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PRODUCTIVITY OF HYBRID GOLDFISH (*Carassius auratus*) HATCHERIES USING THE SMART-K MODEL

Produktivitas Pembenihan Ikan Koki Baster (*Carassius auratus*) Menggunakan Model Smart-K

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ABSTRACT

The productivity of hybrid goldfish (Carassius auratus) hatcheries remains relatively low due to non-standardized hatchery management, particularly in broodstock management, larval rearing, and water quality control. This study aimed to analyze the effect of implementing the SMART-K model (Technology and Partnership-Based Aquaculture Management System) on the productivity of hybrid goldfish hatcheries. The study was conducted from November to December 2025 at hatchery ponds located in Cicantayan, Nagrak Cisaat, and Cimenteng, Sukabumi Regency. A quantitative approach was applied by comparing fry productivity before and after the implementation of the SMART-K model in the same hatchery units. Observed parameters included fry productivity at the end of the rearing cycle and water quality parameters, namely temperature, pH, and dissolved oxygen (DO). Data were analyzed descriptively and further examined using a paired t-test. The results showed that the average fry productivity increased from 3.61 liters before SMART-K implementation to 15.72 liters after implementation, with a statistically significant difference ($p < 0.05$). The application of the SMART-K model had a significant effect on improving the productivity of hybrid goldfish hatcheries.

Keywords: Goldfish, Productivity, SMART-K

ABSTRAK

Produktivitas pembenihan ikan koki baster (*Carassius auratus*) masih rendah akibat pengelolaan pembenihan yang belum terstandar, khususnya pada manajemen induk, pemeliharaan benih, dan pengendalian kualitas air. Penelitian ini bertujuan menganalisis pengaruh penerapan model SMART-K (Sistem Manajemen Akuakultur Rekayasa Teknologi dan Kemitraan) terhadap produktivitas pembenihan ikan koki baster. Penelitian dilaksanakan pada November–Desember 2025 di kolam pembenihan Cicantayan, Nagrak Cisaat, dan Cimenteng, Kabupaten Sukabumi. Metode penelitian menggunakan pendekatan kuantitatif dengan membandingkan produktivitas benih sebelum dan sesudah penerapan model SMART-

K pada unit pembenihan yang sama. Parameter yang diamati meliputi produktivitas benih pada akhir siklus pemeliharaan serta kualitas air berupa suhu, pH, dan oksigen terlarut (DO). Analisis data dilakukan secara deskriptif dan menggunakan uji *t* berpasangan. Hasil penelitian menunjukkan bahwa rata-rata produktivitas benih meningkat dari 3,61 liter menjadi 15,72 liter setelah penerapan model SMART-K, dengan perbedaan yang signifikan secara statistik (p < 0,05). Penerapan model SMART-K berpengaruh nyata terhadap peningkatan produktivitas pembenihan ikan koki baster.

Kata Kunci: Ikan Baster, Produktivitas, SMART-K

INTRODUCTION

The goldfish (*Carassius auratus*) is a freshwater ornamental fish prized for its high aesthetic value, characterized by a rounded body shape, broad and flowing fins, and attractive color variations. These traits make the goldfish a high-value ornamental fish commodity that is in great demand by the public, both as a decorative pet and as a species for aquaculture (Setiawan & Handoko, 2019; Rizmauliana et al., 2023).

Demand for freshwater ornamental fish continues to rise alongside the growth of the ornamental fish industry in Indonesia and the international market. According to data from the Ministry of Marine Affairs and Fisheries, the value of Indonesia's ornamental fish exports in 2023 reached approximately USD 39.06 million, with freshwater ornamental fish accounting for the majority of this export value. As one of the world's leading exporters of ornamental fish, Indonesia presents highly promising opportunities for developing hatchery businesses for ornamental fish, including goldfish (KKP, 2024; Tarihoran et al., 2023; Tarihoran et al., 2024).

This increasing demand must be met with a supply of high-quality, uniform, and sustainable seed stock. The success of a hatchery business depends on various factors, including broodstock quality, spawning success, fertilization rates, egg hatchability, water quality, feeding, disease control, and the implementation of sound production management. Integrated management of these factors has been shown to improve egg hatching success, larval survival, seed growth, and overall ornamental fish hatchery productivity (Rizmauliana et al., 2023; Mulya et al., 2022; Ministry of Marine Affairs and Fisheries, 2021). Field surveys at the research site indicate that hybrid goldfish farmers still face various challenges, including limited human resources—regarding both technical (hard) and non-technical (soft) skills—low egg hatchability, high fry mortality, suboptimal broodstock management, infrequent water quality monitoring, limited production facilities and infrastructure, restricted access to capital, and suboptimal marketing access (both online and offline). These obstacles hinder hatchery productivity, resulting in inconsistent fry production and reduced business competitiveness. Issues such as inconsistent product quality, unstable production continuity, weak institutional capacity, and limited market access have also been identified as primary factors impeding the growth of Indonesia's ornamental fish industry (Tarihoran et al., 2023; Tarihoran et al., 2024).

Previous studies have shown that successful goldfish hatchery operations depend on broodstock quality, water quality, and feed management. However, research integrating technical cultivation aspects, production management, and farmer support through an integrated management model remains scarce. Therefore, this study employs the SMART-K model as an approach to enhance hybrid goldfish hatchery productivity. To address these challenges, the study implements the SMART-K model (an Aquaculture Management System based on Technology Engineering and Partnerships). The SMART-K model integrates broodstock management, the provision of hatchery facilities and infrastructure, the application of Good Aquaculture Practices (CBIB), periodic water quality monitoring, production record-keeping, and the strengthening of partnerships between researchers and farmers. The implementation of standardized hatchery management is expected to improve production process efficiency, enhance fry quality, boost productivity, and support the sustainability of hybrid goldfish hatchery businesses. This approach aligns with modern aquaculture management concepts that emphasize the standardization of production processes, quality control, operational efficiency, and institutional strengthening to enhance the competitiveness of ornamental fish commodities (Ministry of Marine Affairs and Fisheries, 2021; Tarihoran et al., 2023; Tarihoran et al., 2024).

Based on this context, the implementation of the SMART-K model is expected to improve the management effectiveness of hybrid goldfish (*Carassius auratus*) hatchery operations by integrating technical aquaculture aspects, production management, water quality monitoring, production record-keeping, and partnerships with fish farmers. Therefore, this study aims to evaluate the effectiveness of the SMART-K model in enhancing the productivity of hybrid goldfish hatcheries.

RESEARCH METHODS

Place and Time

This study was conducted over three cycles from November 22, 2025, to January 10, 2026, in three different ponds located in Cimenteng, Cicantayan, and Nagrak Cisaat, Sukabumi Regency.

Tools and Materials

Table 1. Tools and Materials

Tool Name	Amount	Unit	Description
Hapa measuring 6 x 1 x 1 m	3	Piece	Spawning medium
Quay	90	Piece	Spawning medium
Hapa measuring 3 x 1 x 1 M	3	Piece	Temporary post-harvest quarantine medium
DO Meter	1	Piece	DO meter
pH Meter	1	Piece	pH meter
Termometer	1	Piece	Temperature gauge
Human	3	Piece	Harvesting tool
Seser	3	Piece	Harvesting tool
Iron sieve	3	Piece	Harvesting tool
According to 3 in	3	Piece	Harvesting tool
Material Name	**Amount**	**Unit**	**Description**
Hybrid fish roe	90	Piece	Fish roe for partners
Fengli pellets 1	90	Kg	Fish feed
Manure	27	Bag	Organic fertilizer
Dolomite lime	6	Bag	pH neutralizer

Research Procedure

Research Preparation

Research preparations were carried out prior to the commencement of hatchery activities to ensure that all necessary components were ready and met established standards. These preparatory activities included selecting the research site, cleaning the ponds, and setting up the required facilities and infrastructure.

The research ponds were cleared of mud, organic debris, and algae to prevent contamination that could interfere with the hatchery process. Following cleaning, the ponds were allowed to dry for three days. Subsequently, they were filled with water to a minimum depth of 50 cm. Initial water quality testing was conducted to ensure that physical and chemical parameters—such as temperature, dissolved oxygen (DO), and pH—fell within the optimal ranges for egg and fry development. Additionally, all supporting equipment—including *hapa* nets, *KAJO* (hatching nets), dip nets, buckets, and water quality measuring instruments—was prepared and tested for functionality.

Egg Distribution

Eggs obtained from the BOSSBATER spawning pond are subsequently distributed to research ponds for the hatching process. Each research pond is equipped with one *hapa* unit and 30 *kakab hejo* (KAJ0) units to serve as hatching media.

Provision of facilities and infrastructure

Cultivators are provided with facilities and infrastructure to support cultivation activities, including the supply of feed, fish eggs, fertilizer, and dolomite lime, as well as the equipment used throughout the rearing and harvesting processes.

Seed treatment

During the research, the pond was fertilized on the first day with manure at a dosage of 200 g/m². Fertilization aims to enhance water fertility by supplying nutrients that stimulate the growth of phytoplankton and zooplankton, which serve as natural food for fish fry during the initial rearing phase. The application of manure has been shown to influence water quality and support the availability of natural food in the nursery pond (Anjeliani et al., 2022).

Subsequently, the fry were reared and their growth monitored; observations were conducted at the beginning, middle, and end of the rearing period to characterize growth dynamics over a single cycle. Water quality assessments were also performed three times—at the start, midpoint, and conclusion of the cycle—measuring parameters such as pH, dissolved oxygen (DO), and temperature. These three parameters are key indicators of water quality, as they influence metabolic processes, growth, and the survival rate of the fish fry (Puluhulawa et al., 2022).

On the fifth day post-hatching, the fry began receiving artificial feed via the *ad libitum* method, administered twice daily at 11:00 WIB and 15:00 WIB. *Ad libitum* feeding aims to meet the fry's nutritional requirements, thereby optimizing growth and minimizing competition for food. Proper feeding management plays a crucial role in enhancing growth efficiency and supporting aquaculture productivity.

Harvest

Seed harvesting is carried out at the end of the maintenance period by preparing equipment such as nets, lambits, buckets, sieves, plastic bags, rubber bands, and oxygen cylinders. Before harvesting, the pond water volume is gradually reduced until only water remains in the upper part of the pond to facilitate catching the seeds. Harvesting is carried out in the morning (07:00 WIB) using nets or lambits carefully to minimize stress and physical damage to the seeds. The harvested seeds are then transferred to a hapa or netting as a temporary storage area before sampling and packaging (FAO, 2023).

Data Analysis

The first stage of analysis involved a descriptive assessment of water quality parameters (temperature, DO, and pH) during the rearing period. The subsequent stage involved a paired t-test analysis of the productivity of hybrid goldfish fry.

RESULT

Productivity of Hybrid Goldfish Breeding

Table 1. Paired t-test results for hybrid goldfish hatchery productivity

Parameter	Before	After
Productivity (L/cycle)	3,61	15,72
The p value (two-tailed)		0,00012

Water Quality
pH

The pH values ranged from 7.37 to 8.31 prior to the implementation of SMART-K, whereas they ranged from 7.14 to 7.80 following its implementation. These values remain within the optimal range for hybrid goldfish hatchery operations.

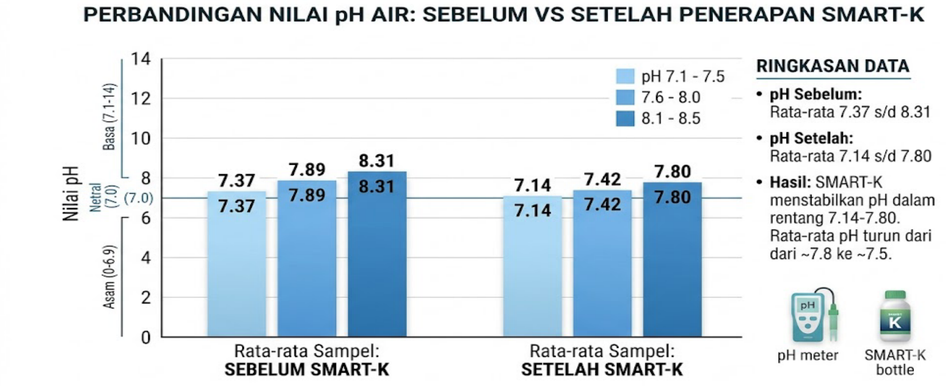

Figure 1. pH Value Graph

Dissolved Oxygen (DO)

The dissolved oxygen (DO) value increased from 2.84 mg/L before the implementation of SMART-K to 5.50 mg/L after the implementation of SMART-K.

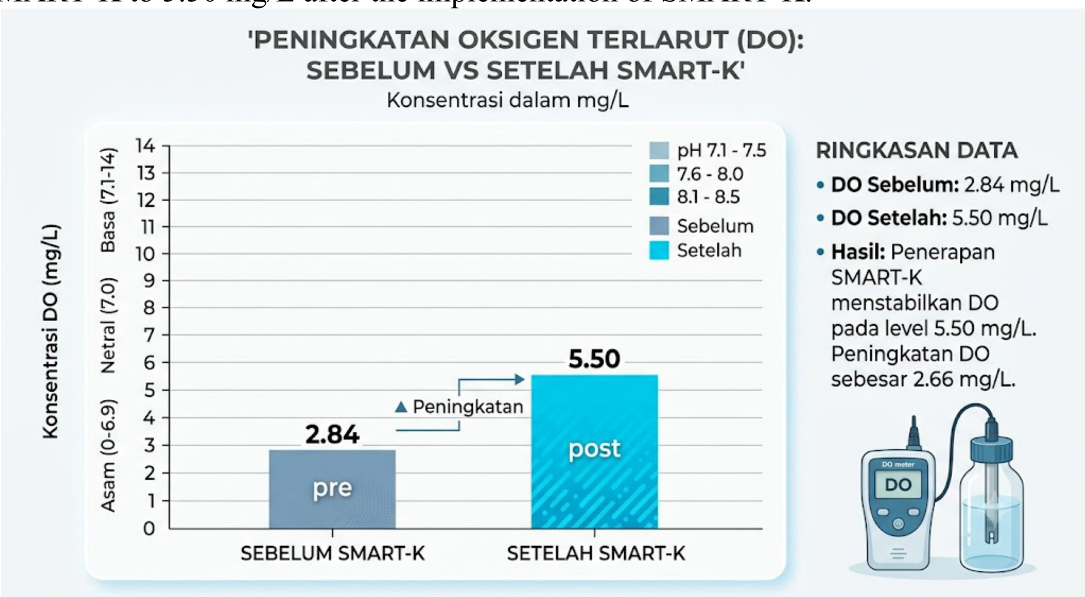

Figure 2. Dissolved Oxygen Graph

Temperature

Water temperature ranged from 24.1–25.76°C before the implementation of SMART-K, whereas it ranged from 25.12–26.73°C after the implementation of SMART-K.

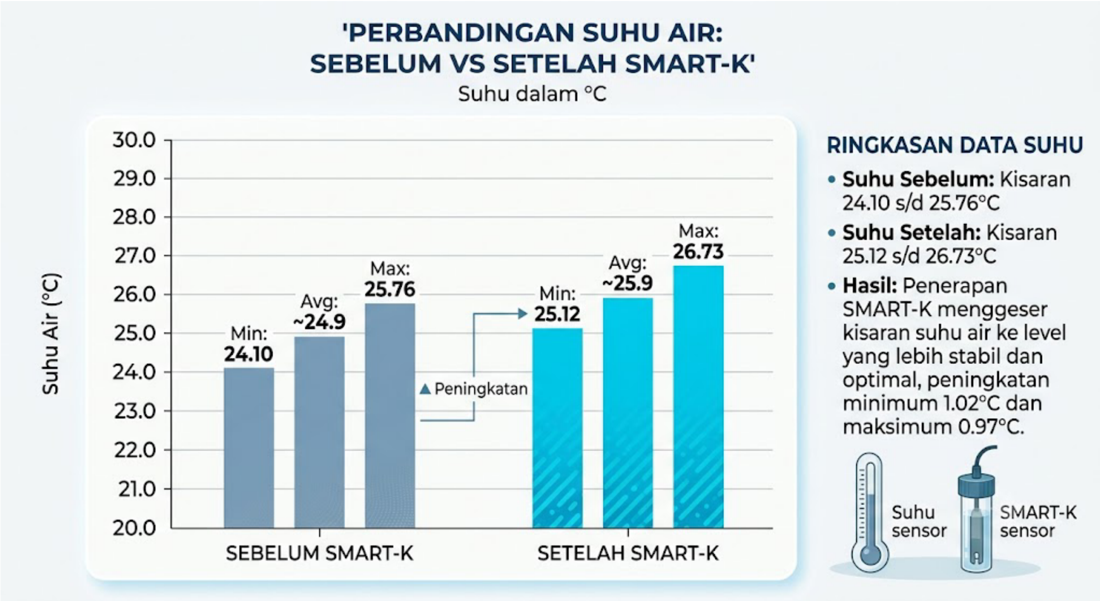

Figure 3. Water Temperature Graph

DISCUSSION

Productivity

Based on the data in Table 3.1, the average yield of hybrid goldfish fry prior to the implementation of the SMART-K model was 3.61 liters, whereas after implementation, it increased to 15.72 liters. These results demonstrate a productivity increase of 12.11 liters compared to the initial conditions. This increase indicates that the SMART-K model improves the hatchery system by managing production factors in a more planned, integrated, and sustainable manner (Fauzan & Effendi, 2023; Prayoga et al., 2025). The low productivity prior to SMART-K implementation was attributed to suboptimal hatchery management—including broodstock quality, feeding practices, pond fertilization, and water quality management—as well as the absence of consistently applied standard operating procedures. These conditions resulted in suboptimal spawning success and larval survival rates, leading to a relatively low yield of fry. According to SNI 6141.1:2014 regarding fish fry production, hatchery success is heavily influenced by broodstock quality, rearing medium management, feeding, and water quality control. Research by Fauzan and Effendi (2023) indicates that implementing sound production management enhances hatchery efficiency through the management of production inputs, water quality monitoring, and the provision of feed tailored to the fry's requirements.

Following the implementation of the SMART-K model, all hatchery stages were conducted based on production management principles: planning, organizing, actuating, and controlling. The planning stage involved procuring production inputs, selecting superior broodstock, scheduling spawning, and determining feed requirements. The implementation stage included pond fertilization with manure to stimulate natural food growth, the application of dolomite lime to maintain pH stability, and the provision of Fengli 1 feed (40% protein content) to meet the fry's nutritional needs. Subsequently, water quality monitoring and production record-keeping were carried out periodically as part of the control process. This approach makes the entire seed-rearing process more targeted, resulting in a significant increase in productivity (Fauzan & Effendi, 2023; Dindin et al., 2026).

Improved harvest yields were also driven by better rearing environment quality. Throughout the study, temperature, pH, and dissolved oxygen levels remained within the optimal range for the growth of hybrid goldfish fry. Stable water quality helps reduce stress levels, boost metabolic activity, improve appetite, and enhance the efficiency of energy utilization for growth. These findings align with research by Nurhayati et al. (2022), which indicates that successful koi breeding depends on water quality management from the spawning stage through to larval rearing.

In addition to water quality, the green color of the pond water indicated the development of a phytoplankton community serving as natural food. Phytoplankton acts as an initial nutrient source for larvae, while zooplankton serves as natural food during the fry stage. The availability of this natural food helps meet nutritional needs during early growth, thereby increasing fry survival rates. These conditions were further supported by the provision of Fengli 1 artificial feed—which contains approximately 40% protein—ensuring that the fry's protein requirements were consistently met throughout the rearing period.

The success of the SMART-K model is not driven by a single factor but results from the synergy of various production management components. Implementing hatchery standard operating procedures (SOPs), managing water quality, utilizing appropriate production inputs, conducting routine monitoring, and maintaining production records enable each stage of the hatchery process to operate more effectively. This system also facilitates the identification of obstacles, allowing for faster corrective actions. This approach aligns with the principles of Good Aquaculture Practices (CBIB), which emphasize integrated cultivation management to produce high-quality, safe, and sustainable seed stock. Furthermore, the implementation of SMART-K during dissemination activities with fish farmers in Sukabumi has been reported to enhance participant skills, seed productivity, and partner income (Dindin et al., 2026).

Statistical analysis using a paired-sample t-test yielded a p-value of 0.00012 ($p < 0.05$). This value indicates a significant difference in hatchery productivity before and after the implementation of the SMART-K model. Consequently, the hypothesis that the SMART-K model increases hybrid goldfish seed productivity is accepted. Statistically, the observed increase in production is not attributable to random variation but is a tangible result of the changes made to the hatchery management system.

These research findings support previous studies indicating that the success of fish hatchery operations is influenced by broodstock quality, water quality management, appropriate feeding, and sound production management (Fauzan & Effendi, 2023; Nurhayati et al., 2022; Prayoga et al., 2025). However, this study offers novelty by integrating all aspects of production management into the SMART-K model, rather than evaluating only a single technical hatchery factor. This model combines production input management, SOP implementation, water quality control, periodic monitoring, and production record-keeping into a single, structured management system. The approach proved capable of increasing hatchery productivity more than fourfold compared to the hatchery system used prior to the implementation of SMART-K.

Water Quality

pH

The pH values ranged from 7.70 to 8.31 prior to the implementation of SMART-K, whereas they ranged from 7.80 to 8.12 following its implementation. Although both conditions fell within the quality standard range stipulated by Government Regulation (PP) Number 22 of 2021 (6.5–8.5), the pH range was more stable after the implementation of SMART-K. This stability indicates that the SMART-K system improves water quality management through the use of dolomite lime, controlled pond fertilization, and regular water quality monitoring, thereby enabling the control of pH fluctuations. These conditions facilitate optimal metabolism, respiration, and enzymatic activity in the fish fry. These findings align with research by Lembang and Kuing (2022), who reported that improved water management systems stabilize pH and enhance koi growth, as well as with Nurhayati et al. (2022), who stated that a pH range of 6.5–8.5 is optimal for koi breeding. This pH stability is believed to be a contributing factor to the increased breeding productivity observed in this study, evidenced by the rise in average harvest yield from 3.61 liters before SMART-K implementation to 15.72 liters afterward.

DO

The DO value increased from 2.84 mg/L to 5.50 mg/L after the application of the SMART-K model. The increase in DO is thought to be influenced by cleaning the inlet and outlet channels, reducing the accumulation of organic matter, and increasing the growth of phytoplankton, which produce oxygen through photosynthesis. The increase in dissolved oxygen concentration creates better conditions for the respiration process of fry, allowing more energy from feed metabolism to be utilized for growth rather than maintaining physiological functions due to environmental stress. These conditions support fish growth and performance because adequate oxygen availability plays a crucial role in metabolism and energy utilization (Jiang et al., 2021).

Temperature

Water temperature ranged from 24.10–25.76°C prior to the implementation of SMART-K, whereas it rose to 25.12–26.73°C following implementation. These values fall within the optimal range for the growth and breeding of koi and other freshwater ornamental fish. The rise in temperature is thought to stem from the clearing of vegetation around the pond, which increased sunlight intensity and enhanced phytoplankton photosynthesis. According to Nurhayati et al. (2022), the optimal temperature for koi breeding is 25–27°C, while Pratama et al. (2022) state that temperature control is a crucial factor in maintaining water quality for koi culture. Stable temperatures support metabolic activity and feed consumption, allowing energy to be utilized optimally for growth. These conditions likely contributed to the increased yield of fry following the implementation of SMART-K.

CONCLUSION

The implementation of the SMART-K model has successfully increased the productivity of hybrid goldfish (*Carassius auratus*) hatchery operations. This productivity gain demonstrates that the SMART-K model supports more effective and structured management of hatchery activities. Consequently, the SMART-K model can be adopted as a technological innovation in fish farming to help boost aquaculture yields.

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