



## CHAPTER 5

# Basic Techniques in Fish Taxonomy

In the global context, approximately 36088 valid marine and freshwater species under 515 families and 5213 genera (Nelson, 2006; Fricke et al. 2021). A stable naming and indexing system is essential for global communication about organisms and this system is maintained by the International Code of Zoological Nomenclature. The species are named according to the protocol set by Linnaeus' binomial nomenclature system (Enghoff, 2009). The identification and description of fish species is important not only for taxonomy and systematics but also for natural history and ecology studies, fishery management, tracking the dispersal patterns of eggs and larvae, estimations of recruitment and spawn areas, and food product authentication (Anderson et al. 2007; Fischer, 2013).

Among other things, the science of taxonomy provides methods and manuals for identifying organisms. Taxonomical aids are tools that help us identify and classify organisms when studying taxonomy. The tools used to identify plants and animals are not the same. Plant taxonomy can be studied with the help of a herbarium and a botanical garden. Museums, Taxonomical Keys, and Zoological and Marine Parks are all traditional tools in animal studies. Field visits, surveys, identification, classification, preservation, and documentation are all important components of taxonomical tools. For taxonomical studies, a variety of tools are used; some of the most important tools are discussed below.

### 1) Expert authority

#### *On-site taxonomist*

A taxonomist is an expert who is familiar with a large number of species and has specialised knowledge in a specific group. They are well-versed in nomenclatural rules and morphometric methods for species identification, and they are aware of the precision with which their identifications are made. Individual taxonomists may have conceptual differences that limit the repeatability of certain identifications, but the accuracy should still be high.

#### **Advantage**

They can usually identify species quite fast, and expert judgements made on-site by taxonomists are ready to use. The use of a taxonomist is really convenient.

**Disadvantage**

Unavailability and scarcity of experts in a specific field, and if they are available, inaccessibility to the general public and high consultation fees. A taxonomist may specialise in one or more taxonomic groups or geographical areas.

***Folk expert***

Local fishermen and residents living near a river, a wetland or coastal waters would learn to identify fish at an early age. This is due to long-term observational knowledge and memory, as well as oral tradition passed down from elders. Many researchers have incorporated such traditional knowledge into modern ichthyology (Calamia, 1999; Drew, 2005; Stacey et al. 2008; MacLean et al. 2009; Ferreira et al. 2014), and the term for it is “traditional ecological knowledge” (TEK) (Berkes et al. 2000).

**Advantages**

It takes less time, no consultation charge

**Disadvantages**

Folk taxonomies do not follow scientifically established norms and classification. They lump together many biological species under a single name, or place species from several biological orders in the same group.

**2) Local reference collection**

Local reference collections are primarily found in research institutions and are geographically limited. Whole fish, otoliths, disarticulated bones, scales, pharyngeal bones, and other body parts preserved in reference collections are used in identification work. Local reference collections may be an adequate tool for identification work in a limited area, reducing the need for expert consultation, keys, field guides, and other methods. They are especially useful for smaller institutions in field-like situations, and they can also be used for ongoing staff training.

**Advantages**

Local collections have ready-to-use reference specimens that can be compared immediately to the organism for which identification is required. The skill required is relatively low and only a minimal amount of introductory training usually is sufficient for an operator.

**Disadvantages**

Transferability is limited because fauna differs throughout geographic regions and local collections typically only contain the fauna of the relevant geographical area.

**3) Image recognition system**

In this method, the user provides a photograph (image) of the fish as input, and the fish is identified to a taxonomic level using software (IRS). The identification process is based on computer vision techniques, such as image retrieval and/or classification approaches that use feature vectors and similarity functions to automatically characterise image visual properties (e.g. colour, texture, and shape).

**Advantages**

Desired identifications should be achieved with minimal effort, resulting in high and immediate usefulness as well as the highest level of reproducibility possible. A bit of training may be required to get started with the procedure. Software is easily available at free of cost.

**Disadvantages**

The transferability and resolution are somewhat limited because the fauna will differ between geographic regions, and, therefore, the characterization of fish image properties (e.g. colour, texture and shape) may vary for the same species from different regions.

**4) Dichotomous keys**

Diagnostic taxonomic keys are a common traditional method of identifying unknown specimens based on diagnostic (morphological) characters refer to measurable structures such as fin lengths, head lengths, eye diameters, or ratios between such measurements, and meristic characters that correspond to body segments such as countable structure including number of scales, gill rakers, cephalic pores, and so on, that leads to a reliable identification of an organism. A dichotomous key is a set of statements with two options that describe characteristics of unidentified organism's features. The user must decide which of the two statements best represents the unknown organism, based on that choice, then proceed to the following series of statements, ultimately ending in the identity of the unknown.


**Advantages**




Keys are logical choice systems that are easy to use by both unskilled and highly skilled individuals.

**Disadvantages**

If a single wrong decision is made at any juncture, a wrong identification will result.

**As an example for identifying US Atlantic shark species using dichotomous key.**

<p>1a) Body flattened dorso-ventrally, skate-like in appearance.</p>	 <p><i>Squatina dumeril</i> – Atlantic angel shark</p>
<p>1b) Body round in cross section.</p>	<p>Go to question 2</p>

<p>2a) Seven gill slits, single dorsal fin.</p>	 <p><i>Heptranchias perlo</i> – sharpnose sevengill shark</p>
<p>2b) Six gill openings, single dorsal fin.</p>	<p>Go to question 3</p>
<p>2c) Five gill openings, two dorsal fins.</p>	<p>Go to question 4</p>
<p>3a) Snout short, blunt and broad; eye small; distance between rear base of dorsal fin and origin of caudal fin about 1.5 to 2 times length of dorsal fin base; lower jaw with six rows of teeth.</p>	 <p><i>Hexanchus griseus</i> – bluntnose sixgill shark</p>
<p>3b) Snout more pointed and narrow; eye large; distance between rear base of dorsal fin and origin of caudal fin about 2.5 to 3 times length of dorsal fin base; lower jaw with five rows of teeth.</p>	 <p><i>Hexanchus nakamurai</i> – bigeye sixgill shark</p>

(Photo Source: Fishbase)

## 5) Ipez (morphometric software)

Ipez is a tool for taxonomic identification of fish that is based on machine learning techniques. It successfully recognises all new members of this species that aren't already in the database. The key morphometric features that have promoted or are promoting divergence among closely related species can be determined by this software. The software is available for download for free at <http://www.ipez.es/index%20ingles.html>. To learn how to operate the system, you'll need one day of training. A computer is necessary, and the time required for fish identification is usually less than five minutes, depending on the user's ability.

## 6) Biochemical taxonomy

Proteins are the building blocks of all biological processes. Each species is chemically made up of different proteins at varying levels. Proteomics is a large-scale examination of proteins in a biological system at a specific time. Proteomics encompasses not only the study of protein structure and function but also protein modifications, protein interactions, protein intracellular

localization, and protein abundance quantification. Proteomics has been used to identify a variety of seafood species, including mussels (Lopez et al. 2002) and shrimps (Ortea et al. 2009); however, it has rarely been employed to authenticate Teleostei species.

#### **Advantages**

Helps to identify protein modification, intracellular localization and protein abundance quantification

#### **Disadvantages**

Not cost effective. Technologically demanding

### **7) Molecular method**

Molecular taxonomy is the identification of specimens based on molecular rather than morphological characters. Molecular technique has become a major tool for systematics at the species level and above. Because all organisms contain DNA, RNA, and proteins but closely related organisms show a high degree of similarity in molecular structures, especially nuclear DNA and mitochondrial DNA have become increasingly useful at all levels of classification.

#### ***DNA-Based Methods for Species Identification***

DNA based taxonomy system provides a new scaffold for the accumulated taxonomic knowledge and is a convenient tool for species identification and description. DNA polymorphisms, or genetic variations that emerge as a result of naturally occurring mutations in the genetic code, are used to identify genetic species (Liu and Cordes 2004). DNA is taken from the target organism and then the DNA fragment(s) of interest is amplified using PCR to discover species-specific genetic variations. The resulting PCR amplicons are then analysed to reveal the characteristic polymorphisms. Molecular markers can be categorized into two classes, nuclear DNA which includes random amplified polymorphic DNA (RAPDs), amplified fragment length polymorphisms (AFLPs), variable number of tandem repeats loci (VNTRs: minisatellites, microsatellites), and single nucleotide polymorphisms (SNPs) and mitochondrial DNA (mtDNA) markers includes Barcoding which is widely used today.

#### ***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 are available from the same site. Cytochrome oxidase subunit I gene (COI) which has been proposed as a global bio-identification system for animals. Barcoding to be successful, within-species DNA sequences need to be more similar to each other than to sequences of different species. Successful barcoding will facilitate identification of fishes, linking larvae with adults, forensic identification of fish fillets and other items in commerce, and identification of stomach contents.

#### **Advantages of molecular taxonomy**

Molecular entities are strictly heritable. The description of molecular features is unambiguous. There is some regularity to the evolution of molecular traits. Molecular data are amenable to

quantitative treatment. Homology evaluation is less difficult than morphological characteristic evaluation. There is a plethora of molecular data available.

### **Disadvantages**

Homoplasy is more prevalent in nucleotide sequences than in morphological features. Homology between characters is not always easy to determine, and require an intensive training time.

### **8) Integrated approach to fish taxonomy**

Modern taxonomy in general is heading towards an integrated approach to taxonomy (Osterhage et al. 2016), especially in case where ambiguities are to be resolved among highly cryptic species. Integrated taxonomy compiles and analyse taxonomic information from all the available resources like classical taxonomy (morpho-meristic features) and modern tools (DNA based methods). The integrated approach most often provides a better resolution than the individual methods. Further, the classical approach to taxonomy itself has evolved substantially and provides much more insights than ever before. Classical taxonomy mostly revolves round the observation of external characters like major morphometric measurements or counts and subsequently on anatomical features like neurocranium, facial bones, caudal vertebrae, etc (Alexandre and Menezes, 2007). At present, in addition to these, even shapes of otolith and scales have been incorporated in species differentiation and description (Jawad and Al-Jufaili, 2007). The science of taxonomy also changed in the way the morphological data is being collected. Presently, several images based techniques like truss networks or fourier descriptors are used to objectively represent the morphometry and shape of the species (Pavlov, 2016; Renjith et al. 2014; Afanasyev et al. 2017; Gupta et al. 2018). These advancements in the classical approach to taxonomy and support extended by molecular science are given rise to an integrated approach to taxonomy, which is now being accepted as best practices in taxonomy.

### **9) Web-based fish identification and information resources**

Experts and non-experts can find a lot of information and tools on the internet to help them identify fish. Web resources are especially useful for double-checking species information and confirming a first identification. Many other (typically local or regional) sources, such as FishBase ([www.fishbase.org](http://www.fishbase.org)), SeaLife Base ([www.sealifebase.org](http://www.sealifebase.org)), FAO FishFinder online ([www.fao.org/fishery/fishfinder/en](http://www.fao.org/fishery/fishfinder/en)), publications, and many others, offer descriptions of diagnostic features and distribution maps, as well as bio-ecological and fisheries data.

Another important use of web resources consists in confirming the validity of scientific names (in particular for older publications, field guides or keys). The Catalog of Fishes (<http://research.calacademy.org/ichthyology/catalog>), is the most authoritative site for taxonomic names of finfishes but FishBase and FishWisePro ([www.fishwisepro.com](http://www.fishwisepro.com)), may be used if the name is not found in the CoF. SeaLifeBase, World Register of Marine Species (WoRMS) ([www.marinespecies.org](http://www.marinespecies.org)), Catalogue of Life ([www.catalogueoflife.org](http://www.catalogueoflife.org)), and the Integrated Taxonomic Information System ([www.itis.gov](http://www.itis.gov)), are good sources for taxonomic information on invertebrate aquatic species.

There are an increasing number of websites that can help you identify aquatic species. However, there is currently no generic platform that can route consumers to the optimal identifying tool for their needs.

### Suggested Readings:

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