©Journal of Aquatropica Asia
e-issn: 2721-7574; p-issn: 2407-3601
Volume 10, Nomoor 2, Tahun 2025
Jurusan Akuakultur, Universitas Bangka Belitung

# TAXONOMIC AND ECOLOGICAL STUDY OF WILD BETTA FISH ON BANGKA ISLAND, INDONESIA: DIVERSITY, DISTRIBUTION, AND HABITAT CONDITIONS

# STUDI TAKSONOMI DAN EKOLOGI IKAN CUPANG LIAR DI PULAU BANGKA, INDONESIA: KEANEKARAGAMAN, DISTRIBUSI, DAN KONDISI HABITAT

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## Abstract

Bangka Island is one of Indonesia's regions with significant potential in terms of freshwater fish diversity, particularly within the genus Betta, commonly known as wild bettas. This study aims to document species diversity, geographic distribution, and natural habitat characteristics of wild Betta populations on Bangka Island, which inhabit peat swamp ecosystems, blackwater rivers, and abandoned tin-mining ponds. Field surveys were conducted from August to October 2025 across peat swamp ecosystems, blackwater rivers, and abandoned tin-mining ponds in all four administrative regions of Bangka Island: South Bangka, Central Bangka, West Bangka, and North Bangka. Through field exploration and morphological identification, seven primary Betta species were recorded: Betta burdigala, *B. schalleri, B. edithae, B. chloropharynx, B. uberis, B. cracens,* and *Betta sp. Bangka*. Each species occupies a distinct habitat type characterized by extreme water parameters, including low pH (4.2–5.8), minimal dissolved oxygen levels (0.8–2.5 mg/L), relatively stable water temperatures (26–30°C), and low conductivity. Certain species, such as B. burdigala and B. chloropharynx, exhibit unique physiological adaptations via the labyrinth organ, which enables aerial respiration. The species distribution is uneven across the island, with some species being restricted to specific localities, rendering them endemic. Major threats to these species include habitat degradation due to tin mining, oil palm plantation expansion, and environmental pollution. Recent data indicate that several populations are experiencing severe declines, with some nearing local extinction. Consequently, the findings of this study provide a critical foundation for ecosystem-based conservation strategies and the restoration of vital habitats. Scientifically, Bangka Island qualifies as a Betta biodiversity hotspot of strategic importance in the context of Southeast Asian biogeography and the conservation of endemic freshwater species.

*Keywords: Freshwater fish diversity, Peat swamp ecosystem, Tin mining impact, Wild Betta*

## Abstrak

*Pulau Bangka merupakan salah satu wilayah di Indonesia yang memiliki potensi keanekaragaman ikan air tawar yang tinggi, terutama dari genus Betta, yang umumnya dikenal sebagai ikan cupang liar. Penelitian ini bertujuan untuk mendokumentasikan keanekaragaman spesies, distribusi geografis, dan karakteristik habitat alami populasi Betta liar di Pulau Bangka, yang menghuni ekosistem rawa gambut, black water, dan kolong bekas tambang timah. Survei lapangan dilakukan dari bulan Agustus hingga Oktober 2025 di seluruh ekosistem rawa gambut, black water, dan kolong bekas tambang timah di keempat wilayah administratif Pulau Bangka meliputi Kabupaten Bangka Selatan, Bangka Tengah, Bangka Barat, dan Bangka Utara. Melalui eksplorasi lapangan dan identifikasi morfologi, tercatat sebanyak tujuh spesies Betta yang tersebar di Pulau Bangka yaitu: Betta burdigala, B. schalleri, B. edithae, B. chloropharynx, B. uberis, B. cracens, dan Betta sp. Bangka. Setiap spesies hidup pada habitat yang berbeda yang dicirikan oleh parameter air yang ekstrem, termasuk pH rendah (4,2–5,8), kadar oksigen terlarut minimal (0,8–2,5 mg/L), suhu air yang relatif stabil (26–30°C), dan konduktivitas rendah. Spesies tertentu, seperti B. burdigala dan B. chloropharynx, menunjukkan adaptasi fisiologis yang unik melalui organ labirin, yang memungkinkan respirasi udara. Distribusi spesies tidak merata di seluruh pulau, dengan beberapa spesies terbatas pada lokasi tertentu, menjadikannya endemik. Ancaman utama bagi spesies ini meliputi degradasi habitat akibat penambangan timah, perluasan perkebunan kelapa sawit, dan pencemaran lingkungan. Data terbaru menunjukkan bahwa beberapa populasi mengalami penurunan yang signifikan, dengan beberapa spesies*

*mendekati pada kepunahan lokal. Akibatnya, temuan penelitian ini memberikan landasan penting bagi strategi konservasi berbasis ekosistem dan pemulihan habitat vital. Secara ilmiah, Pulau Bangka memenuhi syarat sebagai hotspot keanekaragaman hayati Betta yang memiliki kepentingan strategis dalam konteks biogeografi Asia Tenggara dan konservasi spesies air tawar endemik.*

*Kata Kunci: Keanekaragaman ikan air tawar, Ekosistem rawa gambut, Dampak penambangan timah, Cupang Liar*

## INTRODUCTION

Indonesia is globally recognized as a megadiverse country, renowned for its rich flora and fauna, including a remarkable array of freshwater fish species (Medrano, 2023; Robin *et al.,* 2023a). Among these, the genus Betta—commonly known as "fighting fish" or "bettas"—has received considerable scientific and public attention. Distinct from the domesticated Betta splendens, which is widely bred in captivity (Valen *et al.,* 2023a; Budi *et al.,* 2025), a lesser-known group referred to as "wild bettas" (Betta spp.) occupies natural habitats and exhibits significantly different morphological and ecological traits (Syarif *et al.,* 2023; Hasan *et al.,* 2023; Khairul *et al.,* 2024).

Bangka Island, part of the Bangka Belitung Archipelago, harbors an extraordinary diversity of wild Betta species (Valen *et al.,* 2023a; Robin *et al.,* 2023a). The island's landscape is dominated by peat swamp forests and blackwater river systems, which create highly specific environmental conditions—darkly stained water due to high concentrations of humic acids and tannins, extremely low pH, and minimal dissolved oxygen levels (Syarif *et al.,* 2025a). Despite these harsh conditions, several wild Betta species have evolved remarkable physiological and ecological adaptations that enable them to thrive in such extreme habitats (Priyadi *et al.,* 2025).

Seven primary species of wild Betta have been recorded during surveys and field explorations across Bangka Island: *Betta burdigala, B. schalleri, B. edithae, B. chloropharynx, B. cracens, B. uberis,* and *Betta sp. Bangka* (Ramadhanu *et al.,* 2023; Khanati *et al.,* 2024; Prananda *et al*., 2024; Amelia *et al.,* 2024). Each species exhibits distinctive morphological features, behavioral patterns, and habitat preferences. Some, such as *B. burdigala*, are endemic to Bangka and thus hold particular importance for conservation efforts and biogeographical research (Valen *et al.,* 2023a; Syarif *et al.,* 2025b).

Betta burdigala, for instance, is exclusively found in highly acidic, tannin-rich peat swamps. Known colloquially as the "red-wine betta" due to its deep reddish coloration, it is primarily observed in areas such as Bikang and Central Bangka (Syarif *et al.,* 2025a). Its presence serves as an indicator of ecosystem integrity and peat swamp specificity (Valen *et al.,* 2023b). In contrast, species such as *B. edithae* and *B. schalleri* are found in densely vegetated, shallow freshwater systems, highlighting their differing microhabitat preferences (Syarif *et al.,* 2023; Khanati *et al.,* 2024).

However, these unique habitats are under increasing anthropogenic pressure. Land conversion for oil palm plantations, tin mining, and pollution from domestic and industrial sources have led to significant habitat degradation (Pratiwi *et al.,* 2025). In particular, Bikang—recognized as the type locality of B. burdigala—has experienced habitat loss of up to 95% within the past two years, resulting in a drastic decline in local populations and an elevated risk of local extinction (Valen *et al.,* 2023b).

This threat is further exacerbated by the absence of formal protection for key wild Betta habitats on the island. Regions such as Pergam and Central Bangka, despite their high species richness, remain unprotected and lack conservation status (Wijayanti *et al.,* 2023; Syarif *et al.,* 2025a; 2025b). Without the implementation of ecosystem-based conservation strategies and active community participation, there is a growing concern that several endemic species may vanish before they are fully documented (Wardhani *et al.,* 2025; South *et al.,* 2025).

This study aims to describe and analyze the species diversity, geographic distribution, habitat characteristics, and ecological threats facing wild Betta populations on Bangka Island. By presenting updated ecological, taxonomic, and conservation data, this research seeks to provide a scientific foundation for the protection and sustainable management of Indonesia's endemic freshwater fish. Moreover, this study reinforces Bangka Island's significance as a natural laboratory for the study of evolution, adaptation, and conservation of Southeast Asia's tropical freshwater biota.

## MATERIALS AND METHODS

### *Study Area and Research Period*

This study was conducted on Bangka Island, located in the Bangka Belitung Islands Province, Indonesia. The island comprises four main administrative regions: South Bangka, Central Bangka, West Bangka, and North Bangka. Field exploration focused on three primary natural habitats known to support wild Betta populations: peat swamp forests, blackwater rivers, and abandoned tin-mining ponds (locally known as kolong). Fieldwork and data collection were carried out over a three-month period from

August to October 2025, encompassing both the dry and rainy seasons. This temporal coverage allowed for the assessment of seasonal variation in habitat conditions and species occurrence.


**Figure 1.** Map of the study area on Bangka Island, Indonesia, showing key sampling sites across South Bangka, Central Bangka, West Bangka, and North Bangka.

### *Fish Sampling Methods*

Fish specimens were collected manually using non-destructive techniques to minimize disturbance to natural habitats and preserve the integrity of local populations. The sampling procedures comprised the following steps: Shallow-water sweeping with fine-mesh hand nets among aquatic vegetation; Collection of substrates and leaf litter from the bottom of water bodies using transparent plastic containers; Passive trapping employing modified plastic bottles baited with natural attractants such as insects or earthworms; and In situ and ex situ identification, which involved documenting major morphological traits—such as body coloration, fin shape, and patterning—prior to releasing the fish back into their original habitats. For each captured specimen, total length (TL) and standard length (SL) were measured, and live photographs were taken for visual documentation. A limited number of individuals were retained for further taxonomic and molecular analyses (e.g., DNA barcoding), conducted under approved ethical and collection permits.

### *Environmental Parameter Measurement*

To assess habitat characteristics, direct measurement of physicochemical parameters was conducted at locations where Betta species were encountered. The measured water quality parameters and corresponding instruments are summarized in Table 1.

Measurements were conducted during morning and afternoon sessions to capture natural daily variation in environmental conditions. Additionally, aquatic vegetation and bottom substrate were recorded through visual inspection, including observations of dominant aquatic plant species, vegetation density, and the presence of leaf litter.

**Figure 2.** Fish sampling procedures in natural habitats on Bangka Island. Methods included shallow water sweeping using a fine-mesh hand net, manual collection of substrate and leaf litter with transparent containers, and passive trapping using baited modified plastic bottles.

**Table 1.** Water quality parameters and instruments used

| Parameter kualitas air | Alat yang digunakan |
|---|---|
| Water pH | Portable pH meter |
| Water temperature | Digital thermometer |
| Dissolved Oxygen (DO) | Digital DO meter |
| Electrical conductivity (µS/cm) | Conductivity meter |
| Total Dissolved Solids (TDS) | Portable TDS meter |
| Water transparency (turbidity) | Secchi disk |

### *Species Identification and Taxonomic Analysis*

Species identification was conducted based on morphological characters following the taxonomic frameworks of Kottelat & Ng (1994) and Tan & Ng (2005). The identification parameters included: Fin ray counts (meristic data); Body and fin coloration patterns; Shape of the head, dorsal, anal, and caudal fins; Presence of diagnostic characters, such as lateral spots or iridescent sheen. Morphometric data—including total length, body height, and head width—were measured using a digital caliper with a precision of 0.1 mm.

### *Data Analysis and Interpretation*

The collected data were analyzed using descriptive and comparative approaches. Species distributions were mapped using D-MAPS software and digitally refined with Paint for visual presentation. Environmental parameters were correlated with species presence to assess habitat preferences. Additionally, habitat degradation levels were evaluated based on: Direct field observations; Photographic documentation; and Secondary data on land cover changes between 2023 and 2025.

## RESULTS

### *Species Diversity of Wild Betta on Bangka Island.*

Field exploration across various freshwater ecosystems on Bangka Island led to the identification of seven wild Betta species inhabiting peat swamp forests and blackwater river systems. These species are: *Betta burdigala, Betta schalleri, Betta edithae, Betta chloropharynx, Betta cracens, Betta uberis* and *Betta sp. Bangka* (Figure 3). Eanj0076ch species was found occupying distinct microhabitats within these acidic, low-oxygen environments, reflecting a high degree of ecological specialization.

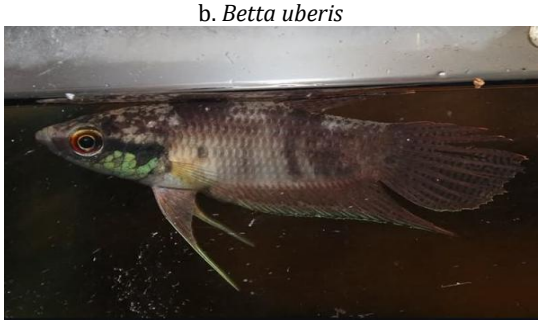
### *Species Identifications of Wild Betta on Bangka Island*

Meristic characteristics were recorded from all Betta specimens collected across Bangka Island. These counts included dorsal, anal, pectoral, and caudal fin rays, as well as lateral line scales, following established taxonomic standards (Kottelat & Ng, 1994; Tan & Ng, 2005). The meristic data formed the basis for species-level identification and are summarized in Table 2.

a. *Betta burdigala*

b. *Betta uberis*

c. *Betta cracens*



d. *Betta schalleri*

e. *Betta chloropharynx*

f. *Betta edithae*

g. *Betta sp. Bangka*

**Figure 3.** Live specimen of Wild Betta from Bangka Island

**Table 2.** Meristik ikan Betta Pulau Bangka

| Spesies | Dorsal rays | Anal rays | Ventral rays | Pectoral rays | Caudal rays | Lateral line scales |
|---|---|---|---|---|---|---|
| *Betta burdigala* | D.14 | A.25 | V.I.5 | P.12 - 14 | C.13 | LL.29 - 31 |
| *Betta uberis* | D.15 - 16 | A.II.22 - 26 | V.I.5 | P.13 - 14 | C.10 -11 | LL.29 - 31 |
| *Betta cracens* | D.II.8 | A.II.29 | V.9-11 | P.12 | C.13 | LL.28 |
| *Betta schalleri* | D.II.8 | A.II.24-25 | V.I-II.4 | P.11-12 | C.III.10 | LL.31-32 |
| *Betta chloropharynx* | D.I.8 - 9 | A.II.27 - 28 | V.I.4 | P.12 - 14 | C.14 - 16 | LL.29 - 30 |
| *Betta edithae* | D.I.7 – I.8 | A.23 | V.I.4 | P.6 -8 | C.12 | LL.30 - 32 |
| *Betta sp. Bangka* | D.11 | A.II.29 | V.6 | P.12 | C.III.9 | LL.34 |

***Distribusi Geografis dan Preferensi Habitat***

The distribution and conservation status of the seven wild Betta species identified on Bangka Island show varying patterns of geographic range and habitat specialization (Table 3). Three species *Betta burdigala, B. cracens,* and *B. uberis* exhibited localized distributions, confined to specific regions of the island. *B. burdigala* was restricted to South and Central Bangka, primarily inhabiting dark, highly acidic peat swamps, and is currently classified as Critically Endangered by the IUCN. Similarly, *B. cracens* was found only in small upland streams in West Bangka and also holds Critically Endangered status. *B. uberis*, recorded in North Bangka, was associated with peat swamp habitats and is listed as Vulnerable.

In contrast, four species *B. schalleri, B. chloropharynx, B. edithae,* and *Betta sp.* Bangka were recorded across multiple regions of Bangka Island. *B. schalleri* and *B. chloropharynx* were found in diverse freshwater environments, including swamps, forest margins, and blackwater streams, although both are considered threatened, with B. chloropharynx listed as Critically Endangered and *B. schalleri* as Endangered. *B. edithae*, which showed a broader ecological tolerance, was commonly found in shallow swamps and abandoned mining ponds and is currently assessed as Least Concern. *Betta sp.* Bangka, although widespread, was consistently associated with peat swamp habitats and is categorized as Vulnerable.

These findings underscore the high degree of endemism and ecological specificity among Bangka's Betta species and highlight the urgent conservation priority for habitat-restricted taxa, particularly those in degraded or unprotected ecosystems.

**Table 3.** Geographic Distribution, Habitat Type, and IUCN Conservation Status of Wild Betta Species on Bangka Island

| **Species** | **Primary Distribution** | **Habitat Type** | **IUCN Status** |
|---|---|---|---|
| *Betta burdigala* | South & Central Bangka | Dark, acidic peat swamp | Critically Endangered |
| *Betta uberis* | North Bangka | Peat swamp | Vulnerable |
| *Betta cracens* | West Bangka | Small upland streams | Critically Endangered |
| *Betta schalleri* | Widespread across Bangka | Swamps and small streams | Endangered |
| *Betta chloropharynx* | Widespread across Bangka | Peat swamps and forest margins | Critically Endangered |
| *Betta edithae* | Widespread across Bangka | Shallow swamps and abandoned mining ponds | Least Concern |
| *Betta sp.* Bangka | Widespread across Bangka | Peat swamp | Vulnerable |

Each species exhibited specific adaptations to its respective habitat. Betta burdigala, for example, was found in sites characterized by very low pH levels (4.2–4.5) and dark, tannin-rich blackwater. It is recognized as one of the smallest Betta species (2.5–3 cm in total length), distinguished by its deep red, wine-colored body. Other species, such as B. edithae and B. schalleri, were recorded across a broader range of habitats and were observed throughout all regions of Bangka Island. These species were frequently encountered in abandoned mining ponds (kolong), particularly those surrounded by secondary vegetation, suggesting greater ecological tolerance and adaptability (Figure 4).

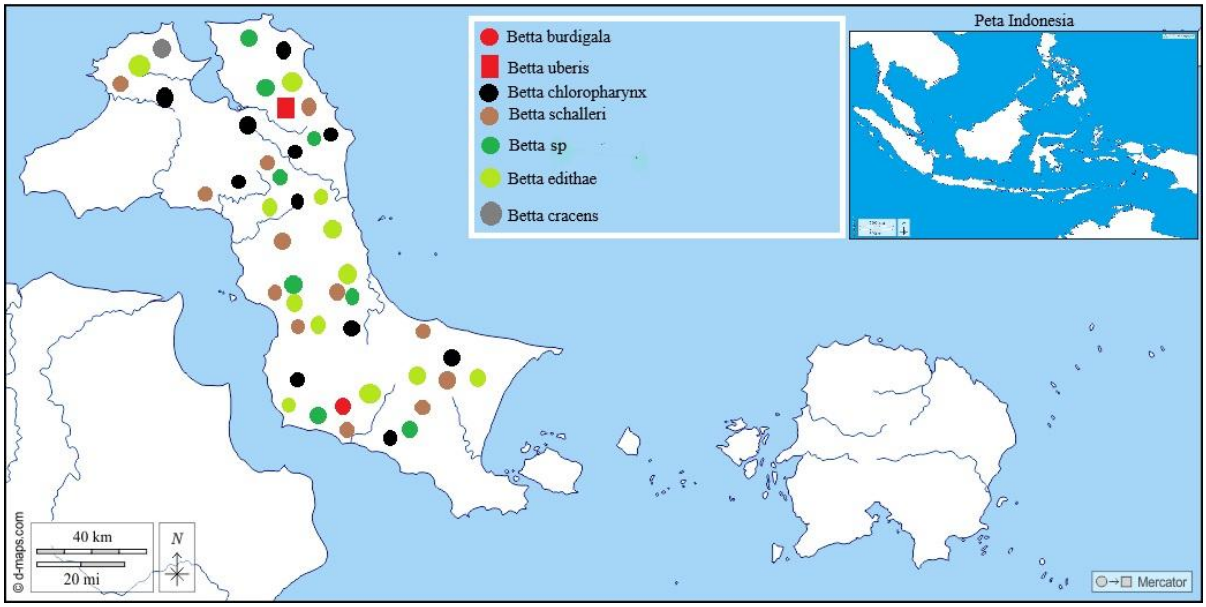



**Figure 4.** Geographic distribution of wild Betta species recorded on Bangka Island. Sampling points indicate confirmed occurrences of *B. burdigala, B. edithae, B. schalleri, B. chloropharynx, B. uberis, B. cracens,* and *Betta sp. Bangka* across various habitat types, including peat swamps, blackwater streams, and abandoned tin-mining ponds.

**Table 4.** Water Quality Measurements at Natural Habitats of Wild Betta Species on Bangka Island

| Species | Habitat Description | Parameter | Range | Remarks |
|---|---|---|---|---|
| *Betta burdigala* | Shallow peat swamps with dense vegetation and dark blackwater | pH | 4.2 – 5.8 | Highly acidic; typical of natural peat water |
| | | Temperature | 26 – 30 °C | Stable due to canopy cover |
| | | Dissolved Oxygen | 0.8 – 2.5 mg/L | Low; species adapted via labyrinth organ |
| | | Conductivity | 30 – 80 µS/cm | Low ionic content |
| | | TDS | 15 – 40 mg/L | Low dissolved mineral content |
| | | Water Clarity | 10 – 30 cm | High organic matter, dark coloration |
| *Betta uberis* | Forest peat swamps and ephemeral blackwater ponds | pH | 4.2 – 5.5 | Highly acidic |
| | | Temperature | 26 – 29 °C | Stable, humid tropical climate |
| *Betta cracens* | Small forest streams shaded by dense riparian vegetation | pH | 4.5 – 5.8 | Moderately acidic |
| | | Temperature | 27 – 30 °C | Relatively stable |
| *Betta schalleri* | Blackwater streams in secondary peat swamp forest | pH | 4.5 – 5.7 | Acidic, with dominance of humic compounds |
| | | Temperature | 26 – 29 °C | Consistently moderate |
| | | Dissolved Oxygen | 1.0 – 2.3 mg/L | Low, due to stagnant conditions |
| *Betta chloropharynx* | Natural ditches with slow flow and peat-rich substrate | pH | 4.3 – 5.6 | Strongly acidic; typical peat swamp conditions |
| | | Dissolved Oxygen | 0.9 – 2.1 mg/L | Low; consistent with labyrinth adaptation |
| *Betta edithae* | Shallow rivers with sandy bottoms and leaf litter | pH | 4.8 – 6.0 | Slightly acidic |
| | | Temperature | 27 – 30 °C | Stable under vegetative canopy |
| *Betta sp.* Bangka | Ditches and shallow peat swamps with dark brown water | pH | 4.3 – 5.6 | Strong acidity from decomposing organic matter |
| | | Dissolved Oxygen | 0.8 – 2.0 mg/L | Very low |
| | | Water Clarity | 10 – 20 cm | Dark water due to high humic content |

***Habitat Characteristics and Environmental Preferences of Wild Betta Species***

The habitat preferences of wild Betta species are closely associated with specific environmental parameters, which reflect the ecological specialization of each taxon. These parameters—such as water pH, temperature, dissolved oxygen (DO), conductivity, total dissolved solids (TDS), and water clarity—were measured at sites where each species was recorded. The results are summarized in Table 4.

The vegetation surrounding Betta habitats consists of plant species such as Pandanus, Melastoma, and understory aquatic plants, including Cryptocoryne and Nymphaea (Figure 5). These plants not only provide shading to the aquatic environment but also offer critical structural elements that support key biological functions for fish, such as spawning sites, protection from predators, and sources of food in the form of small aquatic invertebrates. Dense vegetation and overhead canopy cover significantly reduce light penetration, contributing to low water transparency and dark water coloration—conditions that strongly support the ecophysiological resilience of wild Betta species in response to localized environmental stressors.

**Figure 5.** Water quality measurement and habitat conditions at wild Betta sampling sites on Bangka Island. The images show field-based assessments of key physicochemical parameters (pH, temperature, DO) alongside representative habitat types, including peat swamps, blackwater streams, and shaded forest ditches

**Table 5.** Species-Specific Behaviors and Adaptations of Wild Betta from Bangka Island

| Species | Observed Behavior / Adaptation |
|---|---|
| *Betta burdigala* and *B. chloropharynx* | Exhibit substrate-burrowing behavior to seek refuge during the dry season. |
| *Betta simorum* | Displays strong sexual dimorphism; males have longer fins and more vibrant coloration. |
| *Betta schalleri* and *B. edithae* | Build bubble nests beneath floating leaves as part of their reproductive strategy. |
| *Betta uberis* | Highly territorial; males require dense vegetation for shelter and bubble nest construction. |
| *Betta cracens* | Reproduces via bubble nests built by males under floating leaves, requiring shaded water surfaces. |

***Specific Behaviors and Adaptive Traits***

All Wild Betta species recorded in this study possess a labyrinth organ, a specialized accessory respiratory structure that allows them to breathe atmospheric oxygen (Apriliani *et al.,* 2018). This adaptation is critical for survival in environments characterized by low dissolved oxygen (DO) levels. Several unique behavioral and morphological traits were also observed. These include dark body coloration, streamlined body shapes, and compact fins, which are commonly found in species inhabiting narrow, densely vegetated aquatic environments. Such traits facilitate maneuverability and concealment in structurally complex habitats.

***Threats and Conservation Status***

Wild Betta species on Bangka Island face a range of significant and escalating threats that directly impact their survival and long-term viability. The primary threats identified include Land-use change into oil palm plantations, ongoing mining activities, which alter soil structure and disrupt the hydrological dynamics of wetland ecosystems, water pollution and habitat fragmentation. Recent data indicate a dramatic rate of habitat loss in key conservation

sites. For example, the type locality of Betta burdigala in Bikang experienced a decline in intact habitat from 20% in 2023 to only 5% in 2025, representing a 95% loss over two years (Figure 6). Similarly, habitats in Central Bangka have degraded by approximately 75% during the same period.

These findings highlight the urgent need for targeted conservation strategies, including habitat protection, ecological restoration, and community-based management, to prevent further decline of these endemic freshwater species.

**(A) Bikang, 2023** — Intact peat swamp forest with rich canopy and blackwater conditions. This site supported a healthy *B. burdigala* population during the 2023 survey. This location is also the species' holotype site.

**(B) Bikang, 2025** — fully converted into an oil palm plantation landscape. Representing a 95% habitat loss over two years.

**Figure 6.** Habitat condition of Wild Betta (Holotype of *B. burdigala*)

## DISCUSSIONS

This study confirms that Bangka Island supports a high diversity of wild Betta species, including seven taxa, among them an undescribed form (*Betta sp.* Bangka). The diversity is notable considering the island's size and habitat degradation (Helmizuryani *et al.,* 2024). Morphological differences, especially in meristic traits, allowed for accurate species identification, following established taxonomic keys.

Bangka Island's location in the Sunda Shelf makes it a key area for understanding species distribution and freshwater fish evolution in Southeast Asia (Tan & Ng, 2006; Liew *et al.,* 2020; Šlechtová *et al.,* 2021; Kurniawan *et al.,* 2025). The presence of several distinct Betta species within a limited geographic range suggests that both habitat specialization and geographic isolation have played important roles in driving speciation (Albert *e al*., 2011).

The diversity observed may be the result of ecological divergence or localized adaptation, a pattern that fits with previous studies in similar insular environments (Vøllestad & Primmer, 2019; Van der Sleen & Albert, 2022). Further research comparing Bangka's Betta lineages with those from nearby islands would help clarify their evolutionary history and regional biogeography.

Species such as *B. burdigala* and *B. cracens* were found only in limited areas, suggesting endemism and ecological isolation (Gulo *et al.,* 2023; Anggara *et al.,* 2024; Syarif *et al.,* 2025a). The discovery of *Betta sp*. Bangka indicates that more undocumented species may exist, possibly due to past habitat fragmentation and ecological pressures that led to local adaptation. Similar findings have been reported from other parts of Southeast Asia, such as Sumatra and Borneo, where the Betta genus shows high local endemism (Khairul *et al.,* 2025; Syarif *et al.,* 2025c).

Moreover, each species was associated with distinct habitat types, mostly in acidic, low-oxygen water bodies like peat swamps and blackwater streams. These habitats typically have pH values ranging from 4.2 to 5.8 and very low dissolved oxygen levels (Tan & Ng 2005; Schindler & Schmidt, 2006: Syarif *et al.,* 2025b; Priyadi *et al.,* 2025). Such conditions require special physiological adaptations, such as the labyrinth organ, which enables aerial respiration and is common among anabantoid fishes (Tate *et al.,* 2017; Apriliani *et al.,* 2018; Adamek-Urbańska *et al.,* 2021; Huang *et al.,* 2015).

Species like *B. burdigala* and *B. chloropharynx* were found in highly acidic microhabitats and showed traits such as dark coloration and small body size, which may help survival in low-visibility environments (Tan & Ng, 2005; Valen *et al.,* 2023c; Syarif *et al.,* 2025a). Behavioral adaptations like bubble-nest building and substrate burrowing were also observed, supporting reproductive success and seasonal survival. These findings suggest that ecological and behavioral flexibility play a key role in species persistence under stressful habitat conditions (Kang *et al.,* 2010; Brown *et al.,* 2012; Nasir *et al.,* 2025; Syarif *et al.,* 2025b; Budi *et al.,* 2025).

However, Wild Betta populations on Bangka Island are under serious threat due to rapid land use change. Activities such as tin mining, oil palm plantation development, and peatland conversion have significantly reduced and fragmented aquatic habitats (Valen *et al.,* 2023c; Syarif *et al.,* 2025a). For example, in Bikang, the holotype of *B. burdigala*, habitat loss reached 95% between 2023 and 2025.

According to the IUCN Red List, several species recorded in this study are already classified as threatened. *B. burdigala, B. cracens*, and *B. chloropharynx* fall under the Critically Endangered category, while *B. uberis* and *Betta sp.* Bangka are considered Vulnerable. These data highlight the urgent need for habitat protection and stronger conservation measures, particularly for species with narrow distributions and specific habitat needs (South *et al.,* 2025; Budi *et al.,* 2025b).

However, to safeguard the unique Betta species of Bangka Island, an integrated and multi-faceted conservation strategy is essential. Priority should be given to habitat protection by designating critical peat swamp and stream ecosystems—particularly in areas like Bikang and Central Bangka—as protected zones (Valen *et al.,* 2023c; Syarif *et al.,* 2025a; South *et al.,* 2025). Simultaneously, ecological restoration of abandoned tin-mining ponds (kolong) through the reintroduction of native aquatic vegetation and hydrological rehabilitation can create suitable secondary habitats for adaptable species (Geist & Hawkins, 2016; Mustika & Kurniawan, 2024). Active community involvement is also vital; engaging local residents through awareness programs, participatory biodiversity monitoring, and citizen science initiatives can enhance grassroots stewardship and long-term conservation outcomes (South *et al.,* 2025; Budi *et al.,* 2025b).

Although this study successfully identified seven wild Betta species and characterized their unique habitats on Bangka Island, further research is warranted to enhance taxonomic resolution through the use of molecular approaches (Kurniawan *et al.,* 2021). One such approach is DNA barcoding, which has proven effective in resolving taxonomic ambiguity, particularly among cryptic or morphologically similar species (Bingpeng *et al.,* 2028; Chan *et al.,* 2024; Ashour *et al.,* 2025). DNA barcoding, which targets the mitochondrial cytochrome c oxidase subunit I (COI) gene, has been extensively applied in freshwater ichthyology and could be instrumental in confirming the taxonomic status of *Betta sp.* Bangka and other potentially undescribed taxa (Valen *et al.,* 2023b; Syarif *et al.,* 2025c). In addition, environmental DNA (eDNA) metabarcoding presents a efficient method for detecting species presence in inaccessible or heavily degraded habitats. This technique is especially valuable in monitoring low-density populations where traditional survey methods are limited or ineffective (Nakamichi *et al.,* 2023). Integrating molecular tools such as DNA barcoding and eDNA metabarcoding into conservation monitoring programs would not only increase species detection accuracy and reduce field effort but also offer an early warning system for population decline, thereby supporting more responsive and evidence-based conservation planning.

## CONCLUSION

This study documents the diversity and habitat preferences of seven wild Betta species on Bangka Island, including a potentially undescribed taxon. The results highlight the ecological specialization of these species, particularly their adaptation to acidic, low-oxygen peat swamp and blackwater ecosystems. Several species, such as *Betta burdigala* and *B. cracens*, exhibit restricted distributions and are increasingly vulnerable due to ongoing habitat loss caused by mining, land conversion, and pollution.

The findings emphasize the importance of Bangka Island as a center of freshwater fish diversity and call for urgent conservation action. Protecting key habitats, restoring degraded areas, and involving local communities in conservation efforts are critical steps forward. In addition, the integration of molecular approaches such as DNA barcoding and eDNA metabarcoding is recommended to improve species identification, monitor populations, and support long-term biodiversity management. Overall, this research provides a valuable baseline for future taxonomic, ecological, and conservation studies of wild Betta species in Southeast Asia.

## ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to the Institute for Research and Community Service (LPPM), Universitas Bangka Belitung (UBB) for funding and supporting this research through the Off-Campus Student Research Program. Appreciation is also extended to Universitas Bangka Belitung for institutional support, as well as to the field team and local communities who provided valuable assistance during data collection and field exploration.

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