Journal homepage: www.fishtaxa.com

Citizen science and mobile apps engaging the public in fish taxonomy

Jodie Rummer Tréhin
[1] *MARBEC, Université Montpellier, Montpellier, France*

Abstract
Mobile applications and citizen science have completely changed the way the public may get involved in scientific research, especially when it comes to fish taxonomy. This research study examines how these two phenomena interact, emphasizing how mobile applications may include and enable individuals to provide essential data that advances our knowledge of the variety of fish species. The research presents that citizen science and mobile apps engage the public in fish taxonomy. The proliferation of smartphone accessibility has enabled broad involvement in citizen scientific projects about fish taxonomy. Users may easily take and share photos of fish they see in their local environs with the help of mobile applications. These photos, together with pertinent metadata, go to an open database that helps scientists categorize and identify different kinds of fish. Through user-friendly applications, fans and casual observers contribute data that would otherwise be difficult to get, giving researchers access to many data. This research is based on numerical data and theory-based analysis related to them. Participation from the general population improves database comprehensiveness and encourages environmental care and community involvement. The research study also expressions at the benefits and problems that might arise from using citizen science and smartphone apps in studies on fish taxonomy. It talks about how important it is for scientists and citizen contributors to communicate effectively and how to standardize data quality. The overall research found positive and significantly engaging fish taxonomy related to citizen science and mobile apps. The research highlights the revolutionary impact that mobile applications and citizen scientists have had in democratizing fish taxonomy research. Scientists may develop a feeling of shared responsibility for the well-being of aquatic ecosystems and get a more thorough knowledge of fish biodiversity by utilizing the combined power of public engagement.

Keywords: Citizen Science (CS), Mobile Apps (MA), Fish Taxonomy (FT), Engaging

Citation: Jodie, T, 2023. Citizen science and mobile apps engaging the public in fish taxonomy. FishTaxa 30: 14-26.

Introduction

Collecting data regarding the aquatic ecosystem is very important for understanding the behavior of various aquatic species. The citizen sciences are a modern concept that aids the data collection process regarding the aquatic environment. For managing the aquatic and ecological resources, the citizen science approach is gaining tremendous importance. Citizen science is the approach that is most commonly used by scientists. The scientific data related to different ecosystems are gathered through this approach as it is a cost-effective technique. Citizen scientists engage the general public in activities that provide them with more knowledge regarding various fisheries activities(Potts et al., 2021). The initiative taken by citizen sciences working on the aquatic environment is to engage the public in meaningful activities.

The citizen sciences help distribute scientific data about various marine species to the relevant people by properly engaging the public in the knowledge-gaining process. The research citizen science works on various aquatic system-related fields to comprehend the morphology of all aquatic species. The research on the ecology of reef structures and the study of water quality of aquatic ecosystems are the topics used by citizen

Accepted: 08 December 2022; Published: 07 November 2023

scientists(Dwivedi, 2021). Moreover, the use of mobile apps for correlating data regarding aquatic species is increasing at higher rates. The recreational anglers help in getting data regarding the fisheries activities. The mobile app uses a logistic approach and gathers data from remote locations. This data then provides authentic information about various aquatic species and their behavioral movement.

The citizen science approach is used for assessing and managing the shifting patterns of aquatic organisms. The Texas Shark Rodeo's shifting behavior from conservation-based practices to catch and release activities is explained through citizen sciences. This shifting pattern helps in identifying the unique characteristics associated with this shark. Citizen sciences provide a large amount of data regarding shark fisheries(Eyng et al., 2022). The large data creates problems in understanding the behavior of sharks. So, to solve this problem, anglers are used for assessing the location of sharks when they go through shifts in practice. Anglers use advanced technology techniques to identify the sharks'. The identification of shark species by anglers proved that it is a more authentic way of getting detailed data regarding species(Gundelund et al., 2020). also, using the citizen sciences approach for getting data regarding sharks provides data with less error. This less error-based data helps in managing the shark species found in the aquatic environment and for assessing the sharks found in the Sea of Mexico.

Fish species are an important source of protein. Almost fifty percent of world vertebrates are fished, as they play a critical role in maintaining the stability of the ecosystem. Various human activities like pollution and industrial water runoff disturb the natural ecosystem of the sea. The disturbance in the natural aquatic ecosystem poses a significant threat to the lives of aquatic organisms(Encarnação et al., 2021). various agricultural and industrial problems badly influence the fish present in the aquatic environment. To save the fish species from disturbed environmental conditions, the spatial patterns of fish species are studied. The citizen sciences approach provides knowledge About the spatial patterns of fish species.to study the fish species across marine ecosystems it is critical to use technology-based devices for monitoring the aquatic species(Bonney et al., 2021). The technology-based devices capture images of fish species from every angle and then provide detailed data regarding the fish assemblages found in different aquatic zones. The small species and microorganisms present in the aquatic environment go unnoticed while studying the marine environment. To ensure that every micro and macro species of the sea is studied, the use of the citizen sciences approach is used by researchers along with technology-based monitoring devices. To make sure that tracking of aquatic species is done at a broad scale, modern tracking systems are employed in marine ecosystems.

The citizen science approach allows the general public to indulge themselves in science-related activities that connect them with nature. Engaging the public with science through the citizen sciences approach provides the public with deep insight into the natural ecosystems. Many countries and states worldwide are trying their best to adopt effective sustainable management programs and strategies to save the aquatic ecosystem at any cost. CITES is a program that works to conserve the natural fauna as well as the flora of the aquatic environment (Lemmens et al., 2021). The conservation process is made by getting the whole knowledge and information regarding the flora and fauna found in different sea regions. This information is provided using the citizen sciences approach that aids the effective strategy-making process(Dalby et al., 2021). For further improving the efficiency of conservation strategies, they are used along with the expectational monitoring system. so that all the errors in the aquatic data-gathering process can be minimized to a great extent.

Despite the immense use of the citizen sciences approach, this concept still has some limitations. These limitations make it less suitable to use for gathering aquatic data in bulk.to improve the efficacy of the citizen science approach, it is used along with a modern technology-based monitoring system called anglers. The anglers make the data collection process more accessible and error-free(Jakuschona et al., 2022). also, many aquatic management authorities all over the globe are trying their best to improve the data collection methods by integrating the data collection methodologies with the concept of citizen science. Furthermore, in the present

era, it is crucial to identify the presence of alien species found in aquatic environments. To identify the presence of alien species in the sea, the use of citizen sciences methods is prominent in the aquatic-based research field. Certain mobile apps also asses the process of identification of IAS in water(Aguayo & Decima, 2020). The mobile apps are so advanced that they explain the taxonomic and ecologic background of every aquatic alien species without minimum chances of error in data. To save aquatic life, proper conservation-based strategies must be implemented in the management system of every global ecosystem.

Research objectives

This research article describes the concept of Citizen science and mobile apps engaging the public in fish taxonomy.

Literature review

Researchers claim that providing knowledge to people about the aquatic ecosystem is made using digital citizen science. The digital citizen science approach allows young people to learn about various environments. for gaining information about the open sea species, the use of the digital-based citizen science approach is widely used by scientists(AGUAYO, 2022). Studies explain that shark reserves are found in a large number in the Mediterranean Sea. In the recent few years, a sharp decline in the number of shark species has been observed in the pelagic region. For conserving the shark population in the Mediterranean Sea, the approach of citizen science is applied in the conservation strategies(Bargnesi et al., 2020).studies show that for effectively maintaining the environment, the use of monitoring systems is common. the monitoring system helps in providing information about various environments by assessing the environmental activities of a particular ecosystem. great barrier reef environment is assessed using the hybrid monitoring technology. This hybrid technology uses citizen sciences-derived data and provides an effective framework(Becken et al., 2019).scholars suggest that image-based data provides detailed information regarding various flora species of aquatic ecosystems. Deep learning-based algorithmic devices are used for gathering images of aquatic flora.

The information about specific plant morphology is provided through the citizen science approach. The citizen science approach has numerous applications in determining the features of various flora(Boho et al., 2020).studies highlight that the marine-based citizen science approach provides immense applications in understanding the science behind the functioning of aquatic microorganisms. the citizen science approach associated with marine ecosystem studies is widely used in European states for getting information about marine species. the development of innovative technology has resulted in advancing citizen science-based approaches. these advanced citizen programs provide thorough data regarding the aquatic species(Garcia-Soto et al., 2021).studies predict that complex ecological systems have increased the population of recreational fish. the recreational fisheries programs help in assessing the data related to the fish stock and improve the fish management strategies(Gervasi et al., 2022).scholars show that managing various aquatic resources is possible by using the workable approach of citizen sciences. the approach of citizen science is gaining popularity as it provides tremendous application in the management of the ecosystem of the sea.

Utilizing the citizen science approach for research purposes on aquatic ecosystems reduces the chances of data error(Gibson et al., 2019).scholars explain that advanced citizen science-based technology applications have replaced the traditional methods of collecting aquatic data. The old methods used to assess recreational fisheries activities are replaced with smartphone technology. The platforms that use the electronic citizen science approach can provide the most authentic data related to the functioning observed in the aquatic environment(Gundelund et al., 2023).studies claim that for managing small-scale recreational fisheries activities, the use of the citizen science approach is applied. The data regarding the blue swimmer crab of

Australia is collected through the citizen science services(Harris et al., 2021).studies explain that marine citizen science allows scientists to learn more about the species found in aquatic environments. The complexity associated with obtaining reliable data regarding aquatic life is solved through citizen sciences.

The diversity associated with certain species of aquatic life is explained through the advanced information provided by citizen sciences-based information-providing platforms(Krželj et al., 2020).studies explain that the involvement of people in research work in the aquatic field becomes easy using the citizen sciences. The conservation of the process of marine species is enhanced as a result of citizen science-based programs. The dolphin research program is based on the concept of citizen sciences that helps in understanding the movement of dolphin fish(Merten et al., 2022).also, scientists are working hard to engage the general public in research works on the aquatic environment. The public's indulgence in research work allows them to comprehend the sciences behind the sea ecosystem and its species. The approach of applied citizen sciences is widely used for researching freshwater species. .engaging local people in the decision-making process is made possible through the use of the citizen sciences concept(Metcalfe et al., 2022). Studies show that using the approach of citizen sciences in digital mobile apps helps study the various activities associated with the marine ecosystem. CBWM is a technique used for analyzing the structures of aquatic species(Millar et al., 2023).studies explain that citizen sciences is an approach that is widely used in the health sector because of its tremendous applications.

The biomedical citizen sequence concept is used in the health field for enhancing health-related medical services(Mintz & Couch, 2022).studies explain that KMMN helps in collecting data related to marine mammals. This program engages the public and marine resource users in activities to conserve marine mammals. The KMNM programs are based on the advanced concept of citizen sciences and provide updated information about the aquatic species found in Kenya's sea. The current data about aquatic species then helps conserve the aquatic species of Kenya(Mwango'mbe et al., 2021). Studies of research scholars predict that using the citizen sciences helps in gaining insight into the non-indigenous species present in the marine ecosystem. For managing the NIS, the use of innovative technology is essential as it reduces the risk associated with the data collection process of NIS(Parretti et al., 2023).scholars suggest that citizen sciences is the approach that uses the latest technological tools to help people tackle sustainability problems. The use of mobile capturing techniques by communities using the aquatic ecosystem management program helps them monitor aquatic activities(Pejovic & Skarlatidou, 2020).studies claim that collection through georeferenced images is obtained using citizen science platforms. machine learning programs are used for efficiently managing the data related to small-scale fisheries(Silva et al., 2022).scholars explain that mussels found in freshwater have diversity that allows them to show a significant role in the ocean ecosystem. These mussels and other macroinvertebrates present in aquatic ecosystems are highly monitored using citizen science monitoring programs.

The reduction in the species of unionids has resulted in the decline of this species.to save unionids from becoming extinct, their abundance is assessed through the use of a citizen sciences monitoring system(Tolin, 2023).scholars explained that the identification of alien species in the Danube River basin is predicted through the use of smartphone apps(Trichkova et al., 2021). A new wave of involvement is cresting the waves in the vast and enigmatic domain of aquatic life, where many fish species float through the currents. With the use of citizen science and technology, smartphone applications are expanding their reach and allowing people to learn more about fish taxonomy. By transforming every smartphone user into a prospective ichthyologist and every beach walk into a scientific expedition, this ground-breaking method goes beyond established scientific bounds. Fish taxonomy and smartphone applications together are more than just a passing fad they are revolutionizing marine science and conservation. Smartphones are growing more and more like constant companions in our daily lives, and they are opening doors to the ocean's depths. This introduction explores citizen science in the ocean, highlighting the value of mobile applications in publicizing fish taxonomy, their influence on scientific

study, and their spillover effects on environmental consciousness.

The Digital Age's Ocean of Opportunity: Citizen Science

The idea of citizen science, a cooperative endeavor that welcomes people from all walks of life to participate in scientific endeavors, is at the core of this aquatic journey. The public now can explore the ocean, a far cry from the days when marine study was restricted to specialists working in labs. By transforming enthusiasts into engaged participants, citizen science dissolves the divide between the general population and scientific specialists. Mobile applications link citizen scientists and the fascinating field of fish taxonomy in the digital era when connection is king. These applications are more than just tools; they are portals that enable people to catalog, categorize, and advance their knowledge of aquatic environments. Suppose there was a community of smartphone users all over the world that collaborated to solve the secrets of the undersea realm, fish by fish.

Getting Around: How Fish Taxonomy Apps Operate

The download of a mobile app for fish taxonomy is where the magic starts. These applications, which frequently have cutting-edge capabilities, act as virtual companions for beachcombers and seasoned naturalists. Their ability to help users identify fish species using cutting-edge methods like picture recognition and extensive species databases is essential to their operation. When users go fishing or explore the shore, they may take pictures with their iPhones of fish they come across. By analyzing these photos, the app functions as a digital taxonomist and provides real-time identification and details about the observed species. This guarantees the accuracy of user-contributed data and promotes an interactive learning environment. The core function of these apps is data collecting.

Users are asked to enter details about their fish sightings, including the location, date, and weather, in addition to the species they have observed. The accurate geotagging made possible by incorporating GPS technology results in a comprehensive dataset that covers the geographical distribution of different fish species in addition to taxonomy. These applications' educational features improve the user experience by providing

information about fish behavior, ecological functions, and the importance of conservation. By means of identification support, data gathering, and teaching materials, the user is elevated from a spectator to a knowledgeable participant in the field of marine research.

A Radical Shift in Scientific Investigation

Mobile applications have a far wider influence on public participation in fish taxonomy than just the user's own experience. A huge and dispersed network of observations is represented by the aggregated data gathered by various applications, creating a mosaic of knowledge that is vital to scientific inquiry. Numerous advantages arise for scientific research from this abundance of data. Researchers are able to study seasonal migratory patterns, observe changes in fish populations over time, and evaluate the condition of aquatic ecosystems. A more dynamic knowledge of marine ecosystems is made possible by the real-time nature of data collecting, which provides insights that conventional research approaches would find difficult to get. Furthermore, the scope of citizen science projects made possible by these applications offers a degree of coverage that would be difficult to get using traditional research methods. It's as though a worldwide net is thrown, gathering data from many habitats, ranging from peaceful freshwater lakes to active coral reefs.

A more thorough and complete understanding of the condition of our seas is ensured by the democratization of data collecting. These apps also act as stimulants to collaborate across disciplines. Through the virtual spaces made possible by the applications, scientists, environmentalists, and citizen scientists come together to promote a community-driven approach to marine research. The way in which ideas are shared, conclusions are discussed, and cooperative efforts are made to tackle environmental issues highlight how mobile technology has the capacity to revolutionize the field of scientific research.

Ecology and Preservation: From Pixels to Preservation

Outside of science, the combination of fish taxonomy and smartphone apps greatly raises public awareness of environmental issues. Users who interact with these applications become environmental stewards as well as contributors to scientific research. These applications' immersive learning opportunities help users have a greater

understanding of the complex web of life that exists throughout aquatic habitats.

Users learn about the relationships between different species, the delicate balance of marine environments, and how human activity affects these sensitive ecosystems. This increased awareness has an impact on real-world conservation behaviors and attitudes outside of the digital sphere. Equipped with information on the significance of conserving biodiversity, citizen scientists turn into proponents of sustainable behaviors. This awareness may have a variety of knock-on impacts, from community-led conservation projects to ethical fishing practices. As a result, the applications act as triggers for a more widespread cultural movement towards environmental awareness by highlighting the part that each person plays in preserving the health of our seas.

Correlations							
		Citizen science 1	**Citizen science 2**	**mobile apps 1**	**mobile apps 2**	**fish taxonomy 1**	**fish taxonomy 2**
Citizen science 1	Pearson Correlation	1	.156	-.249	-.223	.079	-.175
	Sig. (2-tailed)		.279	.082	.119	.588	.225
	N	50	50	50	50	50	50
Citizen science 2	Pearson Correlation	.156	1	.120	-.247	.092	-.276
	Sig. (2-tailed)	.279		.407	.084	.524	.053
	N	50	50	50	50	50	50
mobile apps 1	Pearson Correlation	-.249	.120	1	.227	-.027	.069
	Sig. (2-tailed)	.082	.407		.113	.850	.635
	N	50	50	50	50	50	50
mobile apps 2	Pearson Correlation	-.223	-.247	.227	1	-.051	.311*
	Sig. (2-tailed)	.119	.084	.113		.723	.028
	N	50	50	50	50	50	50
fish taxonomy 1	Pearson Correlation	.079	.092	-.027	-.051	1	.338*
	Sig. (2-tailed)	.588	.524	.850	.723		.016
	N	50	50	50	50	50	50
fish taxonomy 2	Pearson Correlation	-.175	-.276	.069	.311*	.338*	1
	Sig. (2-tailed)	.225	.053	.635	.028	.016	
	N	50	50	50	50	50	50
***. Correlation is significant at the 0.05 level (2-tailed).**							

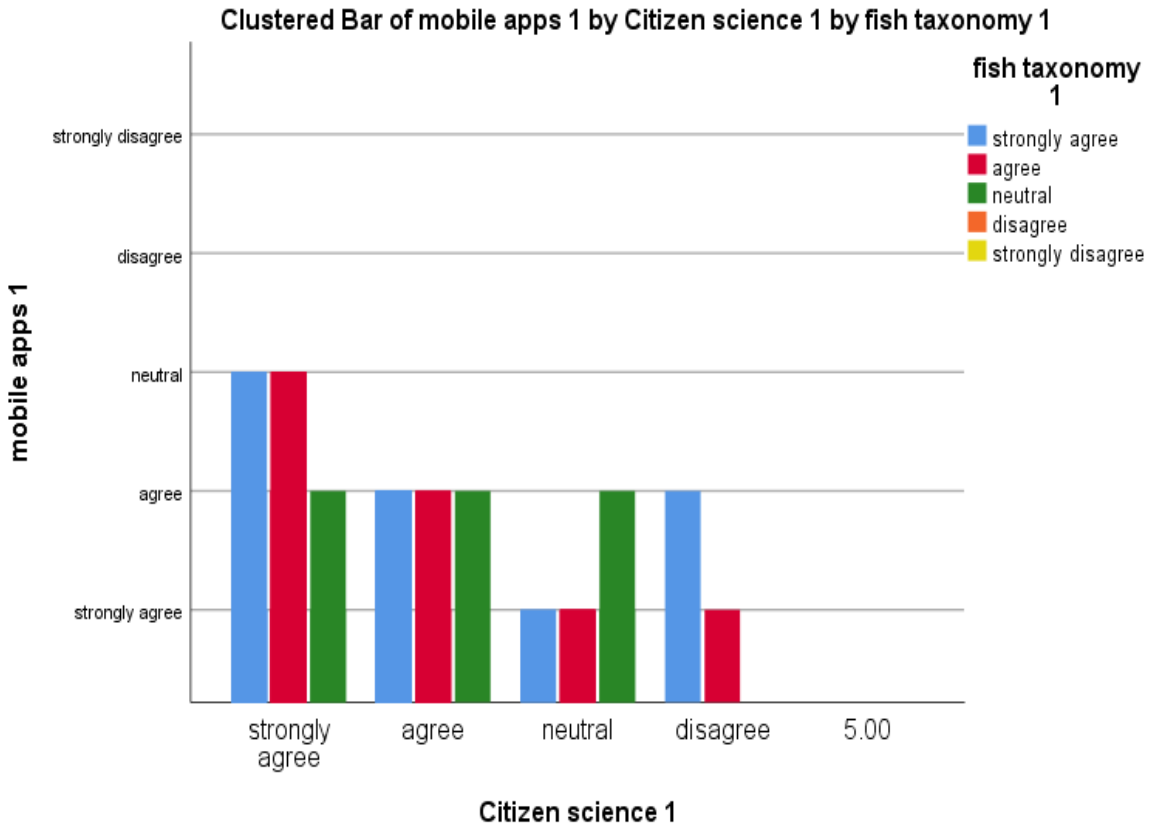
Table-1

The above result represents a correlation analysis between fish taxonomy and mobile apps related to the citizen sciences. The citizen science shows that there is a 15% positive and significant relation between them. the mobile apps represent a negative link but a significant relation with citizen science. The fish taxonomy describes 7%, 9%, 33%, and 5% positive and some negative relations with the mobile apps. The fish taxonomy shows that 22%, 5%, 63%, 2%, and 16% significant relation between citizen science and mobile apps. The overall result shows a significant interrelation between citizen science and mobile apps related to fish taxonomy.

Problems and Prospects for the Future

Although it signals the beginning of a new age in citizen research, the combination of mobile apps and fish taxonomy is not without its difficulties. All citizen scientific effort faces inherent challenges such as data accuracy, species misidentification, and possible bias in data gathering. It's still difficult to strike a balance between scientific rigor and inclusion. Prospects for these applications' continuous development are bright.

Developments in machine learning and artificial intelligence may improve species identification even further, decreasing the need for human confirmation. Enhanced cooperation among scientists, app developers, and environmental organizations can result in the development of standardized methods that guarantee the accuracy and consistency of data gathered via these platforms. Furthermore, these applications may be expanded beyond fish classification into more comprehensive investigations of marine biodiversity, which creates additional opportunities for citizen research involvement. The combination of virtual reality and augmented reality experiences has the potential to take viewers into immersive underwater environments, strengthening their bond with marine life as technology advances.



The above graph presents a clustered bar analysis related to mobile apps and citizen science by the fish taxonomy. The blue bar line presents that strongly agree, agree, neutral, and disagree and 5.00 respectively. The vertical side shows mobile apps, and the horizontal side shows Citizen Science 1.

Applications

Encourage the Use of Apps

• Raise awareness of fish taxonomy applications via social media, academic institutions, and neighborhood gatherings.

• Work together with educational institutions and environmental organizations to include these applications in curricula, inspiring the next wave of citizen scientists.

Improve the User Experience

• Release updates often to enhance the functionality of the app, such as more precise species identification and

streamlined user interfaces.

• Use gamification features, such as badges, prizes, or friendly competitions, to encourage users to stay engaged.

Building Communities:

• Encourage users to contribute their questions, experiences, and discoveries in order to create a feeling of community within the app.

• Organise live events or forums where users may engage with industry professionals and one another, building a community of like-minded maritime enthusiasts.

Outreach in Education:

• Create more educational materials for the app, such as interactive guides, tests, and multimedia materials, to help users get a deeper grasp of marine environments and fish taxonomy.

• Work with specialists in marine biology to provide webinars or online lectures that users can attend via the app, giving them the chance to learn from experts.

Quality Assurance of Data:

• Put in place procedures for quality assurance and data validation to guarantee the accuracy of user-contributed information.

• Establish methods for data verification and incorporation into larger research endeavors by working with researchers and scientific institutions.

Extend the Taxonomic Range:

• To provide users with a deeper grasp of marine biodiversity, think about broadening the app's scope beyond fish taxonomy to encompass other marine creatures.

• Work along with experts in other marine domains to include characteristics for identifying marine algae, invertebrates, and other essential elements of aquatic environments.

Combining Conservation Initiatives with Integration:

• To ensure that app projects are in line with larger marine conservation programmers, collaborate with conservation organizations.

• Create characteristics that draw attention to a species' state of conservation, educating people about vulnerable or endangered marine life and encouraging focused conservation efforts.

Localization and International Coordination:

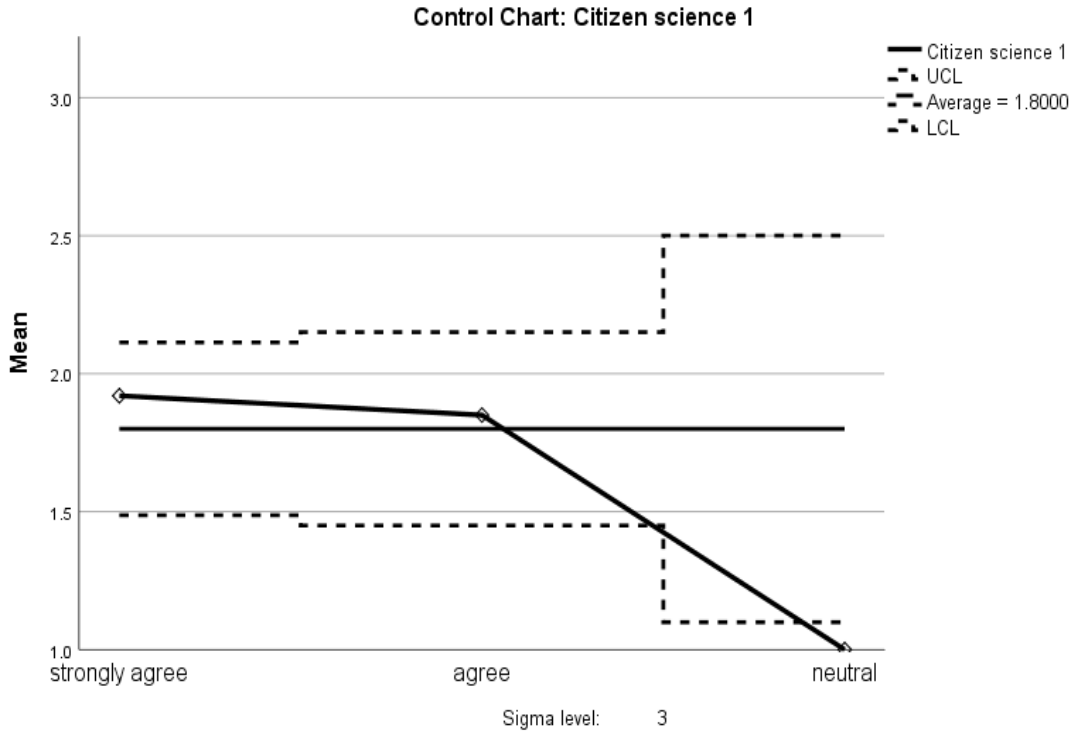
• Take into account regional differences in fish species and offer bilingual assistance to guarantee that the software is relevant and accessible to users everywhere.

• Form alliances with worldwide marine research institutions to build a global network of citizen scientists who contribute to a common database.

Inclusivity and Accessibility:

• Take into account accessibility features to make the app accessible and useable by a wide range of users, including those with impairments.

• Expression into collaborating with neighborhood organizations to give those who might have entry-level obstacles access to cellphones or app training.



The above graph presents that control chart; the vertical side shows that the mean value starts from 1.0 and ends at 3.0, and the horizontal side presents that strongly agree, agree, or neutral. The graph presents that the average rate is 1.8000 between citizen science and fish taxonomy; the horizontal side also presents sigma levels between them.

Conclusion

In conclusion, there has been a paradigm change in how we study, comprehend, and protect our oceans brought about by the union of mobile applications and fish taxonomy. Citizen science's democratization of marine research not only broadens the scope of scientific investigation but also piques people's curiosity to the core. Using these tools to navigate the digital currents, we set off on a joint exploration expedition. Every fish that is recognized, every data point that is noted, and every instance of amazement and wonder add to a body of information that goes beyond individual experiences. By using our cell phones as a telescope, we are able to actively participate in the continuing story of marine life rather than only being passive viewers of the underwater environment.

Mobile applications that include the public in fish taxonomy act as compasses in this never-ending sea of possibilities, pointing the way toward a day when people and scientists will have to work together to preserve our marine ecosystems. These smartphone apps have an influence that goes much beyond the walls of academic research facilities. It touches communities' coasts, igniting in people a sense of environmental responsibility who may have previously shied away from attempts to save the maritime environment. Due to the democratization of information enabled by smartphone accessibility, users become marine ambassadors, promoting the preservation of marine life and its environments. Challenges may come up as we sail through this revolutionary moment, but they are simply ripples in the enormous ocean of opportunity. With the commitment of academics, developers, and citizen scientists, these applications will continue to be improved, which bodes well for the future of our understanding of fish taxonomy and marine biodiversity.

Every thread made on the massive canvas of citizen science—every picture taken, every data point recorded—weaves a story of discovery. With the use of cell phones and a common interest, people work together to build a mosaic that is not limited by place. It is evidence of the strength of teamwork when the whole really does exceed the sum of its parts. As we get to the end of our investigation into the field of mobile applications that teach fish taxonomy to the general public, let us acknowledge the revolutionary potential that lies ahead of us. Let's honor those who add to our understanding of our seas just by taking the time to observe and document them. These applications are more than simply tools; they are change agents that unite people all over the world in a shared interest in and concern for the health of the environment.

The voyage continues into the realm of potential futures rather than coming to an end with this exploration. Waves of change will continue to reshape our knowledge of the aquatic environment as long as technology keeps developing and more people become citizen scientists. As a team, let's go deeper, go farther, and ultimately become sea stewards, bound by a common dedication to the preservation of the aquatic marvels that enthrall us and keep life on Earth afloat.

Future Research

1) Carry out in-depth research on the attitudes and actions of people using mobile applications for fish taxonomy. Recognize the elements that promote long-term involvement, the ways in which users view their place in scientific research, and the potential obstacles to their participation.

2) Assess the long-term effects of mobile app-enabled citizen science programs on users' attitudes, behaviors, and environmental awareness. Evaluate if involvement in fish taxonomy initiatives results in more extensive conservation efforts or lifestyle modifications.

3) Examine how well the instructional materials in the applications contribute to users' comprehension of fish taxonomy, marine environments, and conservation. Examine various learning inclinations and types to customize instructional materials for optimum effect.

4) Investigate the social dynamics in the communities that these applications create. Aspect at how user interactions—discussions, exchange of knowledge, teamwork—help foster a feeling of community and collective learning.

5) Examine how to use data created by citizens in more general scientific studies. Examine the ways in which information gathered via mobile applications might enhance conventional research techniques, add value to scholarly works, and impact choices on marine policy and management.

6) Work together with specialists in machine learning and artificial intelligence to constantly improve the precision of species identification algorithms. Examine how new technologies, including developments in computer vision, may be incorporated to provide stronger identifying skills.

7) Conduct long-term research projects that make use of the information gathered by these applications to monitor changes in fish populations over time. Examine how human activity, environmental variables, and climate change affect fish species distribution and abundance.

8) Aspect at the possibility of involving app users in neighborhood-based conservation initiatives. Examine the viability and effects of projects like neighborhood habitat restoration, environmentally friendly fishing methods, or neighborhood-run marine protected zones.

9) Encourage cooperation between educators, environmental psychologists, marine biologists, and developers to produce comprehensive, multidisciplinary research initiatives. Examine how integrating knowledge from different disciplines can result in a more thorough understanding of the efficacy of citizen science programs.

10) Keep up with technology developments and investigate how new technologies, including virtual and augmented reality, might be used in fish taxonomy apps to improve user experiences and learning objectives.

11) Perform comparative research between various places to comprehend variances in species variety, environmental problems, and user involvement. Examine the effects of socioeconomic, regional, and cultural variables on data quality and participation.

12) Examine ethical and privacy issues pertaining to the gathering and application of user-generated data. Create strong frameworks to handle ethical issues in citizen science programs, such as data anonymization, informed permission, and open communication.

These avenues for further investigation may advance our knowledge of the interactions among mobile applications, citizen scientists, and the marine environment. We can increase the efficiency of fish taxonomy applications, promote long-term citizen scientific participation, and expand our understanding of marine ecosystems by tackling these study topics.

References:

AGUAYO, C. (2022). HOW FAST CAN SALP SWIM? EDUCATING YOUNG CITIZENS THROUGH HANDS-ON AND DIGITAL CITIZEN SCIENCE CLAUDIO AGUAYO, MOIRA DÉCIMA. *Advancing Public and Industry Participation in Coastal and Marine Sciences*, 198.

Aguayo, C., & Decima, M. (2020). When do salps bloom? Engaging Primary students in underwater citizen science. Scholarship of Technology Enhanced Learning,

Bargnesi, F., Lucrezi, S., & Ferretti, F. (2020). Opportunities from citizen science for shark conservation, with a focus on the Mediterranean Sea. *The European Zoological Journal*, *87*(1), 20-34.

Becken, S., Connolly, R. M., Chen, J., & Stantic, B. (2019). A hybrid is born: Integrating collective sensing, citizen science and professional monitoring of the environment. *Ecological informatics*, *52*, 35-45.

Boho, D., Rzanny, M., Wäldchen, J., Nitsche, F., Deggelmann, A., Wittich, H. C., Seeland, M., & Mäder, P. (2020). Flora Capture: a citizen science application for collecting structured plant observations. *BMC bioinformatics*, *21*(1), 1-11.

Bonney, R., Byrd, J., Carmichael, J. T., Cunningham, L., Oremland, L., Shirk, J., & Von Harten, A. (2021). Sea change: using citizen science to inform fisheries management. *Bioscience*, *71*(5), 519-530.

Dalby, O., Sinha, I., Unsworth, R. K., McKenzie, L. J., Jones, B. L., & Cullen-Unsworth, L. C. (2021). Citizen science driven big data collection requires improved and inclusive societal engagement. *Frontiers in Marine Science*, *8*, 610397.

Dwivedi, A. K. (2021). Role of digital technology in freshwater biodiversity monitoring through citizen science during COVID-19 pandemic. *River Research and Applications*, *37*(7), 1025-1031.

Encarnação, J., Teodósio, M. A., & Morais, P. (2021). Citizen science and biological invasions: A review. *Frontiers in Environmental Science*, *8*, 602980.

Eyng, V., Gomes, M., Câmpera, L., & Hercos, A. (2022). Engagement in a citizen science Project in the Amazon basin. *Citizen Science: Theory and Practice*, *7*(1).

Garcia-Soto, C., Seys, J. J., Zielinski, O., Busch, J. A., Luna, S., Baez, J. C., Domegan, C., Dubsky, K., Kotynska-Zielinska, I., & Loubat, P. (2021). Marine citizen science: Current state in Europe and new technological developments. *Frontiers in Marine Science*, 241.

Gervasi, C. L., Massie, J. A., Rodemann, J., Trabelsi, S., Santos, R. O., & Rehage, J. S. (2022). Recreational Angler Contributions to Fisheries Management Are Varied and Valuable: Case Studies from South Florida. *Fisheries*, *47*(11), 469-477.

Gibson, K. J., Streich, M. K., Topping, T. S., & Stunz, G. W. (2019). Utility of citizen science data: A case study in land-based shark fishing. *PLoS One*, *14*(12), e0226782.

Gundelund, C., Arlinghaus, R., Baktoft, H., Hyder, K., Venturelli, P., & Skov, C. (2020). Insights into the users of a citizen science platform for collecting recreational fisheries data. *Fisheries Research*, *229*, 105597.

Gundelund, C., Venturelli, P., Hartill, B. W., Hyder, K., Olesen, H. J., & Skov, C. (2023). Spatiotemporal and multispecies comparisons between a citizen science platform and recall surveys in recreational fisheries. *Marine Policy*, *155*, 105780.

Harris, D., Johnston, D., & Yeoh, D. (2021). More for less: Citizen science supporting the management of small-scale recreational fisheries. *Regional Studies in Marine Science*, *48*, 102047.

Jakuschona, N., Niers, T., Stenkamp, J., Bartoschek, T., Schade, S., & Cardoso, A. (2022). *Evaluating image-based species recognition models suitable for citizen science application to support European invasive alien species policy*.

Krželj, M., Cerrano, C., & Di Camillo, C. G. (2020). Enhancing diversity knowledge through Marine citizen science and social platforms: The case of Hermodice carunculata (Annelida, Polychaeta). *Diversity*, *12*(8), 311.

Lemmens, R., Antoniou, V., Hummer, P., & Potsiou, C. (2021). Citizen science in the digital world of apps. *The Science of Citizen Science*, *461*.

Merten, W., Appeldoorn, R., Latour, J., Glaser, C., Becker, E., & Hammond, D. (2022). A citizen science approach to enhance dolphinfish (Coryphaena hippurus) data collection to improve species management. *Fisheries Management and Ecology*, *29*(5), 502-515.

Metcalfe, A. N., Kennedy, T. A., Mendez, G. A., & Muehlbauer, J. D. (2022). Applied citizen science in freshwater research. *Wiley Interdisciplinary Reviews: Water*, *9*(2), e1578.

Millar, E., Melles, S., & Rinner, C. (2023). Screens, streams, and flows: Implications of digital platforms for aquatic citizen science. *Geoforum*, *146*, 103864.

Mintz, E., & Couch, J. (2022). Biomedical Citizen Science at the National Institutes of Health. *Citizen Science: Theory and Practice*, *7*(1).

Mwango'mbe, M. G., Spilsbury, J., Trott, S., Nyunja, J., Wambiji, N., Collins, T., Gomes, I., & Pérez-Jorge, S. (2021). Cetacean research and citizen science in Kenya. *Frontiers in Marine Science*, *8*, 642399.

Parretti, P., Monteiro, J. G., Gizzi, F., Martínez-Escauriaza, R., Alves, F., Chebaane, S., Almeida, S., Pessanha Pais, M., Almada, F., & Fernandez, M. (2023). Citizen Science and Expert Judgement: A Cost-Efficient Combination to Monitor and Assess the Invasiveness of Non-Indigenous Fish Escapees. *Journal of Marine Science and Engineering*, *11*(2), 438.

Pejovic, V., & Skarlatidou, A. (2020). Understanding interaction design challenges in mobile extreme citizen science. *International Journal of Human–Computer Interaction*, *36*(3), 251-270.

Potts, W., Mann-Lang, J., Mann, B., Griffiths, C., Attwood, C., de Blocq, A., Elwen, S., Nel, R., Sink, K., & Thornycroft, R. (2021). South African marine citizen science–benefits, challenges and future directions. *African Journal of Marine Science*, *43*(3), 353-366.

Silva, C. N., Dainys, J., Simmons, S., Vienožinskis, V., & Audzijonyte, A. (2022). A Scalable Open-Source Framework for Machine Learning-Based Image Collection, Annotation and Classification: A Case Study for Automatic Fish Species Identification. *Sustainability*, *14*(21), 14324.

Tolin, A. (2023). *Citizen Science Monitoring of Freshwater Mussels (Unionidae) in the Huron River Watershed, Michigan*

Trichkova, T., Paunović, M., Cogălniceanu, D., Schade, S., Todorov, M., Tomov, R., Stănescu, F., Botev, I., López-Cañizares, C., & Gervasini, E. (2021). Pilot Application of 'Invasive Alien Species in Europe'Smartphone App in the Danube Region. *Water*, *13*(21), 2952.