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Economically Important Freshwater Fish Native to Indonesia: Diversity, Ecology, and History

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Abstract: This paper aims to enlighten native Indonesian freshwater fish species to play a bigger role in building the Indonesian economy. Diversity, ecology, and environmental sciences related to these economically important fish are discussed in this paper. Forty-one publications were used as baseline data. Collected data and information were then used to figure out the present situation and condition of the topics of this study. This study has several points: 1) understanding of the diversity of local fish that have high economic value such as pangas catfish (“Patin”), red tail catfish (“Baung”), sheat catfish (“Lais”), walking catfish (“Lele”) and snakehead (“Gabus”); 2) knowledge of fish ecology in Indonesia as the basis for native species management considering that inland water ecosystems are the habitat of various types of fish; 3) The connection between major rivers in the past is following the geological history of the Southeast Asian region which shows the similarity of diversity and distribution of fish in connected areas in the past. The distribution of the *Pangasiid* fishes pattern supports the region's geographic boundaries, which suggests that the Salween basin is the eastern boundary for several genera in India and the boundary for genera from Southeast Asia. The results showed that many types of freshwater fish with important economic value had not been utilized optimally for their potential in various ecosystems in Indonesia. The study concluded that past and present causes of species loss and increase were due to different causes.

Keywords: ecology, freshwater, native species.

原產於印度尼西亞的具有重要經濟意義的淡水魚：多樣性、生態和歷史

摘要: 本文旨在提供有關印度尼西亞本地淡水魚類的啟示，這些魚類可以在印度尼西亞經濟建設中發揮更大的作用。本文討論了與這些具有重要經濟意義的魚類相關的多樣性、生態學和環境科學。 41 篇出版物被用作基線數據。然後使用收集的數據和信息來確定本研究主題的現狀和狀況。本研究有以下幾點：1）了解當地具有較高經濟價值的魚類，如鯰魚（”帕廷”）、紅尾鯰（”邦”）、鯰魚（”萊斯”）、步行鯰（”鯰魚”）的多樣性（“樂樂”）和蛇頭魚（”加布斯”）；2）考慮到內陸水域生態系統是各種魚類的棲息地，印度尼西亞魚類生態學知識作為本地物種管理的基礎；3）過去主要河流之間的連接符合東南亞地區的地質歷史，顯示了過去連接地區魚類多樣性和分佈的相似性。它反映在 Pangasiid 魚類的分佈格局支持該地區的地理邊界，這表明薩爾溫江盆地是印度幾個屬的東部邊界，也是東南亞各屬的邊界。結果表明，在印度尼西亞的各種生態系統中，許多具有重要經濟價值的淡水魚尚未得到最佳利用。該研究得出結論，物種喪失和增加的過去和現在的原因是由不同的原因造成的。

关键词： 生態, 淡水, 本地物種。

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1. Introduction

Indonesia is known as the rich country in the world's diversity of aquatic genetic resources (AqGR). However, this abundance of AqGR has not been properly inventoried due to the limitations of comprehensive, ongoing research and documentation. The re-documentation of AqGR two decades ago was a breakthrough after nearly two decades of this activity being discontinued. With the development of science and technology in molecular and biometrics, many new species have been discovered and revised.

"The fishes of Indo-Australian archipelago" is the earliest fish species recorded in Indonesia, followed by taxonomy and identification, as well as the local common name of Indonesian fish. Nowadays, reportedly 329 species exist in Papua, in eastern Indonesia, and 1,248 species of freshwater fish in western Indonesia and Sulawesi, which account for nine percent of the world's freshwater fish [1]. Several species have been declared extinct, experiencing population decline to rare or endangered conditions. [2] reported that as many as 253 fish species from the territory of Indonesia were included in the endangered category.

Currently, there are 19 species (giant gourami, dwarf gourami, kissing gourami, climbing perch, hoven's carp, mahseer group, silver barb, tinfoil barb, barred loach, *Osteochilus kalabau*, bonylip barb, *Systomus orphoides*, giant featherback, red tail catfish, wallago catfish, sheat catfish, djambal catfish, and nasutus catfish), native freshwater fish that have been developed as genetic resources for aquaculture activities to support aquaculture diversification [3].

Considering Indonesia's geographically vast territory and rich in genetic resources, this advantage should be used as a development asset. The specific potential of the area should be filled with suitable genetic resources. This principle will be in line with the "blue economy" concept in using natural resources more efficiently and not damaging the environment, a more efficient and cleaner production system, producing products and greater economic value, increasing employment, and providing opportunities to provide benefits to everyone equitably. This paper aims to enlighten native Indonesian freshwater fish species to play a bigger role in building the Indonesian economy. Diversity, ecology, and environmental sciences related to these economically important fish are discussed in this paper.

2. Materials and Methods

Forty-one publications were used as baseline data of the economic importance of native species and their diversity, ecology, habitat of freshwater fish in Indonesia, and the history of the river systems. Collected data and information were then used to figure out the present situation and condition of the topics of this study. An analysis was also considered to problems faces, constraints, and challenges.

3. Results and Discussion

The results obtained are presented in sub-chapters on aspects of diversity, ecology, and environmental science. The three aspects of the above discussion will be discussed in detail below.

3.1. Diversity of Economically Important Species of Rivers and Swamps

Understanding of the diversity of local fish that have high economic value, such as pangas catfish ("Patin"), red tail catfish ("Baung"), sheat catfish ("Lais"), Walking catfish ("Lele"), and snakehead ("Gabus") is expected to provide a broader scientific point to the general public. All stakeholders to further increase the utilization of AqGR and further encourage its conservation efforts.

3.1.1. Pangas Catfish ("Patin")

In general, patin catfishes live in large rivers that spread from mainland India to the Indonesian archipelago. However, five species live in estuarine areas, such as *Pangasius* Hamilton, 1922; *P. krempfi* Chaux & Fang, 1949; *P. kunyit* Pouyaud et al., 1999; *P. mekongensis* Gustiano, Pouyaud & Teugels, 2003. Moreover, *P. sabahensis* Gustiano, Pouyaud & Teugels, 2003. Its slender, elongated body shape can recognize the Pangas or patin catfish family, having two pairs of barbel (mandibular and maxillary), the single fin on the dorsal equipped with hidden spines before the second one, fatty fins, elongated anal fins, and robust pectoral fins, forked caudal fins, and smooth skin. Although there are 14 species of pangas catfish in Indonesia, the main commodity being cultivated is *Pangasianodon hypophthalmus* Sauvage, 1878 introduced from Thailand in the mid-1970s. Of the 28 species of pangas catfish in the world, only a few have been domesticated, including *P. hypophthalmus* since 1966, *Pangasius bocourti*, *P. djambal*, *Pangasianodon gigas*, and the most recent are *P. nasutus* [4].

According to [5, 6], fourteen species of pangas catfishes exist in Indonesia: *Helicophagus typus* Bleeker, 1858; *H. waandersii* Bleeker, 1858; *Pangasianodon hypophthalmus* Sauvage, 1878; *Pteropangasius micronemus* Bleeker, 1847; *Pangasius nieuwenhuisii* Popta, 1904; *P. humeralis* Roberts, 1989; *Pangasius lithhostoma* Roberts, 1989; *P. polyuranodon* Bleeker, 1852; *P. macronema* Bleeker, 185; *P. kunyit* Pouyaud, Teugels & Legendre, 1999; *P. mahakamensis*

Pouyaud, Gustiano & Teugels, 2002; *P. djambal* Bleeker, 1846; *P. nasutus* Bleeker, 1862; *P. rheophilus* Pouyaud & Teugels, 2000. All pangas species are economically important fish species for fishing communities in the areas where these fish are caught. Therefore, it is necessary to preserve the above types of fish from threatening activities.

3.1.2. Redtail Catfish ("Baung")

The red tail catfish or baung fish, *Hemibagrus mumurus* Valenciennes, 1840, is a member of the *Bagridae* family. This family catfish lives in fresh and brackish water in Asia and Africa has many members with 20 genera and more than 200 species. The general characteristics of the *Bagridae* are as follows: there are hard fin rays on the dorsal fin, six or seven soft fin rays, fat fins vary widely in size, and the spines of the pectoral fins are serrated and has two pairs of barbels [7]. The genus *Hemibagrus* Bleeker 1862 has synonyms as *Mystus* Scopoli 1777 or *Macrones* Dumeril 1856.

Redtail catfish has three synonymous names known as *Bagrus nemurus* Valenciennes, 1840, *Macrones nemurus* Valenciennes, 1840, and *Mystus nemurus* Valenciennes, 1840. In Indonesia, the genus *Hemibagrus* has ten species [8] consisting of *Hemibagrus nemurus* Valenciennes, 1840; *H. planiceps* Valenciennes 1840; *H. hoevenii* Bleeker 1846; *H. wyckii* Bleeker 1858; *H. bongan* Popta 1904; *H. fortis* Popta 1904; *H. olyroides* Roberts 1989; *H. Velox* Tan & Ng 2000; *H. caveatus* Ng, Wirjoatmojo & Hadiaty 2001; *H. lacustrinus* Ng & Kottelat 2013. Many species of baung are favorite foods and have been cultivated in Sumatra and Java.

3.1.3. Sheat Catfish ("Lais")

The sheat catfish or lais, the local name for a group of freshwater sheat catfish, is a member of the *Siluridae* family. The morphological features lacking fatty fins in some species, dorsal fin short and spineless, pectoral fins having hard rays, pelvic fins very short, recognize this family and anal fins very long with 41-110 soft fin rays; do not have a barbell nose [7, 9].

The body size of species in this family varies from small to large. In general, this family lives in the lower layers of rivers and lakes and feeds on smaller fish. In Indonesia, the genus that has a large size is "tapah" or wallago catfish. The types of lais known in Indonesia are generally species of the genus *Ompok* and *Kryptoterus*, which have some differences in morphology. Lais is a first-class freshwater fish commodity that has economic value. The public consumes this commodity in a new state or processed products such as smoked fish/sold/jam and salted.

Ompok genus lives in large lakes and rivers in South Asia to Southeast Asia. This genus has the characteristics of a short dorsal fin; there are at least four rays, the caudal fin is deeply forked, free (top almost free) from the anal fin, the eyes are located behind the corners of the mouth. Of the 28 species in the world, as many as 15 species are found in Indonesia. The *Ompok* species are *O. siuroides* Lacepede 1803; *O. hypophthalmus* Bleeker 1846; *O. leiacanthus* Bleeker, 1853; *O. eugeneiatus* Vaillant, 1893; *Ompok borneensis* Steindachner, 1901; *O. myostoma* Vaillant, 1902; *O. Jayney* Fowler, 1905; *O. weberii* Hardenberg, 1936; *O. javanensis* Hardenberg, 1938; *O. fumidus* Tan & Ng 1996; *O. pluriadiatus* Ng 2002; *O. binotatus* Ng 2002; *O. rhadianurus* Ng 2003; *O. supernus* Ng 2008; *O. brevirictus* Ng & Hadiati 2009. It is known that this lais fish is a fish that is very popular with people on the islands of Sumatra and Kalimantan.

3.1.4. Walking Catfish ("Lele")

The family *Clariidae* or known as walking catfish, are diagnosed based on the unique structure of their "suprabranchial organ" as an extension of the second and fourth "epibranchials" [10]. The widely distributed taxa in Africa, Asia Minor, Mainland India, East Asia, and Southeast Asia is *Clarias* Scopoli, 1777.

Clarias is recognized by slender and elongated body equipped with elongated dorsal and anal fins, have "villiform" dental bands on "premaxillary" and "vomerine", small eyes, bony tops and sides of the head or only covered by very thin skin, has four pairs of barbels, the pelvic fins have six soft rays, and only the pectoral fins have spines, and two swim bladders available. The *Clarias* exist in Indonesia according to [11,12] are *Clarias nieuhofii* Cuvier and Vallenciennes, 1840; *Clarias teijsmani* Bleeker, 1857; *Clarias pseudonieuhofii* Sudarto, Teugels & Pouyaud, 2004; *Clarias intermedius* Teugels, Sudarto & Pouyaud, 2001; *Clarias meladerma* Bleeker 1846; *Clarias leiacanthus* Bleeker, 1851; *Clarias olivaceus* Fowler 1904; *Clarias punctatus* Valenciennes, 1840; *Clarias microptomus* Ng 2001; *Clarias pseudoleiacanthus* Sudarto, Teugels & Pouyaud, 2003; *Clarias kapuasensis* Sudarto, Teugels & Pouyaud, 2003. Currently, walking catfish is the number two main food fish in Indonesia. However, local catfish farming is less popular than African catfish (*Clarias gariepinus*), introduced from Africa [11].

3.1.5. Snakehead ("Gabus")

Snakehead fish, a type of fish that can breathe from the air using suprabranchial organ, is a member of the *Channidae* family. The snakehead family has the following general characteristics: elongated body, cylindrical in front and flattened at the back, jaw prominent lower, dorsal and anal fins long, pelvic fins have six soft rays and no pelvic fins in some types of cork, no spines on all fins, ctenoid or cycloid scales.

Some snakehead fish are as small as 17 cm, but some larger ones can reach up to 1.8 m [25]. The type of snakehead fish from Indonesia with the largest size is the Indonesian snakehead or "toman" (*Channa micropeltes*). In Asian countries, the snakehead group is very important for both capture and aquaculture

fisheries. Snakehead fish is a type of predator and predator of fish in adult size. Some species that have a small size have beautiful colors, very favored by ornamental fish lovers.

According to [14,15], there are ten species recorded in Indonesia. They are *Channa bankanensis* Bleeker, 1852; *C. cyanopilos* Bleeker, 1853; *C. gachua* Hamilton, 1822; *C. Lucius* Cuvier, 1831; *C. marulioides* Bleeker, 1851; *C. melasoma* Bleeker, 1851; *C. micropeltes* Cuvier, 1831; *C. pleurophthalmus* Bleeker, 1851; *C. striata* Bloch, 1783; *C. melanopterus* Bleeker, 1855.

3.2. Ecology and Habitat of Freshwater Fish in Indonesia

Indonesia has inland water ecosystems with 13.85 million ha, consisting of rivers and floodplains 12.0 million ha, natural lakes 1.8 million ha, and artificial lakes 0.05 million ha. The number of rivers in Indonesia reaches 5,590 main rivers with a total length of 94,573 km, while lakes in Indonesia reach 840 lakes, 735 lakes, and 162 reservoirs (16).

Hydrological and topographical conditions play a very important role in shaping the variation and typology habitat of various fish genetic resources. Terrestrial, aquatic ecosystems form a water system consisting of rivers, lakes, and swamps. In the island of Sumatra, large lakes such as Lake Toba, Lake Maninjau, and Lake Singkarak are famous for fish genetic resources and native fish that have important cultural and economic values such as mahseer, rasbora, and *Mystacoleucus padangensis* or “bilih”. The Batanghari and Musi River are famous for their large catfish, baung, and lais. The island of Kalimantan has many large beautiful lakes such as Sentarum Lake, Semayang Lake, Melintang Lake, and small lakes, which are generally seasonal horseshoe-shaped lakes (oxbows) in flooded rivers rich in catfish and snakehead fish. In Papua Island, ornamental rainbow fish, endemic to Papua, inhabit Lake Sentani and other lakes.

The character and shape of the inundated area (flooded lake, oxbow lake, inundated swamp, etc.) make the water level and depth fluctuate depending on the season. This condition will create a diversity of habitats for aquatic organisms and allow various species of fish to use the area to carry out various life processes such as reproduction, maintenance, foraging, and maintenance. Some species migrate to flooded areas to fulfill part of their life cycle or shelter from environmental changes. Mostly they are “air-breathing” fish. Some pangas catfish are known as species that migrate from the downstream or estuary to the upstream part of the river to trigger spawning activities.

Based on the characteristics and habitat type (“ecological guild”), fish that live in tropical flooded lake ecosystems are classified as river fish or white fish; eurytopic or gray fish is an intermediary between whitefish and blackfish, and limnophilic fish are classified as lake fish or blackfish [17,18,19,20]. Whitefish use only limited flood exposure lake ecosystems; Blackfish mostly live in flooded lakes, they are resistant to low dissolved oxygen and high temperatures, tend to let the lake ecosystem inundate when the tide is too low. Crayfish migrate from adjacent rivers or permanent water bodies to flooded lakes when floods or monsoons [17,20]. Some catfishes (pangas, red tail, and sheat) are called crayfish, while walking catfish and snakehead are blackfish.

On Sumatra Island, red tail and sheat catfish are the dominant species in the Batang Hari River, Rokan River, Siak River, and Musi River [21]. This gray fish utilizes flooded swamps widely found around these large rivers as a habitat to reproduce at the beginning of the rainy season [22].

On the island of Kalimantan, sheat catfish are commonly found in Sentarum Lake, a flooded lake [23]. As a gray fish, this fish migrates to Lake Sentarum during high water for spawning. In the dry season, they enter the Kapuas River as the main river. In the Mahakam River, the sheat catfish, *Ompok myostoma*, an endemic species, has the highest spawning location in the flooded swamp of Lake Semayang [24]. In Oxbow lake Hanjalutung in Central Kalimantan, another sheat catfish, Ompok hypophthalmus, were found in the rainy season, while snakehead fish were found in the transition season [25]. Groups of snakehead fish are found in Sumatra, Java, Kalimantan, Sulawesi and Papua. Especially in South Sumatra, they are commonly found in the waters of Lebak Lebung or flooded swamps.

Migratory fish make it possible to adapt very well to changes in the natural environment but are susceptible to sudden changes due to anthropogenic activities. Therefore, many migratory fishes are at risk of extinction based on the list issued by the IUCN. The giant catfish (*Pangasianodon gigas*) weighing up to 300 kg, which migrates for seasonal spawning in the Mekong, is critically endangered, and during 2001 and 2002, no fish were caught [26]. The same condition is also found in fish in river and lake ecosystems in Indonesia.

Large fish species such as pangas, red tail, sheat catfishes are the main targets for catching by local anglers because of their high prices. When the ecosystem is healthy and fish are abundant, anglers prefer to harvest big fish. However, when the number of fish begins to decrease, selective fishing does not occur. All sizes and types of fish are caught [27].

The diversity of native fish in two major rivers in West Java from 1890-2010 showed a significant decrease. For example, in the Ciliwung River, the loss rate of fish species reached 92.5%, from 187 species to 20 species, while in the Cisadane River, the loss rate of local fish species reaches 75.6%, from 135 species to 39 species [28]. Investigation of the diversity of fish species in the Cirata and Djuanda Reservoir for 40 years

(1968-2008) also shows that there has been a significant change in native fish species, from 31 species to 18 species, while the ratio between native fish and exotic fish has changed from 23:9 to 9:11 [29]. The decline in fish species diversity also occurred in Lake Maninjau, West Sumatra. The number of fish species reported by Weber and de Beaufort in 1916 was about 33 species, whereas in 2008, only 14 species were found, of which six species had never been reported before (some introduced fish) [30]. Therefore, the knowledge of fish ecology is very important as a basis for fisheries management. Inland water ecosystems are the habitat of various species of fish, which are the foundation of human life in meeting their present and future needs. They provide a source of animal protein food derived from fish and are a source of genetic resources.

3.3. History of River Systems

In Southeast Asia, two types of processes have localized the shape of river systems [31,32]. The first is climate change, which causes the sea level to rise, and the second is tectonics, which causes and shifts and changes the earth's surface. Both operate simultaneously with erosion and deposition processes [33]. Sundaland is a form of land on the continental shelf when sea level declines, which shows how great the diversity of tropical Asian fauna is. The extended Pleistocene watersheds have become a major source of aquatic faunal exchange in only a few places in the world. Indeed the river configurations have changed considerably during the Quarternary. Due to local tectonic or hydrological processes, river catchments of varying magnitude have changed river alignment [32,33,34]. The remarkable feature of Southeast Asia is an extended continental shelf is known as the Sunda Shelf, part of which is currently exposed as a series of large islands, the Greater Sunda Islands, Java, Sumatra, and Kalimantan (Fig. 1). [35] were the first to note that the entire shelf region may have been exposed during the Pleistocene glacial period. The extent of continental surface exposure varied greatly during the Pleistocene, and the shallow seabed connecting the islands was a system of submerged river valleys [36].

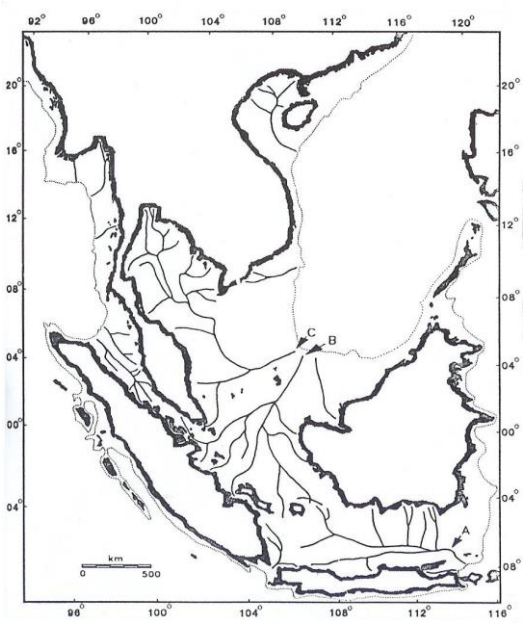

Fig. 1 Extended Pleistocene rivers of South East Asia, drawn to 160 m isobath (not shown: dotted line follow 200 m isobath). A. East Sunda River; B. West Sunda River; C. North Sunda River [35]

The rivers of eastern Sumatra and western Kalimantan, and even some from India, Thailand, and Indo-China, were tributaries of this vast system, which accounts for many similarities in the fish fauna between the islands and mainland [33,36]. A detailed description of the history and geology of Southeast Asian river systems has been summarized and presented recently by [32]. [38] provide records of late-glacial transgressions in the Sunda Shelf, the largest shelf area outside the Polar Regions, covering an area of 1.8 x 106 km^2 between the Indonesian archipelago and Vietnam.

During the last glacial maximum, the Sunda Shelf was widely exposed subaerial. Their records provide additional evidence to show that sea levels rose dramatically by 16 m in the last 300 years (14.6 to 14.3 thousand years ago). The sea-level curve shows continuous sea-level rise before and after a brief accelerated period due to massive melting events in the Polar Regions.

The only large-scale attempt to reconstruct former river courses on the East Asian continent was by Gregory [39]. In his view (Fig. 2), in the time between post-Oligocene and present, the Upper Yangtze was previously connected to the Red River, Upper Mekong to Chao Phraya (via present-day Mae Nam Yom, Upper Salween to Chao Phraya (via present-day Mae Nam Ping), Upper Irrawady to Sittang, Tsangpo to Chinwin and Lower Irrawady. The current fish fauna supports some of his conclusions and contradicts others [31]. This does not apply to the Salween-Chao Phraya relationship. [40] presents the geology and geomorphology of the Mekong River system. Recent discoveries have added to the region's knowledge, and all indications are that the history of the Indochina Peninsula is complex and fascinating [32].

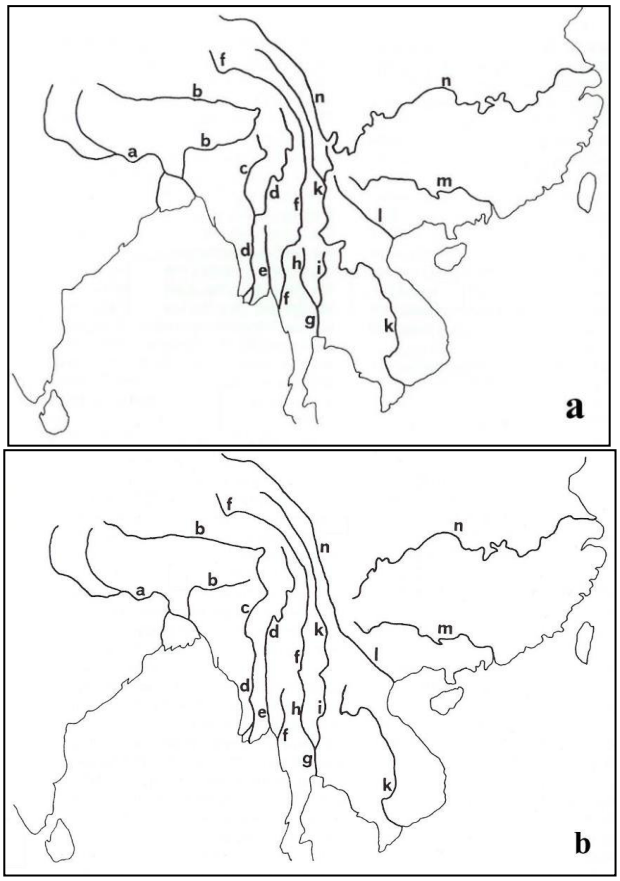

Fig. 2 a. Existing river system of South East Asia; b. The post-Himalayan river system hypothesized by Gregory (501925). The existing river systems are a. Ganges, b. Brahmaputra-Tsangpo, c. Chinwin, d. Irrawaddy, e. Sittang, f. Salween, g. Chao Phraya, h. Mae Nam ping, i. Mae Nam Yom, k. The Mekong, l. red River, m. Nanpang-Jiang, n. Yangtse [31]

Based on similarities among cyprinid fish species, their distribution reflects the current major drainage relationships in the region (Figure 3). There is a connection between the great rivers of the past. The hypothesis obtained from the distribution of pangas catfish also follows the Southeast Asian region [41]. This distribution pattern supports the geographical boundaries of the area proposed by [31], who suggests that the Salween basin is the eastern boundary for several genera widely distributed in India and the western boundary for many Southeast Asian genera.

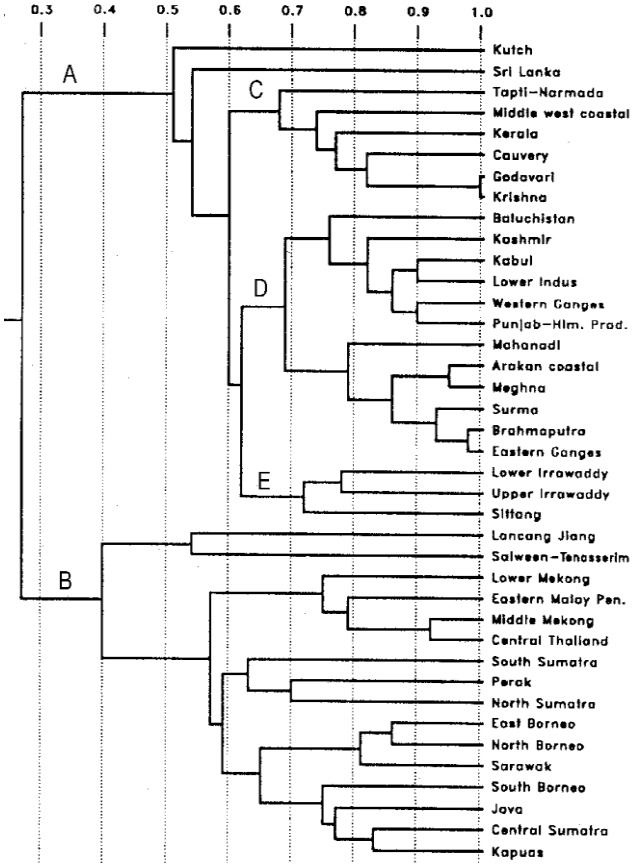

Fig. 3 Dendrogram of cyprinid faunal similarity, based on UPGMA clustering of similarity coefficient. Major branch label: A. Indian subcontinent; B. Southeast Asia; C. Peninsular India; D. Indo-Gangetic; E. Central Myanmar [37]

4. Conclusion

The study concluded that many freshwater fish species had not been utilized optimally for their potential in various ecosystems in Indonesia. The connection between major rivers in the past follows the geological history of the Southeast Asian region, which shows the similarity of diversity and distribution of fish in connected areas in the past.

The loss and increase of fish species in the past were caused by environmental changes and ecological constraints due to rising sea levels and geological processes. This incident resulted in numerous fish populations being cut off from their habitat and not continuing their lives. Meanwhile, those who can adapt to the new environment will continue their survival, forming a new population.

Currently, the changes that occur in the loss of species are caused by the role of human activities in environmental changes that destroy fish habitats. At the same time, the increase in the number of species occurs due to advances in taxonomy and molecular genetics.

The rate of loss and addition of new species as genetic resources of freshwater fish is very important for Indonesia. However, recent research, publication documentation related to current conditions is still very lacking.

With the richness of diverse and high genetic resources and a very varied environment, Indonesia must be able to take advantage of these advantages for the development of the country and the welfare of its people.

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