International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Review on Fish Identification Tools and Their Importance in Biodiversity and Fisheries Assessments

Adil Sidahmed Omer*

Department of Environment &Natural Recourses, Faculty of Applied Sciences, Red Sea University, Sudan
Email: adilomer12@rsu.edu.sd

Abstract

The present review provides an appraisal of existing, state-of-the-art fish identification (ID) tools and shows their potential for providing the right solution in different real-life situations. The ID tools reviewed are: Use of scientific experts (taxonomists) and folk local experts, taxonomic reference collections, image recognition systems, field guides based on dichotomous keys; interactive electronic keys (e.g. IPOFIS), morphometrics (e.g. IPez), scale and otolith morphology, genetic methods (Single nucleotide polymorphisms [SNPs] and Barcode [BOL]) and Hydroacoustics. It is expected that it will help fisheries biologists, environmental administrators and other end users to select the best available species identification tools for their own purposes.

Keywords: identification; tools; fisheries; experts; species.

1. Introduction

Fishes show an astonishing diversity of shapes, sizes, and colours. The delimitation and recognition of fish species is not only of interest for taxonomy and systematics, but it is also a requirement in studies of natural history and ecology, fishery management, tracking the dispersal patterns of eggs and larvae, estimations of recruitment and spawn areas, and authentication of food products [1]. Fish identification is traditionally based on Morphological features. However, due to high diversity and morphological plasticity, in many cases, fish and their diverse developmental stages are difficult to identify by using morphological characteristics alone.

---

* Corresponding author.

Although the need for taxonomic expertise has never been as pronounced as it is today, this has not translated into training more taxonomists and providing more funding for necessary developments in taxonomy [4,6]. Instead, more and more individuals without a taxonomic background, such as fishery inspectors and observers, customs officers, data collectors, traders and others, have been tasked with the complex and often difficult assignment of identifying aquatic species. These less- experienced users are often faced with confusing and inadequate information on the species they encounter and how to identify them reliably. Products such as the species catalogues and field guides produced by the FAO Fish Finder Programme can help in countries and regions for which they exist, and web resources, such as Fish Base [8,10] the Catalog of Fishes [9] offer guidance to resolve issues regarding the correct scientific name for a species. Nonetheless, greater efforts are needed to ensure a correct identification of aquatic resources under management and conservation regimes. In recent decades, many new and promising techniques for the identification of fishes have emerged, in particular based on genetics, interactive computer soft- ware, image recognition, hydroacoustics and morphometrics. However, with few exceptions, such advances in academic research have not yet been translated into user-friendly applications for non-specialists and still require further investments to mature into globally applicable tools [16]. Public consciousness about the need to conserve biodiversity has recently been growing. In all parts of the world, policy-makers, funding agencies and scientists have made it a priority to advance policies and knowledge for this purpose. This interest was prompted by the realization that taxonomic resources around the world are declining at a rapid pace and that this is having a negative impact on human well-being and survival. It has become clear that taxonomic information is not a luxury – it is a real need in a world with a still-growing human population generating enormous pressure on natural resources. More and more organisms are shipped around the world and marketed continents away from their origins, thus generating an increased need for global fish identification tools to provide reliable information to consumers, customs officers and fishery inspectors. However, worldwide, there exist more than 32 500 species of fin fishes and the amount of information required to separate them all is extremely difficult to process; therefore, fish identification is usually conducted at local or regional scales [3,15]. The increasing globalization of fishery products thus introduces new challenges to the identification of aquatic organisms. In addition, new emerging applications require accurate species identification (e.g. marine hydrokinetic energy and ocean observatories). The collection of species- and population-specific information for the purpose of sustainable fishery management has a long tradition. For many decades, FAO has been collecting global statistical catch data and analyzing the results in two of its flagship publications: (i) The State of World Fisheries and Aquaculture and the Review of the state of world marine fishery resources. While progress has been made in the reporting of fishery data, much improvement is still needed for a more reliable and comprehensive assessment of the stock status of many commercially exploited aquatic species. Not only the taxonomic resolution of catch data could be better for many areas and species, but there is a real concern about the proportion of possible misidentifications in the catch statistics received by FAO, with severe implications for the ability to manage aquatic organisms sustainably [12]. With its Fish Finder Programme, FAO has contributed to improving fish identification everywhere and produced more than 200 species identification guides including taxonomic descriptions for more than 8 000 species and an archive of more than 40 000 scientific illustrations

[2,5]. Although the program struggles owing to funding constraints and competing priorities at FAO, it continues generating products to assist with fish identification in many parts of the world.

2. Fish Taxonomy in Biodiversity and Fishery Assessment and Management

A stable naming and indexing system is essential to global communication about organisms, and such a system is maintained by the International Code of Zoological Nomenclature. The science of taxonomy, among other things, provides the methods and the manuals for the identification of organisms. Although largely based on observations of characters that local fishers may also use, taxonomic research offers the tools for a regionally and globally valid identification. Some examples of fundamental taxonomic tools for the use in fisheries include Fish Base [11], the book Fishes of the North-eastern Atlantic and the Mediterranean and a series of catalogues and regional checklists provided by FAO. Although surveying, mapping, taxonomic characterization, and naming of the global marine and freshwater fish fauna are fundamental to a healthy fishery, the importance of taxonomic work is not fully recognized in the fisheries sector, particularly not in the boreal regions where "everything is known". However, a lack of pertinent taxonomic information or lack of user experience can actually or potentially lead to undesired consequences for fishery management, and fish taxonomists are urgently needed to provide reliable name standards and identification tools for fishery purposes. In many regions of the world, fish stocks are being exploited without much taxonomic assistance. However, it is impossible to develop conservation plans and long-term management without knowing what species are involved, and preferably also whether subpopulations exist, and how to identify them. Important faunal guides have been published by South Africa, Japan and Australia, but in these regions new species continue to be discovered, both from fresh material and from old museum specimens [2,3,7].

Taxonomic resources may also play a role in prospecting for new resources as is done particularly in aquaculture. Involving taxonomists in aquaculture is always recommended in order to prevent expensive errors based on the erroneous identification of species, e.g. to avoid a "new" species being imported to locations where it (or a very similar form) already exists but is known under an incorrect name.

3. Species IdentificationTools

Species Identification Tools included in this review

This review covers most methods that are currently used for the identification of aquatic species. They include traditional, long-trusted and tested tools, such as the use of trained taxonomists, reference collections or field guides based on dichotomous keys, as well as more recently developed tools, some of which are still in the experimental stage, e.g. image recognition systems (IRSs), interactive electronic keys, computer-based morphometric identification (IPez) and genetic methods. In addition, the use of local (folk) expertise, scales, otoliths and hydroacoustics are reviewed.

A few methods are not assessed in detail as they are either too generic, e.g. identification of fishes by browsing images (using the web), or because they are of limited application, e.g. the use of bones, animal

sounds or electric signals (Table 1)

Table 1: Species Identification Tools

CATEGORY	METHODS REVIEW	METHODS NOT REVIEWED
WHOLE ORGANISMS		
Expert authority	t Scientific expert (taxonomist) onsite t Folk local experts	
Images/specimen only	t Local reference collections t Image recognition systems	Image browsing (addressed under web tools)
Identification keys, text- and/or image-based	t Field guides based on dichotomous keys: printed or electronic products; may use text or images for characters and taxa t Interactive electronic keys, e.g. IPOFIS t Polythetic keys; morphometrics, e.g. Ipez	
BODY PARTS		
Anatomy	t Scales t Otoliths	Bones (addressed under web tools)
Genetics	t With SNPs t With BOL	
EXTRINSIC AND OTHER ATTRIBUTES		
Acoustics	t Hydroacoustics	Sounds produced by organisms
Electrics		Electric signals[Note]

Source: Fischer, J. ed. 2013

3.1 On-site Taxonomist

Trained taxonomists, preferably with a PhD in systematic biology and postdoctoral experience, are familiar with a large number of species and have specialist competence in a special group (e.g. a family or a fauna). They know about nomenclatural rules and morphometric methods for species identification and have a high awareness of the level of accuracy of their identifications. Moreover, they usually identify species

relatively quickly. There may be conceptual differences between individual taxonomists that could lead to limited repeatability of certain identifications, but the accuracy should still be high. Taxonomists are most helpful with fresh or preserved whole specimens. However, there is a severe lack of taxonomists in many regions limiting the access to this ID tool.

3.2 ID-tool: Local (folk) expert

Folk taxonomies are systems of categorization created by non-scientists in order to organize, name, and understand the natural world. Folk taxonomies frequently diverge on some points from the phylogeny established by the scientific study of taxonomy but they also tend to align with scientific classifications on other points. Sometimes, folk taxonomies lump together many biological species under a single name, or place species from several different biological orders in the same group.

Sometimes there is one-to-one correspondence, and sometimes folk taxonomies differentiate where scientific taxonomies do not. Differentiation between types in folk taxonomies is determined by a wide variety of attributes, some of which may not be immediately obvious to outsiders; morphology and behavior are important but so are the cultural significance and practical utility of the species constituting each group.

3.3 Local reference collection

Reference collections consist of preserved specimens of whole fish, otoliths, disarticulated bones, scales, pharyngeal bones, or similar body parts used in identification work. Local reference collections are mainly found in research institutions (and fisheries agencies) and are dedicated to a restricted geographical area (or a special purpose research).

Local reference collections may be a sufficient tool for identification work in a restricted area and reduce the need for expert consultancy, keys, field guides and other methods. They are especially useful for smaller institutions in field-like situations and can be used also for continuous training of new staff.

3.4 Image recognition system

In this method, the user provides a photograph (image) of the fish as input and a software (IRS) identifies the fish to a taxonomic level. The identification process is based on the automatic characterization of image visual properties (e.g. color, texture and shape) using computer vision techniques, i.e. image retrieval and/or classification approaches that exploit feature vectors and similarity functions. Image processing methods are used to encode visual properties into feature vectors, and similarity functions are used to compute the similarity of two images by taking into account their feature vectors.

3.5 Field guides based on dichotomous keys

Diagnostic taxonomic keys are a common traditional means to identify organisms, and they form an

important part of most field guides. A taxonomic key is an ordered sequence of alternative choices, as provided by diagnostic (morphological) characters of organisms, that leads to a reliable identification of an organism or class of organisms. Diagnostic characters used in a key are defined and may be illustrated for clarity. The formal or taxonomic scope of a key is usually restricted to printed material or presented in digital format.

3.6 Integrated Photo-based Online Fish-Identification System (IPOFIS) exemplifying Interactive Electronic Keys (IEKs)

An IPOFIS is a photo-based online fish identification system that integrates three methods: visual inspection, dichotomous keys, and a multi attribute query procedure. Each fish species is represented by multiple color photographs of different individuals and close-ups of important identification features. The system efficiently organizes and presents these photographs and associated morphometric information in an interactive format that facilitates fast and accurate identification. An IPOFIS is designed to be applied by users with no scientific training. Costs are relatively low and are generally limited to online access on a computer. The time required for fish identification generally ranges from 3 to 30 minutes, depending on how distinctive the specimen is.

3.7 IPez (morphometric software)

IPez is an automated, computer- software-based species identification system for marine and freshwater fish species. It uses a large number of morphometric measurements and it is based on machine learning techniques.

One day of training is needed in order to learn how to use the system. The user needs a computer, and the time required for fish identification will usually be lower than five minutes and depends on the user's expertise. The software can generate results with100 percent accuracy provided it has been fed with baseline measures of at least 15 to 20 individuals of different sizes per species.

3.8 Scales

Fish scales have been extensively used in fish species identification since the early1900s. Not only is their count important in key classification; also descriptions of their shape and particular features have been used in keys to recognize families or distinguish between close species. Moreover, alternative methods of shape analysis, based on landmark data, have found wide applicability in biology because of the natural links between homologies and measurements, the statistical properties of the resulting shape spaces and good statistical power. Fish-scale shape is especially useful for discrimination among genera, species and also sympatric populations.

3.9 Otoliths

The use of otoliths for species and stock identification is well established. While this method is more

laborious than the use of fish scales and also requires more knowledge and training, its superior accuracy (exceeding 80 percent for congeneric species) can justify the additional effort. The main limitation of this ID tool consists in its destructiveness (the extraction of otoliths kills the fish) and in the fragility of the otoliths (they easily break during extraction and manipulation). In addition, the morphometric analysis is difficult because of the concave form of otoliths and overall variability of shape.

3.10 Genetic identification through single nucleotide polymorphisms (SNPs)

Single nucleotide polymorphisms (SNPs) are single mutational differences among individuals at specific loci in the genome that are typically distributed throughout the genome of individuals and are highly abundant. At the population level for example, the frequencies of the various mutational differences can yield population- specific genetic signatures. Importantly, the SNPs to be applied can be readily tailored to accommodate a wide range of differing levels of genetic differentiation, also at spatial scales relevant for fishery policy and management. To enable the use of SNPs for fish population identification, a genetic baseline has to be created. Specimens of a given species are collected across a geographical range and SNPs identified that reveal population-specific genetic signatures. A major asset of DNA-based analytical procedures is that they can be applied throughout the food supply chain, from whole specimens to trace samples (e.g. scales and fins), through to highly processed fish products. In addition, DNA analysis is readily used not only on contemporary fish samples but also on archived historical material (e.g. bones and/or scales from museums, and archived otoliths from fishery agencies).

3.11 Genetic Identification Using Barcoding

Barcoding is defined as the use of a standardized short region of DNA to verify species identity, which typically for fish is the CO1 region of mitochondrial DNA, with the generation of publicly accessible and highly comparable data. All publicly accessible data are available from one website (Barcode of Life Database), and information on specimen vouchers, photographs and other biological information is available from the same site (fish barcode of life(on line)). Currently, the practice relies on high throughput DNA sequencing, which is typically undertaken by commercial sequencing centers. Effort is currently being put into the development of hand-held barcoding devices for use in the field.

3.12 Acoustic Fish Identification

Active acoustic technologies use sound to sample distributions, densities, individual lengths and, potentially, species through the entire water column. A pulse of sound is sent into the water, and then reflected echoes are used to derive the location and size of individual and aggregations of fish and zooplankton. Two current technologies used include echo sounders with single or multiple discrete frequencies, and broadband sonars that transmit a continuous frequency band. Analytic techniques compare echo amplitudes from single animals or aggregations as a function of frequency. In addition to identification algorithms, trawl samples are regularly used to verify the identity of acoustic targets.

4. Conclusion

Each of the presented species ID methods has its particular strengths and weaknesses, and its best uses depend on the requirements and available resources for the fish identification. The selection of the best species ID tools should start at the planning level of an activity and consider budgetary and staffing implications.

Acknowledgment

The author would like to thank everyone contributed in a way or another while conducting this piece of work.

References

[1]. Anderson, C.I.H, J.K. Horne, and J. Boyle. Classifying multi-frequency acoustic data using a robust probabilistic classification technique. J. Acoust. Soc. Am.121: EL230-EL237, 2007

[2]. Cutter, G.R. and D.A. Demer. Accounting for scattering directivity and fish behaviour in multibeam-echosounder surveys. ICES J. Mar. Sci. 64: 1664, 2007

[3]. Fernandes, P.G. Classification trees for species identification of fish-school echotraces. ICES J. Marine Sci. 66: 1073–1080, 2009

[4]. Haralabous, J. and S. Georgakarakos. Artificial neural networks as a tool for species identification of fish schools. ICES J. Marine Sci. 53: 173–180,1996

[5]. Horne, J.K. Acoustic approaches to remote species identification: a review. Fish. Oceonogr. 94: 356–371, 2000

[6]. Information on http://en.citizendium.org/wiki/Folk_taxonomy

[7]. Information on www.fish bol.org/ fish barcode of life.

[8]. Information on www.fishbase.org/search

[9].Informationonhttp://researcharchive.calacademy.org/research/ichthyology/catalog/collections.asp

[10]. J. Fischer ed. Fish identification tools: review and guidance for decision-makers. FAO Fisheries and Aquaculture Technical Paper No. 585. Rome, FAO.107 p, 2013

[11]. Kang, M., M. Furusawa, and K. Miyashita.Effective and accurate use of dif- ference in mean volume–backscattering strength to identify fish and plank- ton. ICES J. Mar. Sci. 59: 794–804, 2002

[12].Kloser, R.J., T. Ryan, P. Sakov, A. Williams, and J.A. Koslow. Species identifi- cation in deep water using multiple acoustic frequencies. Can. J. Fish. Aquat. Sci. 59:1065–1077, 2002.

[13]. Korneliussen, R.J. The acoustic identification of Atlantic mackerel. ICES J,2010 [14]. R. Froese & D. Pauly eds. 2013.

[15]. Rose, G.A. and Leggett, W.C . Hydroacoustic signal classification of fish schools by species. Can. J. Fish. Aquat. Sci. 45: 597-604, 1988

[16]. Scalabrin, C. and J. Massé. Acoustic detection of the spatial and temporal distribution of fish shoals in the Bay of Biscay. Aquat. Living Resour. 6:269–283, 1993