REVIEW ARTICLE

SIGNIFICANCE OF MORPHOLOGICAL STUDY OF FISHES FOR MOLECULAR AND TAXONOMIC RESEARCH

Dhanshree M. Jagtap* and Dnyaneshwar S. Rathod

Department of Zoology and Fishery Science,

Rajarshi Shahu Mahavidyalaya, [Autonomous] Latur 413512 Maharashtra

Corresponding author E-mail: jagtapakshu09@gmail.com

DOI: https://doi.org/10.5281/zenodo.15156133

Abstract:

Fish morphological studies form a crucial foundation for molecular research, aiding in accurate species identification, taxonomy, and evolutionary analysis. Examining external traits like fins, scales, and body shape provides essential data for guiding molecular phylogenetic studies and interpreting outcomes such as DNA barcoding. Morphological features reveal how fish adapt to environments and help identify potential molecular markers. Despite advancements in genetics and other fields, morphology remains central to ichthyology, supporting conservation and management efforts. Modern techniques like image analysis and 3D scanning complement traditional methods, enhancing the precision of morphological investigations and their integration with molecular tools for comprehensive fish research.

Keywords: Fish, Morphological Study, Molecular Study.

1. Introduction:

Fish morphological studies are essential for molecular research because they set the basis for studying fish diversity, evolution, and taxonomy all of which are important for correctly analyzing molecular data and identifying the correct species. The primary strategy for identifying fish species is to study fish morphology, which includes external characteristics like fins, scales, and body form. This is a crucial starting point for any molecular study. Molecular phylogenetic studies can be led by morphological features that highlight the evolutionary links among various fish species. Understanding fish ecology and evolution needs an awareness of their morphological characteristics, which show how they have adjusted to their surroundings.

Researchers can find possible molecular markers (DNA regions) that can be utilized to differentiate between species or populations by comparing or contrasting morphological features. By offering context and confirming the results, morphological data might assist researchers in interpreting the outcomes of molecular investigations like DNA barcoding or phylogenetic trees. Morphological studies are a vital component of conservation and management initiatives, which depend on accurate species identification and understanding of fish diversity.

For taxonomic and evolutionary research, fish morphology has traditionally been the main source of data. Even though genetic, physiological, behavioral, and ecological data are valuable and readily available for these kinds of investigations, systematic ichthyologists still primarily rely on morphology to determine taxonomic traits. A species' distinctive sizes, forms, color patterns, fin arrangement, and other outward characteristics help in identification, categorization, and recognition. Furthermore, dissection or other interior examination techniques can be used to analyze significant features. Important morphological characteristics and study techniques are described in this chapter (1). Traditional approaches like measuring body components and counting fins, scales, and spines (meristics) are combined with more sophisticated methods like image analysis, 3D scanning, and molecular tools to investigate fish morphology.

2. Traditional Methods:

2.1 External Anatomy:

Examining and recording a fish's outward characteristics, including its body shape, scales, fin types, and colors.

2.2 Morphometric Study:

For the purposes of identification, comparison, and growth and maturity research, morphometric measurements of fish entail measuring several dimensions of their body, such as length, width, height, and fin lengths (2).The operculum and lateral line are examples of the body elements that make up a fish's external anatomy. The pectoral and pelvic fins are the two pairs of fins that make up fish fins. The dorsal, anal, caudal, and adipose fins are among the fins that are not paired.

Common Morphometric Measurements:

- **Total Length (TL):** The fish's whole length, measured from the tip of its snout to the tip of its caudal fin (tail), is known as its total length
- **Standard Length (SL):** The length of the fish from the tip of the snout to the end of the vertebral column (midpoint of the caudal fin base).
- **Fork Length (FL):** The distance between the the tip of its snout and caudal fin fork.
- **Head Length (HL):** The measurement of the head's length from the snout tip to the operculum's (gill cover) posterior end.
- **Body Depth (BD):** The vertical distance, usually at the deepest point, between the body's dorsal and ventral midlines.
- **Eye Diameter (ED):** The measurement of the eye’s diameter.
- **Snout Length (SNL):** The distance between the front margin of the eye and the tip of the snout.
- **Pre-dorsal Length (PDL):** The measurement of distance between the tip of the snout to the dorsal fin origin.
- **Pre-pectoral Length (PPL):** The measurement of distance from the tip of the snout to the pectoral fin origin.
- **Pre-pelvic Length (PVL):** The measurement of distance from the tip of the snout to the pelvic fin origin.
- **Caudal Peduncle Length (CPL):** The length of the narrow portion of the body that comes before the caudal fin is known as the caudal peduncle length
- **Caudal Peduncle Depth (CPD):** The depth of the caudal peduncle is known as the caudal peduncle depth .
- **Fin Measurements:** Dorsal, pectoral, pelvic, anal, and caudal fin lengths and heights(3,4).

2.3 Meristics:

Meristic analysis involves the detailed counting and measurement of specific, repeatable features of a fish, commonly used in fish taxonomy, systematics, and ecology. These "meristic characters" or "meristic traits" are essential for distinguishing species or populations, understanding their evolution, and interpreting their ecological adaptations.

Meristic characters are countable traits or features that are usually consistent within a species but may vary across species or populations. The most common meristic traits include:

- **Fins**: Number of fin rays or spines in different fins.
  - Dorsal fins (back)
  - Pectoral fins (sides)
  - Pelvic fins (lower sides)
  - Anal fins (ventral side)
  - Caudal fin (tail)
- **Scales**: Counting the number of scales in certain regions.
  - Lateral line scales (scales along the body's midline).
  - Scales along the back or belly.
- **Gill Rakers**: The number of gill rakers, which are comb-like structures on the gills.
- **Vertebrae**: Counting the number of vertebrae in the spinal column.
- **Lateral Line Pores**: The pores or scales that make up the lateral line, which helps fish detect movement and vibration in the water.

Other meristic features could include:

- Teeth count
- Fin spines count
- Number of branchiostegal rays (which support the gill arches)

3. **Advanced Techniques:**

Advanced techniques for studying fish morphology involve modern technologies that provide more precise, detailed insights into the structure and function of fish. Key techniques include:

3.1. 3D Morphometric Analysis

3D morphometrics uses modern imaging technology to analyze the shape and size of biological structures in three dimensions. Unlike traditional 2D measurements, 3D morphometrics provides a more accurate and comprehensive understanding of morphological variation.

Techniques Involved:

- Surface Scanning: This technique uses laser scanners, structured light scanners, or 3D photogrammetry to capture the external shape of the fish. These technologies can create detailed, accurate 3D models of the fish's body or specific parts.
- Geometric Morphometrics: This method focuses on quantifying and analyzing the geometric properties of fish shapes. Researchers use landmark points (specific points on the body such as the eye, fin base, or tail) to map out the shape. Using software like TPS (Thin Plate Spline), Geomorph, or RStudio, the collected 3D data can be analyzed statistically to explore shape differences across species or populations.
- Volume and Surface Area Measurement: 3D models allow for the measurement of volumes and surface areas of different body parts, which can help in studying growth patterns or adapting to specific environmental conditions.

Applications:

- Understanding how environmental factors, such as water current or predation pressure, influence the body shape of fish.
- Examining evolutionary changes, especially in adaptive radiation.
- Identifying species or population-level differences that are not apparent from traditional 2D measurements.

3.2. CT Scanning (Computed Tomography)

CT scanning, often used in medical imaging, is a powerful tool for non-destructive examination of internal structures in fish. In fish morphology studies, CT scanning can provide detailed images of bones, organs, and soft tissues in 3D, without the need for dissection.

Techniques Involved:

- Micro-CT Scanning: For small specimens, micro-CT scanners capture high-resolution images of the internal skeletal structure of fish, including the cranial bones, vertebrae, and gill arches.
- Virtual Dissection: CT scans can be used for "virtual dissection" of fish, enabling researchers to study internal morphology without physically damaging the specimen.
- Voxel-Based Analysis: CT data is often represented in a 3D grid of small cubes (voxels). This allows for detailed quantification and reconstruction of the fish's internal anatomy.

Applications:

- Studying the detailed internal skeletal structures of fish, especially the inner ear (otoliths) or teeth.
- Investigating developmental processes and anatomical variations among species or populations.
- Exploring the relationship between skeletal morphology and ecological or evolutionary pressures.

3.3. High-Resolution Photography and Imaging

Advanced photographic techniques, combined with digital image analysis, allow for extremely detailed studies of fish morphology. These techniques can capture minute morphological details such as scale patterns, fin ray counts, and body proportions.

Techniques Involved:

- Macro Photography: High-resolution cameras with macro lenses capture highly detailed images of small features (e.g., fin rays, teeth, scales, or skin texture).
- Image Processing Software: Software like ImageJ, Adobe Photoshop, or Fiji can be used to analyze images. These programs can measure distances, surface area, count features, and even track changes over time.
- Fluorescence Microscopy: Fluorescent dyes can be applied to specific structures (such as muscles, bones, or nerves) to make them more visible under a microscope, enhancing the analysis of morphology at the cellular level.

Applications:

- Identifying and documenting morphological features for taxonomic purposes.
- Studying fine-scale variations in body parts (e.g., fin shapes) across populations or species.
- Understanding developmental changes in the morphology of fish, from larvae to adult stages.

3.4. Functional Morphology and Biomechanics

Functional morphology examines how the form of a fish relates to its function and how its body structure enables it to survive in a specific ecological niche. Advanced biomechanics studies the mechanical principles behind fish movement and body function, including swimming, feeding, and respiration.

Techniques Involved:

- Hydrodynamic Modeling: Computational fluid dynamics (CFD) is used to simulate how water flows around a fish's body, helping researchers understand how fish body shape influences swimming efficiency. This can be used to study the relationship between body shape and swimming performance (e.g., drag, propulsion).

- Force Plates: Used in laboratory settings, force plates measure the forces generated by fish when swimming, such as thrust and lift. This can be used to understand how specific body structures (e.g., fins or tail) contribute to propulsion.
- Motion Capture Systems: High-speed cameras and motion sensors are used to capture the movement of fish in real-time. These tools help scientists understand how specific morphological features (like fin shapes) contribute to locomotion.

Applications:

- Understanding the relationship between body shape and ecological niche (e.g., deep-sea fish have different body shapes than surface-dwelling fish).
- Investigating how swimming efficiency is affected by variations in body morphology.
- Exploring how fish use their morphological traits to perform specific functions, such as hunting or avoiding predators.

3.5. Genomic Approaches to Morphology (Eco-Morphology)

Recent advances in molecular biology and genomics have allowed researchers to explore how genetics influence fish morphology. This approach helps in understanding the genetic basis of morphological traits and how these traits evolve.

Techniques Involved:

- Genome-Wide Association Studies (GWAS): GWAS involves scanning the genome of different fish species or populations to identify genes associated with specific morphological traits (e.g., body size, fin shape).
- Transcriptomics and Proteomics: By analyzing the RNA and proteins expressed in fish tissues, scientists can identify molecular pathways involved in morphological development. This includes studying gene expression during key developmental stages to understand how certain morphological traits are formed.
- CRISPR and Gene Editing: Gene editing techniques like CRISPR-Cas9 can be used to directly modify genes that influence fish morphology, helping researchers identify the role of specific genes in shape development.

Applications:

- Understanding the genetic underpinnings of specific morphological traits and their variation across populations.
- Investigating how genetic differences contribute to adaptive changes in morphology, such as the development of body shapes suited for specific environments.
- Studying evolutionary processes and speciation through the lens of gene-morphology relationships.

3.6. Laser Scanning Confocal Microscopy (LSCM)

Confocal microscopy uses laser light to scan specimens and create detailed, high-resolution, optical section images. This technique is particularly useful for studying fine morphological details in tissues, especially when examining internal structures or soft tissues.

Techniques Involved:

- Fluorescent Labeling: Tissues can be stained with fluorescent markers that bind to specific components (e.g., bones, muscles, or nerves). The confocal microscope then captures detailed images of these components at high resolution.
- Z-Stack Imaging: Confocal microscopy can capture multiple layers of a specimen, creating 3D reconstructions that allow researchers to study structures in three dimensions, much like CT scanning, but at a much finer scale.

Applications:

- Studying cellular and tissue-level morphology, such as the arrangement of muscle fibers, bone development, and organ structures.
- Detailed examination of bone and cartilage development in fish larvae or embryos.
- Understanding the cellular basis of morphological changes in response to environmental factors.

Conclusion:

Advanced techniques in fish morphology, such as 3D morphometrics, CT scanning, functional biomechanics, and genomic studies, have revolutionized the way scientists study and understand fish structure and function. These methods allow for a deeper, more precise understanding of how fish shape relates to their behavior, ecology, and evolutionary history. By combining these tools, researchers can explore a wide range of questions in fish biology, from species identification to the adaptive significance of morphological traits.

References:

1. Strauss, R. E., & Bond, C. E. (1990). Taxonomic methods: Morphology. In *Methods for fish biology* (pp. 109–140).
2. Mojekwu, T. (2015). Advanced techniques for morphometric analysis in fish. *Journal of Aquaculture Research & Development, 6*(354). https://doi.org/10.4172/2155-9546.1000354
3. Husen, M., Gurung, T., Nepal, A., Raymajhi, A., & Chand, S. (2019). First report of two fish species: *Chanda nama*, and *Hetropneustes fossilis* from Begnas Lake.
4. Kara, C., Alp, A., & Şimşekli, M. (2010). Distribution of fish fauna on the upper and middle basin of Ceyhan River, Turkey. *Turkish Journal of Fisheries and Aquatic Sciences, 10*, 111–122.
5. Verma, D. K., & Josef. (2024). Application of modern tools and techniques in fish taxonomy. https://doi.org/10.5281/zenodo.12738911
6. Luo, D. (2024). Quantitative analysis of fish morphology through landmark and outline-based geometric morphometrics with free software. *Bio-protocol, 14*(20), e5087. https://doi.org/10.21769/BioProtoc.5087