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Behavioral Management Strategies for Enhancing Ornamental Fish Welfare

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Abstract-- Ornamental fish are maintained in home aquaria, commercial breeding facilities, public aquariums, and research environments, where appropriate welfare management is essential for maintaining health and natural behavioral expression. Behavior is an important indicator of fish welfare because changes in feeding, swimming, exploration, aggression, social interaction, shelter use, and respiratory activity can reflect environmental stress or inadequate husbandry. This review examines behavioral management strategies for improving the welfare of ornamental fish, with particular emphasis on environmental enrichment, habitat complexity, social management, feeding practices, stocking density, handling, and behavioral monitoring. Environmental enrichment can provide opportunities for exploration, foraging, shelter use, and other species-appropriate activities while potentially reducing abnormal or stress-related behaviors. Evidence from aquatic-animal research indicates that physically enriched environments can improve several welfare outcomes, although responses vary according to species, life stage, enrichment type, and environmental conditions. Recent research also emphasizes physical, sensory, dietary, occupational, and social enrichment as complementary approaches to welfare management. A species-specific approach is particularly important because ornamental fish differ substantially in social organization, habitat preference, activity patterns, feeding behavior, and environmental requirements. Regular behavioral assessment, combined with water-quality and health monitoring, can provide an effective basis for identifying welfare problems and evaluating management interventions. Overall, behavioral management should move beyond simply preventing stress and focus on providing captive environments that allow ornamental fish to express appropriate natural behaviors and experience positive welfare. Further research is needed to establish standardized behavioral indicators and practical welfare protocols for different ornamental fish species.

Keywords-- Ornamental fish; fish welfare; behavioral management; environmental enrichment; captive husbandry; behavioral indicators; stress; habitat complexity; social behavior; aquarium management.

I. INTRODUCTION

The ornamental fish sector has become an important component of the global aquatic-animal industry, with freshwater and marine species maintained for aesthetic, educational, recreational, and commercial purposes.

Unlike fish kept primarily for food production, ornamental fish may remain in captivity for prolonged periods and are frequently maintained in relatively restricted artificial environments. Consequently, the quality of the captive environment can have substantial effects on their behavior, health, and welfare.

Fish welfare is a multidimensional concept involving physical health, environmental conditions, behavioral opportunities, and the animal's ability to cope with its surroundings. Behavior is particularly useful because it represents the response of an animal to the environment as it perceives it. Changes in foraging, swimming, aggression, ventilation, exploration, and abnormal repetitive behaviors can therefore provide important information about welfare status. Traditional aquarium management has often emphasized water quality, nutrition, disease prevention, and appearance. Although these factors remain fundamental, increasing attention is being given to behavioral requirements and environmental complexity. Research on ornamental angelfish, for example, has highlighted the importance of understanding social, reproductive, feeding, and cognitive behaviors when developing welfare-oriented husbandry practices.

Behavioral management provides a framework for connecting husbandry practices with the behavioral needs of fish. It includes environmental enrichment, appropriate social conditions, suitable habitat structures, predictable and biologically appropriate feeding, reduction of unnecessary disturbances, and systematic behavioral observation. Environmental enrichment is particularly promising because it can provide sensory and motor stimulation and help meet behavioral and physiological requirements while reducing stress and abnormal behaviors.

II. OBJECTIVES OF THE REVIEW

The major objectives of this review are to examine the relationship between behavior and welfare in ornamental fish. Identify important behavioral indicators of good and poor welfare. Discuss environmental enrichment strategies suitable for ornamental fish. Examine the importance of social conditions and stocking density. Discuss feeding and behavioral management approaches.

Highlight the importance of habitat complexity and species-specific aquarium design. Explain the role of behavioral monitoring in welfare assessment. Identify challenges and future research priorities in ornamental fish welfare management (1).

III. BEHAVIOR AS AN INDICATOR OF ORNAMENTAL FISH WELFARE

Behavioral assessment is a non-invasive method of evaluating the condition of captive fish. Because fish continuously interact with their physical and social environment, behavioral changes may occur before obvious clinical signs become apparent.

Important behaviors that can be monitored include Swimming activity and swimming pattern, feeding and foraging behavior, exploration, use of shelters, social interactions, aggressive behavior, territorial behaviour. Schooling or shoaling, resting behavior, response to disturbance, ventilator activity, abnormal repetitive behaviours. Reduced feeding, unusual inactivity, excessive hiding, persistent aggression, abnormal swimming, or excessive ventilation may indicate that environmental conditions require attention. Conversely, appropriate exploration, feeding, social interaction, and species-typical activity can provide evidence that environmental conditions are supporting normal behavioral functioning. Behavioral indicators should, however, be interpreted together with environmental and health information rather than being treated as isolated measures.

IV. ENVIRONMENTAL ENRICHMENT

Environmental enrichment is one of the most important behavioral management approaches for captive fish. It involves modifying the environment to provide biologically relevant stimuli and opportunities for natural behaviors.

Research indicates that enrichment can improve welfare by increasing environmental complexity and providing opportunities for exploration, foraging, learning, and shelter use. A large systematic review and meta-analysis involving aquatic animals found an overall positive effect of physical enrichment on welfare, although the magnitude and direction of responses depended on enrichment type, animal group, developmental stage, and welfare measure.



Fig 1: Fish environmental enrichment

4.1 Physical Enrichment

Physical enrichment can include: Aquatic plants, artificial vegetation rocks and suitable structures, Caves and shelters, substrate, driftwood or other appropriate naturalistic structures, different spatial zones, visually separated areas. Such structures can provide hiding places, territorial boundaries, exploration opportunities, and environmental complexity. Physical enrichment has been associated with improvements in behavioral and welfare outcomes in captive fish, although the design should be appropriate for the species and aquarium system.

4.2 Sensory Enrichment

Sensory enrichment involves providing appropriate visual, tactile, chemical, or other environmental stimuli. However, enrichment should not simply maximize stimulation. Excessive or inappropriate stimulation may create additional stress. Therefore, enrichment should be evaluated according to whether it produces desirable behavioral outcomes rather than being provided solely for visual complexity.

4.3 Dietary Enrichment

Feeding can be used as a behavioral enrichment opportunity. Instead of relying exclusively on highly predictable feeding routines, appropriate variation in feeding presentation can encourage natural foraging and searching behaviors. Cognitive-enrichment research suggests that predictability, learning opportunities, and controlled interactions with feeding systems may influence fish welfare. However, effects can differ among species, and enrichment should be designed according to the ecology and behavioral capabilities of the fish.

V. HABITAT COMPLEXITY AND AQUARIUM DESIGN

The aquarium should not be considered merely a container for fish; it should function as an environment that supports species-specific biological and behavioral requirements.

A complex habitat can provide: Refuge from aggressive tank mates, areas for exploration, resting locations, territorial boundaries, visual barriers, and foraging opportunities. Species-specific reproductive sites, opportunities for normal social behavior

For example, fish that naturally inhabit structurally complex environments may benefit from appropriately arranged vegetation, shelters, and visual barriers. In contrast, excessive structures may reduce swimming space or interfere with maintenance. Therefore, aquarium complexity should be carefully matched to species biology and tank size.

Recent welfare research emphasizes that enrichment is context dependent and should consider species, life stage, system design, and operational conditions rather than following a universal formula



Fig 2: Fish habitat complexity and aquarium design

VI. SOCIAL BEHAVIOR AND GROUP MANAGEMENT

Social organization differs greatly among ornamental fish. Some species are naturally solitary or territorial, whereas others form pairs, shoals, or schools. Maintaining inappropriate social conditions can result in chronic aggression, competition, social stress, or reduced access to food and shelter.

Behavioral management should therefore consider: Natural social structure, appropriate group size, sex ratio, territoriality, compatibility between species, availability of hiding areas, competition for food and space

Social enrichment is increasingly recognized as an important category of environmental enrichment. Current research describes social strategies such as adjusting group size and composition and providing appropriate opportunities for social interaction (2).

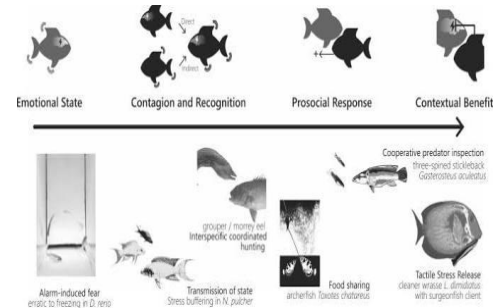


Fig 3: Social behavior and group management

VII. STOCKING DENSITY

Stocking density has important behavioral and welfare consequences. Excessively high densities can increase competition for food and space and may intensify aggression and social stress. Conversely, maintaining social species individually may also prevent normal social interactions (3).

Therefore, stocking decisions should be based on species-specific requirements rather than applying a single density standard to all ornamental fish.

Important considerations include: Adult body size, swimming activity, territorial behavior, social organization, aquarium volume and dimensions, habitat complexity, filtration capacity, water quality, availability of shelters/Stocking density should be evaluated together with behavioral observations and environmental measurements.

VIII. FEEDING BEHAVIOR MANAGEMENT

Feeding is essential not only for nutrition but also for behavioral welfare. Natural feeding behavior may involve searching, selecting, chasing, manipulating, and consuming food.

Behaviorally appropriate feeding management may include: Providing nutritionally suitable diets, establishing appropriate feeding frequency, avoiding excessive competition, observing individual feeding responses, adjusting food presentation according to species, preventing prolonged food deprivation, using feeding opportunities as enrichment where appropriate

Feed-related behavioral changes can be useful welfare indicators. Reduced appetite, unusual feeding aggression, or failure to compete normally for food may signal environmental, social, or health problems. Cognitive enrichment research has identified feeding predictability and learning opportunities as potentially relevant welfare-management approaches, although further species-specific validation is needed(4).



IX. REDUCING STRESS THROUGH HANDLING AND ROUTINE MANAGEMENT

Handling, transportation, aquarium cleaning, sudden environmental changes, and frequent disturbance can affect ornamental fish behavior. Stressors encountered in the ornamental trade include poor water quality, handling, transportation, confinement, inadequate social environments, and disease. Behaviorally informed management should aim to minimize unnecessary disturbance and maintain consistent routines where possible. Staff and fish keepers should observe changes in behavior before, during, and after routine procedures.

A useful approach is to record:

Baseline behavior → Management intervention → immediate response → Recovery behavior → Long-term response

This provides a simple framework for determining whether a husbandry procedure is compatible with good welfare.

Behavioral indicator

Normal feeding

Active exploration

Normal swimming

Excessive hiding

Persistent aggression

Reduced activity

Abnormal swimming

Excessive ventilation

Normal social interaction

Repetitive abnormal behavior

Possible interpretation

Appropriate appetite and environmental response

Environmental engagement

Appropriate activity

Possible stress or unsuitable environment

Social or territorial problem

Possible environmental or health concern

Possible stress or health problem

Possible environmental or physiological problem

Appropriate social conditions

Possible inadequate environment

These indicators should not be interpreted independently. Behavior can vary naturally with species, age, time of day, feeding schedule, reproductive condition, and environmental circumstances. A combination of behavioral, physiological, health, and environmental measures provides a more reliable assessment (7,8).

XII. SPECIES-SPECIFIC BEHAVIORAL MANAGEMENT

One of the major challenges in ornamental fish welfare is the enormous diversity of species kept in captivity. Fish differ in habitat preference, swimming patterns, feeding ecology, social organization, territoriality, reproductive behavior, and environmental tolerance.

X. WATER QUALITY AND BEHAVIOR

Although water quality is primarily an environmental factor, it has a direct relationship with behavior. Poor water conditions can alter swimming, feeding, respiratory activity, social interaction, and general activity(5).

Important environmental variables include: Temperature, Dissolved oxygen, ph. Ammonia, Nitrate, and Salinity where applicable, Water clarity, Appropriate water movement. Behavioural monitoring should therefore complement routine water-quality assessment. An unexplained behavioral change should prompt evaluation of both biological and environmental factors(6).

XI. BEHAVIORAL MONITORING AS A WELFARE TOOL

Regular behavioral observation can be incorporated into routine aquarium management. A simple behavioral monitoring protocol may record:

For example, the behavioral requirements of a territorial cichlid may differ considerably from those of a schooling cyprinid. Consequently, welfare management should be based on the biology of each species rather than relying on generalized aquarium practices. Research on angelfish demonstrates the value of integrating knowledge of social, reproductive, feeding, and cognitive behavior into welfare-oriented husbandry (9).

XIII. BEHAVIORAL MANAGEMENT FRAMEWORK

An effective behavioral management program can follow five major stages:

Stage 1: Identify Natural Behavior

Determine the species' normal feeding, swimming, social, reproductive, and shelter-seeking behaviors.

Stage 2: Identify Welfare Risks

Assess potential problems associated with environmental conditions, stocking density, handling, social incompatibility, feeding, and habitat design (10).

Stage 3: Select Management Strategies

Choose appropriate enrichment, habitat modifications, social arrangements, feeding practices, and routine-management approaches.

Stage 4: Monitor Behavior

Record behavioral responses before and after management changes.

Stage 5: Evaluate and Modify

Retain strategies associated with desirable behavioral outcomes and modify interventions that produce stress, aggression, or abnormal behavior (12).

This adaptive approach is consistent with recent recommendations that enrichment should be selected according to defined welfare objectives and then evaluated and refined according to species and system characteristics (13).

XIV. CHALLENGES IN BEHAVIORAL MANAGEMENT

Despite increasing interest in fish welfare, several challenges remain.

14.1 Limited Species-Specific Information

Many ornamental fish species have not been sufficiently studied with respect to their natural behavioral requirements.

14.2 Difficulty in Interpreting Behavior

The same behavior may have different meanings under different environmental conditions. For example, hiding can represent normal shelter use in one species but stress in another.

14.3 Lack of Standardized Indicators

There is no universally applicable behavioral welfare scale for all ornamental fish species.

14.4 Variable Effects of Enrichment

Enrichment does not produce identical outcomes across species or systems. Evidence shows that enrichment type and species characteristics can strongly influence welfare outcomes.

14.5 Commercial Constraints

Commercial ornamental-fish facilities must balance welfare improvements with cost, maintenance requirements, hygiene, disease control, and production efficiency.

XV. FUTURE RESEARCH PERSPECTIVES

Future research should focus on developing scientifically validated and practical behavioral welfare tools for ornamental fish. Priority areas include (14):

Development of species-specific behavioral ethograms. Standardized behavioral welfare scoring systems. Long-term studies of environmental enrichment. Investigation of cognitive and sensory enrichment. Use of automated video monitoring and artificial intelligence for behavior detection. Development of evidence-based aquarium design guidelines. Research on social compatibility and stocking density. Integration of behavioral and physiological welfare indicators. Development of welfare protocols for commercially important ornamental species. Assessment of positive welfare rather than focusing only on stress and disease. Recent enrichment research increasingly emphasizes physical, sensory, dietary, occupational, and social approaches and recommends goal-oriented implementation rather than a one-size-fits-all model (15).

XVI. CONCLUSION

Behavioral management represents an important component of modern ornamental fish welfare. Fish behavior provides a practical, non-invasive means of evaluating how animals respond to their captive environment and can help identify potential welfare problems before severe health consequences develop. Environmental enrichment, habitat complexity, appropriate social conditions, suitable stocking density, biologically appropriate feeding, reduced disturbance, and systematic behavioral monitoring can collectively improve captive conditions.

The evidence indicates that enrichment can produce beneficial welfare outcomes, but its effectiveness depends on species, enrichment type, life stage, environmental context, and management objectives. Therefore, ornamental fish welfare should not be based on a universal aquarium-management formula. Instead, management should be species-specific, behavior-informed, evidence-based, and continuously evaluated.

A shift from simply maintaining fish alive and disease-free toward providing environments that allow natural and positive behaviors represents an important step in responsible ornamental fish husbandry.



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Continued research combining behavioral science, environmental management, physiology, technology, and welfare assessment will help establish stronger welfare standards for ornamental fish in aquaria, breeding facilities, public collections, and the ornamental fish trade.

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