taken in SPMLS. Snapseed is a mobile application, which is available at no cost on both the Google Play store and Apple iStore, and can assist in further accuracy and sharpness of images.

The application comes with a full package of editing features and can reduce the burden of using challenging photograph editing software. Most insect pests are nocturnal and act during the night hours. It is very challenging for a researcher or an individual to get an accurate photograph during the night hours. However, using this application for editing photographs can aid in creating accurate and detailed shots of every aspect of the body of an object. Some of the specifics (image tuning, selective, image details) on how to edit an image precisely using the Snapseed application are presented in Additional file 4: Fig. 2.

After capturing flawless and precise photographs of the specimens and performing any necessary editing for the underexposed images, the subsequent crucial phase involves publishing these photographs. Valuable input from experts and pertinent literature can greatly aid in the identification of each specimen. Simultaneously, researchers or passionate individuals with an interest in the subject can share these images on various online data

(a)



(b)

(c)

Fig. 5 Photographs of some mounted specimens captured using the SPMLS device and edited using Snapseed application **a** *Aglais caschmirensis caschmirensis*, **b** *Thysanoplusia orichalcea*, **c** *Cleonis pigra* showing accurate body details for easy identification and publication

repositories dedicated to monitoring biodiversity worldwide (Suprayitno et al. 2017). Conversely, photography enthusiasts can also capitalize on these photographs by selling them through various online platforms. In the present era, many individuals are earning substantial incomes by sharing their photographs, videos, and short reels on diverse social media platforms such as Facebook, Instagram, TikTok, YouTube, and others. Table 3 provides a comprehensive list of online data repositories, social media platforms, marketing channels, distribution channels, and upload sites available for this purpose.

Miscellaneous applications embedded in the smart phones used in field-based biodiversity studies

Apart from studying live specimens through photography and videography, smart phones can be used for a variety of other purposes in field-based biodiversity studies (Teacher 2013). The integrated GPS and map functionalities of smartphones enable users to record real-time locations and coordinates, facilitating the provision of specimen capture locations for future research purposes. Likewise, freely accessible altimeter applications on smartphones can track the altitude of specific locations during live species sampling activities (Luna et al. 2018). Besides navigation, coordinates, and maps of a particular area, a number of applications embedded in smart phones can be helpful during field surveys. Some of the important aspects to be noted down during field surveys are abiotic factors such as temperature, humidity, wind, and precipitation that help researchers to analyze the ecological aspects of many species that can be measured using smart phone applications. With the advent of artificial intelligence (AI), a number of smart phone applications are used for the preliminary identification of macrofauna and flora. These applications will use artificial intelligence to try to match it with one of the over a thousand species catalogued in them. Users can also share photographs with each other for second opinions

Table 3 A list of online data depositories and standard uploading sites for citizen scientists, researchers, and photographers

S. No.	Popular photograph uploading online data depositories for researchers and citizen scientists	Range	Publicizing/sharing/selling/posting/stocking online standard websites and social media handles	Range
1	inaturalist https://www.inaturalist.org/	Global	Flicker https://www.flickr.com/photos/tags/flicker/	Global
2	GBIF https://www.gbif.org/	–	500px https://500px.com/	–
3	India Biodiversity Portal https://indiabiodiversity.org/	India	Facebook https://www.facebook.com/	–
4	Vanessa Migration Project https://vanessa.ent.iastate.edu/2021-vanessa-migration-project-vanessa-butterfly-biogeography-study	Global	Instagram https://www.instagram.com/	–
5	Pieris Project https://www.pierisproject.org/	–	Google photos https://www.google.com/photos/about/	–
6	Biodiversity Heritage Library | Flickr https://www.flickr.com/people/biodivlibrary/	–	Getty images https://www.gettyimages.com/	–
7	Wikispecies https://species.wikimedia.org/wiki/Main_Page	–	Shutterstock http://www.shutterstock.com/	–
8	Anecdata https://www.anecdata.org/	–	istock https://www.istockphoto.com/	–
9	Operation Wallacea https://www.opwall.com/	–	123f https://www.123rf.com/	
10	Ontario Butterfly Atlas Online https://www.ontarioinsects.org/atlas/	Canada	Alamy http://www.alamy.com/	
11	NatureWatch NZ http://naturewatch.org.nz/	New Zealand	Adobe Stock https://stock.adobe.com/	
12	Natusfera https://natusfera.gbif.es/	Europe	Etsy https://www.etsy.com/in-en/	
13	Odonata Central https://www.odonatacentral.org/	North America	Fotomoto https://www.fotomoto.com/	
14	National Moth Week (NMW) http://nationalmothweek.org/	Global	Crestock http://www.crestock.com/	
15	Instant Wild https://instantwild.zsl.org/	–	Snapped4u https://snapped4u.com/	
16	Kelab Alami https://kelabalami.weebly.com/	Malaysia	PhotoShelter https://www.photoshelter.com/	
17	Taxon expeditions https://taxonexpeditions.com/	Borneo, Montenegro	TourPhotos https://tourphotos.com/	
18	Wildlife Spotter https://scistarter.org/wildlife-spotter	Australia	Dreamstime https://www.dreamstime.com/	
19	Monarch Watch https://monarchwatch.org/	Canada, USA	CanStock Photo http://www.canstock.photo/	
20	BioNote https://www.climate-kic.org/start-ups/bionote/	Global	Canva http://www.canva.com/	

on what type of insect or specimen is pictured. Some of the applications used for field surveys and specimen identification purposes are listed in Table 4.

Discussion

Throughout history, humanity has relied on the richness of biodiversity, making use of its various components. Even in this age of remarkable scientific and technological progress, humans still heavily depend on the vast array of resources offered by biodiversity for their own sustenance. Our planet's biodiversity has generously provided us with its resources without cost for countless generations (Folke et al. 2021). However, over the past five decades, human activities have caused significant damage to biodiversity, leading to a sharp decline in its existence. Human actions such as overexploitation of resources have posed a severe threat to precious wildlife worldwide. Biodiversity plays a crucial role in our environment, where different species are interconnected. Sadly, this essential biodiversity is rapidly decreasing,

Table 4 Miscellaneous smartphone applications used in field-based biodiversity studies

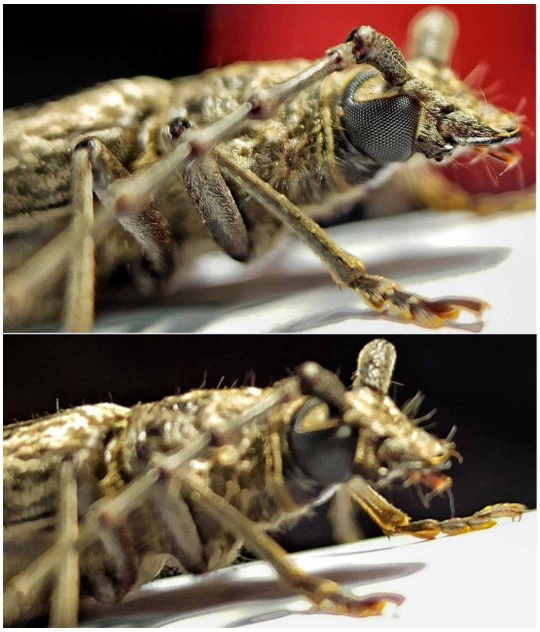
S. No.	Application	Supported Software		Functions
		Android	IOS	
1	Navigation (Google Maps)	https://play.google.com/store/apps/details?id=com.rdh.mulligan.myelevation	https://apps.apple.com/us/app/google-maps/id585027354	Navigation, real-time updates on traffic jams, accidents, road closures and speed traps
2	GPS (Coordinates) (Google Earth)	https://play.google.com/store/apps/details?id=com.google.earth&hl=en_IN&gl=US	https://apps.apple.com/us/app/google-earth/id293622097	Satellite image visualizing and analyzing, coordinate tracker and recorder
3	Altimeter	https://play.google.com/store/apps/details?id=com.rdh.mulligan.myelevation	https://apps.apple.com/us/app/travel-altimeter-elevation/id486556174	Altitude measurement
4	Weather	https://play.google.com/store/apps/details?id=com.weather.forecast.weatherchannel	https://apps.apple.com/us/app/weather/id1069513131	Recording temperature, precipitation, wind, humidity, etc.
5	Notes	https://play.google.com/store/apps/details?id=com.evernote	https://apps.apple.com/us/app/notes/id1110145109	Typing field notes on smartphones
6	Specimen identification (inaturalist seek)	https://play.google.com/store/apps/details?id=org.inaturalist.seek	https://apps.apple.com/us/app/seek-by-inaturalist/id1353224144	Identifies biological specimens through AI (Ideal for plants, insects and mushrooms)
6	Insect identification applications	https://app.adjust.com/obc1lwq	https://apps.apple.com/us/app/picture-insect-bug-identifier/id1461694973	Ideal for insect identification uses AI
7	Plant Identification applications	https://play.google.com/store/apps/details?id=org.plantnet	https://apps.apple.com/us/app/plantsnap-identify-plants/id1451054346	Ideal for plant identification uses AI
8	Mushroom Identification applications	https://play.google.com/store/apps/details?id=com.picturemushroom.mushroom.identifier	https://apps.apple.com/us/app/mushroom-identificator/id1227854971	Mushroom identification uses AI

resulting in the visible and devastating impact of many plant and animal species going extinct (Marske et al. 2023).

Biodiversity and conservation research are among the most pondered subjects in the present era of technological and scientific advancements. Both developed and developing countries are utilizing all available resources to monitor and conserve their fauna and flora wealth (Maxwell 2020). As the world is witnessing growing populations, urbanization, industrialization, deforestation, forest fires, rising global temperatures, and pesticide toxicity, there has been a decline in both fauna and flora communities across the globe that have not been taken into consideration in full swing (Glidden et al. 2021; Uhl and Brühl 2019; Morelli et al. 2020). The highest observed decline in different life forms is observed among insect populations across the globe and has already prompted an alarm for mass management and conservation of insect species threatened by human activities and climate change (Sánchez-Bayo and Wyckhuys 2019, 2021; Simmons et al. 2019). Insects are one of the most fascinating groups of animals that evolved in the Devonian period, some 300 million years ago. Because of their symmetrical body shapes, varying sizes, flight adaptability, and ability to withstand any environmental condition, they became the most dominant group of organisms ever seen on Earth. Insects deliver a number of ecosystem services, and most importantly, they pollinate around 80% of the world's flowering plants. The conservation and management of biodiversity is the need of the hour (Crespo-Pérez et al. 2020; Lambert and Donihue 2020; Riyaz et al. 2022). Throughout the world, various entities such as governmental and non-governmental organizations, research institutions, colleges, and universities are actively collaborating and utilizing diverse approaches to collectively contribute to the monitoring and conservation of biodiversity (Hoban et al. 2022; Khan et al. 2022). A collective effort of scientists, researchers, and the public that can serve as natural volunteers can solve a number of environmental issues. On the contrary, citizen science (CS) is a joint initiative between professional researchers, scientists, and CS volunteers, including hobbyists, wildlife photographers, and the general public (Day et al. 2022). The aim of this initiative is to monitor biodiversity across the globe and to spread knowledge among citizen science volunteers. Across the globe, most citizen science projects are active in North America, Europe, South America, India, and Australia (Battisti and Cerfolli 2021).

Field-based biodiversity studies, particularly the examination and analysis of live specimens, can be useful in robust sampling, thus sidestepping the sample collections of threatened or vulnerable macroorganisms. The use of photography in field-based biodiversity studies avoids bulk sampling and wastage of collected specimens by monitoring the detailed aspects of the live specimens. Rather et al. (2019) reported the use of smart phone-integrated field microscopy while working on the biology of *Ephedra intermedia* as the subject. The method involved the integration of a smart phone, a field microscope, OTG cable, power bank, and a charger cable with a cost of $656.25 USD. Studying specimens in the wild or in a field requires hefty and costly photographic and field-based equipment (Bricelj, 2018; Hämmerle and Höfle 2018).

Some modern smartphones come equipped with built-in macro cameras. However, it is important to note that the study primarily focuses on enhancing the photography capabilities of more budget-friendly smartphones. The novelty of the SPMLS lies in its cost-effectiveness and portability, making high-quality macro photography accessible to a broader audience who may not be inclined to invest in expensive standalone cameras. By utilizing the SPMLS, we aim to bridge the gap and empower amateur taxonomists, biodiversity researchers, and citizen enthusiasts with an affordable tool for documenting and studying macroorganisms, contributing to the democratization of biodiversity research and conservation efforts. The present study demonstrates that SPMLS resolves and overcomes many of the limitations commonly associated with field-based biodiversity studies that are designed to monitor the macrofauna and flora. The SPMLS device allows users to avoid purchasing and carrying (a) huge lenses, (b) camera bodies, (c) batteries and power banks, (d) chargers and cables for field-based biodiversity studies. To the best of our knowledge, the attached macro lenses are by far the most handheld, portable, and low-cost photography equipment to examine live biological specimens compared to the tools mentioned above. The limitations of the SPMLS are a consequence of the choices. First, the macro lenses, in some cases, block the flashlight of a smart phone. Therefore, for night photography or videography of the specimens, particularly the nocturnal organisms like moths, an alternative flashlight or headlight is needed, which is always available during the night surveys of organisms. Second, the quality of the images also depends on the camera of a smart phone. The average smart phone camera has more or less 12 MP. However, some smart phones have upwards of 20–60 MP, which gives more sharpness and accuracy while having the macro lens attached compared to high-end cameras. However, we recommend using a macro lens while capturing macro subjects since, without one, the details of their physical features will not be distinct and accurate (Fig. 6).



(a)

(b)

Fig. 6 A comparison of photographs of *Tirrachys holosericeus* taken with and without a macro lens **a** using the SPMLS device, **b** without the SPMLS device

Finally, SPMLS is designed to overcome the limitations of field-based biodiversity studies and serves as a better alternative to high-cost photography gear to study live macro subjects. Wide ranges of macro lenses (20–50 mm) with more or less 20–50 mm are available at a low cost and are easy to use for precise and in-depth photography of macro subjects. Users of SPMLS can capture high-quality pictures of macro subjects ranging in size from 2.5 mm (head louse) to 100 mm (dragonfly), thereby overcoming the limitations of monitoring and studying the minute characteristics of macro diversity of fauna as well as flora (Fig. 7).

Conclusions

Biodiversity represents the complete array of life forms within an environment, encompassing everything from backyards to deserts. Our planet's total biodiversity is vast, with countless species yet to be discovered. This intricate web of life plays a crucial role in maintaining the delicate balance of ecosystems. Interestingly, humans stand out as the primary consumers of resources derived from our incredibly biodiverse planet. Unfortunately, factors such as habitat fragmentation, industrialization, urbanization, and the rapid expansion of the human population have significantly impacted the environment, leading to the direct extinction of numerous animal and plant species. To prevent the vulnerability, endangerment, and extinction of thousands of species, immediate attention must be given to implementing effective management and conservation strategies. In this regard, engaging the public, including volunteers, in environmental assessments, and having researchers assist in biological monitoring and conservation becomes imperative. A collaborative effort is necessary to upload casual species observations into online data depositories, contributing to a more comprehensive understanding of biodiversity.

The SPMLS device, as introduced in this study, offers a valuable tool for researchers, scientists, students, citizen enthusiasts, and the general public involved in monitoring and conserving animal and plant species worldwide. This innovative device is specifically designed to aid those who wish to contribute to biodiversity conservation and monitoring but lack access to expensive photography equipment. Its user-friendly features make it accessible to a broad spectrum of individuals, thereby encouraging wider participation in preserving our planet's precious biodiversity. The distinctive feature of the SPMLS lies in its cost-effectiveness and portability, opening the door to a broader

(a) (b)

Fig. 7 A comparison of the subjects across different sizes (body length) ranging from **a** 2 mm (Human head louse) to **b** 45 mm (A dragonfly) captured in SPMLS device audience, even those who are reluctant to invest in more expensive standalone cameras, allowing them to partake in high-quality macro photography. Our utilization of the SPMLS effectively can reduce barriers and offer an affordable tool for amateur taxonomists, biodiversity researchers, and citizen enthusiasts to document and explore macroorganisms, thus contributing to the democratization of biodiversity research and conservation initiatives.

Abbreviations

SPMLS	Smart phone-macro lens-based setup
GPS	Global positioning system
AI	Artificial intelligence
EXIF	Exchangeable image file format
JPG or JPEG	Joint Photographic Expert Group
SLR	Single-lens reflex camera
DSLR	Digital single-reflex digital camera
MP	Megapixels
USB	Universal serial bus
OTG	On the go

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42269-023-01120-y.

Additional file 1: Fig. 1. Location of the field-based demonstration area of this device (Hirpora Wildlife Sanctuary, Shopian Kashmir, India).

Additional file 2: Video 1. Showing a dragonfly basking in the sun to generate heat before taking flight.

Additional file 3: Video 2. Showing a honeybee foraging around to collect nectar and pollinating flowers.

Additional file 4: Fig. 2. Essentials of the editing and processing of the photos captured using the SPMLS device on the Snapseed application.

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Author contributions

MR conceptualized the study, executed field surveys, performed the experiment, curated the data, conducted the investigation, applied and operated the equipment, edited the manuscript, validated the results, and prepared the original draft of the writing. SI edited and reviewed the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate

Not Applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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