frontiers in Marine Science

TYPE Hypothesis and Theory
PUBLISHED 26 August 2026
DOI 10.3389/fmars.2026.1918530

OPEN ACCESS

EDITED BY
Seyyed Morteza Hoseini,
Iranian Fisheries Science Research Institute (IFSRI), Iran

REVIEWED BY
Hao Tian,
Ocean University of China, China
G. M. Kabir,
Department of Fisheries, Bangladesh
Mohammadreza Mirzaei,
Anton Dohrn Zoological Station Naples, Italy

*CORRESPONDENCE
Dhanya M. Lal
dhanya.ml@incois.gov.in

RECEIVED 24 June 2026
REVISED 10 August 2026
ACCEPTED 13 August 2026
PUBLISHED 26 August 2026

CITATION
Lal DM, Karthik TNC, Jha S, Sathish C, Raulo S, Premkumar R, Baliarsingh SK, Samanta A, Joseph S and Nair TMB (2026) Development and deployment of a pilot multilingual citizen- science mobile application for georeferenced marine catch observations in India. *Front. Mar. Sci.* 13:1918530. doi: 10.3389/fmars.2026.1918530

Development and deployment of a pilot multilingual citizen-science mobile application for georeferenced marine catch observations in India

Dhanya M. Lal*, T.N.C. Karthik, Sneha Jha, Chennuri Sathish, Susmita Raulo, R. Premkumar, Sanjiba Kumar Baliarsingh, Alakes Samanta, Sudheer Joseph and T.M. Balakrishnan Nair

Indian National Centre for Ocean Information Services, Ministry of Earth Sciences, Government of India, Hyderabad, India

Marine fishery advisory services represent a translation of satellite-derived scientific information into actionable guidance for marine fishing communities in India, enabling fishers to locate potential fishing grounds more efficiently and reduce search time. To transform the advisories into forecasts and develop species-specific predictions of fishery grounds, high-quality and high-frequency georeferenced fish catch data over a large spatial scale is essential. To enhance data collection, INCOIS has developed a citizen science approach using a user-friendly Android App named 'Fisheries Information Source Hub (FISH)', enabling widespread citizen participation, mainly by the fishers using their mobile phones. This initiative simplifies data gathering and supports the long-term goal of reliable, species-specific fishery predictions. The data collected through the FISH App is transmitted to a central processing facility at INCOIS and undergoes necessary quality control before further analysis. This study introduces the FISH App, which has demonstrated encouraging outcomes during its initial deployment, with nearly a thousand installations and a 20-fold increase in data submissions between the first two years of implementation. The initiative holds significant potential for future development into a citizen science-based information hub, facilitating broader stakeholder participation and data-driven fisheries management.

KEYWORDS
citizen science, fishery, fishery advisories, potential fishing zone, remote sensing

1 Introduction

The fisheries sector plays a vital role in India's socio-economic development. It is recognized as a significant source of income and employment, stimulating the growth of various subsidiary industries. Especially, the marine fisheries sector provides affordable and nutritious food, serves as a foreign exchange earner, and, most importantly, supports the livelihoods of a large section of nearly 3.8 million coastal population (Sathianandan et al., 2021).

With its extensive coastline of over 11,000 km and an Exclusive Economic Zone (EEZ) of two million square kilometers, India offers vast opportunities for marine fisheries. However, the sector is predominantly confined to inshore waters, relying on a complex multi-species multi-fleet fishery consisting of artisanal, motorized, and mechanized fishing vessels (Ayyappan and Krishnan, 2004). It is estimated that about 90% of the catch comes from the depth zone up to 50 m, indicating over-utilization near the coasts and under-explored deep-sea resources (Najmudeen, 2023). The non-mechanized sector (artisanal and motorized together) comprises approximately 74% of the fishing fleet (Najmudeen, 2023), but contributes only about 24% of the annual fish landings. In contrast, the mechanized sector, representing nearly 26% of the fleet, accounts for over 76% of the total catch (CMFRI, 2025), highlighting a substantial inter-sectoral income disparity across different fishing sectors.

Sustainable fisheries for the future require targeted and accountable operations not only in coastal areas but also in deeper, relatively underexplored waters. Addressing the disparity in reduced catch per unit effort (CPUE) among motorized and small-scale sectors is essential, and this can be improved by diversifying fleet structures and leveraging scientific knowledge of fish abundance for practical use by fishers. Accurate and timely fishery predictions, including species-specific forecasts, can significantly enhance the economic viability of fisheries. Understanding resource potential and abundance aids sustainable resource management through appropriate input/output control measures. Resolving CPUE disparities between mechanized, motorized, and small-scale sectors can also foster trust between fishers and fishery managers, contributing to sustainable ecosystems and economically balanced communities- the fundamental aim of a sustainable blue economy. However, these efforts depend on reliable fishery data, achievable only through a participatory approach in close collaboration with the ultimate stakeholders, the fishers.

The Potential Fishing Zone (PFZ) advisories generated and disseminated by the Indian National Centre for Ocean Information Services (INCOIS) provide daily information on probable fishing locations across the Indian EEZ based on satellite-derived oceanographic variables (Solanlki et al., 2001). The service has demonstrably reduced fish search time and improved catch per unit effort. However, advancing these advisories towards species-specific fishing ground forecasts requires continuous, large-scale, georeferenced fish catch observations and direct feedback from fishers on actual catch locations, which are largely absent in conventional fisheries data collection systems. To address this gap, INCOIS has adopted a citizen science approach by developing a user-friendly multilingual Android application that enables fishers to contribute standardized georeferenced catch observations directly from the field.

Against this background, the present study presents the context, development and deployment of a multilingual citizen science application for collecting georeferenced marine catch observations in India. Specifically, the study seeks to: (i) establish the conceptual framework and system architecture for participatory fishery data collection to support the improvement of fishery advisory services, (ii) design and implement a multilingual mobile application along with a standardized data management workflow, and (iii) evaluate its initial deployment through direct engagement with fishers and assess its potential to support fisheries advisory, forecasting, and management systems.

2 Fishery data: need and applications

Fishery data can vary significantly depending on its purpose, use, and the expected scientific outcomes. The most commonly collected fisheries data includes landing center data, which is gathered from landing centers and provides a comprehensive account of total fisheries landings. This information is crucial for estimating the overall performance of the fishery sector at regional, sub-regional, state, and national levels, as well as for analyzing fishery trends over extended temporal scales. Species-wise and group-wise landings further provide a detailed picture of the composition of fish landings. These data are critical as inputs for stock assessment models, which evaluate the exploitation status of fish stocks and recommend sustainable harvest limits for different species and regions. When integrated with biological information, such as length-weight relationships, maturity stages, and diet composition, fishery data support the development of advanced analytical models. These models improve the understanding of stock-recruitment relationships, trophic linkages, and yield predictions, thereby providing a stronger scientific basis for sustainable fisheries management.

In India, marine fishery data collection is primarily undertaken by the Fisheries Departments of State Governments/Union Territories (UTs) and the Central Marine Fisheries Research Institute (CMFRI). This is achieved through a stratified multi-stage random sampling technique (Srinath et al., 2005; Mukesh et al., 2019). Additionally, the Fishery Survey of India (FSI) conducts sea-based exploratory surveys to assess the fishery resources in the Indian EEZ. However, collecting fishery data poses significant challenges, especially when focusing on deeper scientific insights, such as species-specific habitat suitability for predictive modeling. A significant hurdle is the need for frequent and continuous field observations, including geotagged catch data. Fish landing data, provides only quantitative estimates of catches without specifying the exact capture locations, while geotagged catch data records precise latitude and longitude information of capture sites.

Although researchers are developing participatory approaches to collect geotagged data, such as engaging with fishers during cruises or recording capture site locations from fishers when fish are landed at harbors, manual data collection remains challenging. This approach is labor-intensive, often restricted to accessible regions, and requires significant manpower, leading to inefficiencies and time constraints for researchers conducting harbor visits.

The Global Fishing Watch Program (https://globalfishingwatch.org/) is an innovative platform that leverages vessel GPS, satellite imagery, data analytics, and machine learning to deliver a dynamic picture of human activities at sea. It tracks industrial fishing vessels, small-scale fishing boats, and non-fishing vessels, applying customized algorithms to estimate fishing effort in real-time. The platform enables comprehensive monitoring and mapping of commercial activities at sea, enhancing transparency and sustainability in global fisheries. Although such approaches are promising, at present, they cannot capture information on the type and species of the catch from the field, which is the ultimate requirement of habitat suitability models. On the other hand, nighttime satellite remote sensing has emerged as a valuable tool for monitoring fishing activities and assessing the spatial and temporal dynamics of offshore fisheries (Tian et al., 2022a; 2022b). Recent studies have demonstrated the potential of satellite-derived nighttime light data, in combination with environmental variables and vessel information, for refined monitoring of fishing effort, resource assessment, and fisheries management (Tian et al., 2024). Such integrated approaches, combining satellite observations, Automatic Identification System (AIS) data, and environmental proxies, provide promising opportunities for species-specific habitat characterization and fisheries resource assessment.

In Europe and the United States, real-time catch reporting systems exist, and electronic monitoring and advanced technology are used to report the type and quantity of fish caught from the field (Marshall et al., 2017; Helmond et al., 2020). In the United States, NOAA Fisheries utilizes electronic reporting to gather data directly from commercial fishing fleets, enhancing the speed and precision of data collection. The European Union mandates electronic logbooks for vessels exceeding 15 meters long, requiring captains to record and submit their fishing operations data to national authorities. However, the adoption of similar strategies in India faces challenges. The vastness of the Indian fishery sector, with over 2 lakh fishing vessels with considerable diversity across the coastline poses significant challenges to the effective implementation of mandatory automated data reporting systems. These challenges are further amplified by the predominance of motorized and artisanal vessels, which together account for approximately 74% of the national fishing fleet (ReALCRaft portal, Govt. of India-https://realcraft.gov.in/).

In this scenario, citizen science-based approaches, that engage stakeholders with regular access to the marine environment and a willingness to contribute observations offer an effective framework for collecting fisheries-related data. When carefully designed and thoughtfully implemented, citizen science can serve as a valuable collaborative method for addressing critical data gaps in fisheries, environmental science, and management (Bonney et al., 2021; Song et al., 2025). Further, considering the vast potential of multisource fishery observation frameworks in the present era, citizen science approaches can complement satellite-based monitoring systems by providing georeferenced field observations of fish species occurrence, thereby bridging the gap between remotely sensed environmental information and *in situ* biological observations. The integration of such occurrence records with satellite-derived oceanographic variables has significant potential to improve habitat suitability modelling, validate fishery advisories, and support the development of species-specific fisheries advisory services.

3 Fishery advisory services and research

The INCOIS provides fishery advisory services to society, particularly fishers, through daily PFZ advisories. These advisories identify oceanic areas with a high probability of fish aggregation based on satellite observations of Sea Surface Temperature (SST) and chlorophyll-*a* concentration (Solanki et al., 2005). Disseminated through various communication channels, these advisories provide fishers with timely and actionable information about fish abundance. INCOIS has established strong collaborations with partners, including NGOs, research and academic institutions, and industries, particularly in coastal states, to ensure these services reach grassroots communities. These efforts enable society to benefit from the technical expertise derived from scientific research. The PFZ advisories are validated through *in situ* sampling and field trials, which consistently demonstrate higher catch rates and CPUE in designated PFZ areas compared to non-designated areas (Solanlki et al., 2001; Dwivedi et al., 2005; Pillai and Nair, 2010; George et al., 2013).

As part of its commitment to advancing fisheries prediction, INCOIS has also developed species-specific advisory services for commercially important species such as tuna, utilizing habitat suitability studies, satellite telemetry, and tagging experiments in collaboration with institutions like CMFRI & FSI (Nimit et al., 2020). This multi-institutional collaboration has resulted in a tuna fishery advisory, which is currently operational, benefiting thousands of fishers engaged in tuna fishing.

Ongoing research at INCOIS aims to achieve long-term goals, including developing species-specific prediction models for other commercially important marine species. The success of such models depends on the quality and quantity of *in situ* observations, particularly georeferenced fish catch data. By leveraging this data, scientists can identify the environmental parameters that influence the occurrence and abundance of target species, enabling the development of accurate and reliable prediction models. The accuracy of these models improves as the volume of observations increases (Tommasi et al., 2017). Ultimately, the end-users of these innovative products will be fishers who can utilize such advisories to effectively plan and execute targeted fishing operations with a higher degree of certainty.

4 The citizen science-based fishery data collection model

Recognizing the importance of georeferenced data collection in enhancing fishery predictions, INCOIS has developed and implemented a citizen science approach for fishery data collection with active participation from fishers. The basic workflow of this approach is illustrated in Figure 1.

4.1 Component 1: the FISH app

The data collection system's primary component and tool is an Android-based app named 'Fisheries Information Source Hub (FISH)', which can be installed on the fisher's mobiles.

The App is designed primarily to enhance *in situ* data collection, specifically focusing on georeferenced catch information from the field. The initial prototype included features for embedding images of catches alongside textual data detailing the quantity and

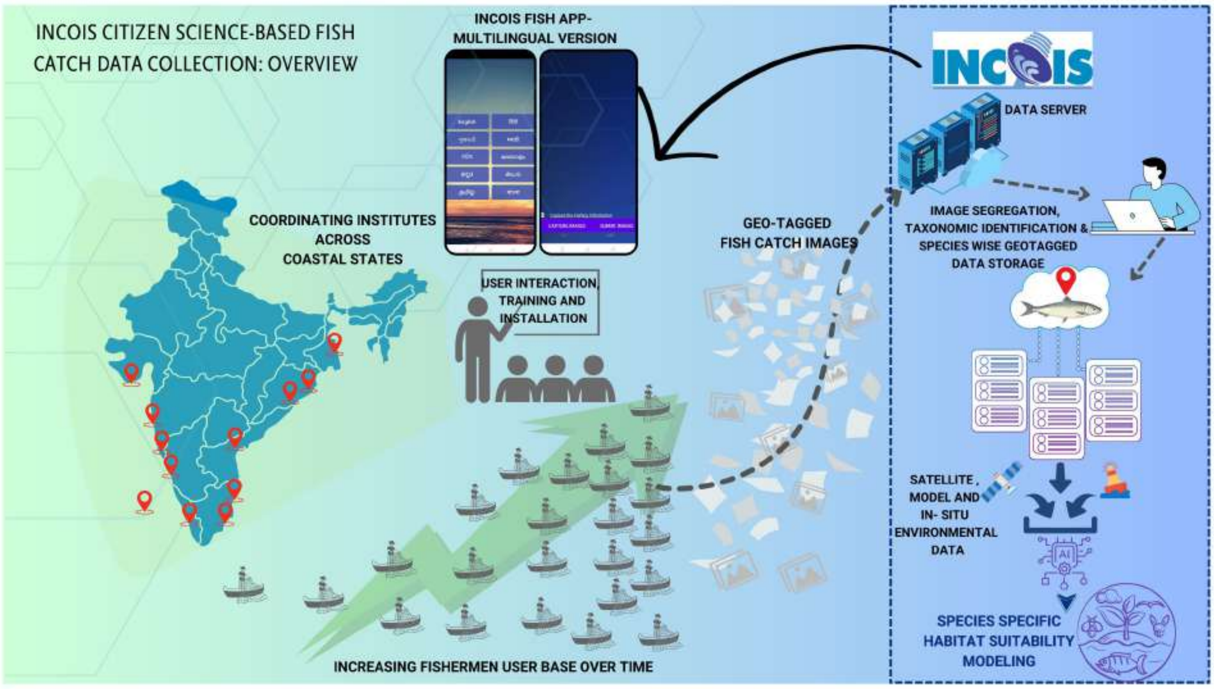

FIGURE 1
Overview of INCOIS citizen science-based fishery data collection approach.

variety (type of species) of the catch. However, consultations with experts as well as users nationwide highlighted the need to simplify the App in the initial stage. Based on this feedback, the App was streamlined to include only the image submission feature with automatic geotagging. This simplification ensured easier adoption by fishers, as overly complex processes might discourage them from using the App. Fishers, who are engaged in one of the riskiest occupations globally, require intuitive and efficient tools to be used in the field. It was also noted that the detailed data collection systems used in other regions are not directly applicable to the Indian context due to the country's vast and small-scale nature of fisheries. Such systems are more suited for scientists, researchers, exploratory vessels, and industrial fishing fleets, which are relatively limited in number in India. Thus, a simpler version of the App was prioritized during the initial implementation phase to maximize data collection and ensure widespread adoption among fishers. This approach balances the need for effective data collection with the practical realities of engaging a large number of small-scale fishers. The App has been developed in multiple Indian languages to ensure its easy accessibility and usability for fishers across the country.

The FISH App is developed on a native Android technology stack using Java and the standard Android software development kit, and the version reported here is v1.0. The interface is fully localized and currently supports English and Hindi together with Gujarati, Marathi, Kannada, Malayalam, Tamil, Telugu, Odia, and Bengali, covering the principal languages spoken along the Indian coastline so that fishers can operate the App in their own language. The App is designed with several key modules to facilitate field information collection. The Registration module allows users to fill out a form with demographic details such as state, district, landing center, and boat information. The Image Gallery displays images captured by the user and their submission status to the server. In the Capture Images module, users can take photos using the device camera, with geolocation data automatically embedded into the images. The App includes an Image Status Database, typically implemented as an SQLite database on the device, to store the submission status of captured images. Finally, using a REST API framework, the Submit Images module enables users to transfer images to the server. Upon submission, the image status is updated in the database and reflected in the gallery based on the server's response. The Fish App Architecture and flow diagram are provided in Figure 2.

Because fishers frequently operate beyond the range of mobile networks, the App is designed to function offline. Images can be captured without connectivity; at the moment of capture the App reads the current position from the device Global Navigation Satellite System (GNSS) receiver, annotates the image with this location information, and writes it to a dedicated directory on the internal storage of the device. The positional accuracy is therefore that of the consumer-grade GNSS receiver of the handset, typically of the order of a few meters to a few tens of meters under open-sky conditions at sea, and coarser when the device is used inside a cabin or under obstruction. Images that have not yet been transmitted are retained on the device and are clearly flagged as unsent in the image gallery module, so that no observation is lost while the device is offline. When the device comes online, the user can initiate the upload by pressing the send button, and the pending images are then transmitted to a Java-based REST API endpoint hosted on a dedicated server at INCOIS. The georeferenced images are held in restricted-access storage on this server, available to the project team for further analysis and processing.

All communication between the App and the server takes place over HTTPS, so that images and the associated location information

10.3389/fmars.2026.1918530

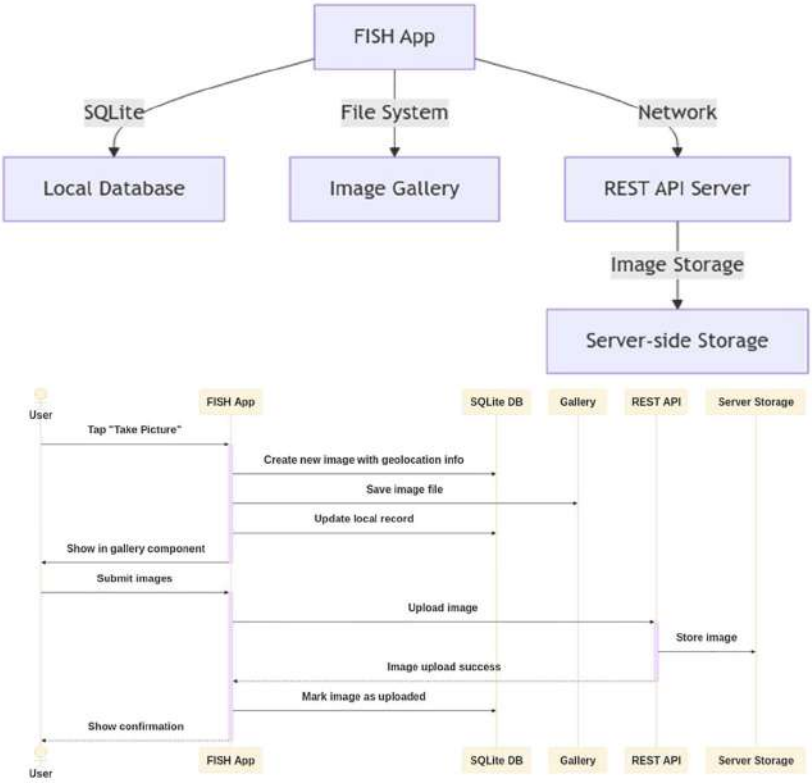

FIGURE 2
FISH app architecture and flow diagram.

are encrypted in transit using SSL/TLS, and access to the raw submissions and geolocation data on the server is restricted to the INCOIS project team. Marking an image as submitted only after the server acknowledges its receipt prevents repeated transmission of the same image, while duplicate submissions and records sharing identical timestamp and coordinate combinations are also identified and removed during the quality-control stage described in Section 4.3.

As the FISH App is currently a research tool rather than a consumer product, it has not been released through any app store and is not presently intended for open public distribution. It is installed directly on the devices of informed participants during the training workshops and one-to-one demonstrations as described in Section 4.2, where the purpose of the initiative and the intended use of the contributed data are explained. Participants are invited to contribute on the understanding that their contributed images feed into the improvement of advisories described in Section 3, whose eventual beneficiaries are fishers themselves. This controlled mode of deployment keeps the participant base known to the project team, enables direct feedback from active users, and limits the circulation of the application and the data it generates. Consistent with this scope, the present version relies on a one-time registration completed when the App is first launched, in which the user selects the interface language and provides few demographic details noted earlier; these are retained on the device and reused for subsequent submissions until the App is uninstalled or its stored data are cleared, rather than a password- or token-based authentication. Widening the participant base would be subject to a policy decision of INCOIS and would be accompanied by stronger user authentication, encryption of data at rest, formal versioning and release management, and the optional quantitative reporting features discussed in Section 6.

4.2 Component 2: dissemination of the app through training and workshops

INCOIS, in collaboration with partner institutes, has actively conducted user interaction workshops to demonstrate and install the FISH app on fishers' Android devices. To facilitate better understanding, specialized multilingual leaflets were developed and distributed among fishers in selected coastal villages across India (Supplementary Figure 1).

The user engagement strategy combines group interactions, such as workshops, and individual contact methods, including one-to-one demonstrations and installations. INCOIS representatives also participated in fishing cruises, where they provided onboard demonstrations of the App for data collection. One of the key challenges faced by our team in the field was convincing fishers, who frequently questioned how using the App would benefit them. Despite this, our team made concerted efforts to explain the process, highlighting the App's role in improving future fisheries predictions and emphasizing the critical importance of their participation in the successful implementation of this initiative. These collective efforts have successfully installed the App on over 1000 fishers' mobile devices during the initial phase of implementation.

4.3 Component 3: data retrieval, decoding, and database development

The data in the form of images is received on a dedicated server at INCOIS, which has consistently increased submissions, with over 1000 georeferenced images collected during the first two years of pilot implementation. User interaction efforts are ongoing to expand the App's user base by installing it on more fishers' mobile devices nationwide, enhancing data collection. Upon receipt, all image submissions undergo a quality-control procedure in which test images, duplicate submissions, non-fish photographs, and other non-informative records are removed. The remaining geotagged images are retained as georeferenced catch photographs, with the associated GPS coordinates representing the location where the photograph was captured. Considering the issues of incorrect reporting of location, as fishers may capture photographs after moving away from the actual catch locations, each submission is carefully evaluated based on the nature and context of the photograph. Images depicting freshly caught fish immediately after capture are preferentially retained, whereas photographs taken after sorting, segregation, transport, or landing are excluded, as they are more likely to represent locations other than the actual catch site. Furthermore, continuous user training and direct communications with active users emphasize the importance of capturing photographs at the fishing location, thereby progressively improving the spatial accuracy and overall quality of the submitted georeferenced catch photographs over time. Representative examples of geotagged catch photographs received through the FISH App are shown in Figure 3. Subsequently, two independent fish taxonomy experts examine each georeferenced catch photograph to identify the catch to the lowest possible taxonomic level, preferably to species, or otherwise to the genus or family level depending on image quality and the visibility of diagnostic morphological characters. The independent identifications are compared, and any discrepancies are resolved through mutual discussion and consensus before finalizing the taxonomic assignment. For mixed catches, all visually distinguishable taxa are identified to the lowest possible taxonomic level. As the FISH App is currently in its pilot phase, the data collection is limited to documenting species' occurrence through photographic evidence, avoiding more complex reporting requirements that could reduce user participation.

The validated records are then compiled into a georeferenced fish catch photograph database, which provides a valuable resource for species occurrence analyses and habitat suitability studies, while acknowledging the inherent uncertainty that the recorded coordinates may not always correspond to the precise fishing location.

FIGURE 3
Representative geotagged images received through the INCOIS FISH App from various locations along the Indian coast. The geographic coordinates (latitude and longitude) are embedded in the bottom-left corner of each image.

5 Case study on initial user response

Although the pilot implementation of the citizen science initiative during 2023–2024 resulted in nearly a thousand fishers installing the app, the proportion of active users and regular image submissions remained low. This was primarily because integrating the additional technical task of image capture into labor- intensive fishing operations requires more than app installation; it also depends on adequate user training, awareness of the purpose and value of feedback and data collection, and a clear understanding of how participation can benefit fishers while contributing to the improvement of fisheries advisory services. Figure 4 presents the state-wise app installation, active user, and image submission statistics, along with the growth from 2023 to 2024.

Among the coastal states, Odisha stands out with both a high installation share and the highest active-user share, indicating strong adoption and consistent usage. Tamil Nadu exhibits comparatively fewer installations but a disproportionately higher share of active users, suggesting excellent user retention and engagement. Kerala and Gujarat show a balanced pattern, with active-user shares broadly matching their installation shares. In contrast, Goa–Karnataka and Andhra Pradesh have relatively high installation shares but lower active-user shares, implying that a smaller proportion of installed users remain actively engaged. Maharashtra also falls into this category, while West Bengal and Lakshadweep have lower installation shares but comparatively better active-user representation than expected from their installation levels. Overall, the analysis identifies states that require focused attention by highlighting regions where targeted, location-specific interventions are needed to improve FISH App adoption, user engagement, and sustained usage.

The distribution of the geotagged fish catch data points received from the pilot implementation of the FISH app is provided in Figure 5. During 2023 only 48 out of nearly 500 received images were geotagged (Figure 5a). This low adoption rate necessitated immediate action. To address this, several measures were undertaken, such as *(a) Up gradation to multilingual form-* to enhance accessibility and user-friendliness, the App and accompanying information brochures were translated into multiple regional languages; and *(b) intensive training and support-* the project team, in collaboration with Principal Investigators (PIs) from each state, conducted comprehensive training sessions, provided ongoing technical support, and actively addressed user troubleshooting issues.

These efforts resulted in a significant surge in app usage and data contribution. By the end of December 2024, 1,011 useful images had been received from many states (Figure 5b), bringing the total to 1,059 geotagged images, a dramatic increase from the previous year. West Bengal, Orissa, Tamil Nadu, and Kerala demonstrated high levels of participation along their coastlines. Andhra Pradesh, Maharashtra, Lakshadweep, and Gujarat showed more localized participation, primarily concentrated around specific areas such as Visakhapatnam and Kakinada in Andhra Pradesh, Agatti, Kavaratti, and Kalpeni islands in Lakshadweep, Ratnagiri in Maharashtra, and Somnath in Gujarat. Karnataka and Goa still exhibited lower levels of participation.

The collected images provide valuable insights into various aspects of fishing operations, including precise geolocation data, which is crucial for understanding fishing grounds and the spatial distribution of catches. Images often depict the total catch and, in some cases, individual species, enabling estimation of the species composition of each haul. These figures also provide information about the types of fishing vessels and gear employed, contributing to a better understanding of fishing practices.

Data Management and Analysis: Monthly categorization of geotagged and non-geo-tagged images is conducted, and PIs are regularly informed about the progress. Collected data is systematically entered into a primary database. Data visualization techniques validate the location information and refine the dataset for further analysis.

This initial case study provides valuable insights into the challenges and successes of implementing a citizen science initiative

FIGURE 4
(a) Scatter plot showing illustrating the state-wise relationship between the share of pilot scale FISH App installations and the share of active users during 2023-24. States are distributed over four quadrants based on the relative proportions of installations (high/low) and active users (high/low), enabling comparison of app installations and user engagement across regions. and **(b)** the state wise image submissions during 2023 vs 2024.

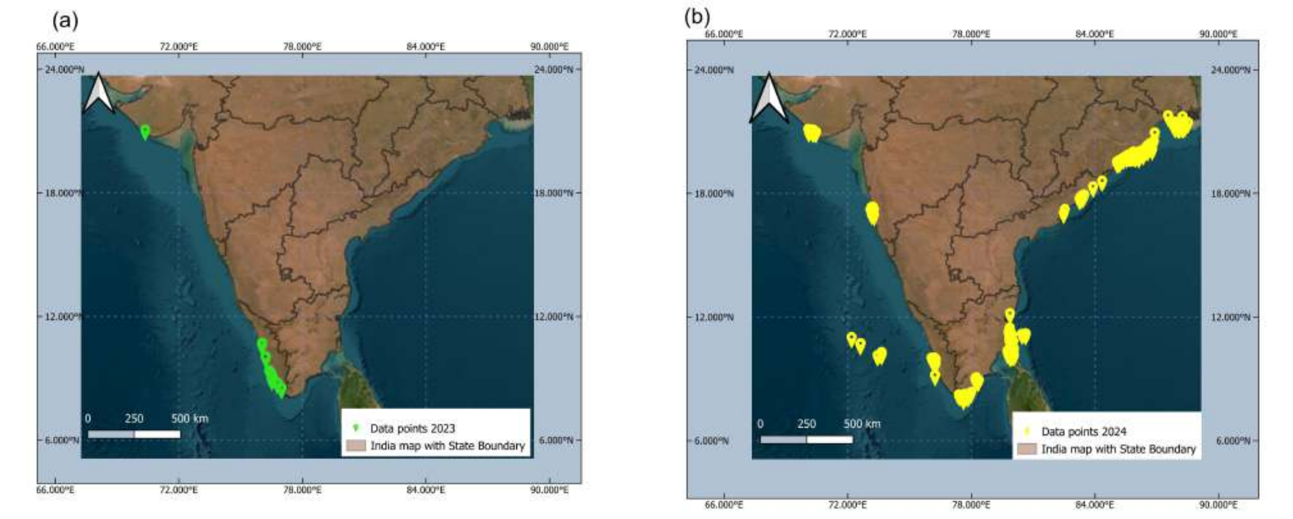

FIGURE 5
A map of Indian coastal states with locations of geotagged images received through the FISH app in 2023 **(a)** and 2024 **(b)**.

for marine fisheries data collection in India. The significant increase in data contribution demonstrates the effectiveness of targeted outreach and training programs.

Future research will focus on analyzing the collected data to extract key findings on spatial and temporal patterns of fishing activity, species distribution, and the impact of environmental factors, improving data quality by implementing more robust quality control measures to ensure the accuracy and reliability of the collected data and exploring innovative strategies for expanding user engagement to increase user participation and data contribution further. Two limitations of the present study should be emphasized before it is used for predictive modelling. First, the observations are opportunistic and presence-only, and their spatial distribution reflects the intensity of training, and user participation across states as much as the underlying distribution of fish; these sampling biases, and the absence of true absence records, must be quantified and accounted for in any subsequent species-distribution or habitat-suitability analysis. Second, the proportion of records that could be resolved to species, genus and family, and a formal measure of agreement between the two independent taxonomists, have not yet been quantified for this pilot dataset and will be reported as the database grows.

6 Discussion and conclusions

The marine fisheries sector in India currently faces several challenges, including the over-exploitation of coastal resources and income disparity between the sectors. One of the key concerns is that the mechanized sector, which primarily consists of the trawl fisheries, poses a challenge to the fishery's sustainability due to the nonselective nature of the gear. Bottom trawls sweep large areas of the seabed with little or no selectivity for species or size classes, resulting in substantial bycatch and ecosystem impacts. Obviously, the inherent uncertainty of catches in vast oceanic areas has likely driven the expansion of trawl fisheries in India, ensuring consistent catch volumes, even though it is ecologically unsustainable. This raises the need to maximize the potential of the artisanal and motorized sectors, which typically use more specific fishing methods using seines and gill nets. Thus, the key strategies for sustainable marine capture fisheries for the future can be (i) providing economically balanced fishing opportunities for motorized and small-scale sectors and (ii) Diversifying the mechanized sector towards deep-sea fishing. Accurate and reliable fisheries predictions can significantly enhance the performance of non-mechanized sectors by increasing certainty in catches. This would indirectly support resource sustainability while directly addressing economic disparities between sectors. Additionally, advancements in predictive capabilities for offshore and deeper zones may facilitate the diversification of the currently trawl-dominated mechanized sector towards underexploited deep-sea pelagic resources, provided such expansion is supported by comprehensive stock assessments, ecological risk evaluations, and sustainable fisheries management measures. It should also be recognized that more accurate prediction of fishing grounds can raise fishing efficiency and concentrate effort on aggregation hotspots, so the resulting advisories need to be paired with effort controls and other management safeguards to ensure that reduced search time does not translate into additional pressure on already exploited stocks. In this endeavor, citizen science-based data collection to improve future fisheries forecasts is a promising initiative.

Currently, the scope of INCOIS's citizen science-based data collection model is limited to species occurrence data, as it does not provide quantitative information on catch or catch composition. However, future upgrades to the App will include optional features for quantitative data submission for interested users. Also, it is designed as a participatory monitoring data collection platform. While fishers serve as the primary contributors, students, researchers, and other stakeholders participating in fishing expeditions also contribute observations. The platform is not restricted to fishers alone, and its future expansion aims to broaden public participation, including data collection on for jellyfish swarming, algal bloom, floating macroplastic including fishing gear debris, fishery bycatch (e.g., turtles), etc. Additionally, the INCOIS team is actively exploring methods for quantitative data extraction and automated species detection from images. These advancements will enhance the value of the citizen science-based data collection approach, contributing significantly to the development of future fisheries forecasting models.

Data availability statement

The original contributions and data presented in this study are included in the article and Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

DL: Data curation, Formal analysis, Investigation, Project administration, Validation, Writing – original draft. TK: Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – review & editing. SJh: Data curation, Formal analysis, Investigation, Validation, Visualization, Writing – review & editing. CS: Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – review & editing. SR: Data curation, Formal analysis, Investigation, Writing – review & editing. PR: Data curation, Formal analysis, Investigation, Writing – review & editing. SB: Data curation, Formal analysis, Investigation, Project administration, Writing – review & editing. AS: Data curation, Formal analysis, Project administration, Software, Validation, Writing – review & editing. SJo: Project administration, Supervision, Writing – review & editing. TN: Conceptualization, Investigation, Project administration, Supervision, Validation, Writing – review & editing

Funding

The author(s) declared that financial support was received for this work and/or its publication. This work was carried out as a part of INCOIS's ongoing programme- Ocean Modeling Applied Research and Services (OMARS).

Acknowledgments

The authors extend their heartfelt gratitude to Dr. S. Velvizhi (M.S. Swaminathan Research Foundation, Tamil Nadu), Dr. Kamal Kumar Barik (Centurion University of Technology and Management, Bhubaneswar), Dr. V.R. Madhu (Central Institute of Fisheries Technology, Kochi), Dr. S. Chinnadurai (Central Institute of Fisheries Technology, Veraval), Dr. S. Suresh Kumar (Kerala University of Fisheries and Ocean Studies, Kochi), Dr. Jatisankar Bandyopadhyay & Dr. Sourav Maity (Vidyasagar University, West Bengal), Dr. Bhaware B.G. (Vedak College of Science, Raigad), Dr. J.L. Rathod (Karnataka University), Prof. P. Rama Rao (Andhra University, Visakhapatnam), Dr. Rabindro Nath Samal (Chilika Development Authority, Bhubaneswar), and their dedicated project staff for their invaluable contributions in mobilizing and sensitizing fishers. Their coordinated efforts have been instrumental in fostering active participation and facilitating the collection of citizen science-based data through the FISH App. The authors also gratefully acknowledge the dedicated contributions of our late colleague, Ms. Naga Swetha, whose invaluable efforts greatly contributed to the development of the citizen science app, from its inception through the initial stages of implementation.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2026.1918530/full#supplementary-material

References

Ayyappan, S., and Krishnan, M. (2004). Fisheries sector in India: Dimensions of development. *Indian J. Agric. Econ.* 59, 392–412.

Bonney, R., Byrd, J., Carmichael, J. T., Cunningham, L., Oremland, L., Shirk, J., et al. (2021). Sea change: Using citizen science to inform fisheries management. *Bioscience* 71, 519–530. doi: 10.1093/biosci/biab016

CMFRI (2025). *Annual report 2024* (Kochi: ICAR-Central Marine Fisheries Research Institute), 295.

Dwivedi, R. M., Solanki, H. U., Nayak, S. R., Gulati, D., and Somvanshi, V. S. (2005). Exploration of fishery resources through integration of ocean colour with sea surface temperature: Indian experience. *Indian Journal of Marine Sciences*, 34(4), 430–440.

George, G., Krishnan, P., Dam Roy, S., Sarma, K., Goutham Bharathi, M. P., Kaliyamoorthy, M., et al. (2013). Validation of potential fishing zone (PFZ) forecasts from Andaman and Nicobar Islands. *Fish. Technol.* 50, 1–5.

Global Fishing Watch *Global Fishing Watch*. Available online at: https://globalfishingwatch.org/ (Accessed 7th February 2025).

Helmond, A. T., Mortensen, L. O., Plet-Hansen, K. S., Ulrich, C., Needle, C. L., Oesterwind, D., et al. (2020). Electronic monitoring in fisheries: lessons from global experiences and future opportunities. *Fish Fish.* 21, 162–189. doi: 10.1111/faf.12425

Marshall, C. T., Wiff, R., and Cornulier, T. (2017). Commercial and survey data were used to infer real-time fish distribution in the North Sea at high resolution. *Scottish Mar. Freshw. Sci.* 8, 74. doi: 10.7489/1973-1

Mukesh, S. P., Pandey, S., and Ramalingam, L. (2019). Marine fisheries data collection methods in India–an update. 5, IOTC-2019-10th Working Party on Methods (WPM)Donostia-San Sebastian, Spain. Available online at: https://www.iotc.org/fr/documents/WPM/10/21.

Najmudeen, T. M. (2023). "Overview of marine fisheries of India," in *International workshop-cum-training on fisheries management and aquaculture* (ICAR-Central Marine Fisheries Research Institute, Kochi), 12–22.

Nimit, K., Masuluri, N. K., Berger, A. M., Bright, R. P., Prakash, S., TVS, U., et al. (2020). Oceanographic preferences of yellowfin tuna (Thunnus albacares) in warm stratified oceans: A remote sensing approach. *Int. J. Remote Sens.* 41, 5785–5805. doi: 10.1080/01431161.2019.1707903

Pillai, V. N., and Nair, P. G. (2010). Potential fishing zone (PFZ) advisories- Are they beneficial to the coastal fisherfolk? A case study along Kerala coast, South India. *In Biol. Forum* 2, 46–55.

Registration And Licensing of Fishing Craft (ReALCRaft) portal, Govt. of India *Registration and Licensing of Fishing Craft (Realcraft) Portal, Govt. Of India*. Available online at: https://realcraft.gov.in/ (Accessed 2nd August 2026).

Sathianandan, T. V., Mohamed, K. S., Jayasankar, J., Kuriakose, S., Mini, K. G., Varghese, E., et al. (2021). Status of Indian marine fish stocks: modelling stock biomass dynamics in multigear fisheries. *ICES J. Mar. Sci.* 78, 1744–1757. doi: 10.1093/icesjms/fsab076

Solanki, H. U., Mankodi, P. C., Nayak, S. R., and Somvanshi, V. S. (2005). Evaluation of remote-sensing-based potential fishing zones (PFZs) forecast methodology. *Cont. Shelf Res.* 25, 2163–2173. doi: 10.1016/j.csr.2005.08.025

Solanlki, H. U., Dwivedi, R. M., Nayak, S. R., Jadeja, J. V., Thakar, D. B., Dave, H. B., et al. (2001). *Application of Ocean Colour Monitor chlorophyll and AVHRR SST for fishery forecast: Preliminary validation results off Gujarat coast, northwest coast of India*. Available online at: http://nopr.niscpr.res.in/handle/123456789/4613 (Accessed January 22, 2026).

Song, C., Lim, C. H., Choi, H. A., Kim, W., Han, D., Paia, M. T., et al. (2025). Mapping ecosystem services based on citizen science for integrated coastal zone management in the Solomon Islands. *Ecol. Inf.* 88, 103142. doi: 10.1016/j.ecoinf.2025.103142

Srinath, M., Kuriakose, S., and Mini, K. G. (2005). Methodology for the estimation of marine fish landings in India. *CMFRI Special Publ.* 86, 1–57.

Tian, H., Liu, Y., Li, J., Xing, Q., Sun, H., and Tian, Y. (2024). Satellite nighttime remote sensing promotes the spatially refined monitoring and assessment of offshore fishery. *Int. J. Digital Earth* 17, 2322762. doi: 10.1080/17538947.2024.2322762

Tian, H., Liu, Y., Tian, Y., Alabia, I. D., Qin, Y., Sun, H., et al. (2022a). A comprehensive monitoring and assessment system for multiple fisheries resources in the Northwest Pacific based on satellite remote sensing technology. *Front. Mar. Sci.* 9, 808282. doi: 10.3389/fmars.2022.808282

Tian, H., Liu, Y., Tian, Y., Jing, Y., Liu, S., Liu, X., et al. (2022b). Advances in the use of nighttime light data to monitor and assess coastal fisheries under the impacts of human activities and climate and environmental changes: A case study in the Beibu Gulf. *Mar. Policy* 144, 105227. doi: 10.1016/j.marpol.2022.105227

Tommasi, D., Stock, C. A., Pegion, K., Vecchi, G. A., Methot, R. D., Alexander, M. A., et al. (2017). Improved management of small pelagic fisheries through seasonal climate prediction. *Ecol. Appl.* 27, 378–388. doi: 10.1002/eap.1458