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Risk Management of Koi (*Cyprinus carpio*) Hatchery Production in Kediri Regency Using the House of Risk Approach

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Abstract

The Koi fish aquaculture sector is closely tied to risk. Various factors, such as delays and uncertainties in delivering feed, infections, and pests affecting koi fish as a result of delays and improper feeding, and extreme weather conditions, can all cause fish death. It is crucial to monitor the increasing risks industriously, as inadequate risk management procedures can lead to losses and can potentially disrupt the industry progress. The purposes of this risk management on koi fish hatchery production are: 1). Identifying and defining risk events and risk agents in koi fish farming production in Kediri Regency, 2). Analyzing risk events and risk agents in the production of koi fish, 3). Analyzing risk management in koi fish aquaculture. The proportional sampling method was used to select the research sample. The House of Risk (HOR) data analysis method was employed in this study to analyse data. Based on the data analysis, 17 risk events were identified in the four processes of koi fish seed production, including risk events in the pond preparation process, risk events in the spawning process, risk events in the rearing process, and risk events in the harvesting process. These risk events were caused by 33 risk agents. The top three risks prioritized for mitigation based on HOR phase 1 data included high ammonia levels and decreased water quality, extreme weather events, and uncontrolled fish stocking density. The most effective preventive actions were to transfer or divide koi fish eggs to another pond and improve aeration.

INTRODUCTION

One of the main centers for koi fish breeding in East Java is Kediri Regency, which is divided into 26 districts with 343 villages. According to the data, 124 of these villages have the potential for various fisheries activities, including fish breeding, consumption fish breeding, ornamental fish breeding, and capture fisheries in public waters. The production of koi fish in Kediri Regency has been increasing year by year. The increase in koi fish production from 2018 to 2021 reached 9.5%. The production

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and population of ornamental fish in the Kediri Regency reached 320 million individuals. Koi fish production solely contributed to 70 million individuals with an economic value of Rp 288 billion. However, the Kediri Regency still ranks second in terms of the largest koi fish breeding production in East Java after Blitar (Atmodjo, 2021; BPS, 2021; Diskominfo, 2021).

Breeding koi fish carries inherent risks. Fish mortality may stem from issues such as delayed feed delivery, disease outbreaks due to pond neglect, improper feeding practices, and susceptibility to severe weather conditions. Breeding koi fish demands careful attention and precision. To ensure optimal fertilization of koi fish eggs, breeding usually involves one female and two males in the same pond. Additional males are introduced if the initial fertilization fails. Fluctuating temperatures in the pond, particularly during extreme weather like the rainy season, can hinder or prevent the successful hatching of fertilized koi fish eggs (Aldimas *et al.*, 2021; Basalamah, 2022).

The obstacles faced in the production of koi fish breeding in Kediri Regency must be promptly investigated to determine the causes that hinder the breeding activities. Even though koi fish production in Kediri Regency is increasing, koi fish farmers still do not consider the risks that will occur. The breeding risks must be carefully considered, as inappropriate actions in managing risks can lead to losses and disrupt breeding activities. Risk management begins with risk identification, risk level measurement, risk level mapping, and formulation of strategies in koi fish breeding. This is carried out to facilitate decision-making in koi fish breeding activities and minimize risks and losses caused by the risks.

The koi fish breeding can be considered difficult due to the sensitive characteristics of the fish to extreme weather conditions (Mitra *et al.*, 2023). These characteristics make koi fish breeding vulnerable to the risk of failure in the production process (Waluyo *et al.*, 2023). When risk management is not properly implemented, it threatens the sustainability of koi fish breeding in Kediri Regency. Therefore, an analysis of production risk management for koi fish breeding is crucial to prevent risks that may lead to losses. The result of this research will determine the risks in the koi fish breeding process.

METHODOLOGY

Ethical Approval

Ethical approval was not sought for the present study because this research only focuses on analyzing the risks that arise from the hatchery process and researchers only observe when the hatchery process takes place. So that researchers do not interact directly with the animals as the object of research. Koi fish are treated with care and all koi fish farmers have a business license.

Place and Time

The research was conducted in the districts of Plosoklaten, Wates, Kandat, Kras, Ringinrejo, Gurah, and Ngadiluwih. The selection of these locations was intentionally carried out based on the consideration that these seven districts are the centers of koi fish breeding in the Kediri Regency. The research was conducted in December 2022 to April 2023.

Research Materials

The materials used in this study are male and female koi fish cultivated by koi fish farmers in some districts belonging to Kediri Regency which will be observed starting from the process of selecting broodstock until the harvesting process. The instruments employed in this investigation included fish ponds, aerators (Jebo P50, China), stone and dacron filters, and water pumps (SUNSUN JTP 16000, Indonesia).

Research Design

This research used a mix method where qualitative data was converted into numbers. Primary data in this study was collected through field observations, Focus Group Discussions, Questionnaires, and

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structured interviews with koi fish hatchery owners. Secondary data for this study was collected from BPS and literature (books) to estimate the production and potential of koi fish farming in Kediri District. Simple random sampling was used to collect the research sample in proportion. The House of Risk (HOR) technique was utilized to analyze the data in this study.

Work Procedure

Population and Sample

There are 428 koi fish farmers in Kediri Regency. Based on the existing population, researchers determined the sample using the Taro Yamane formula. The number of samples used in this study was 40 samples, following the formula from Yamane (1973) as follows:

$$n = \frac{N}{1 + N(e)^2}$$

Where: n is the number of samples, N is total research population, e is error rate (15%).

First Phase of House of Risk

House of Risk Phase 1 was utilized to determine the prioritized risk agents that would subsequently be subjected to preventive measures (Cahyani *et al*., 2016; Pujawan and Geraldin, 2009).

First, identifying the division of company activities aimed at determining where risks may arise. Second, identifying risk events (Ei) in each company activity. Third, identifying the impact of risks and assessing the severity level (Severity, S) where a severity level assessment scale of 1-10 can be given regarding the severity level (severity) as shown in the following Table 1.

Table 1. Severity level for identifying the impact of risk on koi fish production in Kediri Regency.

Scale	Severity	Description
1	None	No effect
2	Very little	Very little effect on performance
3	Slight	Slight effect on performance
4	Very low	Very low effect on performance
5	Low	Low affects performance
6	Medium	Moderate effect on performance
7	Height	Height affects performance
8	Very high	The effect is very high and cannot operate
9	Serious	Serious effects and failures are preceded by warnings
10	Dangerous	Dangerous effects and failures are not preceded by warnings

The fourth step is to identify the causes of risks and assess the frequency level of risk occurrences (Occurrence, O), identifying risk agents by providing a scale of 1-10, can be seen in the following Table 2.

Table 2. Occurrence scale for identifying the causes of risk and the frequency level.

Score	Criteria	Historic
1	Almost never	Failure is impossible
2	Very small	The range of failures
3	Very few	Very few failures
4	Few	Some failures
5	Low	Number of occasional failures
6	Moderate	Number of failures moderate
7	Quite high	Quite high the number of failures
8	High	Number of failures is high
9	Very high	Very high number of failures
10	Almost always	Failure is almost certain

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Measurement of the correlation value between a risk event and a risk agent. If a risk agent causes a risk event, then it can be determined as a correlation. The correlation value (Rij) consists of 0: no correlation, 1: weak correlation, 3: moderate correlation, and 9: strong correlation.

The ranking of risk agents is determined based on the ARP value.

$$ARP_j = O_j \sum S_i R_{ij}$$

Explanation:
ARP : Aggregate Risk Potentials
Si : Severity of risk events
Oj : Occurrence of risk causes
Rj : Correlation between j risk causes and i risk events

Then, deetermining the ARP rating of each (risk agent) Aj and finally select Aj priorities using the Pareto diagram.

Second Phase of House of Risk

House of Risk Phase 2 was used to determine the handling actions that must be carried out first based on the results of the House of Risk Phase 1 analysis. According to (Cahyani *et al*., 2016) there are seven stages in House of Risk Phase 2. First stage is mitigation preparation is based on Aj's high priority based on the output of HOR Phase. Second, identifying relevant Preventive Action (PA) steps to prevent risks. Third, determining the correlation relationship R between each Preventive Action (PA) and risk agent. The value used is 1,3 or 9. This number shows the low, moderate, and high relationship between action k and agent j. The fourth stage is calculating the total effectiveness value of each Preventive Action using the following formula:

$$TE_k = \sum (ARP_j \cdot E_{jk})$$

Information:
TE_k = Total Effectiveness
ARP = Aggregate Risk Potentials
Ej_k = Relationship

The fifth stage is the measurement of the degree of difficulty (D_k) in implementing preventive action (PA_k) with the following scale:

Table 3. Degree of Difficulty (Dk).

Score	Description
1	Mitigation actions are very easy to implement
2	Mitigation actions are easy to implement
3	Mitigation actions are quite easy to implement
4	Mitigation actions are difficult to implement
5	Mitigation actions are very difficult to implement

The sixth stage is the calculation of Effectiveness to Difficulty (ETD) using the formula:

$$ETD_k = \frac{TE_k}{D_k}$$

Description:
ETDk = Effectiveness to Difficulty
TEk = Total Effectiveness
Dk = Degree of Difficulties

The last stage is calculating PA_k priority ranking based on ETD_k

Description:
Si = severity level of risk
Oj = occurrence risk agent
Rij = Correlation between risk event i and risk agent j
ARPj = Aggregate risk potentials from risk agent j
TE_k = Assess the effectiveness of each mitigation action k
Ej_k = Correlation between risk agent j and risk mitigation k
ETD_k = effectiveness to difficulty ratio
D_k = degree of difficulty performing action

Data Analysis

This study employed the House of Risk (HOR) method. The House of Risk method was divided into two stages, namely the first phase of House of Risk and the second phase of House of Risk.

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RESULTS AND DISCUSSIONS

Identification of Koi Fish Hatchery Production Risks in Kediri Regency

Identifying Risk Events

In general, koi fish hatcheries have four processes: pond preparation, spawning, rearing, and harvesting (Hendriana *et al*., 2021). Pond preparation for koi fish spawning had to be carried out carefully. Starting with inspecting the flaws in the concrete pond, the state of the drains, and the water quality. This was carried out since water quality could influence fish growth, color, and pond productivity (Fakhriza *et al*., 2021; Yanuhar *et al*., 2022). Koi fish reproduce naturally, so the selection of female and male broodstock had to be based on their readiness. Male broodstock that were ready to spawn had the following characteristics: They had rough gill coverings and concave urogenital orifices. The female broodstock had a bulging abdomen, protruding urogenital orifices, and a reddish hue. In addition, various factors had to be considered, including spawning timing, spawning techniques, male-female ratios, and broodstock removal. Of course, each of these processes had risks.

Seventeen risk events were identified in four production processes. These seventeen risk events have been validated by experts. Identification of the risk events can be seen in Table 4.

Table 4. Identify Risk Events.

Process	Code	Risk Event
Pond preparation	E1	The walls of the concrete pond are prone to cracking (leakage occurs)
	E2	Pond irrigation is not good
	E3	Pond water quality
Spawning	E4	Stressed broodstock
	E5	Male koi fish do not produce sperm
	E6	Koi fish have immature gonads
	E7	Koi fish eggs do not hatch
Maintenance	E8	Sick fish fry
	E9	Fish seeds are sick and die by carrying diseases that can be transmitted to other koi fish
	E10	Stressed koi fish seeds
	E11	Most of the koi fish seeds die
	E12	The number of koi fish seeds has decreased drastically
	E13	The growth of koi fish seeds is not optimal/slow
	E14	Maintenance pool water is cloudy
Harvesting	E15	The harvest of koi fish seeds is not optimal
	E16	Low-quality koi fish seeds
	E17	Stressed koi fish seeds

The most common risk events found in the process of rearing koi fish larvae were seven risk events. This occured since the larval rearing phase was the most important phase to prevent mortality in koi fish larvae. The most important phase in koi cultivation was when the koi fish were still in larval form. This was caused by poor larval resistance and they were still vulnerable to environmental changes (Fauzan *et al*., 2024).

Identifying Risk Agent

Koi fish hatcheries faced various sources of risk, such as weather conditions, pests, diseases, water quality issues, stressed koi fish, high stocking density, poor hatching of eggs, insufficient feed, and low survival rates. Among these risks, water quality stood out as the primary factor since it served as a vital medium for the larvae of koi fish. Challenges encountered during the hatchery process include pests, fluctuations in water quality, inadequate dissolved oxygen levels, temperature changes,

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weather conditions, and diseases (Rajesh and Rehana, 2022). Effective management of water quality in ponds significantly impacted the survival rate and overall quality of koi fish offspring (Ramadhan and Sari, 2019).

The identification results obtained 33 causes of risk sources. Sources of risk were obtained from the results of focus group discussions with experts. The identification results can be seen in Table 5.

Table 5. Identifying Risk Agent.

Code	Risk Agent
A1	The material is not good and does not meet the standards
A2	A natural disaster occurred
A3	Too strong water load
A4	There is a lot of grass growing around the water channel
A5	Lots of dry leaves and twigs clog waterways
A6	The remaining uneaten fish food settles at the bottom of the pond
A7	Extreme weather
A8	Ammonia levels are high and water quality decreases
A9	Koi fish are attacked by the parasite Myxobollus sp
A10	Koi fish are attacked by Koi Herpes Virus (aeromonas)
A11	The transfer is not accompanied by adjustment to the new pool environment
A12	The female koi fish is tired from being chased by the male koi fish
A13	The broodstock quarantine process doesn't take long
A14	Lack of oxygen (O2)
A15	Males are larger than females
A16	The new male is spawned
A17	Koi fish are still too young
A18	Stressed koi fish
A19	The sperm quality of male koi fish is not good
A20	Eggs undercooked
A21	Eggs are not fertilized
A22	The pool is not sterile
A23	The density of fish stocking in the pond is not controlled
A24	Genetic factors due to inbreeding
A25	Koi fish seeds are attacked by pests/predators
A26	Lack of water quality control
A27	The height of dragonfly larvae and seahorses
A28	Koi fish seeds are eaten by birds/large fish
A29	Delay in removing koi fish seeds
A30	Koi fish fry lack food
A31	High fish seed death rate (low survival rate)
A32	The development of koi fish seeds is slow
A33	Harvesting is done during the day

Risk Management

House of Risk Phase 1

The HOR Phase 1 model is a method for determining dominant risk priorities and then following up with mitigation actions. The results of assessing the impact of severity, frequency of occurrence, and correlation between risk events and risk sources were then calculated in the Phase 1 HOR table to determine the Aggregate Risk Potential (ARP) assessment, then determined the priority sources of risk that would be addressed.

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Table 6. Matrix of House of Risk Phase 1.

Process	Risk Event	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25	A26	A27	A28	A29	A30	A31	A32	A33	SEV
Pool preparation	E1	3	3	9																															
	E2	3	1	1	9	9	1	1																											7
	E3		3				9	9	9																										8
Spawning	E4		1				1	9	9	3		9	3	3	3				9																8
	E5															3	3	3	3																7
	E6																	3																	7
Maintenance	E7							3	1						3		3			9	9	9													8
	E8		1				9	9	9	1					9								9	9			9								9
	E9						3	1	3	9	9												3				9								9
	E10							9	9						9				3					9						3					8
	E11						9	9	9	9	9				3				3					9			3			3					7
	E12									1	1															9	9	9	3						7
	E13								9															9	9		3				3				9
Harvesting	E14					3	9	3																3			3								7
	E15							3		9	9				1									9		9		9	9	1		9		3	7
	E16								9											9				9	9		9	9	3		3		9		8
	E17						3	9	9															9						3				9	8
Occurrence of Risk Agent		3	2	4	4	5	6	6	6	6	4	6	7	6	4	2	2	3	4	6	6	6	4	5	3	4	4	6	6	5	6	4	5	3	
Aggregate Risk Potential		135	144	316	252	420	1710	2634	3390	1482	856	432	168	144	916	42	90	126	552	864	432	432	432	2625	315	504	1464	1188	648	380	306	252	360	279	
Priority Rank of Agent		30	28	21	25	18	4	2	1	5	10	14	27	28	8	33	32	31	12	9	14	14	14	3	22	13	6	7	11	19	23	25	20	24	

Description: the value of correlations 1 (low), 3 (moderate), and 9 (high). The code E1-E17 can be seen in table 4, and the code A1-A33 can be seen in table.

The calculation of the ARP value was influenced by the severity level, occurrence level, and correlation value between each risk event and risk agent variable from the Phase 1 HOR results so that the appropriate value was obtained (Wibowo and Ahyudanari, 2021). Based on the HOR Phase 1 calculation, it was known that the risk sources with the highest ARP values were high ammonia levels and decreased water quality (A8) with a value of 3390, extreme weather (A7) with a value of 2634, fish stocking density in uncontrolled ponds (A23) with a value of 2625.

Determination of dominant risk was based on the highest ARP value. The first highest ARP value was high ammonia levels and decreased water quality (A8). This risk agent had a high correlation with 8 risk events including poor water quality (E3), stressed broodstock (E4), unwell fish seeds, stressed koi fish seeds (E10), most koi fish seeds died (E11), growth koi fish seeds were not optimal/slow (E13), low-quality koi fish seeds (E16), and stressed koi fish seeds (E17). Based on these results, it was known that water quality was crucial to pay attention to since it could cause several events at once. This is in line with research Wang *et al*. (2021), stating that water quality is the most important factor in supporting the success of fish farming. Water quality measurements are of course necessary so that water quality is maintained. Water quality measurements include pH, DO, nitrite, nitrate, and ammonia levels in the water.

The second highest ARP value was extreme weather (A7). This risk agent had a high correlation with 6 risk events, including poor water quality (E3), stressed broodstock (E4), sick fish seeds (E8), stressed koi fish seeds (E10), most koi fish seeds die (E11), stressed koi fish seeds (E17). The results of this research showed that koi fish were vulnerable to extreme weather throughout the production process which was shown in the high correlation according to table 13. This was in line with the research of Sari *et al*. (2022), stating that the fish's immune system is very dependent on the fish's flexibility to food, climate, stocking density, and adequate water quality for fish survival. The main consideration in fish cultivation is

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water temperature because water is a living medium for fish. In addition, the components contained in water can determine water quality, water saturation, and influence the amount of dissolved oxygen in water.

The third highest ARP value was the density of fish stocking in uncontrolled ponds (A23). This risk agent had a high correlation with 7 risk events, including sick fish seeds (E8), stressed koi fish seeds (E10), most koi fish seeds died (E11), growth of koi fish seeds was not optimal or slow (E13), the yield of koi fish seeds was not optimal (E15), the quality of koi fish seeds was low (E16), and the koi fish seeds were stressed (E17). This showed that the density of koi fish stocking could cause many risk events at once. This statement is in line with research by Sihite *et al*. (2020), stating that uncontrolled and high fish stocking densities caused the space for fish to move narrower so that competition for oxygen and fish food was higher, as a result fish growth was not optimal and water quality decreased.

Pareto Diagram Calculation

The ARP value of each risk agent was known from the calculation results of HOR Phase 1. The next step was to determine the dominant ARP value using the Pareto diagram to group the risk agents that would carry out risk mitigation actions. The Pareto diagram was created based on the cumulative ARP percentage value. Pareto calculations were carried out by determining the percentage value of Aggregate Risk Potential (%ARP), the percentage of the cumulative value of Aggregate Risk Potential (%Cumulative ARP), and the priority ranking. The cumulative ARP percentage was sorted from highest to lowest ARP value to determine the priority of mitigation actions to be carried out. The results of the Pareto calculation can be seen in the table below:

Table 7. Cumulative ARP Calculation.

Code	Risk Agent	ARP Value	%ARP	% Cumulative	Priority Rank
A8	Ammonia levels are high and water quality decreases	3390	14%	14%	1
A7	Extreme weather	2634	11%	25%	2
A23	The density of fish stocking in the pond is not controlled	2625	11%	36%	3
A6	The remaining uneaten fish food settles at the bottom of the pond	1710	7%	43%	4
A9	Koi fish are attacked by the parasite Myxobollus sp	1482	6%	49%	5
A26	Lack of water quality control	1464	6%	55%	6
A27	The height of dragonfly larvae and seahorses	1188	5%	60%	7
A14	Lack of oxygen (O2)	916	4%	63%	8
A19	The sperm quality of male koi fish is not good	864	4%	67%	9
A10	Koi fish are attacked by Koi Herpes Virus (aeromonas)	856	4%	71%	10
A28	Koi fish seeds are eaten by birds/large fish	648	3%	73%	11
A18	Stressed koi fish	552	2%	75%	12
A25	Koi fish seeds are attacked by pests/predators	504	2%	78%	13
A11	The transfer is not accompanied by adjustment to the new pool environment	432	2%	79%	14
A21	Eggs are not fertilized	432	2%	81%	14
A22	The pool is not sterile	432	2%	83%	14
A20	Eggs undercooked	432	2%	85%	14
A5	Lots of dry leaves and twigs clog waterways	420	2%	86%	18

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Code	Risk Agent	ARP Value	%ARP	% Cumulative	Priority Rank
A29	Delay in removing koi fish seeds	380	2%	88%	19
A32	The development of koi fish seeds is slow	360	1%	89%	20
A3	Too strong water load	316	1%	91%	21
A24	Genetic factors due to inbreeding	315	1%	92%	22
A30	Koi fish fry lack food	306	1%	93%	23
A33	Harvesting is done during the day	279	1%	94%	24
A4	There is a lot of grass growing around the water channel	252	1%	95%	25
A31	High fish seed mortality rate (low survival rate)	252	1%	97%	25
A12	Tired of being chased by male koi fish	168	1%	97%	27
A13	The quarantine process doesn't take long	144	1%	98%	28
A2	a natural disaster occurred	144	1%	98%	28
A1	material that is not good and does not meet standards	135	1%	99%	30
A17	koi fish are still too young	126	1%	99%	31
A16	A new male is spawned	90	0%	100%	32
A15	the stud is too big	42	0%	100%	33

Risk handling was carried out by the dominant risk agent using the Pareto concept. Based on data above 80% of risk sources, there were 15 risk agents for risk management. By the Pareto concept and after discussing with experts, 36% of the risk agents handled failed to carry out mitigation actions to be more focused and directed. The selected risk agent that needed to be mitigated was a risk source with code A8, namely high ammonia levels and decreased water quality, which had the highest value, namely an ARP value of 3390 (14%). Therefore, high ammonia levels and decreased water quality (A8) were considered the highest-priority risk sources that required risk mitigation strategy recommendations. Then extreme weather (A7) with an ARP value of 2634 (11%) and fish stocking density in uncontrolled ponds (A23) with an ARP value of 2625 (11%). The Pareto diagram is presented in Figure 1.

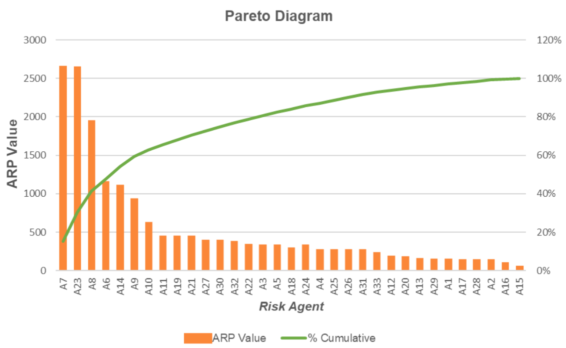

Figure 1. Pareto diagram of ARP Value.

House of Risk Phase 2

The results of House of Risk Phase 1 showed the priority sources of risk that had to be handled based on the highest ARP value. Then a Phase 2 HOR analysis was carried out to follow up on priority risk sources for which mitigation actions would be carried out. The initial step taken was identifying risk mitigation strategies obtained from observations, interviews, and FGDs with experts. Based on the results of the identification of priority risk sources that have been determined, 12 recommended risk handling strategies (preventive actions)

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are obtained. There were the preventive action code: Roofing the pond area (PA1), Moving/sharing fish eggs to other ponds (PA2), Moving/sharing fish fry to other ponds (PA3), Creation/addition of new ponds (PA4), Regular water replacement (PA5), Salt application to each pond (PA6), Vitamin and antibiotic supplementation (PA7), Washing filter media in koi fish ponds (PA8), Addition of water plants (water hyacinth) (PA9), Reducing fish feeding dosage (PA10), Increasing aeration (PA11), and Raising water (e.g. from 80 cm to 120 cm) (PA12).

Degree of Difficulty (Dk) and Correlation Rating

Risk handling strategies with the lowest degree of difficulty values were considered the easiest to implement, and vice versa. Then an assessment of the relationship between the priority risk sources and the risk management strategy was carried out. Degree of Difficulty (Dk) and Correlation can be seen in the table below.

Table 8. Matrix of House of Risk Phase 2

Risk Agent	Preventive Action												
	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11	PA12	ARP
A8	9	9	9	3	9	3	9	9	1	9	9	3	3390
A7	0	9	9	9	3	3	3	3	1	3	9	3	2634
A23	1	9	9	1	9	3	3	9	3	9	9	3	2625
Total Effectiveness of Action	35769	77841	77841	36501	62037	25947	46287	62037	13899	62037	77841	25947	
Degree of Difficulty	5	1	1	5	2	3	2	1	1	1	1	2	
Effectiveness to Difficulty Ratio	7153,8	77841	77841	7300	31019	8649	23144	62037	13899	62037	77841	12974	
Rank of Priority	12	1	1	11	6	10	7	4	8	4	1	9	

According to the HOR Phase 2 correlation calculation, the preventive activities with the greatest ETD values included moving/dividing koi fish eggs to another pond (PA2), moving/dividing fish eggs to another pond (PA3), and improving aeration (PA11) with a value of 77841. The ETDk value was calculated using the total effectiveness of action (TE) and the degree of difficulty (Dk).

CONCLUSION

The identification results reveals 17 risk incidents and 33 risk sources (risk agents) in the four production processes of koi fish breeding in Kediri Regency. In Kediri Regency's koi fish seed production, the top three risks prioritized for mitigation are high ammonia levels and decreased water quality, extreme weather conditions, and uncontrolled fish stocking density. The recommended preventive actions with the highest effectiveness are transferring/dividing koi fish eggs to another pond, transferring/dividing fish eggs to another pond, and improving aeration.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTION

All authors have contributed to the final manuscript. All authors discussed the results and contributed to the final manuscript. First author contributed to conceiving and designing the analysis, collected the data, performed the analysis, and wrote the paper. Second author contributed to conceiving and designing the analysis, collected the data, performed the analysis, wrote the paper, and guided the first author to complete the report. The third and fourth author contributed to guide the first author to complete the report and wrote the paper. The fifth author contributed to write the paper and submitted the article.

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