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Fish Anaesthetics in Aquaculture: Promoting Safe Handling, Welfare and Sustainability

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Fish anaesthesia is an important component of modern aquaculture, fisheries research and aquatic animal health management as allows for the safe handling of fish during procedures such as weighing, tagging, vaccination, health examination, transportation, breeding and tissue sampling, while also reducing excessive physical activity and handling-related stress. Commonly used anaesthetic agents include tricaine methanesulfonate (MS-222), benzocaine, 2-phenoxyethanol, metomidate, quinaldine and plant-derived compounds such as eugenol. Their efficacy varies with species, body size, water quality, temperature, physiological condition and procedure. An appropriate anaesthetic should have predictable and reversible effects, adequate safety and fast recovery and its use in food fish must adhere to relevant residual and regulatory standards. This study highlight, characteristics of suitable anaesthetics, stages, commonly used agents, administration methods and recent developments relevant to fish welfare and sustainable aquaculture.

Keywords: Fish Anaesthesia; Aquaculture; MS-222; Eugenol; Benzocaine; Fish Welfare

Introduction

Aquaculture requires regular handling for weighing, grading, tagging, vaccination, health examination, breeding and transportation, which can induce physiological stress and increase the risk of injury, potentially affecting fish welfare and performance. Fish anaesthesia reduces excessive movement and facilitates controlled handling, with the required depth depending on the species, agent and procedure (Fayaz *et al.*, 2026). Common anaesthetics include MS-222, benzocaine, 2-phenoxyethanol, metomidate, quinaldine and eugenol. Their effects vary among species and are influenced by environmental and physiological conditions. Therefore, appropriate agent selection, dosage, monitoring and recovery are essential for effective and welfare-oriented use.

Characteristics of an Ideal Anaesthetic Agent

An ideal fish anaesthetic should provide stable and regulated immobilisation with minimum side effects, while also allowing for rapid and predictable recovery. However, no single anaesthetic is appropriate for all fish species or treatments. The decision should therefore be made based on the fish species, size and physiological state, the purpose and duration of anaesthesia, water temperature and quality, mode of administration, cost and any regulatory requirements (Fayaz *et al.*, 2026).

a) Safety: The agent should minimise adverse effects, mortality and prolonged physiological disturbance while limiting risks to handlers and the environment, with residue limits, withdrawal periods and applicable national regulations considered for food fish, as regulatory requirements vary among countries.

b) Ease of Use and Recovery: A suitable agent should be easy to prepare and administer, with predictable induction and recovery, although response times vary with species, body size, temperature, water chemistry, physiological condition and concentration.

c) Cost and Regulatory Compliance: Cost is important in commercial aquaculture but should not compromise efficacy, safety or regulatory compliance and anaesthetics should be used according to applicable regulations and product-specific instructions (Jia *et al*., 2025).

Table 1. Stages of Fish Anaesthesia and their Practical Applications

Stage	Condition	General behavioural/physiological response
I	Sedation	Reduced activity and responsiveness; swimming and ventilation may decrease
II	Anaesthesia	Progressive loss of equilibrium and responsiveness to external stimuli
III	Surgical Anaesthesia	Profound loss of equilibrium and response to appropriate stimulation, with marked reduction in muscle tone
IV	Medullary collapse / Excessive Anaesthesia	Severe respiratory depression or cessation of ventilation, potentially followed by cardiovascular collapse and death

Source: Adapted from Ross and Ross (2009).

Table 2. Common Anaesthetic Agents Used in Fish and Their Key Features

Anaesthetic Agent	Major Advantages	Limitations / Considerations	Common Applications
MS-222 (Tricaine methanesulfonate)	Well-established and extensively studied; water soluble; reliable anaesthetic action	Can lower water pH and may require buffering; relatively costly; food-fish use is subject to jurisdiction-specific regulatory requirements	Research, routine handling, tagging, vaccination, breeding and surgical procedures
Benzocaine	Effective synthetic anaesthetic; relatively inexpensive	Poor water solubility; generally requires suitable dissolution or formulation before use	Routine handling, research and laboratory procedures
Quinaldine	Effective in a range of fish species; can provide useful sedation or anaesthesia	Odour associated with quinaldine; induction and recovery characteristics vary among species and concentrations; regulatory status varies	Fisheries research, handling and selected field applications
2-Phenoxyethanol (2-PE)	Relatively inexpensive; widely studied; practical for immersion use	Induction and recovery vary with species and concentration; prolonged or excessive exposure may cause adverse effects; food-fish regulatory suitability must be considered	Aquaculture, hatchery and research applications
Clove oil / Eugenol	Plant-derived; effective in several fish species; relatively accessible and economical	Poor water solubility; formulation requirements; induction and recovery vary among species	Fish handling, research and selected aquaculture applications

Sources: Ross and Ross (2009); Fayaz *et al.* (2026); Jia *et al.* (2025); Félix *et al.* (2023).

Methods of Administering Fish Anaesthetics

Fish anaesthetics can be administered through immersion, injection and oral routes. The appropriate method depends on the anaesthetic agent, fish species, size, intended procedure and required depth and duration of anaesthesia. Species-specific protocols are important because fish can respond differently to the same anaesthetic.

a) Immersion Administration: Immersion or bath anaesthesia is the most commonly used method in aquaculture and fish research. The anaesthetic is mixed with water at an appropriate concentration and fish are exposed to the solution. Anaesthetic uptake occurs predominantly through the gills, allowing systemic absorption and progressive induction of anaesthesia. This method is particularly useful for regular handling, biometric measurements, sampling, grading, tagging and minor procedures.

b) Injection Administration: Anaesthetics may also be administered by injection, providing direct systemic delivery. Injection can be useful in experimental applications where a defined dose is required or immersion is unsuitable. However, it requires appropriate technical knowledge, accurate dose calculation and careful handling, as improper use may cause stress.

c) Oral Administration: Oral administration involves delivering an anaesthetic through the gastrointestinal tract, generally with feed or an appropriate oral formulation. This route has been described for specialised applications but is considerably less common than immersion for routine fish anaesthesia. Drug uptake can be influenced by feed intake, gastrointestinal absorption and the physiological condition of the fish; therefore, achieving a predictable anaesthetic depth may be more difficult.

Monitoring and Recovery

Regardless of the administration route, fish should be continuously monitored during induction and anaesthesia. Following the procedure, the fish should be transferred to appropriate recovery water and monitored until they regain their normal posture and swimming activity.

Emerging Developments in Fish Anaesthesia

Recent developments in fish anaesthesia emphasise efficacy, rapid recovery, safety and fish welfare, with growing interest in plant-derived and other alternative anaesthetics. However, their effectiveness varies with species, concentration and environmental conditions, requiring systematic evaluation before widespread use. Research is increasingly assessing behavioural responses, physiological stability, recovery quality and welfare, rather than focusing only on immobilization (Readman *et al*., 2013). In food-producing aquaculture, drug residues, withdrawal requirements, operator safety and environmental impacts are also important considerations. To promote safe and responsible aquaculture, future research should focus species-specific protocols, welfare-based evaluation, dependable induction and recovery, residual safety and ecologically sustainable anaesthetic methods.

Conclusion

Fish anaesthesia promotes safe handling in aquaculture and fisheries research while reducing stress and injury. Its effectiveness depends on species, physiological condition, dosage, water quality, temperature and procedural requirements. Common agents have distinct benefits and limitations, requiring evidence-based selection and appropriate monitoring. Future developments should focus on predictable anaesthesia, rapid recovery, fish welfare, food safety and environmental sustainability.

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