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A FIELD GUIDE for GLASS EEL SPECIES IDENTIFICATION

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GLASS EEL SPECIES IDENTIFICATION

Research Institute for Inland Fisheries and Extensions

Inland Fishery Resources Development and Management Department (IFRDMD)

Sponsored by

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IKAPI Member No. 019/SMS/20

Size of Book 14,8 cm x 21 cm
Page : iv + 27 page

Print I, May 2024

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PREFACE

The Inland Fishery Resources Development and Management Department of the Southeast Asian Fisheries Development Center (SEAFDEC/IFRDMD) has the mandate and responsibility to manage and coordinate the Anguillid eel projects undertaken by SEAFDEC in Southeast Asia. This current eel project has the main objectives of determining the status of eel fisheries, developing collection methods and statistical data on eel fisheries production, and promoting management plans for eel conservation and sustainable use.

As part of the anguillid eel life cycle, the glass eel stage reaches rivers' mouths in coastal areas by the rising tide. At this stage, glass eels have to deal with freshwater conditions before moving up into the pigmented eel stage. Glass eels come in a school, perhaps comprising different species. Without knowledge and skill in species identification, it is not easy to separate them according to species. Therefore, IFRDMD has prepared this field guide for the identification of glass eels.

As the Chief of IFRDMD, I acknowledge the efforts of all those who have contributed to complete this book. I hope that this field guide will serve its purpose in enabling knowledge and its further use in the effective and sustainable management of Anguillid eel resources.

Andi Soesmono

Chief of IFRDMD

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INTRODUCTION

Anguillid eels are unique catadromous fishes categorized as a group of species that undergo long-distance migrations, traveling between growth habitats in freshwater environments while breeding and spawning in far-deep oceanic areas. Currently, stocks of temperate eels are known to have dramatically decreased since natural and anthropogenic factors have created severe impacts on wild populations. To meet market needs, people have been looking for substitutes by using other eels that inhabit the tropics. Most of the production in the eel culture industry is realized through the rearing of wild-caught juveniles called "glass eels." For this reason, since the mid-1990s, capture fisheries with particular interest in glass eels have increased rapidly.

Previous studies identifying the Anguillid eel species in Southeast Asia were focused on looking at specific pigmentation patterns and morphological characteristics. Nevertheless, it was still hard to identify the glass eels with the naked eye. In the field, the

fishers and consolidators will separate the glass eels into only two species: *Anguilla bicolor* and *Anguilla marmorata*. However, this is not very clear since some species, such as *A. bengalensis* and *A. luzonensis*, look like *A. marmorata*. Therefore, this field guide will describe visual observations of anguillid eels from the wild to enable the identification of glass eel species based on differences in morphological characteristics.

Kotelat *et al.* (1993) identified anguillid eels by comparing them to other anguilliformes based on their characteristics, as shown below:

Key to the taxonomic families of eels migrating into fresh water.

1.a. Anguillid eels have a body with small scales, pectoral fins present, dorsal, anal, and caudal fins well developed, and dorsal origin far behind gill openings.	…….	Anguillidae
1.b. Body without scales	…….	2
2.a. Dorsal and anal fins, if present, not reaching end of tail	…….	Ophichthidae

which has no caudal fin; anus before or behind middle of length; if caudal fin is present, rear nostril is a valve-like flab below eye.		
2.b. Caudal fin (if visible) confluent with dorsal and anal fins (which may be rudimentary)	…….	3
3.a. Pectoral fins present; dorsal, anal, and caudal fins well developed; anus in interior half of length; canine teeth in front part of jaws and on vomer	…….	Muraenesocidae
3.b. Pectoral fins : small, vestigial, or absent	…….	4
4.a. Anus before or just behind the middle of length; pectoral fins absent; dorsal, anal, and caudal fins quite developed and covered by thick skin	…….	Muraenidae

4.b. Anus far behind the middle of length; pectoral fins small, vestigial or absent, dorsal and anal fins continuous around the tail, vestigial in immature males and females, entirely absent along their mid portions in mature male	…….	Moringuidae

Five Anguillidae species were identified based on this reference, namely: *Anguilla bicolor, A. bornensis, A. celebesensis, A. marmorata* and *A.bengalensis.*

Each species has several distinguishing characteristics, as shown below:

Anguilla bicolor

Body plain; dorsal fin origin approximately above anus

Total Length (TL): 100 cm

Distribution: East Africa to the Philippines, New Guinea and North Australia

Anguilla bicolor bicolor

Anguilla bicolor pasifica

A. borneensis

Body plain; dorsal fin origin well in front of anus

Distribution: Borneo, Sulawesi

TL: 652cm

A. celebesensis

Body mottled, broad, undivided maxilliary and mandibulary bands of teeth; distance between imaginary vertical lines through anus and dorsal origin 6-12% TL

Distribution Sulawesi, Bali, Philippines, Moluccas, Irian Jaya

TL: 1500cm

A. marmorata

Body mottled; maxillary and mandibulary teeth bands with a longitudinal groove without teeth, distance between imaginary verticals through dorsal fin origin and anus 14-19% TL

Distribution From East Africa to Polynesia and Ryukyus

TL: 900cm

A.bengalensis

Body mottled, maxillary and mandibulary teeth bands with a longitudinal groove without teeth, distance between imaginary verticals through dorsal fin origin and anus 8-13% TL

Comparison between species based on their origin of dorsal and anal fin (Kotellat et al., 1993).

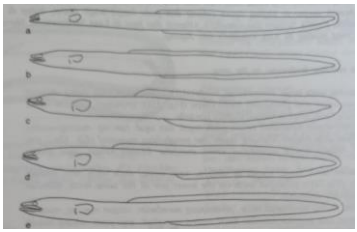
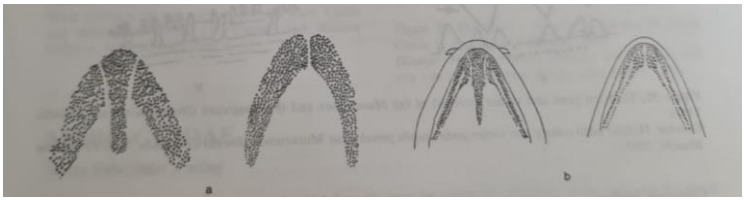


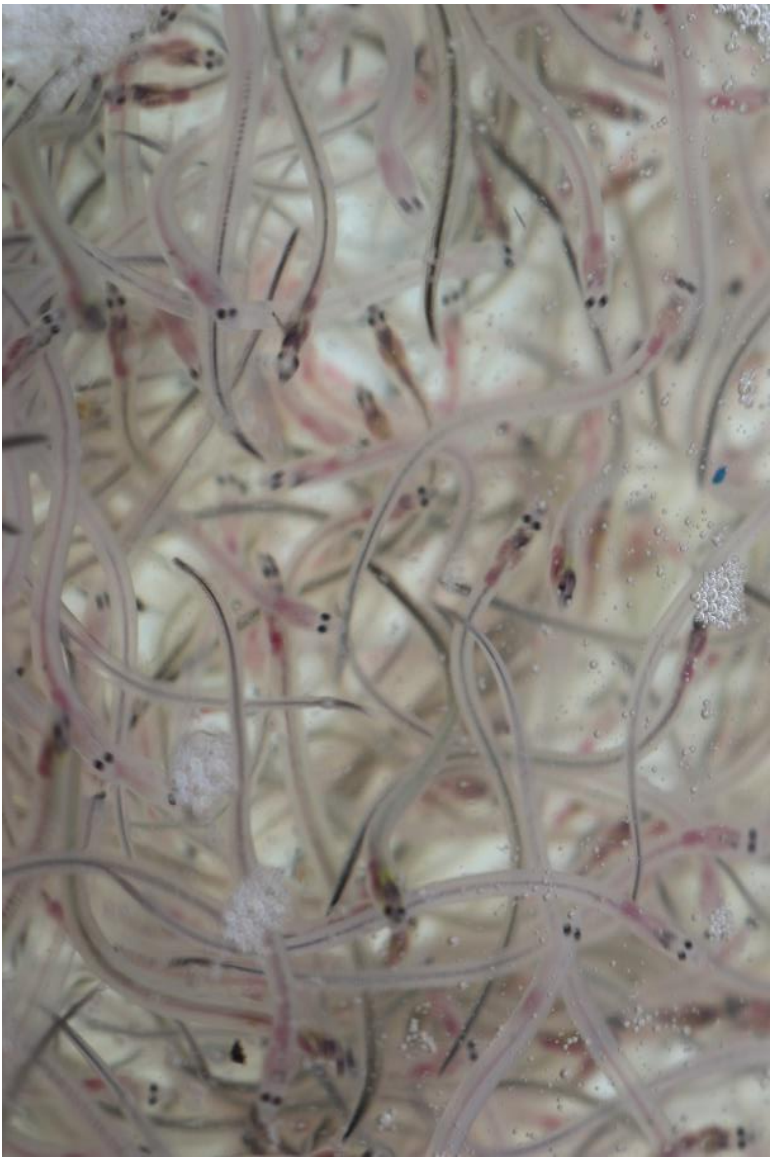
Figure 1. (a) *A. bicolor* 360 mm Standard Length (SL), (b) *A. borneensis*, 650 mm SL, (c) *A. celebesensis* 760 mm SL (d) *A. marmorata* 450 mm SL, (e) *A. nebulosa* 730 mm SL (Kotellat et al, 1993)



a

b

Figure 2. Upper jaw (left) and lower jaw (right) teeth of (a) *A. celebesensis*, (b) *A. marmorata* and *A. nebulosa* (Kotellat et al, 1993)



METHODS

Technically, the scientific methods used in identifying glass eels are based on body coloration or pigmentation pattern, morphometric character (ano-dorsal length ratio), geographic distribution, number of myomeres, and genetic parameters. This field guide focuses on body coloration, ano-dorsal length ratio, and geographic distribution only.

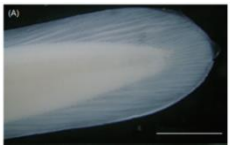
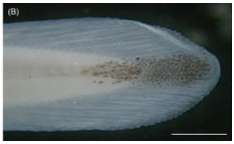
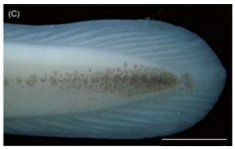
1. Body Coloration or Pigmentation Pattern

Body coloration, or pigmentation pattern, is one of the useful identification keys for glass eels. It is a faster and simpler method developed for sorting and identifying large numbers of glass eel specimens. Glass eels are collected using a systematic and standardized procedure two days before and after the new moon. Specimens are individually labeled and preserved in 96% alcohol for further identification. The specimens are placed on a sheet with a dark background, and the pigmentation pattern of the caudal fin specimens is observed using a binocular microscope under different magnification levels. Each of the caudal fin specimens is photographed and then labeled

accordingly. The glass eels bearing the different caudal fin pigmentation types are classified into groups based on their pigmentation patterns to distinguish each species of eel.

There are three types of Anguillid eels described by Reveilac, (2011) and Leander (2012) as shown in Table 1.

Table 1. Three types of Anguillid eel (Reveillac, 2011)

Type	Characteristic	Species	
A	No pigmentation on the caudal peduncle and caudal fin	*A. japonica, A. Anguilla, A.rostrata*	
B	Pigmentation on the caudal peduncle and caudal fin	*A.bicolor, A. borneensis, A. interioris, A. bengalensis, A.mossambica*	
C	Pigmentation on the caudal peduncle only	*A.marmorata, A.celebecensis, A.luzonensis*	

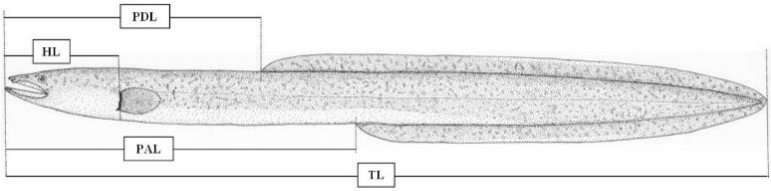
According to the Ege (1939) in Reveillac (2011), *A. marmorata* shows pigmentation only on the tail, not on the fin, and "along the mediolateral line there is a streak of pigment, which extends, in the early glass eel stages, through the posterior two-thirds area. At the tip of the tail, this streak forms a fairly broad belt with many melanophores close together, changing further forward to a single, irregular row of relatively large stellate melanophores, the spaces between being filled up with faint, structureless pigment". On the other hand, A. *bicolor* pigmentation shows the end of the tail, which "bears mediolaterally a double row of five large, stellate melanophores, continues forward by a single row of three melanophores. The pigment on the caudal fin is a network of melanophores, which extends over more of the length of the fin". *A.marmorata* and *A. mossambica* are long-finned species, i.e. their dorsal fin origin is closer to the jaw than to the anus. Conversely, *A.bicolor* is a short-finned species, with its dorsal fin beginning closer to the anus than to the jaw.

2. Morphometric Character (Ano-dorsal Length Ratio)

The morphometric character, especially based on ano-dorsal length ratio, is

It is used to identify the species as seen in Fig. 3.

$$\frac{AD}{TL}\% = \frac{PAL - PDL}{TL}$$



Remark: Head Length (HD), Pre-Dorsal Length (PDL), Pre-Anal Length (PAL), and Total Length (TL)

Figure 3. Morphological Character on Anguillid eel.

After caudal pigmentation examination, the specimens are measured for their morphometric characters. There are at least 12 quantitative characters that can be used to identify anguillid eel species. Since glass eel is predominantly an underdeveloped stage, it is difficult to measure all the characters. However, there are at least three main characters that can be used for the robust grouping of glass eel species.

The three morphometric characters of glass eels, i.e., head length to total length (HL/TL), distance between verticals through the anus and the origin of the dorsal fin to total length

(AD/TL), portions of preanal length to total length (PA/TL), and total length (TL).

The specimens are laid on top of white paper under the binocular microscope. Each component of the morphological characters, as mentioned previously, is measured based on Figure 1. TL is measured from the tip of the lower jaw, mouth closed, to the end of the tail. HL is measured from the tip of the lower jaw to the lower point of the gill opening. PA is measured from the tip of the lower jaw, mouth closed, to the vertical through the anus. PD is measured from the tip of the lower jaw to the vertical through the origin of the dorsal fin. All the data can be collected and processed in MS Excel.

Moreover, the ano-dorsal length ratio is the only character that can be used to effectively distinguish between longfin and shortfin species. Morphometric characteristics used for glass eel must be carefully examined, as diagnostic characters may overlap between species.

Comparison of the morphometric characters among Anguillid species uses criteria based on literatures (Watanabe, 2004; Watanabe, 2009; Arai, 2016), as shown in Table 2.

Table 2. Estimated ranges of morphometric character measurements in Anguillid species

Species	**HL/TL**	**AD/TL**	**PA/TL**
Anguilla celebesensis	11.5 - 17	6 – 14	37 - 45
Anguilla interioris	12 – 17.5	7 – 15	38 - 46
Anguilla megastoma	11 – 17	7 – 12	37 - 45
Anguilla bengalensis	12 – 16	9 – 13	37 - 42
Anguilla marmorata	11 – 18.5	13 – 20	39 – 48.5
Anguilla reinhardtii	12 – 17	9 – 12	39 - 48
Anguilla borneensis	12 – 15	10 – 12	38 - 44
Anguilla japonica	10 – 14	7 – 12	35 - 43
Anguilla rostrata	10.5 – 16	6 – 12	39.5 - 46
Anguilla Anguilla	11 – 15	8 – 15	40.5 – 47.5
Anguilla dieffenbachii	12.5 – 17	9 – 15	39 – 45.5
Anguilla mossambica	12 – 17	11 – 17	39.5 - 46
Anguilla bicolor pacifica	12 – 16	-5 – 4	40 – 47
Anguilla bicolor bicolor	13 – 16.5	-2 – 5	38 - 45
Anguilla obscura	12.5 – 17	2 – 8	39 – 45
Anguilla australis australis	11 – 15.5	-2 – 4	42 – 46
Anguilla australis schmidtii	10 – 15	0 – 6	41 – 47
Anguilla luzonensis	10.8 – 15.1	9.3 – 13.9	39.6 – 44.8

3. Geographic Distribution

Information on the geographic distribution of the anguillid eels is needed. According to Ege (1939), geographic information is one of the essential keys to define the eel species. For instance, in the tropical regions, there are two subspecies of *A. bicolor* i.e. *A. bicolor bicolor and A. bicolor pacifica.* They can be distinguished based on their distribution. If *A. bicolor* is found in the Indian Ocean, it is noted as *A. bicolor bicolor, meanwhile* if *A. bicolor* is found in the Pacific Ocean, it is said to be *A. bicolor pacifica.*

4. Number of vertebrae or myomere

The total number of vertebrae (TV) is helpful in identifying the glass eel species. The increase in the number of vertebrae is noted to be correlated with the increase in the latitude of the eel habitat (Fig. 4), where these are found. Generally, the number of eel vertebrae is 100–119 segments. The tropical eel has fewer vertebrae compared to the eels found in the subtropics.

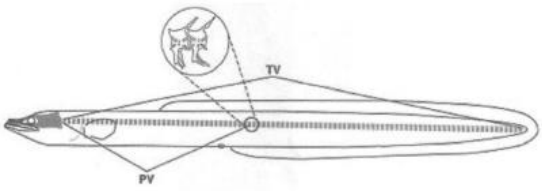


Figure 4. Anguillid eel vertebrae.

For example, Watanabe *et.al.* (2008) reported that the total vertebrae (TV) range of *A. nebulosa nebulosa* are from 106 to 111

segments, *A. nebulosa labiata* from 110 to 114 segments, *A. bicolor bicolor* from 106 to 111 segments, *A. bicolor pacifica* from 104 to 109 segments, and *A. australis australis* from 109 to 115 segments.

5. DNA bar-coding

Through the DNA barcoding method, genetics has become one of the reliable tools that help scientists identify organisms at the species level. DNA barcoding is a method wherein a small fragment of a nucleotide sequence of the mitochondrial genome serves as a DNA barcode for the identification of organisms at the species level. DNA barcoding is based on the fact that intraspecies variation is less distinct than interspecies variation. Single-gene assays can help identify an individual organism at its species level or disclose the inconsistency between its molecular variation and the existing view of species boundaries. It should not be confused with efforts to determine the "tree of life"; rather, it should resolve phylogeny at scales from species to major eukaryotic clades that require proof of the importance of gene selection. Indeed, the unique character that makes the cytochrome oxidase I (COI) gene a candidate for high-throughput DNA barcoding is its highly constrained amino acid sequence. Thus, it enables the broad applicability of primers and restricts their information content to an in-depth phylogenetic level.

FIELD SURVEYS

Philippines

The survey was conducted in Cagayan Province, Philippines, in September 2017. The consolidator collected 84 individual glass eel samples that were preserved in 90% alcohol. The result showed that there were three species of Anguillid eels and a non-Anguillid eel species. The percentage composition was 81% *Anguilla luzonensis*, 17% *A. marmorata*, 1% A. *bicolor pasifica* and 1% non-Anguillid eel (Fig. 5).

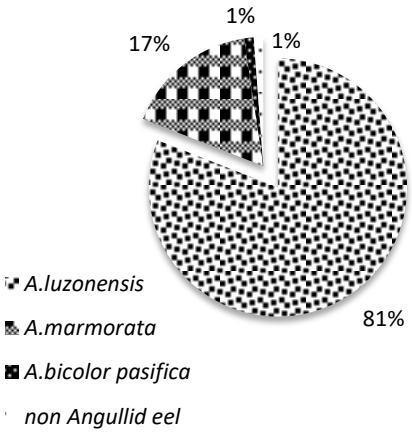


Figure 5. Eel species composition in Cagayan Province, Philippines.

ZSL (2017) reported that the percentage of Anguillid eel in the aforementioned area in September 2015 was dominated by *A. luzonensis* (80%), and the rest were *A.marmorata* and *A.bicolor pacifica*. *A. marmorata* and *A. luzonensis* have similar specific pigmentation patterns mainly on the caudal peduncle. Further analysis using ano-dorsal length measurements showed the differences. The ano-dorsal length percentages length was 10.85±1.41, 15.05±0.57, and -1.54 for *A. luzonensis*, *A. marmorata* and *A. bicolor pacifica,* respectively.

Table 3. Species composition of Anguillid eels in Cagayan Province based on morphological characters and ano-dorsal length

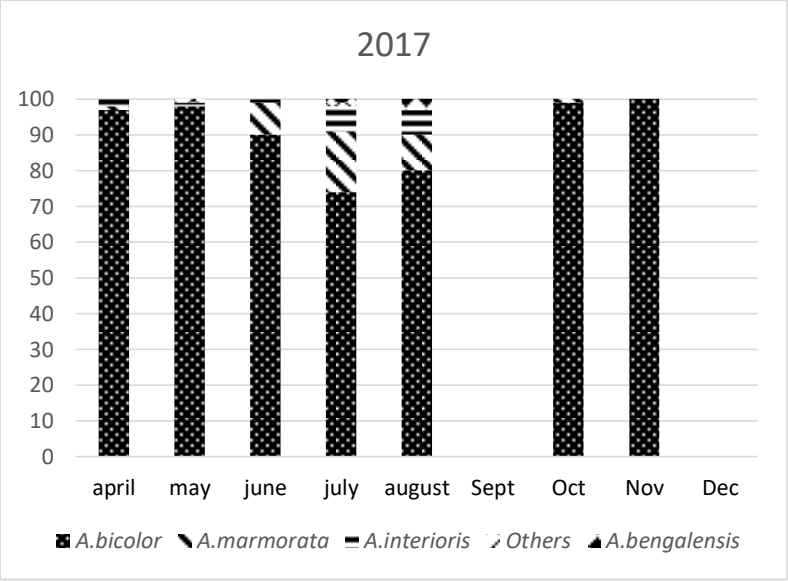
Species	**n**	**AD**	**Reference**
A. luzonensis	69	10.85±1.41	9.3 – 13.9
A. marmorata	13	15.05±0.57	13 – 20
A.bicolor pasifica	1	-1.54	-5 – 4
Non anguillid eel	1	35.04	
Total	84		

(*note: n=number of individual samples; AD= percentage of ano-dorsal length*)

A study by Santos (2017, unpublished data), showed that the glass eel species found in Davao and General Santos, Mindanao Island, Philippines, from February 2014 to February 2015 were *A. marmorata* as the dominant species and *A. bicolor*.

Indonesia

The sampling site was in Palabuhan Ratu, and the samples were observed based on morphological characters and ano-dorsal length. The consolidator collected 100 samples of glass eels per month from April 2017 until August 2018 (Fig. 6), with a total of 1,402 individual samples recorded.



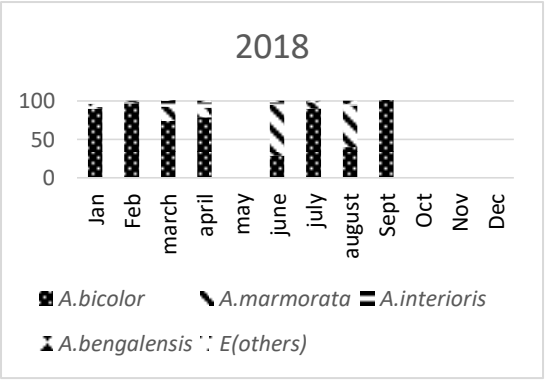


Figure 6. Species Composition of Angullid eels collected from 2017-2018 in Palabuhan Ratu, West Java Indonesia

The result presented four species of Anguillid eels in Palabuhan Ratu namely *A. bicolor bicolor, A. bengalensis, A. interioris* and *A. marmorata* (Table 4).

Table 4. Species composition of Anguillid eels based on Morphological Characters and Anodorsal Length

Species	**n**	**AD**	**Reference AD**
A. interioris	40	8.15±2.11	7-15
A. marmorata	200	15.79±1.28	13 – 20
A.bengalensis	21	10.69±2.32	9-13
A.bicolor bicolor	1,137	1.81±1.08	-2-5
Non-anguillid eel	4	0.17±5.94	
Total	1,402		

(*note: n=number of individual; AD= percentage of ano-dorsal length*)

RECOMMENDATIONS

The results presented in this book are based on actual samples taken from the Indonesia and Philippines. Suggestions from the users of this manual are most welcome. Therefore, it would be advantageous for Anguillid eel researchers and farmers to engage in the exchange of experiences and study outcomes as a topic of discussion during forthcoming workshops, training, and manual updates.

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GLOSSARY

Anguillid Eels : Unique catadromous fishes that migrate long distances, growing in freshwater and breeding in oceanic areas.

Catadromous: Fishes that migrate from freshwater to the sea to spawn.

Glass Eels: Juvenile eels, often wild-caught and reared for the eel culture industry.

Morphological Characteristics: Physical attributes of an organism used for identification.

Pigmentation Pattern : Coloration pattern on the body, useful for identifying eel species.

Pectoral Fins: Fins located on the sides of a fish, near the gills.

Dorsal Fin: The fin located on the back of a fish.

Anal Fin: The fin located on the ventral side of a fish, near the anus.

Caudal Fin: The tail fin of a fish.

Ano-Dorsal Length Ratio: The percentage of the distance between the anus and the origin of the dorsal fin relative to the total length of the eel.

Myomeres: Segmented muscles in fish, the number of which can help identify species.

DNA Barcoding: A method of identifying species using a short genetic marker in an organism's DNA.

Muraenesocidae: A family of eels with well-developed dorsal, anal, and caudal fins, and pectoral fins present.

Muraenidae: A family of eels with developed fins covered by thick skin and pectoral fins absent.

Ophichthidae: A family of eels characterized by a body without scales and a lack of caudal fin.

Moringuidae: A family of eels with pectoral fins small or absent, and dorsal and anal fins vestigial or absent in mature males.

Geographic Distribution: The natural occurrence area of species, crucial for identifying eel species.

Total Vertebrae (TV): The number of vertebrae in an eel, correlated with latitude and used for species identification.

Cytochrome Oxidase I (COI): A gene used in DNA barcoding due to its highly constrained amino acid sequence, aiding in species identification.