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The determination of fish species for freshwater aquaculture based on the conformity of water quality parameters with expert system

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Abstract: This study aims to determine the types of the right freshwater fish based on a range of water quality parameters (physical parameters: temperature and brightness; chemical parameters: dissolved oxygen, ammonia, and nitrite) with an expert system. Common carp (*Cyprinuscarpio*), giant gourami (*Osphronemusgoramy*), and striped catfish (*Pangasianodonhypophthalmus*) represent fish species with low, medium, and high tolerances to poor water quality. The research method consists of several stages, including the acquisition and representation of knowledge by experts, the development of inference machines, the process of defuzzification and implementation. The results of expert system analysis, in the form of a decision, chose fish from the family Cyprinidae to be cultivated in good water quality as the expert system output revealed carp. Meanwhile, fish from the Oshphronemidae family are to be grown in moderate water quality, since the expert system revealed carp. Finally, fish from the Catfish family are to be cultivated in poor water quality because the expert system displayed catfish.
Keywords: Expert system, fish species, parameters, water quality

I. INTRODUCTION

Freshwater fish species that are popular and favored by both the community and farmers include common carp (*Cyprinuscarpio*), giant gourami and striped catfish. Goldfish is still a prospective commodity to be cultivated, although its cultivation is still constrained by feed and requires good water quality [1]. Common carp is known as a consumption fish liked by people because it tastes good. It is also a favorite species among farmers because it is both expensive and stable compared to other cultivated fish [2].

Meanwhile, striped catfish isa prevalent freshwater species favored by the community for its easy cultivation, rapid growth, and adaptability to various adverse environments. It is also one of the exported commodities from fisheries [3]. These three commodities are selected to represent freshwater fish requiring water quality in the categories of good (common carp), medium (giant gourami) and bad (striped catfish).

In fish farming activities, water quality is one of the most important factors that will determine the success of the production. According to [4], water quality has a role in increasing productivity in the fish farming system. However, fish farmers still rarely pay attention to the quality of water used so that their productionsare not optimal and even cause losses due to high mortality. Knowledge of the appropriate water quality (chemical and physical) parameters is important for fish farming because water quality influences the optimality of fish production [1]. One of the problems often experienced by fish farmers is the determinationof the type of fish suitable for cultivation. This problem is allegedly due to different water quality conditions leading to conditions of uncertainty [5]. An effort to solve the problem of uncertainty in determining the type of fish for freshwater cultivation based on the conditions of water quality is to use an expert system decision-making method [6].

Some expert system studies have been carried out in the field of fisheries, namely systems for supporting freshwater fish cultivation decision making in GiriTirtaCikalang[5]. Expert systems were also developed for determining the type of freshwater fish to be cultured based on location and water quality [7], water quality analysis and its relationship with the diversity of aquatic vegetation in the waters of Balige Lake Toba, and water quality in the maintenance of intensive *Oreochromis tilapia* culture in ponds [8]. This study aims to determine the right type of freshwater fish species based on water quality parameters using an expert system.

II. MATERIALS AND METHODS

This study follows the stages of the expert system developed by [9] and covering knowledge acquisition, knowledge representation, inference engine development, implementation, testing and representing experts.

A. Acquisition of knowledge

Knowledge acquisition is the initial stage of creating an expert system. At this stage, it takes an experienced expert on the issue of freshwater aquaculture, particularly knowledge of water quality. Knowledge acquisition techniques were through conducting open interviews with experts, discussing the types of freshwater fish following the physical and chemical parameters of freshwater fish.

B. Knowledge representation

This stage is aimed at entering the knowledge acquired by experts. Furthermore, all parameters relating to determining the quality of water for the optimal growth of fish are included as inputs, and each parameter will be interrelated and affect the output of this system. The expert system in this study is that all parameters are fuzzy parameters. The representation used is in the form of based rules, the number of which is determined by the experts.

C. Inference machine development

Furthermore, the facts and information obtained previously are formulated and represented by methods that have been selected in the previous stages of knowledge representation. In this system, the Fuzzy Inference System is used as an inference engine, and that is where the verification process is carried out. The technique used is the rule-based fuzzy inference system.

D. Implementation

Implementation is the stage where the problem formulation results are translated into computer applications. This expert system was built with Matlab to solve problems with fuzzy parameters based on the desktop. The hardware specification used in the construction of this system is an Intel® Core ™ i5-3230M 2.60GHz processor, 4.00GB RAM. The software specifications used are Windows10 and Matlab R2010a operating systems as applications for creating the expert systems.

E. Testing

At this stage, a trial was carried out by experts in the field of fisheries, and an evaluation related to the system was also carried out such as the accuracy and consistency of the knowledge obtained by the system. If the test results are following the results of an expert's decision, then the expert system is ready to be used. But if the results are still inconsistent or there is an input error, the expert system will return to the previous stage of development.

III. RESULTS AND DISCUSSIONS

A. Knowledge acquisition

The expert knowledge was acquired from expert interviews and the 2001 KLKH PP regarding fishery water quality standards. Knowledge acquisition by experts is presented in Table 1.

TABLE 1. Knowledge acquisition carried out in the present study.

Stages	Results	Following steps
Determine the range of values for each variable	Eliminate the variables of nitrate, pH, alkalinity, total hardness, and suspended solids. Some variables have an incorrect range of values. Fish used in research less representative	Only use dissolved oxygen, ammonia and nitrite as chemical parameters; and temperature and brightness as physical parameters. Conduct another research with the correct range of variable values
Evaluate more representative fish according to expert advice and validate the range of values for each variable.	The fish approved for this study were common carp to represent fish with a low tolerance to water quality, giant gourami for fish with moderate tolerance to water quality, and striped catfish for high tolerance to water quality conditions.	Determine the rules to enter the knowledge representation stage Determine the type of tolerance (low tolerance, moderate tolerance, high tolerance) of fish in each of these variables
Validation rules	Experts provide rules that will be applied to the system later.	Develop inference machines.

The parameters approved by experts consisted of chemical parameters, namely dissolved oxygen, ammonia and nitrite; and physical parameters such as brightness and temperature.

B. Knowledge Representation

Based on the knowledge acquisition and discussion with experts, 26 rules for chemical parameters and nine rules for physical parameters were obtained. The range of fish tolerance values for chemical and physical parameters are presented in Table 2.

TABLE 2. The range of fish tolerance values for chemical and physical parameters

Parameters	**Variable**	**Values**		
		Low tolerance	**Moderate tolerance**	**High tolerance**
Chemical	Dissolved oxygen ($mg.L^{-1}$)	5,000– 8,000	3,000 – 5,000	2,000 – 4,000
	Amonia ($mg.L^{-1}$)	0,010 – 0,023	0,030 – 0,015	0,050 – 0,025
	Nitrite ($mg.L^{-1}$)	0,000– 0,030	0,025 – 0,065	0,060 – 0,100
Physical	Temperature(°C)	25 – 28	27 – 30	29 –32
	Brightness (cm)	60 – 80	40 – 60	20 –40

C. Development of the inference machine

The implementation of this system used two approaches to predict, namely water quality based on chemical parameters as the main parameters consisting of dissolved oxygen, ammonia, and nitrite. Physical parameters as supporting parameters consist of temperature and brightness. The steps taken in the development of inference machines using the Mamdani fuzzy method are presented in Figure 1.

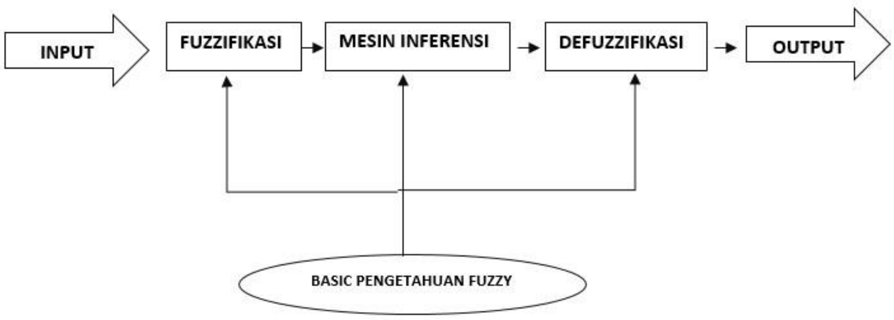

Figure 2. Development of the inference machine

All water quality parameters for the farming of freshwater fish will be processed, namely chemical parameters, i.e., dissolved oxygen, ammonia, and nitrite; and physical parameters, i.e., temperature and brightness. These parameters are processed through both fuzzification and defuzzification.

There are two parameters to be processed in the fuzzification process, namely chemical parameters (dissolved oxygen, ammonia, and nitrites) and physical parameters (temperature and brightness).

D. Defuzzification

Defuzzification is the process of converting values in each fuzzy parameter into real numbers. The parameters for determining the quality of water beforehand will be converted into a rule verified by experts to produce an output. This study used the Mamdani defuzzification method with the COA (centroid of the area) method. The output of the defuzzification process with the centroid method is a crisp value which is the middle value obtained from the fuzzy region, which will be returned as a non-fuzzy parameter.

E. Implementation

The implementation is the process of translating input parameters when all input and output parameters are displayed in the form of an interface so that users of this system can use the system. The appearance of the referenced system is presented in Figure 2.

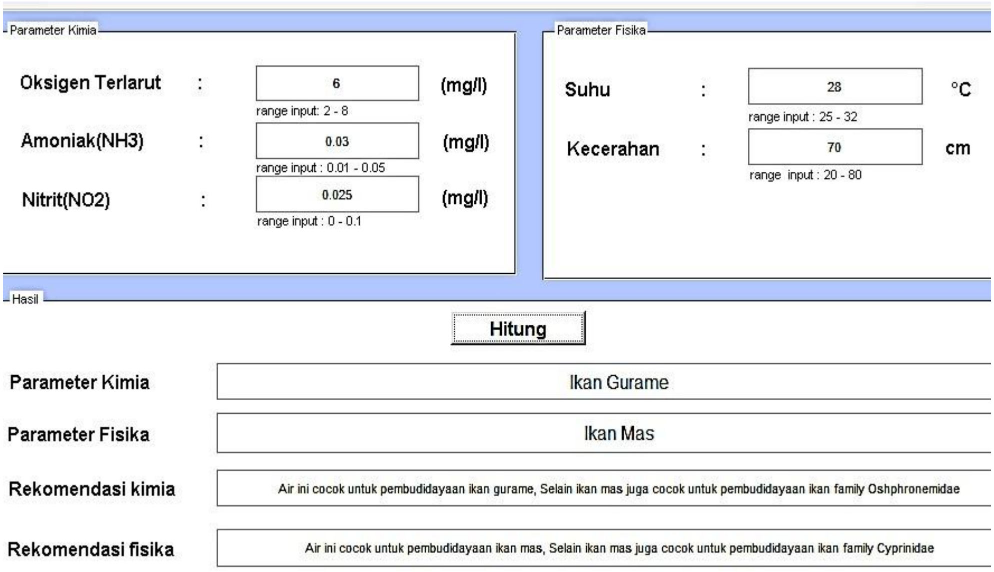

Figure 2.The interface of the Expert system

In Figure 2, the input parameters are divided into chemical parameters with input variables such as 6 mg.L^{-1}of dissolved oxygen, 0.03 mg.L^{-1}of ammonia, and 0.025 mg.L^{-1}of nitrite. The results obtained for these inputs are giant gourami and other fish recommendations, namely fish of the Oshphronemidae family. The input of physical parameters with variables useda temperature of 28°C, and a brightness of 70 cm. The results obtained for this input are common carp and other fish recommendations, namely fish of the family Cyprinidae. System users can choose what types of fish they will be cultivated based on the considerations of the output of this system.

F. System testing

Each input datum was tested, and the obtained accuracy of the data is presented in Table 3. The determination of the accuracy value is done by sliding the lowest and highest values of the defuzzification process value. The shifting is done so that the accuracy of the system is not below 50% for each fish of the two predetermined parameters. The accuracy of giant gouramiwas in the range of 60%, for giant gouramiisa moderate, tolerant fish. Also, the lowest values of each parameter of giant gourami were also equal to the range of the low tolerance fish value; and the highest value of each parameter of giant gourami was the same as the value of high tolerance fish. Thus, the accuracy produced is smaller than the accuracy of other fish. Based on discussions with experts, the performance of the system created was following the experience of the experts.

TABLE 3. The accuracy of the system for the three freshwater aquaculture commodities

Fish species	Accuracy	
	Chemical parameters	Physical parameters
Carp	92 %	85%
Giant gourami	63%	59%
Striped catfish	89%	70%

IV. DISCUSSION

A. Knowledge acquisition

Common carp is a fish of the Cyprinidae family. This fish is classified as a low tolerance fish because common carp cannot grow optimally in water with poor quality, but good quality water [10]. Meanwhile, Common carp can live in a farming environment which is slightly salty because of its high adaptability to the environment. However, the waters recommended for its environment are freshwaters with dissolved oxygen ranging from 3 to 5 mg. L^{-1}[11]. Striped catfish are fish that can survive in environments with low dissolved oxygen levels because these fish have respiratory aids such as labyrinths. Catfish is a high tolerance fish that can survive in water with low dissolved oxygen content, about 3-6 mg. L^{-1}[10].

Chemical parameters are the main parameters in determining which fish will be cultivated because changes in value that occur in water will have a direct effect on fish life. The values of dissolved oxygen and ammonia affect the metabolic processes of the fish, and low ammonia and dissolved oxygen levels will interfere with fish growth because high ammonia levels reduce dissolved oxygen level[12].

Physical parameters are supporting parameters in determining which fish will be cultivated because changes in values that occur in water will not have a direct effect on fish life, but gradually change fish behavior and also affect chemical parameters.

Common carp is a low tolerance fish that can grow well at 25-30°C [10]. The optimal temperature for common carp life ranges from 24 to 28°C [11], while striped catfish can grow optimally at a temperature of 28-30°C [10]. Brightness can be used to estimate the density of plankton if the turbidity of the waters is mainly caused by plankton. It can also show the fertility of water. The depth of the Secchi disk in fertile ponds ranges from 30 to 40 cm [13]. The brightness value of excellent water for fish cultivation is between 15 and 25 cm [14].

B. Inference machine development

The implementation of this system used two approaches to predict, namely water quality based on chemical parameters as the main parameters consisting of dissolved oxygen, ammonia, and nitrite. Physical parameters, as supporting parameters, that consisted of temperature and brightness. Other variables that were not mentioned were pH, phosphorus, suspended solids, and nitrate which were not used as input variables because the values of these four environmentalparameters did not directly affect the fish. Meanwhile, in the chemical parameters, a change in value will affect fish life like, i.e., mortality. Thus, the development of this expert system did not use all variables as input.

The presence of dissolved oxygen in water is influenced by temperature, salinity, water turbulence, and atmospheric pressure. Oxygen plays a role in the process of respiration and metabolism in aquatic biota. Aquatic plants and phytoplankton cause the presence of dissolved oxygen in the water. Therefore their presence is important in the waters. Thelack of dissolved oxygen in aquaculture containers can cause fish susceptible to diseases, parasites and a lack of appetite [15].

Ammonia in the waters is produced through the breakdown of organic nitrogen such as proteins and urea, and inorganic nitrogen which is usually found in soil and water and decomposition of organic matter carried out by microbes and fungi. Free ammonia levels were exceeding 0.2 mg.L^{-1} will be toxic to several fish species. So, it is important to consider ammonia as one of the parameters in determining water quality for freshwater fish farming.

The presence of nitrite in the water is relatively low because the nitrite is immediately oxidized to nitrate. Nitrite in water comes from industrial and domestic wastes. For aquatic organisms, nitrite levels exceeding 0.05 mg. L^{-1} can be highly sensitive and toxic [16]. The high and low water temperature is affected by sunlight entering the water body and absorption and transformation into heat energy.An increase in water temperature also results in increased oxygen consumption resulting in a decrease in oxygen levels and insufficient oxygen for respiration and metabolism. In common carp, the lowest temperature for life tolerance is 25°C [17]. Also, the brightness parameter is a measure of water transparency. Several factors affect water brightness, namely weather conditions, measurement time, turbidity, suspended solids, and accuracy when measuring. The value of water brightness according to the fisheries and marine ministry in 2001 was in the range of 40-70 cm. High and low brightness influences photosynthesis and productivity. So, it is important to monitor the brightness level of the waters [15].

C. Inference machine

Calculation and analysis are carried out in the inference machine by computers based on facts and rules that have previously been obtained in the knowledge representation process. The rule is processed by the system to produce the best conclusion later.

D. Defuzzification process

Defuzzification is the process of converting values in each fuzzy parameter into real numbers. The parameters for determining the quality of water beforehand will be converted into a rule verified by experts to produce an output. This study used the Mamdani defuzzification method with the COA (centroid of the area) method. The output of the defuzzification process with the centroid method is a crisp value which is the middle value obtained from the fuzzy region that will be returned as a non-fuzzy parameter.

The system created in this study is only limited to the parameters of water quality (chemical and physical). This study has not considered a location in which there are parameters such as the distance to the location of waste disposal, water sources, land requirements, type of pond, irrigation, elevation of the land.

CONCLUSION

This expert system can be used to advise on fish to be cultivated such as common carp, giant gourami, and striped catfish. It applies to fish from the family of Cyprinidae if the output system produces the results of common carp, fish from the Oshphronemidae family if the system output produces giant gourami, fish from catfish family if the system output releases striped catfish.

The accuracy of the chemical parameters in common carp was 92% and 85% for physical parameters. The chemical parameters in common carp were 63%, and the physical parameters were 59%. Finally, the chemical parameters in striped catfish were 89%, while the physical parameters were 70%.

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