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Enhancing Fish Taxonomy with AI-Assisted Photographic Identification Tools

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Abstract
Accurate species identification is the cornerstone of every taxonomic investigation and an essential component of biological research protocols. Biologists are calling for more efficient methods to handle the identifying need. Even people without solid experience in computer science may now independently apply state-of-the-art algorithms to their problems and datasets due to machine learning software that is getting easier to use. However, fundamental knowledge and some familiarity with the technology being used are still necessary. Around the world, efforts are being made to use data and automated processes to manage better and increase the efficiency of the fish industry, decrease the need for human labour in fishing and aquaculture, prevent diseases in fish farms, prevent pollution of the environment, and increase the number of fish available for human consumption. The most advanced fish identification (ID) technologies, including those that are still in the early phases of development, are evaluated in this research. It demonstrates how, in a variety of real-world scenarios, they could be the best option. The identification tools that were reviewed included the following: morphometrics (like IPez), scale and otolith morphology, genetic methods (like SNPs and barcodes), interactive electronic keys (like IPOFIS), taxonomic reference collections, image recognition software, dichotomous key-based field guides, the use of taxonomists and folk local experts, and hydroacoustic. It is anticipated to assist environmental administrators, fishery managers, and other end users in choosing the species identification instruments that best meet their needs.

Keywords: Fish Taxonomy (FT), AI-Assisted Photographic (AAG), Identification Tools (II)

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Introduction

According to classical Classification, which was done in ancient times, fishes are divided into three major classes on behalf of their characteristic. These classes are Agnatha, Chondrichthyes and Osteichthyes. The species of fish that have been extinct are sometimes involved in these groups, and sometimes, separate classes are made for these groups. More than half of species of vertebrates are based on fish. The term fish is utilized for vertebrates that belong to different lines based on evolution. Due to its characteristics, it is known as a life form instead of a taxonomic group. As fish is a member of the species Chordata, fish is an animal whose traits also match many other vertebrates (Gedefaw et al., 2023). All the issues generated biologically and made for the arrangement and betterment of fish biology are wiped out and ignored. Fish belongs to the kingdom Animalia. It is further subdivided into two subphyla named phylum Chordata and vertebrate subphylum. The condition to become a member of Chordata is that the following things should be found in fishes a notochord, a tubular nerve chord, and a pair of gills; the body should be segmented and the presence of a tail whose presence should be posted anal. The heart should be Ventral In fish, and the skeleton should be endoskeleton(Bar et al., 2023). Then, the fish will be placed in the phylum Chordata. An explanation based on formal knowledge and the fish taxa should be placed in the system. The term taxonomy involves giving names, elaborating on the animals, and then classifying them into specific groups based on their features. Scientific Classification is based on investigating general principles(Beery, 2023). The division of plants and animals on behalf of their relationship exists

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naturally. Based on the hierarchy, the system shows the movement from the largest general groups towards the smallest group, which will become the most specific. The order 9f Classification of fish is as follows: Kingdom, Phylum, Class, Order, family, genus and species. Here, we will discuss some prevalent properties of fish. Fishes are ectothermic. The presence of a lateral line can also be seen in this group. The heart of fish is based on two chambers (Wang et al., 2020). Fish use the gills to do respiration. Fish do not have ears that can be seen from outside. Eyelids are absent in Fish. Fluorescence in situ hybridization is the procedure whose name is based on fish, and this method is utilized for the detection and nomination of the sequence of fish chromosomes of DNA. A tool utilized for the recognition of images is Google Vision AI, which proves very helpful in identifying and understanding images (Berger-Tal et al., 2024). It permits users to construct models of their images. It also allows them to use the models Google makes. AI-powered tools are those that prove helpful in the removal of those objects, whichever are not required. Creating specific effects, characters, and pictures can be apparent even when the proper light is not found. The presence of a specific chip, known as a Google tensor camera, makes identifying objects very easy, even though all the processes happen in cell-screened phones (Costa et al., 2022). AI drives the identification of visible images and proves very helpful in identifying the location, people, type of objects and even the actions shown in the image. Coastal regions of water bodies involving the marine littoral zone are the powerhouses biologically bearing many nutrients. Many marine animals and other lives move towards this location and get shelter. This thing proves very beneficial for humanity in several ways. Ecosystems in water bodies are crucial in every aspect (Zhang et al., 2023). They are good food sources and economically beneficial as these are amazing recreational sites. Along with it, rocky intertidal systems, especially those found near urban areas, are good points that play an important role in all purposes. Those objectives can be social, economic, and recreational. The inhabitants of urban areas are mostly impressed by the locations like coastal areas. Trapping pictures of various wildlife species has become the greatest source of survival for various organisms, and this thing seems very reliable and a mainstream source (Kopecky et al., 2023). It is a coincidence that a large portion of the public is participating in this type of research (Ubillus et al., 2022). This also appears as an approach, which is also called citizen science. Wildlife public captives of wildlife with the help of a camera. The procedure of camera trapping is too wide, and many wildlife photographs have been collected. Now, it has become tough for researchers to investigate these photos. Citizen science and artificial intelligence are the fields that are increasing and have the solution to all problems. Both of these fields have their benefits and drawbacks taken side by side. When both of these techniques are joined, they will have a strong ability to perform the central role in the upcoming Camera trap research. If one wants to use both of these techniques in such a way that they can prove helpful for themselves, then there is a need to develop people's understanding of both of these topics and camera traps, too. Various research papers collaborate on these techniques separately, but the outcomes are such that those research papers will appear together. Natural and human-caused disturbances can lead to massive reductions in the species that are the basis of ecosystems(Green et al., 2020). Ecology requires the identification and measurement of these events' impacts, but it is challenging to identify a technique that yields results on ecologically meaningful scales. Accurately evaluating the consequences of disturbance on ecology is limited by the effort needed to gather high-resolution data, which also restricts the time and geographical range that may be desired. This is particularly true for marine habitats that are shallow. Fortunately, this problem has been resolved by developments in computer vision technologies aided by artificial intelligence (AI) and underwater photogrammetry. Coral reef ecosystems provide as an example of the difficulties and requirements associated with the use of high-resolution change detection. These highly productive ecosystems house incredible biodiversity dependent on coral reefs(Chen et al., 2024). This study aims to give a broad overview of current, cutting-edge fish identification (ID) technologies—some of which are still in the early stages of development—and show how they might be applied to determine the optimal solution in a range of real-world situations. The review's experts also hope it will help revive public interest in taxonomy and draw attention to the need for taxonomic research, particularly in simply navigable species identification tools. There has never been a greater demand for taxonomic knowledge than now, yet this hasn't translated into more taxonomists being trained or more money being allocated for the essential advancements in taxonomy. As an alternative, an increasing number of people without a background in taxonomy, including traders, customs officials, fisheries inspectors and observers, have been given the challenging and complex responsibility of identifying aquatic species. Often, these inexperienced users are given vague and inadequate information on the species they encounter and how to correctly identify them. In the countries and areas for which they are available, products such as the FAO Fish Finder Program's species catalogues and field guides can be helpful, and online tools like Fish Base and the Catalogue of Fishes can help answer queries regarding a species' correct scientific name. Accurately identifying aquatic resources under conservation and management regimes requires more work. In recent decades, several new and promising techniques for identifying fish have emerged, especially those based on genetics, morphometrics, hydroacoustics, picture recognition, and interactive computer software. With few exceptions, these developments in scholarly research have not yet been converted into apps that are easy for non-specialists to use, and they still need more funding to develop into tools that can be used anywhere in the world. Recently, there has been an increase in public awareness of the need for biodiversity conservation. Policymakers, funding organizations, and scientists worldwide have prioritized advancing knowledge and policies for this goal. This research sparked the awareness that taxonomic resources are rapidly disappearing globally and negatively affecting human survival and well-being.

Research Objective

This research aims to accumulate information about fish taxonomy and AI-assisted tools for photographing fish and analyzing their traits.

Literature Review

Researchers reveal that obtaining information about aquatic life is possible using AI technology tools. Imaging technologies based on machine learning algorithms provide data related to the tax background of species. Camera trap images provide evidence of the presence of species in the ecological systems. Machine learning technology is required to use this information to conserve species (Ala-Mantila, 2024).Studies reveal that understanding marine mammals provides insight into their biodiversity. The marine mammal conservation management system uses UAVs to get knowledge about fish species. the UAVs are specifically designed to study the diverse mammalian species(Álvarez-González et al., 2023).studies suggest that ETP species are effectively managed when fisheries report about the bycatches. However, most of the fisherman feel unsafe reporting about by-by catches. European sturgeon conservation activities are making efforts to make the reporting of bycatches easier by involving government bodies in the strategic plan-making process(Brevé et al., 2024).studies suggest that MPA has been developed to protect endangered or threatened species. Most marine species face threats due to increased tourist fishing activities. Such threatening species are saved in MPA. Also, using hybrid technology assists researchers in understanding the biodiversity of marine species conservation process, which is regulated by combining the AI approach with citizen sciences(Chen et al., 2024).scholars claim that marine life data is obtained through images and videos using image-based technology. To analyze a large database of marine images, researchers use interactive technology. interactive technology-based tools help assess large databases in a short period (Clark et al., 2024). Due to various climatic and environmental factors, the marine ecosystem faces many problems. the main problem is the loss of biodiversity in marine ecosystems. to assess the change in aquatic species' behavior, the use of MCS is made in managing marine ecosystems. The

MCS program is especially designated to develop strategies to sav marine ecosystem biodiversity ems (Coppari et al., 2024). Studies predict that the protection of deep-sea species is directly related to the development of effective conservation strategies. Automated technology systems are used to generate data related to the habitat of marine ecosystems. The deep sea reef biota identification process is carried out using deep learning technology(Deo et al., 2024).studies reveal that the speed of shark fish is related to its body shape. The two features that influence the speed of sharks in water are their fine shape and casual lobe asymmetry. Moreover, the shape of a shark's tail is a prominent feature that determines its speed index (Iliou et al., 2023).Studies suggest that various human activities impact the life of marine species.in VMEs, the protection of coral species is a great challenge. By obtaining seabed images, information regarding the coral reef species is attained. This information is assessed using a deep learning algorithm to determine the declining reef species. Then strategic palling is made to conserve these species and to maintain coral reef biodiversity(Jackett et al., 2023) Studies have claimed that microplastic presence has been detected in many ecosystems.AI technology is used for detecting the microplastic presence in various environments and ecosystems. FTIR is an AI technology employed to control pollution(Jin et al., 2024).studies reveal that the identification of larvae of species is determined using a deep learning approach. Pacific oyster aquaculture in-situ techniques are employed to detect larvae in a short time frame(Kakehi et al., 2024).Ecological studies have focused on understanding the impact of various natural and anthropogenic factors responsible for causing the decline of species. Bleaching events are one of the main factors causing the decline in coral reef species. To detect the impact caused by bleaching agents,, computerized image technology is used for underwater detection of species(Kopecky et al., 2023).studies reveal that sea debris is detected through the applications of deep learning algorithms (Moorton et al., 2024).studies conclude that Victoria Lake is rich in fish biodiversity and is a source of livelihood for a large number of people. However, due to continuous fishing activities and some environmental factors, the population of fish species in Victoria Lake is decreasing at a rapid rate; estimating the extinction of fish species, the fish teeth were obtained from the sediment of the sea that was assessed. the assessment of the fish tooth reveals that some important fish species have declined from Victoria Lake in the last few decades(Ngoepe et al., 2024). scholars suggest that marine population funds in marine caves are monitored using photogrammetry. the presence of benthic assemblages found in the marine cave is assessed by photogrammetry. SfM is another monitoring technique for species submerged in the marine cave(Pulido Mantas et al., 2023).Studies explain that enhanced technological tools are used to classify fish species based on their taxonomy. The biodiversity factor makes the fish species different from each other, and thus, their taxonomic classification process is performed using a deep learning approach. Moreover, the use of AI has suppressed the need for manmade methods for classifying fish fishes based on their taxonomic history(Wasik & Pattinson, 2024).to understand the behavior of aquatic species and to effectively manage aquatic life, the use of AI is made in the aquatic management system. The nature of fish species found in the aquatic ecosystem is determined using innovative AI technology. fish based food supply chain is managed through AI(Wing & Woodward, 2024).studies suggest that marine resources are used as food sources for people. Moreover, to detect the flow of marine species, bionic flexible sensors are used for tracking purposes. The performance of flexible sensors is higher than that of traditional sensors as bionic sensors provide reliable data(Xia et al., 2023).scholars studies reveal that the conservation of aquatic species is possible using AI-assisted management and conservation technology tools are effectively developed to provide the most authentic data about species' biodiversity status and strategies to conserve biodiversity(Xu et al., 2023).Studies reveal that to effectively manage species, AI is used to revolutionize the research process. Also, Anan advanced technology-based monitoring system is prefer to conserve the aquatic resources. studies suggest that the AI tool is an efficient tool implemented in various disease models to predict the onset of any disease in the ecosystem(Zhang et al., 2023).

Figure 1

Role of Fish Taxonomy in Biodiversity and the Evaluation and Management of Fisheries

For international communication about organisms, a standard name and indexing system are maintained by the global Code of Zoological Nomenclature. Among other things, the study of taxonomy offers techniques and recommendations for identifying species. The taxonomy research provides the tools for a regionally and globally recognized identification, even if it is mostly based on observations of traits that local fisherman may also employ. Fish Base, the book Fishes of the North-eastern Atlantic and the Mediterranean, several FAO catalogues, and regional checklists are all crucial taxonomic resources for fisheries. Despite the fact that naming, surveying, mapping, and taxonomic characterization of the world's freshwater and marine fish fauna are essential to a healthy fishery, the fisheries sector does not fully appreciate the significance of taxonomic work, especially in the boreal areas where "everything is known." Fish taxonomists are desperately required to offer trustworthy name standards and identification tools for fisheries purposes, as a lack of user experience or relevant taxonomic competence may actually or potentially have unfavorable consequences on fisheries management. Due to inadequate taxonomic support, fish stocks are being plundered in many parts of the world. However, without understanding which species are involved, ideally if subpopulations exist, and how to identify them, conservation strategies and long-term management cannot be developed. New species are constantly being found in South Africa, Japan, and Australia from new material and old museum specimens, even though these countries have published critical faunal guides. When investigating new resources, particularly aquaculture, taxonomic resources may also be important. It is generally recommended that taxonomists be involved in aquaculture to avoid costly mistakes caused by improper species identification, such as introducing a "new" species to areas where it (or a very similar form) already exists but is called by a different name.

Figure 2

Fish Taxonomy

Fish (plural: fish or fishes) are aquatic, anamniotic, gill-bearing vertebrates without limbs with digits. They have swimming fins and a rigid skull. The more widespread jawed fish, which includes all living cartilaginous and bony fish as well as extinct placoderms and acanthodians, and the more archaic jawless fish are the two categories of fish. Most fish are cold-blooded, and their body temperature varies with the water around them, while certain large, active swimmers, such white sharks and tuna, may sustain a higher core temperature. For instance, many fish may use sound to communicate with one another during courtship displays. Fish started out as small filter feeders during the Cambrian period and evolved into a wide range of morphologies during the course of the Paleozoic. The ostracoderms, the earliest fish with paired fins and respiratory gills, were shielded from invertebrate predators by their enormous bony plates, which served as exoskeletons. The earliest fish with jaws, plasmoderms, first appeared in the Silurian and saw a major period of diversification throughout the Devonian, frequently referred to as the "Age of Fishes." Bony fish, which are distinguished by the presence of swim bladders and later ossified endoskeletons, took over as the dominant group of fish after the end-Devonian extinction of the apex placoderms. Bony fish come in two varieties: lobe-finned and ray-finned. Teleosts, which include more than 96% of all living fish species, are a crown group of ray-finned fish with the ability to protrude their mouths. The tetrapods, a group of primarily terrestrial vertebrates that have dominated the top trophic levels in both aquatic and terrestrial habitats since the Late Paleozoic, replaced lobe-finned fish throughout the Carboniferous. They evolved lungs that breathed air, like swim bladders. "Fish" is a paraphyletic category because, despite the cladistic lineage, tetrapods are generally not considered fish.

An Industry Perspective on the Identification and Commercial Names of Fisheries Products

Today, the majority of the global fish trade is based on accurately identifying fish species and their exact, updated taxonomic ordering. A wider market trust and development will result from providing consumers with accurate and enough information about items and preventing fraud, wrongdoing, or deception. These topics are covered by laws in the majority of nations where the market for fish products has developed more, including the US, Japan, Australia, and the European Union (Member Organization). To what extent should this information be explicit or detailed? Is it troublesome to combine certain species for commercial interests, making it impossible for customers to tell the items apart by species? The responses vary depending on the technological and operational conditions in other nations and the customs and culture. When considering species identification for fishing goods, one should consider the following factors: technical, taxonomical, legal, commercial and operational. The commercial and operational components will consider each nation's or region's cultural tradition that shapes the perception of fish species. The type of fishery—large industrial fisheries that land tens of thousands of tons of fish or small-scale fisheries with limited amounts of catch—must also be taken into account. How should mixed-species capture that are challenging to separate be handled? The fact that around half of the captures are sold as fillets, portions, and developed products presents another challenge. Nonetheless, the ongoing Common Marketing Organization review might change the EU's (Member Organization) laws, which only apply to unprocessed fish and not developed fish products.

Figure 3

Selecting an Identification Tool

It is critical to keep in mind that the success of the activity may depend on selecting the right tool, or combination of tools, for a particular set of circumstances. Using the 24 scenarios described in the research paper, which reflect different contexts and situations necessitating the identification of aquatic species, and comparing the ID tools to a set of selection criteria, the following section aims to offer practical guidance regarding the best ID tools for particular purposes.

Users

Regarding their backgrounds and particular interests or goals, the potential users for aquatic species identification are a varied bunch. The "end user" and the "operator" are distinguished in the following. The individual or group who eventually needs the species information is known as the end user. On the other hand, the operator will identify the species and will be tasked with providing the data. Anyone from highly qualified taxonomists to laypeople lacking formal training or experience might potentially utilize fish identification tools. Fish identification is required for conservation, responsible use and trade, law enforcement, resource use (fisheries and aquaculture), environmental assessment, and responsible trade mechanisms (e.g. certification, non-detriment findings), as per the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Typical end users in this sector include fish farms, fish traders, law enforcement, environmental fisheries statisticians, stock assessment scientists, and fishermen. 2. Nonconsumptive applications include formal education (schools, universities, courses, etc.), tourism (such as diving, sports fishing, and touring), education, awareness-raising, aquaria and museums, and consumer information. Consumers, environmental non-governmental organizations, travel agencies, divers, aquarium employees, and aquatic tour operators are examples of typical end users in this industry. 3. Research and development, which includes scientific evaluations and surveys, fishing and sampling technique development, and fundamental research. Typical end users in this discipline include marine military authorities, ichthyology curators, bio aquatic and fisheries scientists and engineers, and governmental or private research funding sources.

Web-Based Fish Identification and Information Resources

Both specialists and non-experts may identify fish using a wide range of information and tools available on the internet. Web resources may be very helpful for verifying an initial identification and facts about a species. Bioecological and fisheries data and descriptions of diagnostic features and distribution maps may be found on Fish Base, Sea Life Base, FAO Fish Finder, and several other (typically local or regional) websites. Verifying the legitimacy of scientific names is another crucial use of online resources, especially for older publications, field guides, or keys. The most reliable source for finfish taxonomy names is the Catalogue of Fishes (CoF); however, if a name is not listed in the CoF, it can be obtained on Fish Base and Fish Wise Pro. For taxonomy information on aquatic invertebrate species, Sea Life Base, the World Register of Marine Species (Wo RMS), the Catalogue of Life (CoL), and the Integrated Taxonomy Information System (ITIS) are all excellent resources. The number of websites that provide help in identifying aquatic creatures is increasing. However, there isn't yet a generic platform that could point people toward the ideal identifying tool for their needs. Although this initiative is in its early stages, Identify Life could eventually offer such a platform. An overview of online identifying tools is given in the list below.

1. Identification by specialists: Discussion forum users, often informed amateurs who can connect them with professionals, respond to questions based on images (e.g. Fish Base forum40).

2. Recognition through visuals (pictures, films, drawings): It is possible to identify an unknown species by looking at species photos on specialized websites (where professionals assign images to species); however, this

usually requires experienced users who can drastically reduce the number of images that must be viewed in order to locate the species in question (e.g. Fish Base; World Atlas of Marine Fishes.

3. Online dichotomous keys: Dichotomous keys can be found online in a variety of formats, ranging from straightforward text transcription to more complex interfaces (like Lucid Phoenix42), with intermediate developments that make use of markup languages (like HTML and XML) and their navigational capabilities.

Conclusions

New identification techniques, particularly those based on species photos, morphometrics, and genetics, have shown much promise in this study and can be helpful in various contexts and applications. The use of these new ID tools is being hampered by a lack of money for sufficient research and expansion, despite these findings and the fact that few doubt the pressing need for better species identification in biodiversity conservation and sustainable resource management. The workshop participants' views and recommendations, which are aimed at managers and decision-makers in charge of research projects and programs that depend on collecting and identifying aquatic species, are included in the following. The scenarios have shown that various user groups have distinct needs when it comes to identifying fish and that creating new species ID tools and using current ones should be focused on achieving specific goals (for example, fisheries examiners would benefit from IRSs). Furthermore, instruction in the use of various documentation instruments is crucial, and it would be advantageous if, for instance, fish identification using various techniques were regularly covered in fisheries inspector training courses. Training should include new technology like online identification, genetic techniques, and computer imaging. Taxonomic goods like the field and concise guides created by the FAO Fish Finder Program are needed in various geographical areas. In order to include local fishermen in the sampling and reporting of catches, it was specifically recommended that field guides have comprehensive and accurate listings of local names. Due to a lack of definitions and guidelines, it is sometimes impossible to precisely identify early life phases. Particularly challenging to identify are larvae and juveniles, which may call for more specialized training and the development of unique identification tools, such as the establishment of a catalogue for early life stages' photographic identification (Al-Maqrashi et al., 2023). The workshop's experts acknowledged the great usefulness of online taxonomic resources. The sustainability of the existing financing for the Catalogue of Particularly questioned were Fishes and Fish Base, two of the most essential online taxonomic orientation tools for fishes. Providing identification keys, taxonomic and bio-ecological descriptions, geographic distribution maps, FAO names, local vernacular names, and fisheries information was emphasized as the Fish Finder Program's primary goal. Maintaining these programs and activities at a high scientific level is necessary for the correct assessment and management of fisheries and biodiversity. Experts believed that such local and regional inventories of expert-reviewed image sets of aquatic species may be most beneficial for all regions, and the photo-based IEK that was provided to the workshop (IPOFIS) was highly received. It was thought that these kinds of photographic inventory had to cover important biological and/or ecological traits, as well as all life phases and colour variations of a species. Various print and electronic products for species identification might be made using them. The development of systems like IPOFIS is now entirely possible, but costly and time-consuming. However, there is still a long way to go until there are practical automatic fish photo IRSs for local, maybe regional, and even global use. If such an application were to become sufficiently precise, it would be a significant step for a wide range of applications, such as mobile phones; specifically, IRSs for target species would be beneficial for fisheries management. After only a brief amount of initial training, non-experts can now identify fish with a high degree of accurateness due to a new morphometric identification tool called IPez. To be completely functional, it still needs additional fish species added to its database, but it already shows a lot of potential as a wonderful and reasonably priced tool for fish identification, such as in the context of fisheries management. It is known that genetic technologies have a lot of potential for uses where accuracy and resolution are essential. The experts noted that quality assurance and taxonomic key validation—that is, determining the correctness of fish identification using other methods—may also benefit from the use of genetic identification. (e.g., local users). This will require the development of simple and accurate genetic sampling and analysis methods. Genetic baselines for all commercial fishes in all places must be developed, nevertheless, because the global and frequent application of genetic identification techniques depends on the availability of a genetic reference collection. Furthermore, in order to satisfy consumer demands, it is advised to create better markers for the identification of transgenic organisms as transgenic fishes may be commercialized in the future.

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