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# Application of Fuzzy Logic to Determine Gonad Maturity Level Based on Patin Fish Parent Morphology

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The fish gonad maturity detector uses fuzzy logic to provide accurate information about the level of gonad maturity accurately. The utilization of fuzzy logic in determining the level of maturity of catfish gonads offers significant advantages over traditional methods. The data collection method used is qualitative through direct observation of the characteristics of catfish broodstock in the rearing pond as well as a literature study of previous research. Observations were made to understand the physical characteristics, while the literature study was to support the creation of a fuzzy logic system. The system has an initial stage in determining fuzzy sets for input and output variables, as well as the formation of fuzzy rules using IF-THEN. including better accuracy and the ability to accommodate individual variations and environmental conditions. Traditional methods of determining the maturity level of fish gonads, such as visual observation and GSI calculation, have their weaknesses. Therefore, the application of fuzzy logic can help reduce the risks and side effects experienced by fish, and increase the effectiveness and efficiency in determining the level of maturity of catfish gonads.

**Keywords:** fuzzy, gonad, Siamese catfish

## INTRODUCTION

Siamese catfish (*Pangasionodon hypothalamus*) is a fish whose spawning cycle depends on the season. Usually patin fish can only spawn twice a year during the rainy season, so the availability of patin fish seeds outside the spawning season is very rare. The results of observations that have been made in previous studies, it is known that environmental factors that affect fish life are temperature, dissolved oxygen, and pH. The level of gonad maturity is the stage of preparation of prospective broodstock for the spawning process. One of the efforts to mature the gonads is with hormonal induction. Gonad histology is one of the proofs of the actual conditions at the stage of gonad maturity. Observations of gonadal maturity can determine the development of gonads in histology and morphology (Kariyanti, Omar, and Tresnati 2019).

The classification of the level of gonadal maturity is divided into 5 stages, namely GMS I is characterized by the beginning of gonad development the size is still too small, GMS II is still white and already visible small egg grains GMS III is characterized by a black surface, egg grains look bigger than GMS II. GMS IV is the final stage of gonad development, in female fish with GMS IV in the ovaries several groups of eggs that are still small (white) and eggs that have developed (clear yellow). At Gonad Maturity Level V, most of the eggs are already in a highly developed condition (clear yellow) although there are still small eggs found.

Patin broodstock can be spawned after 2-3 years of age. At that age, the mother catfish has a body weight of 2-5 kg/head. The characteristics of female catfish broodstock have a rounded urogenital shape and a relatively more expanded abdomen than male catfish broodstock. Male catfish broodstock have papillae and a slimmer abdomen. According to SNI: 01- 6483.1 (2000) about the parent of Siamese catfish (*Pangasius hypophthalmus*), the main parent class (Parent Stock) states the requirements for the weight of the male parent > 2.0 kg and the female parent > 3.0 kg. Terms for artificial spawning, the main requirement of the success of spawning patin fish must be sexually mature. The characteristics of catfish that are gonadal mature and ready for spawning are as follows: for females, the age of the fish is at least three years (Ihwan et al. 2021), the size is 2 kg - 3 kg, the abdomen is enlarged towards the anus, the abdomen feels soft and soft when touched, the cloaca is swollen and dark red, the skin on the abdomen is soft and thin if around the cloaca is pressed, several eggs will come out which are round and uniform in shape.

Fuzzy logic is the development of primitive logic which has only one state, namely "yes" or "no". The existence of fuzzy logic can recognize linguistic variables such as "rather large", "large", "very large", and so on. Variables in production planning and GMS identification of catfish can have fuzzy values and can be identified using a fuzzy logic approach so that each parameter value constraint can be optimally identified (Santosa et al. 2020). Thus, the application of fuzzy logic will make the system more adaptive. In building a Fuzzy system, several reasoning methods are known, including the Tsukamoto method, the Mamdani method, and the Sugeno method (Wirawan and Azhari 2014). The Mamdani fuzzy logic method, this method is believed to be able to overcome the problems of uncertainty and complexity in fuzzy logic itself is a logic that deals with the concept of partial truth, where classical logic states that everything can be expressed in binary terms (0 or 1). Fuzzy logic allows membership values between 0 and 1. Various theories in the development of fuzzy logic show that fuzzy logic can be used to model various systems.

The implementation of Madani fuzzy has several functions as input data according to 8 parameters, according to Wirawan and Azhari (2014) including altitude (above sea level), water temperature, water depth, water pH, Organic content (mg/liter), CO2 content (mg/liter), water salt content (%), bound Ammonium (mg/liter). The selection of these parameters is based on information from the Yogyakarta fisheries office that these parameters can help determine the appropriate fish. The next thing, the system will calculate using Mamdani fuzzy. Previously, there was already supporting data on freshwater consumption fisheries commodities in the database which included 8 commodities, namely pomfret (*Pampus Argentus*), gourami (*Osphronemusgoramy*), tilapia (*Tilapia nilotica*), catfish (Pangasius pangasius), catfish (*Clarias Batrachus* carp (*Cyprinus carpio*), shrimp (*Macrobanchium Rosenberg*), and takes (*Punctius javanicus*).

## METHODS

1. Data Collection Methods

The data collection method used is a qualitative method with observation and literature study. Observation is done by understanding and seeing firsthand the characteristics of the patin fish broodstock in the rearing pond directly. In the selection of broodstock ready for spawning, sex color and body size of catfish are the initial factors considered by fish farmers, this is because both factors are very striking and easy to observe.

A literature study is carried out by searching and retrieving data from various previous studies to be used as a reference in determining the set components in the fuzzy logic system application that will be applied.

2. System Design

The system used is a fuzzy logic system. The first stage is :

a) Determining fuzzy sets, by creating input and output categories in the use of fuzzy logic, the input variables of the fuzzy system are transferred into fuzzy sets to be used in calculating the truth value of the premises in each rule in the knowledge base. This means that this stage takes firm values and determines the degree to which these values are members of each fuzzy set. This study has two input variables, namely the sex color of female patin fish broodstock and the size of the belly of the broodstock with linguistic input variables including white, pink, and red and small, medium, and large belly sizes.

b) Application of the implication function, by forming fuzzy rules using IF and THEN, fuzzy logic rules obtained.

## RESULTS AND DISCUSSION

The results of determining the input fuzzy set can be seen in Figure 1, as follows :

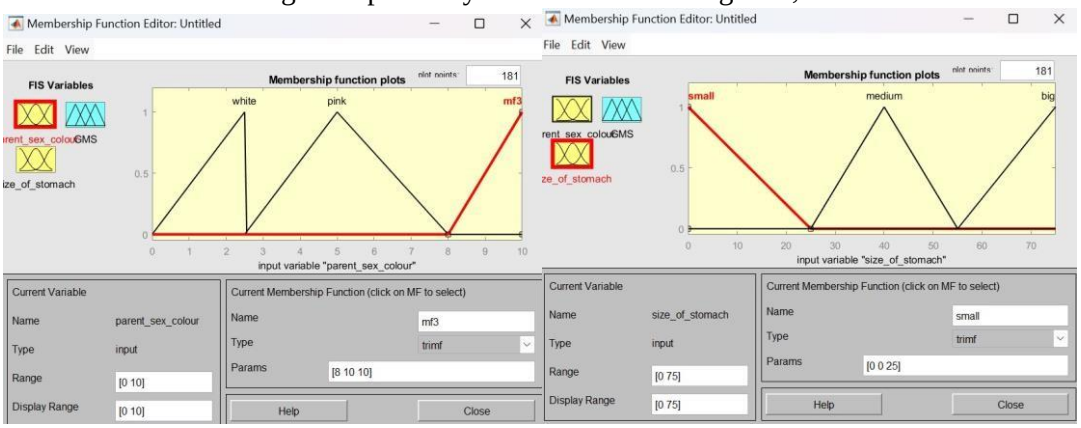


Figure 1. Fuzzy set components

For more clarity, the input fuzzy set can be seen in Table 1.

Table 1. Input fuzzy set

| No. | Parent Sex Colour | Size Stomach | GMS |
|---|---|---|---|
| 1. | White | Small | GMS 1 |
| 2. | Pink | Medium | GMS 2 |
| 3. | Red | Big | GMS 3 |

The inputs include the parent sex color which consists of white, pink, and red. Secondly, there is stomach size which consists of small, medium, and large sizes. Finally, there is the Gonad maturity stage (GMS) which consists of GMS 1, 2, and 3.

2) Application of the implication function, by forming fuzzy rules using IF and THEN, fuzzy logic rules obtained fuzzy rules, namely :


Figure 2. Rules Viewers of Fuzzy

- If (parent sex color is white) and (size of the stomach is small) then (GMS is GMS 1)
- If (parent sex color is pink) and (size of stomach is medium) then (GMS is GMS 2)
- If (parent sex color is red) and (size of stomach is big) then (GMS is GMS 3)
- If (parent sex color is white) and (size of stomach is medium) then (GMS is GMS 1)
- If (parent sex color is red) and (size of stomach is medium) then (GMS is GMS 2)
- If (parent sex color is white) and (size of stomach as big) then (GMS is GMS 1)
- If (parent sex color is pink) and (size of stomach is big) then (GMS is GMS 2)
- If (parent sex color is red) and (size of stomach is small) then (GMS is GMS 1)

The output variables of fuzzy rules can be seen in Figure 3.

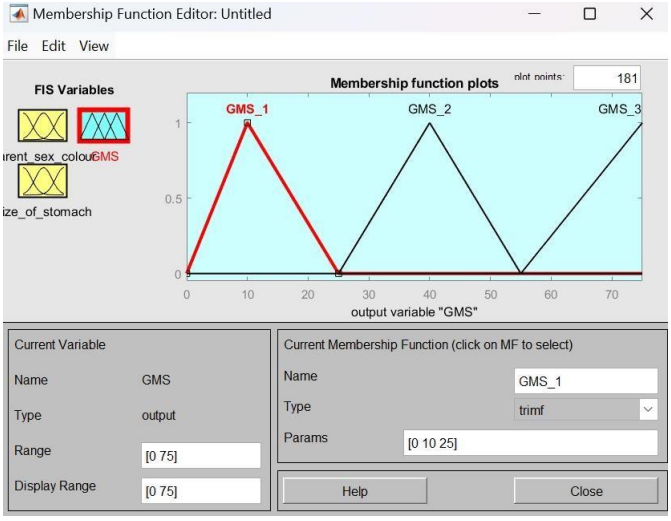


Figure 3. Output variable GMS of catfish broodstock

Table 2.The range of fuzzy output sets

| No. | Variabel Linguistik | Percentage of GMS |
|---|---|---|
| 1. | Immature gonad | 10% |
| 2. | Maturing gonad | 40% |
| 3. | Mature gonad | 70% |

Table 2 above is the output of the system created, having three linguistic variables namely immature, half mature, and mature gonads where the GMS range that comes out is 0-75%. The surface of the fuzzy logic input and output process can be seen in Figure 4.

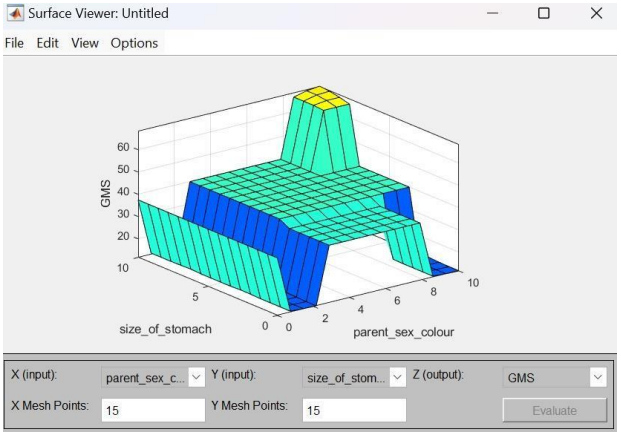


Figure 4. Fuzzy logic results in surface

The development of catfish gonads, also known as gonad maturation, is an important process that determines the reproductive ability of fish. This process is divided into two main stages: vitellogenesis and maturation. Vitellogenesis is the stage of yolk formation through a process called vitellogenesis, while maturation and ovulation are influenced by gonadotropin hormones such as FSH and LH. The development of catfish gonads is influenced by various factors, both internal and external. Internal factors such as fish species and hormones play an important role in the gonadal maturity process, while external factors such as the environment also influence this process (Tahapari et al. 2019).

In the spawning process, the ideal male patin fish is 2 years old with a body weight between 1.5-2 kg. The development of catfish gonads is controlled by hormonal mechanisms that are influenced by various environmental factors such as temperature, season, light intensity, and tides. Steroid hormones and Follicle follicle-stimulating hormone (FSH) are the main hormones that play a role in the process of male fish gonad maturity. Steroid hormones play an important role in stimulating gonad differentiation, spermatogenesis, spawning, and sexual behavior. In addition, androgen hormones, particularly testosterone, also play an important role in male gonad maturation. FSH functions for stimulating androgen release by interstitial cells in male individuals to mature sperm (Azizah et al. 2024).

Gonad maturity level (GMS) is a certain stage of gonad development before and after fish spawning (Malau et al. 2022). Gonad maturity rates as a predictor of fish reproductive status, size, and age at first gonad maturity, the proportion of productively mature stock with an understanding of the reproductive cycle for a population or species. The gonadal maturity of female and male patin fish broodstock has the characteristics of healthy and mature gonads. Female patin fish broodstock have mature gonads characterized by the abdominal part of the female broodstock that looks large and tender, and the genital opening is dark red. The abdomen of the male parent looks slender, with prominent reproductive organs colored bluish-red or dark red, and has no abnormalities or diseases.

The age of the female and male parent should be 2.5- 3 years, the weight of the female parent should be at least 2.5-4 kg, and the weight of the male parent should be at least 2 kg (Agustinus et al. 2023).

(a)

(b)

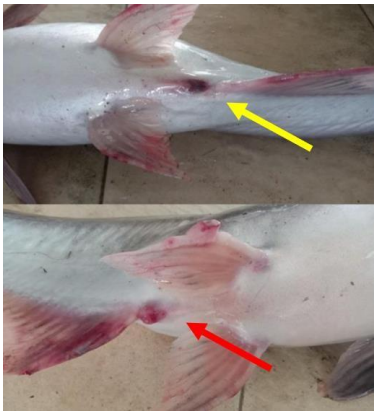

Figure 4. Characteristics of gonadally mature catfish broodstock, urogenital of female broodstock (a) : urogenital of male broodstock (b): indicated by arrows

A fish gonad maturity detector using fuzzy logic works by utilizing a fuzzy inference system to interpret data that is not suitable for fish gonad maturity. The fuzzy logic algorithm in the tool allows uncertain input variables, such as gonad size and color, to be converted into linguistic values such as ripe, semi-ripe, and immature, which are then processed to produce an output of a more accurate fish gonad maturity level. The first step is to take samples of fish images that include information about fish morphology in detail. The data collected from the sample images is then processed and analyzed by the system to produce numbers that represent the maturity level of the fish gonads. Next, it uses fuzzy logic to deduce the results of the analysis and determine whether the fish is gonadally mature or not, such as immature, semi-mature, and mature. This tool provides information that shows the numerical value of the maturity level of fish gonads, so knowing the maturity level of fish gonads can help speed up the process of broodstock selection.

The utilization of fuzzy logic tools offers some significant advantages over traditional methods. It can consider various morphological factors of catfish broodstock simultaneously and non-linearly, such as gonad color, shape, and texture, which are often difficult to measure precisely with traditional methods. This capability allows for more accurate identification of gonad maturity, even under non-ideal conditions, such as when gonads are not fully mature or damaged (Yuwandana et al. 2021). Fuzzy logic can be applied to build an expert system that assists catfish farmers in determining the right spawning time, thereby increasing the efficiency of catfish reproduction and production. This system can also be implemented in software that is easy to use by catfish farmers.

The utilization of fuzzy logic tools in determining the level of maturity of catfish gonads increases the accuracy of the assessment by processing morphological data such as length, weight, and body shape of catfish comprehensively and accurately (Rahmawati et al., 2018). This system can consider various factors simultaneously and non-linearly, resulting in a more precise identification of the level of gonad maturity. In addition, fuzzy logic can be easily modified to accommodate variability between individual catfish and different environmental conditions, provide flexibility in data processing with a high degree of uncertainty, and capture natural variations in the morphological characteristics of catfish. Ease of use is also an advantage, as the system reduces the subjectivity of human judgment through consistent and standardized rules, implemented in easy-to-use software. Decisions made based on fuzzy rules are better because they consider combinations of various morphological parameters without clear limitations as in non-fuzzy methods, and the system can be customized according to the specific conditions of a particular environment or catfish population,

resulting in more relevant and targeted decisions. With the ability to efficiently process large amounts of complex data, fuzzy logic handles analyses that are often impractical to perform manually and can be improved through machine learning, continuously increasing the accuracy and reliability of predictions based on historical and new data that are constantly updated. Overall, the application of fuzzy logic in determining the level of maturity of catfish gonads based on broodstock morphology results in more precise, consistent, and adaptive assessments of data variations, supporting more effective breeding efforts and management of catfish resources.

The utilization of the fuzzy logic system in measuring the maturity of the catfish gonads in terms of fish morphology, fulfilled the utilization of success indicators on the tool when the accuracy of tool measurements can detect in general the condition of the fish's stomach by comparing the results of tool measurements with conventionally measured manual measurements, so that the results obtained are correct and according to actual conditions. The precision of tool measurements needs to produce consistent data and not show significantly varying values in the same measurement. Measurement by considering the calculation of the Coefficient of Variation (CV) of the measurement results. Ease of using the tool is also an important thing that is very considered, the tool needs to be easy to use by users so that there is no need to do special training. The durability of the tool is important in the application and use of the tool so that the measurement and identification data generated is accurate and precise. Failure factors in the application of the tool, when there is a calibration error where the measurement results become inaccurate, it is necessary to calibrate the tool by pressing the Control button twice, then looking at the numerical results on the Surface Viewer, after which the tool can be used again. The accuracy of the data is also determined by placing the fish in front of the camera sensor from the head to the tail end of the catfish. The detection of the entire fish body in front of the sensor camera will place fuzzy logic to detect clearly. The sensor used is the DS18B20 sensor with consideration of being able and resistant to water and high humidity. According to Nusyirwan (2019), the DS18B20 sensor is a type of sensor that is resistant to water (waterproof), so it is very appropriate to use in watery or humid areas. The maturity of the catfish gonads will be detected informed and processed by fuzzy data and produce information on the monitor screen of the tool so that it can see the information conveyed.

Determination of the level of gonadal maturity or GMS of catfish is generally carried out using visual observations through the characteristics or size of GMS inferred by individuals. This determination is also made by looking at the number of sperm through stripping and eggs produced from the use of catheters. This is to research (Ihwan et al. 2021) which states that parent selection is carried out by looking directly at the physical condition of the genitals or (urogenital) colored dark red and observing the eggs (oocyte) to see the maturity of the eggs of the female parent using a catheter. This statement is also supported by the statement that gonadal mature females are seen through catheter cannulation, while males can be done by the stripping method on the abdomen, which releases white sperm fluid containing thick milk (Fitriana et al. 2020). The weakness of this method lies in the process of using a catheter that can hurt female fish. The stripping process in males can also make some of the sperm that the fish has produced wasted.

Another method commonly used is the calculation of GSI (Gonado Somatic Index) by measuring the percentage between gonad weight and fish body weight. This method is supported by a statement stating that GSI is comparative data between gonad weight and body weight which is used as a reference in determining the level of maturity and readiness of cultured fish to spawn (Hartami et al. 2021). The weakness in the method is the process of weighing the body weight of the fish which can stress the fish. The method is also ineffective for use in larger sampling.

Based on the weaknesses possessed by several methods of determining the GMS of catfish, it is therefore necessary to apply the Fuzzy logic method to reduce the risk or side effects experienced by fish. This is because the fish does not need to be lifted ashore and does not stress the fish. This method can also be used to determine parent GMS more effectively and efficiently directly in the

pond using the applied sensor. The use of this fuzzy logic application method can determine the GMS of fish with an implication function that utilizes the sex color and belly size of the fish to be used in calculating the truth value of the premise in each knowledge base rule so that the determination of fish GMS is determined carefully.

## CONCLUSION

The fish gonad maturity detector uses fuzzy logic to provide accurate information on the level of gonad maturity accurately. The utilization of fuzzy logic in determining the maturity level of catfish gonads offers significant advantages over traditional methods, including better accuracy and the ability to accommodate variations in individuals and environmental conditions. Traditional methods of determining the maturity level of fish gonads, such as visual observation and GSI calculation, have their disadvantages. Therefore, the application of fuzzy logic can help reduce the risks and side effects experienced by fish, as well as increase the effectiveness and efficiency in determining the maturity level of catfish gonads.

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