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Effects of Environmental Factors on the Health Status of Turbot (*Scophthalmus maximus*)

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Abstract As an important marine aquaculture species, the health status of the turbot (*Scophthalmus maximus*) is significantly influenced by various environmental factors during intensive farming. This paper systematically reviews the mechanisms by which key environmental factors-such as temperature, salinity, dissolved oxygen, and water quality-affect the physiological homeostasis, immune function, and disease susceptibility of turbot. The results indicate that temperature fluctuations can alter immune responses by inducing metabolic imbalances and changes in heat shock protein expression, thereby increasing susceptibility to pathogens. Salinity variations disrupt osmoregulatory systems, triggering stress responses and compromising disease resistance. Insufficient dissolved oxygen and the accumulation of ammonia-nitrogen lead to chronic stress and tissue damage, exacerbating health risks. Furthermore, environmental stressors enhance the pathogenicity of bacteria (such as **Vibrio** spp.), further promoting disease outbreaks. In high-density aquaculture systems, the coupled effects of multiple factors significantly amplify these health risks. Based on this analysis, the paper proposes strategies for environmental monitoring and integrated regulation to mitigate the adverse effects of environmental stress on turbot health and to enhance the stability and productivity of aquaculture systems.

Keywords Turbot; Environmental factors; Temperature stress; Osmoregulation; Disease outbreak

1 Introduction

Turbot aquaculture has become an important component of marine finfish production, driven both by declining wild stocks and by the species' favorable farming traits. Wild turbot catches have generally decreased since the mid-1990s, and aquaculture production has exceeded capture production since 2002, while the species remains valued for rapid growth, high survival, and efficient feed conversion. Over the past several decades, these attributes have supported the industrial development of turbot farming in Europe, and large-scale expansion in China has made turbot one of the world's most important cultivated flatfish species, with annual Chinese production reported above 60,000 tons in the first two decades after introduction (Fernández-González et al., 2022).

At the same time, the success of turbot culture depends strongly on environmental suitability, because this cold-water marine species performs best within relatively narrow physicochemical ranges. In European production systems, water temperatures of about 15°C-19°C and salinity of 25-35 psu are identified as key conditions for successful farming, highlighting the central role of site quality and water management in production outcomes (Fernández-González et al., 2022). More broadly across fishes, temperature, pH, salinity, and dissolved oxygen shape physiology, metabolism, behavior, and survival, with salinity shifts altering energy allocation and gill function, and low dissolved oxygen reducing growth, reproduction, and disease resistance (Mariu et al., 2023).

For marine fish, environmental factors are not only determinants of growth performance but also major regulators of stress and health status. Temperature increases can act as a direct physiological stressor, especially in ectothermic species approaching their upper thermal tolerance limits, and warming can also worsen oxygen-related constraints and broader population-level vulnerability (Alfonso et al., 2020). Turbot-specific studies show the same pattern at the organismal level: high stocking density suppresses growth, elevates cortisol and glucose, and weakens skin immune defenses, while elevated ammonia activates stress pathways and inhibits humoral immunity, indicating that environmental deterioration can rapidly translate into impaired welfare and disease susceptibility.