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Fish as source of animal protein have been cultured intensively Indonesia. Indonesia is one of the maritime countries in the world where the water areas are larger than the mainland areas. The success of fish culture was strongly influenced by water quality. Parameters of water quality that influence fish culture are temperature, salinity, pH, oxygen, NH_3, NO_2, CO_2 , and water transparency. Determining the suitability of water quality for fish culture is very difficult because not every fish can adapt to it very well. Therefore, it needs a system to help determine the appropriate fish to be cultured based on water quality conditions. This system was created in the form of a computer program with a thinking capability as an expert, known as an expert system. The expert system was developed based on the sequence of steps of knowledge acquisition, knowledge representation, and the construction of an expert system shell. Knowledge was achieved from expert, literature, and field study. This knowledge was represented in rule-based representation. Expert system shell was built in C++ language programming. The expert system was developed using backward chaining method to find the appropriate cultured fish under conditions of water quality parameters. Knowledge of the water quality parameters and appropriate cultured fish was stored in a knowledge base. With the expert system, appropriate cultured fish under conditions of water quality parameters can be identified quickly. Hopefully, users will get optimum fish growth.

Keywords: Appropriate Cultured Fish; Expert System; Water Quality

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Determination of Appropriate Fish Culture Method Based on Water Quality Using Expert System

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Fish as source of animal protein have been cultured intensively Indonesia. Indonesia is one of the maritime countries in the world where the water areas are larger than the mainland areas. The success of fish culture was strongly influenced by water quality. Parameters of water quality that influence fish culture are temperature, salinity, pH, oxygen, NH_3, NO_2, CO_2, and water transparency. Determining the suitability of water quality for fish culture is very difficult because not every fish can adapt to it very well. Therefore, it needs a system to help determine the appropriate fish to be cultured based on water quality conditions. This system was created in the form of a computer program with a thinking capability as an expert, known as an expert system. The expert system was developed based on the sequence of steps of knowledge acquisition, knowledge representation, and the construction of an expert system shell. Knowledge was achieved from expert, literature, and field study. This knowledge was represented in rule-based representation. Expert system shell was built in C++ language programming. The expert system was developed using backward chaining method to find the appropriate cultured fish under conditions of water quality parameters. Knowledge of the water quality parameters and appropriate cultured fish was stored in a knowledge base. With the expert system, appropriate cultured fish under conditions of water quality parameters can be identified quickly. Hopefully, users will get optimum fish growth.

Keywords: appropriate cultured fish, expert system, water quality.

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1. INTRODUCTION

Industrialization-based intensive fish culture keeps on growing in Indonesia in order to increase national fish production. Based on data from Secretary General of the Ministry of Maritime Affairs and Fisheries, aquaculture production in 2010 amounted to 4.78 tons and increased to 6.97 tons in 2011.[1] In fact, according to the report from the Directorate General of Aquaculture Ministry of Maritime Affairs and Fisheries, until the first quarter of 2013, aquaculture production reached 2,250,000 tons.[2] Ministry of Maritime Affairs and Fisheries had targeted by the year 2015 Indonesia would be the largest producer of fishery products in the world. On the fisheries sector, Indonesia ranks fourth after China, Thailand, and India. About 67% of Indonesia's area consists of water area with potential aquaculture production of 57.7 tons per year.

Production of fish culture can be expected but requires fairly complicated calculation because it must be based on several factors. The main problem is that the growth rate of fish is affected by several parameters including the fish condition (immunity to diseases), compliance to the nutritional needs of fish feed, the condition of cultivated land, and water quality as the main medium for fish survival. Meanwhile, fish growth was influenced by two factors, namely internal factors which consist of genetic and physiological condition of fish, as well as external factors related to the environment such as water chemical composition and physical quality, metabolic waste material, availability of food, and disease. [3]

Factors associated with the feed formulation have been studied using an expert system.[4,5] Feed formulations were prepared based on the nutritional content of food constituents and fish nutrition, and kinds of feed ingredients available in various regions in Indonesia.[6-8] In these system, the formulation was also calculated based on feed estimated price. Moreover, study of related fish disease also has been conducted using an expert system, and further development was performed using the method of case-based reasoning (CBR).[9,10]

Expert systems are characterized by knowledge-based systems that enable a computer to reason and draw conclusions from a set of rules. During the process, users can communicate interactively with a computer to solve a problem or an issue. This is possible because the expert system can store the knowledge gained by experience or intuition experts. In other words, the expert system is a computer-based information system that uses expert knowledge to achieve high performance level decisions in a specific problem domain.[11] Additionally, it is stated that the expert system could explain the achieved solution or response, which was the main part and a guarantee of success in the chaining.[12]

Expert systems have been used in various sectors. In education sector, expert systems could be used in problem solving of learning anxiety.[13] In industrial sector, expert systems were capable to help diagnose the computer damage.[14] In medical sector, expert systems were used to help diagnose liver disease.[15] In fisheries sector, expert systems were used to diagnose symptoms of fish diseases and to provide alternatives of how to treat them and to determine the feed formulation using backward chaining.[4-7] Meanwhile, in related fish diseases, expert systems had been developed to diagnose fish diseases.[8]

Based on those problem areas mentioned, this study aims to determine the appropriate cultured fish according to water quality parameters using expert system. This system will facilitate the selection of the most appropriate fish to be cultured by the farmers according to the water quality parameters and conditions that affect the optimal fish growth. Therefore, fish culture production may increase.

2. MATERIALS AND METHOD

System framework would be built according to the design in Figure 1 while the development of expert system was designed as in Figure 2.

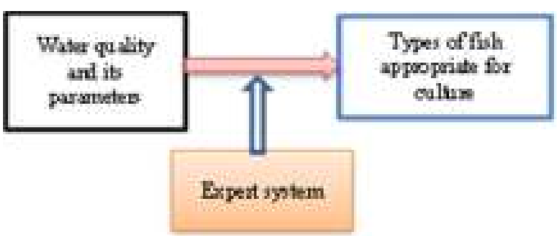

Figure 1. Research framework

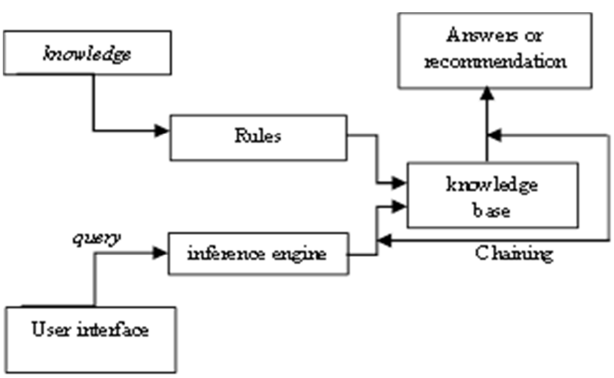

Figure 2. Diagram stage of development of expert systems

Steps in the development of expert systems are:

a. acquisition of knowledge.
   This step consists of data collection about the types of fish and parameters of water quality.
b. knowledge representation.
   The collected knowledge is then presented or compiled using a rule-based knowledge representation techniques.
c. composing the expert system shell

2. RESULTS AND DISCUSSION

This study resulted in a form of a computer program system called an expert system. This system can act like an expert to assist its user to select the appropriate fish to be cultivated based on water quality parameters. Water quality parameters that must be considered in accordance to the guidelines by *Balai Besar Perikanan Budidaya Air Tawar* are:[16]

- Temperature (°C)
- pH
- dissolved O_2 (mg/l)
- dissolved CO_2 (mg/l)
- dissolved NH_3 (mg/l)
- dissolved NO_2 (mg/l)
- Water transparency (cm)

BBPBAT stated that water quality parameters for freshwater fish culture included three characteristics, namely the physical characteristics (temperature, water debit, water tranparency, salinity), chemical characteristics (pH, alkalinity, dissolved oxygen, carbon dioxide, ammonia, nitrites, phosphates) and biological characteristics (density of plankton and benthos).

Knowledge (data) in this study was obtained from various sources, such as books and internet. Knowledge representation was adapted from previous research.[17] Knowledge was represented in Table 1 using the rule (IF premise(s) THEN conclusion). Each field (premise) in Table 1 was connected with AND operator. There are eight premises with one conclusion or eight anticedents with one consequent in each rule. If one of the field's content (premise) had wrong value for each row, it caused wrong value in the solution (conclusion). It means that the system failed to reach any solution of the appropriate kind of fish. These rules are shown in Figure 3.

1. IF Temperature (Celcius) = 28 – 30 AND pH = 6,5 – 8,5 AND Oxygen > 4 AND CO2 < 12 AND NH3 < 0,5 AND NO2 < 0,06 AND Transparency (cm) = 25 – 35 AND Salinity (ppt) = 0 THEN Clarias gariepinus
2. IF Temperature (Celcius) = 25 – 30 AND pH = 6,5 – 8,5 AND Oxygen > 4 AND CO2 < 12 AND NH3 < 1 AND NO2 < 0,06 AND Transparency (cm) = 25 – 35 AND Salinity (ppt) = 0 THEN Local Catfish
3. IF Temperature (Celcius) = 25 – 30 AND pH = 6,5 – 8,5 AND Oxygen 4 – 6 AND CO2 < 12 AND NH3 < 0,5 AND NO2 < 0,06 AND Transparency (cm) = 30 – 40 AND Salinity (ppt) = - 10 THEN Tilapia niloticus

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.

26. IF Temperature (Celcius) = 28 – 32 AND pH = 8,0 – 8,2 AND Oxygen > 5 AND CO2 < 12 AND NH3 < 0,3 AND NO2 < 0,1 AND Transparency (cm) = 70 – 100 AND Salinity (ppt) = 24 - 45 THEN Giant Lobster

Figure 3. Rules in Expert System

Table 1. Rule of Fish and Water Quality

No.	Kind of fish	Temperature (°C)	pH	dissolved O_2 (mg/l)	dissolved CO_2 (mg/l)	dissolved NH_3 (mg/l)	dissolved NO_2 (mg/l)	Water Transparency (cm)	Salinity (ppt)
1	*Clarias gariepinus*	28 – 30	6,5 – 8,5	> 4	< 12	< 0,5	< 0,06	25-35	0
2	Local Catfish	25 – 30	6,5 – 8,5	> 4	< 12	< 1	< 0,06	25-35	0
3.	*Tilapia niloticus*	25 – 30	6,5 – 8,5	4 – 6	< 12	< 0,5	< 0,06	30-40	0 - 10
4	Tilapia (fingerling stadia)	25 – 30	6,5 – 8,5	> 5	< 12	< 0,2	< 0,06	30-40	0
5	Tilapia (adult stadia)	25 – 30	6,5 – 8,5	4 – 6	< 12	< 1	< 0,06	30-40	0
6.	*Puntius javanicus*	20 – 33	6,5 – 7,5	> 5	< 12	< 0,5	< 0,06	50-70	0
7.	Nilem Fish	18 – 28	6,5 – 7,5	> 5	< 12	< 0,5	< 0,06	50-70	0
8	*Tilapia mossambicus*	20 – 25	7 – 8	> 5	< 12	< 0,5	< 0,06	50-70	0
9	*Cyprinus carpio* (fingerling stadia)	25 – 30	6,5 – 8,5	> 5	< 12	< 0,2	< 0,06	10-30	0
10	*Cyprinus carpio* (adult stadia)	25 – 30	6,5 – 8,5	> 5	< 12	< 1	< 0,06	10-30	0
11	Asian Catfish	28 – 32	6 – 7	4,5 – 6,5	< 12	< 0,05	< 0,06	50-70	0
12	Asian Catfish (fingerling stadia)	25 – 28	6,5 – 8,5	> 5	< 12	< 0,01	< 1	30-50	0
13	Asian Catfish (adult stadia)	27 - 32	6,5 – 8,5	≥ 3	< 12	< 0,01	< 1	50-70	0
14	Pomfret Fish	25 – 30	7 – 8	> 4	< 12	< 0,01	< 0,06	50-70	0
15	*Osphronemus gouramy*	24 – 28	6,5 – 8,0	> 4	< 12	< 0,5	< 0,06	40 - 60	0
16	*Osphronemus gouramy* (fingerling stadia)	25 – 30	6,5 – 8,5	> 3	< 12	< 1	< 0,06	40 - 60	0
17	*Osphronemus gourami* (adult stadia)	25 – 30	6,5 – 8,5	≥ 3	< 12	< 1	< 0,06	40 - 60	0
18	Eel	28 – 29	7 – 8	5 – 6	< 12	< 0,5	< 0,06	50-70	0 - 10
19	Head-snake Fish	25,5 - 32,7	6 – 7,5	> 4	< 12	< 0,5	< 0,06	50-70	0 - 10
20	Freshwater Giant Prawn	28-30	6,5-8,5	> 5	< 12	< 0,5	< 0,05	70-100	0 - 15
21	Freshwater Giant Prawn (fingerling stadia)	28-30	6,5-8,5	> 5	< 12	< 1	< 0,06	50-70	0
22	Freshwater Giant Prawn (adult stadia)	28-30	6,5-8,5	> 5	< 12	< 1	< 0,06	70-100	0
23	*Penaeus vannamae*	26-32	7,5 - 8,5	> 5	< 12	< 0,5	< 0,05	30-40	15 - 25
24	*Penaeus monodon*	26-32	7,5 - 8,5	> 5	< 12	< 0,5	< 0,05	30-40	15 - 25
25	Grouper	27-29	8,0 - 8,2	> 5	< 12	< 0,5	< 0,05	> 200	30 - 34
26	Giant Lobster	28-32	8,0 - 8,2	> 5	< 12	< 0,3	< 0,1	70-100	24 - 45

Rules that had been arranged then was implemented in an expert system shell. This shell was built using C++ language programming. Interface of the system was shown in Figure 4.

```
                    MENU
**              (L)oad                **
**              (C)onsultation        **
**              (D)isplay             **
**              e(X)it                **
Choose: _
```

Figure 4. The first view of the expert system

A consultation session in an expert system was the most important part. In general, the consultation session consists of the followings:

1. inquiring about the condition of the water quality parameters (user)
2. providing information about the appropriate fish

At the beginning of the consultation process, questions to be answered by the user will appear on the interface. Questions such as those in Figure 5 and 6 were the premises (IF part of the rule). Figure 5 showed an example of informations where system could not provide any solution of most appropriate fish to the conditions of water quality parameters, while Figure 6 showed a system which was able to provide a solution of appropriate fish information. Appropriateness was a conclusion based on the given premises in accordance to the rule (the sixth rule).

```
Is water condition   : Temperature (Celcius) = 18 – 28? (Y/N) N
Is water condition   : Temperature (Celcius) = 20 – 25? (Y/N) N
Is water condition   : Temperature (Celcius) = 20 – 33? (Y/N) Y
Is water condition   : pH = 6.5 – 7.5? (Y/N) Y
Is water condition   : Oxygen > 5? (Y/N) Y
Is water condition   : CO2 < 12? (Y/N) Y
Is water condition   : NH3 < 0.5? (Y/N) N

No fish appropriate to these condition:
```

Figure 5. Consultation session of expert system with no solution

Is water condition	: Temperature (Celcius) = 18 – 28? (Y/N) N
Is water condition	: Temperature (Celcius) = 20 – 25? (Y/N) N
Is water condition	: Temperature (Celcius) = 20 – 33? (Y/N) Y
Is water condition	: pH = 6.5 – 7.5? (Y/N) Y
Is water condition	: Oxygen > 5? (Y/N) Y
Is water condition	: CO2 < 12? (Y/N) Y
Is water condition	: NH3 < 0.5? (Y/N) Y
Is water condition	: NO2 < 0.06? (Y/N) Y
Is water condition	: Transparency (cm) = 50 – 70? (Y/N) Y
Is water condition	: Salinity (ppt) = 0? (Y/N) Y

Fish appropriate to these condition:
Puntius javanicus

Figure 6. Consultation session of expert system with solution provided

This expert system used backward chaining. Backward chaining is one of inference chaining in expert systems, other than forward chaining. An expert system works like an expert in a particular field of expertise. Acting such an expert in fisheries, the system provided no information of solutions for availability of appropriate fish according to the conditions of water quality parameters. During the dialogue, system may ask many questions. The questions were not contained in the knowledge base, but they were parts of the premises in the rule format of a question form. Users can answer a question in two ways: by providing relevant answers either yes or no. If the answer is "Y" (YES), this answer will be stored in the *yes* database on the shell. If the user answered "N" (NO), the system will search for the next rule. Answer "N" to a question will be saved in the *no* database. The premises that have not been asked by the system are marked in the data base so that repetition of questions on the same premise does not happen. Examination of the premises continues until a system gets a solution. The solution can be obtained if all the premises of a rule are met.

Answer "yes" provides input to the system that the condition of a rule (premise) is met, then the system will continue with a question which is the next premise of a rule. If the user answers "no," then the system will get another new rule. It continues to do so until the system can produce a conclusion or cannot find any conclusion in case where there is no premise that is met.

An expert system was a complement to some other expert systems in fisheries sector.[18] The fisheries sector consists of fish identification, fisheries management, aquaculture management, fish disease diagnosis and health management, diagnosis of symptoms of fish diseases and how to treat them, and determination of feed formulation using backward chaining, information of fisheries management and fish product marketing.[5-8,19]

4. CONCLUSIONS

This research resulted in an expert system using backward chaining method to find an appropriate cultured fish under conditions of water quality parameters. Knowledge of the water quality parameters and appropriate cultured fish was stored in a knowledge base. Using this expert system, appropriate cultured fish according to the conditions of water quality parameters can be identified quickly. Hopefully, users will get optimum fish growth. For further research, a system to determine fish species based on climate and condition of cultivation area can be developed.

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