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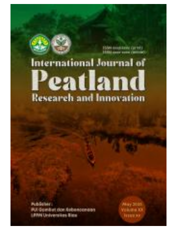

Ecological Roles, Nutritional Value, Conservation Status, and Aquaculture Development of Snakehead (*Channa striata*) in Peatland Ecosystems: A Review

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ABSTRACT

Peatlands and wetlands are unique ecosystems rich in biodiversity that play a crucial role in global carbon sequestration. The snakehead (*Channa striata* Bloch, 1793) is a keystone species in these ecosystems, renowned for its remarkable ability to adapt to extreme environmental conditions, including hypoxia and low pH, facilitated by its suprabranchial labyrinth organ. This review aims to synthesize the current scientific knowledge on the ecology, biology, economic potential, and aquaculture development prospects of snakehead fish in peatland and wetland ecosystems in Indonesia. A systematic literature review was conducted following the PRISMA guidelines, with searches performed across Scopus, Web of Science, Google Scholar, PubMed, and the Garuda Portal databases. The findings reveal that snakehead fish occupy a critical ecological role as apex predators within wetland food webs, while simultaneously demonstrating considerable economic and biomedical value attributed to their high albumin and protein content, which promotes wound healing. Nevertheless, snakehead fish populations are increasingly threatened by overfishing and peatland habitat degradation driven by land conversion for agriculture and oil palm plantations. The development of paludiculture-based aquaculture on restored peatlands presents a promising synergistic solution that reconciles ecosystem conservation with the economic empowerment of local communities. However, persistent challenges including water quality management, limited market access, and the need for regulatory harmonization must be addressed through a comprehensive and integrated approach.

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1. Introduction

Peatlands and wetlands are unique ecosystems that dominate much of Southeast Asia, including Indonesia. Indonesia has the world's second-largest peatland area after Russia, distributed across Sumatra (6.44 million ha), Kalimantan (4.78 million ha), and Papua (3.69 million ha) [1]. These ecosystems are rich in biodiversity, supporting various endangered species such as orangutans, tigers, and numerous bird species [2]. According to [3], peatlands act as significant carbon sinks, storing approximately 70 billion tons of carbon, which is crucial for regulating the global climate. Peatland ecosystems are characterized by extreme physico-chemical conditions, including low pH (3.0-5.0), low dissolved oxygen levels [4], and high levels of organic matter and humic acids [5]. Nevertheless, various types of aquatic organisms, including fish, have adapted to these environmental conditions, making peatlands and wetlands ecosystems with high biodiversity and high conservation value.

The snakehead fish (*Channa striata* Bloch, 1793) is a freshwater fish species of the Channidae family with a wide distribution across Southeast Asia and high economic value [6]. In Indonesia, the snakehead is known by various local names such as haruan (Kalimantan), bogo (West Java), and licingan (Central Java). This species is classified as an apex predator in peatland ecosystems, such as Rawa Danau Panggang in South Kalimantan [7], and is common in wetland areas, such as the seasonal Kaliki wetland in Merauke [8]. It possesses an extraordinary ability to adapt to hypoxic conditions and low pH levels. The suprabranchial labyrinth organ in snakehead fish allows this species to extract oxygen directly from the air, enabling it to survive in water bodies with extremely low dissolved oxygen levels, which are typically found in peatland ecosystems. This adaptive capability makes the snakehead fish an important biological indicator for tropical wetland ecosystems [9].

The snakehead fish has been a primary source of animal protein for local communities. This fish is rich in nutrients, such as high levels of protein and albumin [10], and is also used in traditional medicine to accelerate wound healing [11]. However, excessive fishing pressure (overfishing) and habitat degradation resulting from the conversion of peatlands for agriculture and oil palm plantations have threatened wild snakehead fish populations. Therefore, there is a need for conservation efforts and for the development of planned, sustainable aquaculture.

Given the significant ecological, economic, and biomedical potential of snakehead fish, as well as the importance of preserving peatland and wetland ecosystems as their habitats, a study integrating various related scientific aspects is required. This review article aims to provide information regarding the ecology, biology, economic potential, and prospects for the development of snakehead fish aquaculture in peatland and wetland ecosystems in Indonesia

2. Methods

This review article was compiled using a systematic literature review method based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Literature searches were conducted through several international and national scientific databases, including Scopus, Web of Science, Google Scholar, PubMed, and Portal Garuda. Keywords used in the search included: "*Channa striata*", "snakehead fish", "peatland fish", "wetland aquaculture", "ikan gabus", "peatland", "fish albumin", "Channidae ecology".

3. Results and Discussion

Ecological Characteristics, Distribution, and Physiological Adaptations of Snakehead Fish in Peatland Ecosystems

The snakehead fish is a primary inhabitant of peatland aquatic ecosystems in Southeast Asia. In Indonesia, the distribution of this species spans the entire regions of Sumatra, Kalimantan, Java, Sulawesi, and Papua, with the largest populations found in the peatland ecosystems of Sumatra and Kalimantan [12]. In peatland ecosystems, snakeheads generally inhabit riparian zones and areas with water hyacinth (*Eichhornia crassipes*), sweet flag (*Eleocharis dulcis*), and various types of aquatic macrophytes that provide protection from predators and serve as spawning grounds [13].

The distribution and ecology of the snakehead in peatlands are influenced by various environmental factors and human activities. In the Rawa Aopa Watumohai area, snakehead fish exhibits a uniform distribution pattern in a relatively homogeneous environment, with variations in abundance influenced by location and time [14]. In Sempor Reservoir, snakehead fish was found in various zones, with distribution more influenced by habitat selection behavior than by water quality parameters, such as temperature and depth [15]. In the floodplains of the Musi River, snakehead fish is commonly found in floodplain areas such as the Meriak and Semuntul Rivers. This study estimated population parameters, including growth and mortality rates, indicating a high exploitation rate of 0.67 per year, which exceeds the optimal level. The species' behavior in selecting habitats and its reproductive patterns also play a crucial role in its distribution and abundance [16]. Furthermore, according to [17], in the Singkil peat swamp, snakehead fish is one of the most frequently encountered species, demonstrating its adaptability to peatland conditions. Snakehead fish demonstrates remarkable adaptability to various environmental conditions, including hypoxia and pH fluctuations, which are common in peatland ecosystems. This adaptability is crucial for its survival and reproduction in such habitats [9].

The snakehead fish ability to survive under the extreme conditions of peatlands is the result of complex evolutionary adaptation. Water quality parameters in peatland ecosystems differ significantly from those in normal water bodies, with pH ranging from 3.5 to 5.5. This acidity is primarily due to the high concentration of organic acids in the peat soil [18]. Dissolved oxygen levels are often below 2 mg/L, indicating a low-oxygen environment. This is caused by the high organic content and slow decomposition rate in peatlands, which consume oxygen [19]. Low conductivity (<50 µS/cm). This low conductivity is caused by the lack of salts and dissolved ions in the water [18], as well as high levels of tannins and humic acids, which give peatwater its characteristic brownish color (blackwater) [20].

The snakehead fish possesses a suprabranchial labyrinth organ above the gills, enabling direct air-breathing at the water's surface. The air-breathing ability of snakehead fish allows it to thrive in hypoxic and polluted waters, making it a successful invader of new habitats. This trait is highly advantageous in environments with low dissolved oxygen levels [21]. The species' adaptability to various environmental conditions, such as hypoxia, temperature fluctuations, and salinity, reflects its ecological plasticity and potential for climate-resilient aquaculture [9]. According to [21], the role of the labyrinth organ in modulating behaviors, such as territorial display and mating, further underscores its importance in the ecological success of snakehead fish.

The ecological role of snakehead fish in wetland and peatland ecosystems is crucial. As an apex predator within the fish class, snakehead fish plays a role in regulating populations of small herbivorous fish such as the *Trichopodus trichopterus* and *Anabas testudineus*, thereby indirectly helping to control the overgrowth of phytoplankton and aquatic macrophytes (trophic cascade) [22]. [23] state that the movement and interactions of fish like snakehead fish across different habitats in wetlands and peatlands contribute to ecosystem connectivity. This connectivity is crucial for nutrient cycling and energy flow, which are vital for the resilience and productivity of these ecosystems. Adult snakeheads, as secondary detritivores, play a key role in nutrient cycling within peatland ecosystems by preying on detritivorous invertebrates. This predation activity contributes to the breakdown and recycling of organic matter, facilitating nutrient flow through the ecosystem [24]. By controlling detritivore populations, snakehead fish can modulate decomposition rates and nutrient release.

Population Status, Challenges, and Development of Snakehead Fish Aquaculture

Although the snakehead fish is not yet listed as endangered on the IUCN Red List (status: Least Concern), the population decline across various regions of Indonesia is concerning. Human activities, such as habitat degradation, pollution, and overfishing, pose significant threats to the ecological role of apex predators like snakehead fish. These activities can disrupt predator-prey relationships and lead to trophic instability [22]. According to [25], peat swamp forests, which are rich in biodiversity, are being replaced by monoculture plantations, leading to a decline in species diversity. This affects the entire ecosystem, including fish populations that depend on the complex habitat structures provided by natural peatlands. [26] state that the conversion of peatlands to agriculture affects water quality through increased turbidity, changes in pH, and higher levels of dissolved organic carbon (DOC). These changes can harm sensitive fish species, including snakehead fish, which are particularly sensitive to environmental changes. Fish species composition changes significantly in areas where peatlands have been converted into oil palm plantations.

A new paradigm in sustainable peatland management promotes the development of rewetting systems and paludiculture that is, the cultivation of plants or animals adapted to wet peatland conditions. In this context, snakehead fish farming on restored peatlands offers a synergistic opportunity between ecosystem conservation and community economic empowerment. According to [27] , snakehead fish farming on restored peatlands can provide sustainable livelihoods for local communities. This aligns with the paludiculture model, which promotes the use of wetland cultivation to support both ecological and economic functions. Furthermore, as noted by [28], while snakehead fish farming on restored peatlands offers promising synergies between conservation and economic empowerment, challenges remain. These include addressing environmental vulnerabilities such as water quality and climate variability, as well as overcoming socio-economic barriers such as limited market access and financial insecurity. On the regulatory front, policy harmonization among fisheries, forestry, and land-use planning is essential to enable the development of snakehead fish farming in peatland areas without violating regulations

4. Conclusions

The snakehead fish is a strategic species in Indonesia's peatland ecosystems, possessing high ecological, economic, and biomedical value. Threats of overfishing and habitat degradation demand an integrated approach that combines conservation with the development of sustainable paludiculture-based aquaculture to ensure both the species' survival and the well-being of local communities.

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