Seasonal Trends and Risk Factors of Epizootic Ulcerative Syndrome in Fish

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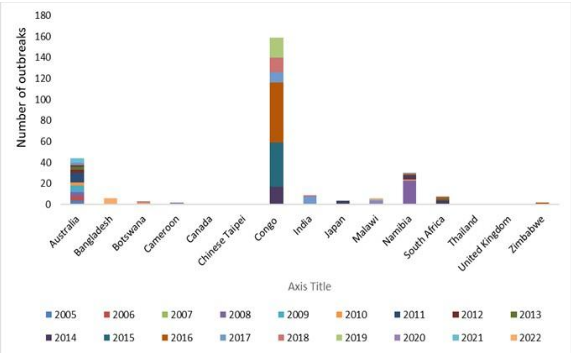
ABSTRACT

Epizootic ulcerative syndrome (EUS) is a severe fish disease caused by the oomycete *Aphanomyces invadans*, affecting both wild and cultured fish in freshwater and estuarine systems. The infection causes skin ulcers, deep muscle necrosis, and granulomatous lesions, leading to significant economic losses, particularly in the Asia–Pacific region. Outbreaks are influenced by seasonal and environmental factors, including low water temperatures, poor water quality, flooding, low dissolved oxygen, and stress. The pathogen's deep tissue invasion reduces the effectiveness of conventional treatments, and its persistence in sediments makes eradication from natural water bodies difficult. Effective management requires integrated strategies, combining strict biosecurity, environmental monitoring,

quarantine of new stock, and enhancement of fish immunity through proper nutrition and stress reduction. Innovative monitoring technologies, including AI-based image analysis and real-time tracking of water quality, enhance the timely detection of EUS and support more effective outbreak management.

INTRODUCTION

Epizootic ulcerative syndrome is a fungal-like oomycete infection that affects both wild and cultured fish leading to skin ulcers, severe muscle damage, and granulomatous lesions. It impacts a wide range of finfish species in freshwater and estuarine systems. Historical outbreaks have caused substantial economic losses across the Asia–Pacific region, and because of its capacity for cross-border spread and its significant threat to fisheries and aquaculture, the disease is recognized by WOAH as a notifiable condition (Gayathri *et al*., 2008).An analysis of global spatiotemporal patterns of EUS outbreaks from 2005 to 2022 showed 277 cases reported to the World Organization for Animal Health (WOAH) across 15 countries and territories, with 76% of these outbreaks occurring in Africa (N.P. Karki, 2023).



Source: (N.P. Karki, 2023)

Agent and pathogenesis

Aphanomyces invadans, an oomycete in the order Saprolegniales, is the recognized causative agent of the disease. It acts as an invasive opportunistic pathogen, penetrating the fish skin and muscle and provoking granulomatous immune responses. Evidence from experimental infections and histopathological studies shows that its zoospores and hyphae infiltrate skin and muscle tissues, resulting in fungal granuloma development, dermatitis, myositis, and widespread physiological stress in infected fish (Das *et al*., 2021).

- **Organism class**: is an oomycete (a fungus-like Chromista/Stramenopile) identified as *Aphanomyces invadans* (Gayathri *et al*., 2008).
- **Pathogenic sequence**: Its pathogenic progression typically begins with zoospore attachment and colonization, followed by hyphal penetration of the epidermis, invasion into deeper muscle tissues, and the development of granulomas and necrotic lesions, which are often accompanied by secondary bacterial infections (Chong, 2022).
- **Host response:** Affected fish exhibit granulomatous inflammation along with changes in leukocyte profiles, serum biochemical parameters, and heightened innate immune activity, as demonstrated in experimental infection studies (He *et al*., 2022).

Seasonal Triggers and Mechanisms

Seasonal environmental fluctuations including changes in temperature, rainfall, flooding, and reductions in water quality place physiological stress on fish, increasing their susceptibility to EUS. These factors help explain why outbreaks consistently occur during specific times of the year. The pathogen *Aphanomyces* invadans acts opportunistically, taking advantage of host stress caused by low dissolved oxygen, acidic conditions, and unfavourable temperatures to initiate infection.

- **Temperature threshold:** Predisposing water temperatures generally fall within 18–22 °C, although published reports show that EUS can occur across a wider range of approximately 10–33 °C (Gayathri *et al*., 2008).
- **Dissolved oxygen and pH**: Low dissolved oxygen and mildly acidic to neutral pH levels are recognized risk factors for EUS. Reports have documented dissolved oxygen concentrations as low as 0.8–2.5 $mg \cdot L^{-1}$ prior to outbreaks, along with pH levels between 6.0 and 7.0 that appear to favor disease development (Gayathri *et al*., 2008).
- **Rainfall and flooding**: Flooding and the conditions that follow are often linked to outbreaks, probably due to factors such as fish being displaced, higher levels of organic material, and changes in water chemistry (Das *et al*., 2021).
- **Low water levels and husbandry**: In aquaculture, outbreaks are often associated with low pond levels and management practices that negatively impact water quality (Gayathri *et al*., 2008).

Regional occurrence patterns

The timing of outbreaks differs across regions and ecological settings, with many documented cases showing distinct seasonal or event-related patterns. In areas with detailed environmental monitoring, outbreaks have been observed alongside cooler late-season temperatures, low oxygen levels, or flooding events.

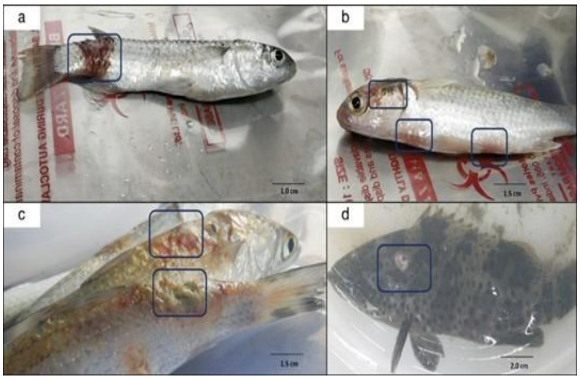
Case studies from affected regions

1. The study examines the factors contributing to Epizootic Ulcerative Syndrome (EUS) in fish within the Zambezi River basin. First detected in 2006, the disease caused high mortality in species such as *Barbus* and *Clarias*, threatening fish biodiversity and the food security of more than 700,000 people in 2,000 villages, with Zambia being the most affected. The outbreak occurred after heavy rains and flooding, and acidic soils that lowered water pH were initially considered the main cause. However, subsequent outbreaks in non-acidic regions indicate that other factors may also play a role. To better understand these risks and determine the disease's prevalence, severity, and spatial distribution, an active surveillance program combined with participatory epidemiological methods is currently being conducted (Nsonga *et al*., 2010).
2. The study reports EUS outbreaks in estuarine fish in Kerala, India, in 2018 thirty years after the initial cases and following severe flooding. Six species were affected (*Mugil cephalus, Platycephalus sp., Scatophagus argus, Arius sp., Planiliza macrolepis, and Epinephelus malabaricus*), with *E. malabaricus and P. macrolepis* showing natural infections for the first time. During the outbreak, water conditions were harsh, with salinity below 2 ppt, temperature at 25°C, dissolved oxygen at 4.1 ppm, and pH near 7.0. The detection of zoonotic bacteria (*Aeromonas veronii, Shewanella putrefaciens, Vibrio vulnificus, and V. parahaemolyticus*) in infected fish highlights possible public health risks if the fish are not handled safely (Sumithra *et al*., 2020).
3. The study analysed water quality and rainfall in Sri Lanka's Bellanwila–Attidiya wetlands from November 1996 to

September 1997 to identify environmental factors linked to epizootic ulcerative syndrome (EUS). Fish were sampled regularly, and EUS was confirmed through clinical and histopathological examination. The outbreak occurred from January to March 1997, following heavy rainfall and was associated with sharp drops in dissolved oxygen, high daily temperature fluctuations, and increased biochemical oxygen demand. Trichogaster pectoralis showed the highest infection rate. Findings suggest that reduced water quality, changing rainfall patterns, and pathogen presence create stressful conditions that trigger EUS in vulnerable fish (Pathiratne & Jayasinghe, 2001).

4. Fish assessments in the Arasalar estuary, India, revealed clear seasonal patterns in Epizootic Ulcerative Syndrome (EUS). Out of 75 fish sampled, 16% showed infection, with the greatest incidence during the rainy season and moderate cases in pre-summer. No infections were detected in summer or post-summer, highlighting strong seasonal impacts on EUS (Saravanan *et al*., 2023).

5. Epizootic ulcerative syndrome (EUS), listed by the OIE, has been reported in 26 countries across four continents and naturally affects 94 fish species with its host range continuing to expand. In 2010–11 severe EUS outbreaks occurred in the wetlands of Uttar Pradesh, India, causing approximately 69% mortality (371/540) across 13 species. Seven species *Aristichthys nobilis, Channa punctatus, Wallago attu, Mastacembelus armatus, Mystus cavasius, Anabas testudineus*, and *Puntius conchonius* were reported infected for the first time. Outbreaks even occurred at a mean water temperature of 31.6°C demonstrating that the disease remains a threat decades after its emergence (Pradhan *et al*., 2014).



EUS-affected fishes (blue rectangles). (a, b) Hemorrhagic lesions and deep ulcers on *Mugil cephalus*. (c) Caudal necrosis and red spots on *Planiliza macrolepis*. (d) Ulcers on *Epinephelus malabaricus,* **Source: (Sumithra *et al*., 2020)**

Monitoring and Surveillance

Aquaculture suffers substantial economic losses from frequent disease outbreaks, highlighting the need for timely and accurate detection. This study presents a combined diagnostic method that integrates deep learning-based image analysis with statistical modelling of water quality. Tested on 100 juvenile Red Malaysian Mahseer, the system reached 87.7% precision in identifying diseases and 85% accuracy in predicting risk. By merging visual assessment with pH and temperature data, the approach enables real-time monitoring and strengthens disease management in aquaculture (Yasruddin *et al*., 2025). The authors evaluate existing and potential aquatic surveillance and diagnostic technologies by comparing them to three key benchmarks: high sensitivity and specificity, rapid detection, and cost-effectiveness (MacAulay *et al*., 2022). In this study, a support vector machine (SVM) model was applied to identify Epizootic Ulcerative Syndrome (EUS) in fish, yielding 85.24% accuracy with a polynomial kernel and 82.75% accuracy with a Gaussian kernel on the original dataset (Sujatha, 2023). This research presents a smartphone-enabled method that applies augmented reality and image processing to identify fish diseases, particularly Epizootic Ulcerative Syndrome (EUS). Using HSV image analysis, the system allows quick, on-site detection and improves diagnostic accuracy (Chakravorty, n.d.2020)

Prevention and Control Strategies

The paper reviews major fish diseases, including their causes, symptoms, and treatment options, and emphasizes the importance of an integrated strategy combining medications, vaccines, and strong biosecurity practices to improve fish health and reduce the risk of antibiotic resistance (Anand & Ghatpande, 2025). Effective prevention relies on strong biosecurity measures. Using certified pathogen-free fingerlings, quarantining any newly introduced fish for 2–3 weeks, and routinely disinfecting nets, tanks, and other gear help prevent diseases from entering the system (Roberts, 2012). A comprehensive review shows that environmental conditions strongly influence disease prevention. Low temperatures and poor water quality heighten fish vulnerability to pathogens. Maintaining optimal temperature, clean water, and close monitoring of these factors helps create resilient culture systems and reduces the risk of disease outbreaks (Das & Das 1993).

Treatment Limitations

Epizootic ulcerative syndrome (EUS), caused by the oomycete *Aphanomyces invadans*, is among the most difficult aquaculture diseases to manage. After infection, the organism infiltrates deep muscle tissues and forms granulomatous lesions, reducing the effectiveness of standard treatments and making full removal from contaminated environments highly challenging. Treating extensive natural water system such as rivers, wetlands, and floodplains on a large scale is neither feasible nor environmentally responsible. Efforts to eliminate the pathogen are further hindered by the long-term survival of *A. invadans* spores within sediments (Lilley & Roberts, 1997). It underscores the importance of the innate immune system in fish for combating diseases, suggesting that enhancing immunity through proper nutrition, optimal environmental management, and stress reduction can effectively prevent or lower the risk of epizootic ulcerative syndrome (EUS) (Saurabh & Sahoo, 2008).

CONCLUSION

Epizootic ulcerative syndrome (EUS) remains a major threat to both wild and cultured fish, driven by the pathogenic oomycete *Aphanomyces invadans*. Seasonal and environmental factors, including low temperatures, poor water quality, flooding, and stress, significantly influence outbreak occurrence. The disease's deep tissue invasion and granulomatous lesions limit treatment effectiveness, while large-scale environmental control is impractical due to spore persistence. Effective management relies on integrated strategies combining strong biosecurity, environmental monitoring, and enhancing fish innate immunity through proper nutrition and stress reduction. Advances in surveillance, including AI-based image analysis and real-time monitoring, offer promising tools for early detection and outbreak mitigation.

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