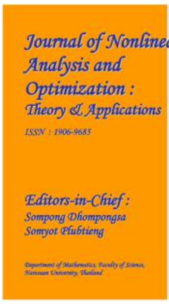

Journal of **N**onlinear **A**nalysis and **O**ptimization
Vol. 15, Issue. 2, No.5 : 2024
ISSN : **1906-9685**

AN ANALYSIS OF CATLA FISH BEHAVIOR AND MARKETS TRENDS USING FUZZY MODELING

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ABSTRACT
This paper describes my experiences designing fishery models, starting from a mathematical background in the fuzzy modeling. One of the freshwater fish that is most commonly consumed worldwide is catla, which is primarily found in Asia. For all parties involved in the aquaculture sector, including farmers, processors, and merchants, it is essential to comprehend market trends and dynamics pertaining to Catla fish. In complex systems where uncertainty and ambiguity are inherent, like market trends and fish behavior, fuzzy modeling is a potent tool for analysis. The purpose of this analysis is to:
1. Determine the major variables affecting trends in the catla fish market.
2. Examine the behavior of catla fish and how it affects the dynamics of the market.
3. Create a fuzzy model to predict the movements and actions of the market.
4. Offer information to stakeholders so they can decide wisely.

This analysis will give a thorough understanding of the intricate relationships between catla fish behavior, market dynamics, and environmental factors by applying fuzzy modeling to catla fish trends and market trends. Ultimately, this will help the aquaculture industry make better decisions.
Keywords: Fuzzy set, Fish growth, Market trends, Fuzzy variable, Fuzzy logic, Fish behavior.

1. INTRODUCTION
Fuzzy modeling is a mathematical approach to deal with uncertainty and vagueness in complex systems in the context of catla fish farming, fuzzy modeling can be used to predict water quality parameters, determine optimal feeding strategies, diagnose disease, forecast market demand, optimize harvesting time. Fuzzy modeling uses sets, fuzzy rules, and fuzzy inference to represent and reason about uncertain and vague information. By applying fuzzy modeling to catla fish farming, farmers can make informed decisions and improve the overall efficiency and productivity of their operations.

Study area: The freshwater catla fish, or labeo catla, is a species that is indigenous to South Asia. It is huge, reaching a length of 1.5 meters (4.9 feet) and a weight of 60 kg (132 lbs). Broad, with a wide mouth and a flat head. Silvery gray in blue, with a white underbelly. Found in Bangladesh, Nepal, India, and Pakistan in lakes, rivers, and marshes. Like soft ground and slow-moving or stagnant water. Omnivorous, consuming algae, plankton, and tiny invertebrates for food. Schools in big clusters, frequently close to the surface. Highly prized for its nutritional value and flavor. Highly prized for its nutritional value and flavor. Significant commercial and aquaculture production value; revered in certain Buddhist and Hindu traditions as a sacred fish; important eating fish in South Asia. Although the IUCN Red list lists them as least concern, habitat loss, overfishing, and pollution are causing population declines. Can reach a height of 1 kilogram (2.2 lbs) in only 6–8 months. Possesses an unusual "thumb-like" extension on its lower lip that is utilized for gripping and feeding. All things considered, the Catla fish is a significant and iconic species in the freshwater ecosystems and cultures of South Asia. During the warm summer months, fish are generally more active. However, this does not imply that they will be incredibly energetic when it reaches 100 degrees or higher. Mornings in the summer are great for fishing. Make sure you get an early start before sunrise because the waters can heat up fast as the sun approaches its zenith.

2. Preliminaries

2.1 fuzzy set: A Fuzzy set is a set whose elements have degrees of membership. Fuzzy sets are an extension of the classical notation of set (known as a Crisp Set). More mathematically, a fuzzy set is a pair $(A, \mu A)$ where A is a set and $\mu A : A \rightarrow [0,1]$. For all $x \in A, \mu A(x)$ is called the grade of membership of x.

2.2 Membership function: A function that maps each element to a degree of membership between 0 and 1. $\mu A(x) = f(X)$ where: $f(x) =$ membership function, $x =$input value, $\mu A(x) =$ output value (degree of membership)

2.3 Fuzzy variable: A variable that takes on fuzzy values, which are fuzzy sets or membership functions. $x^{\sim} = (x, \mu x^{\sim}(x))$ where: $x^{\sim}$=fuzzy variable, x =crisp value, $\mu x^{\sim}(x)$=membership function

2.4 Fuzzy logic: A logic that uses fuzzy sets and membership functions to reason about uncertainty and vagueness, AND (conjuction) :

$\mu A \cap B(x) = min(\mu A(x), \mu B(x))$ OR(disjuction):

$\mu AUB(x) =$ max $(\mu A(x), \mu B(x)$ NOT(negation): $\mu A'(x) = 1 - \mu A(x)$

2.5 Fuzzy model: A mathematical model that uses fuzzy logic to describe a system or process $R = f(x, y, \dots \dots)$ Where: R =fuzzy output $x, y, \dots .$ =fuzzy outputs F= fuzzy model

3. HERE ARE SOME COMMON FUZZY MODELING FORMULAS USED IN FISH RESEARCH

3.1 Fuzzy growth model: $dG/dt = (a * G * (1 - G/K))/(1 + exp(-z))$ where: G=fish weight or length a=growth rate coefficient k=carrying capacity z=fuzzy variable (e,g., food availability, water temperature)

3.2 Fuzzy biomass estimation: B= $\Sigma\ (wi * xi)$ Where: B= total biomass ,Wi= fuzzy weight for each age class ,Xi= number of fish in each age class

3.3 Fuzzy mortality rate model: $M = (1 - exp(-z)) * M - max$ Where: M=mortality rate Z=fuzzy variable (e.g., water quality, disease presence) M-max=maximum mortality rate

3.4 Reproduction model: $R = (1 - exp(-z)) * R - max$ Where: R=reproduction rate Z=fuzzy variable (e.g., food availability. Water temperature) R-max=maximum reproduction rate

3.5 Fuzzy feeding model: $F = (1 - exp(-z))F - max$ Where: F=feeding rate Z=fuzzy variable(e.g., food availability, water temperature) F-max=maximum feeding rate3.

4. POPULATION GROWTH MODEL

The population growth model for fish is a mathematical representation of how a fish population changes over time, Taking into account factors that after growth, such as: Birth rate(recruitment), Death rate(mortality), Immigration, Emigration, Carrying capacity (maximum population size). Thus includes for catla fish formulas;

N-population size (number of fish)

r-intrinsic growth rate (per day)

k-carrying capacity (maximum)

The models describe how the population size (N) change over time(t), based on the growth rate(r) and carrying capacity (k).

4.1 let's build a fuzzy model using fuzzy sets and rules to estimate the market price

Fuzzy mathematical model is a great approach to estimate the market price of catla fish, considering the uncertainty and vagueness in the market dynamics. Let's build a fuzzy modeling using fuzzy sets and rules to estimate the market price.

Assuming we have three fuzzy sets for the market price (p)

Low (l)= Rs(100-250)

Medium(M)=Rs(200-350)

High (H)=Rs(300-450)

And there fuzzy set for the demand(Qd):

Low (l)= 0-500 kg

Medium(M)=500-1000 kg

High (H)= 1000-1500 kg
We can define fuzzy rules based on the demand and supply dynamics:
If Qd is low and supply is high, the price is low
If Qd is Medium and supply is moderate, then price is medium
If Qd is high and supply is low, then price is high
Using fuzzy inference and defuzzification, we can estimate the market price (p) based on the fuzzy inputs.
Let as assume the fuzzy input values:
Qd=700 kg (medium demand)
Supply=800 kg (moderate supply)
The fuzzy output(estimated market price) would be Price ≈ Rs 260
So the estimated market price of catla fish today would be around Rs. 260 per kg.

PIC 1. CATLA FISH

4.2 To estimate the market price from 2014-2024

Fuzzy mathematical modeling can be used to estimate the market price of catla fish from 2014-2024. Here's a simplified approach using fuzzy logic.

1. Define fuzzy sets for market price (mp):
Low (l)= Rs(100-200)
Medium(M)=Rs(200-350)
High (H)=Rs(350-500)
2. Define fuzzy sets for time (T):
Past (P): 2014-2019
Present (pr): 2020-2024
Future (F): 2024-2025
3. Define fuzzy rules:
If Time is past, then Market price is low
If Time is present, then Market Price is Medium
If Time is future, then Market price is high
4. Use fuzzy inference to estimate market price for each year:

Year	Market price
2014	160
2015	170
2016	180
2017	190
2018	200
2019	210
2020	220
2021	230
2022	240
2023	250
2024	260

4.3 Profit and loss

To calculate the profit and loss using fuzzy modeling, we can using the following steps:

1. Define the fuzzy set for the price change:
Negative Big (NB): -100 to -50
Negative Medium (NM): -50 to -20
Negative Small (NS): -20 to 0
Positive Big (PB): 0 to 20

Positive Medium (PM): 20 to 50
Positive Small (PS): 50 to 100
2. Calculate the price change : 260-160=100
3. Determine the membership degree of the price change in each fuzzy set:
NB; 0%
NM; 0%
NS; 0%
PS; 0%
PM; 50%
PB; 50%
4. Calculate the weighted average of the membership degrees to get the fuzzy profit:

$$\text{Fuzzy profit} = (0 \times NB) + (0 \times NM) + (0 \times NS) + (0 \times PS) + (0.5 \times PM) + (0.5 \times PB)$$

Fuzzy profit=0+0+0+0+(0.5×50)+(0.5×100)
Fuzzy profit=25+50
Fuzzy profit=75
5. Defuzzify the fuzzy profit to get the crisp profit:
crisp profit=fuzzy profit $/ (PM + PB)$
crisp profit=75/(50+100)
crisp profit=75/150
crisp profit=0.5
so, the profit is 50% of the original price, which is
profit=0.5×160
profit=80
Using fuzzy modeling, we get a profit of 80, which is different from the exact calculation of 100. This is because fuzzy modeling provides a range of values rather than an exact value.

4.4 To estimate the growth rate of catla fish based on water temperature

Define fuzzy sets for water temperature(T):
Low (l)= 20-24 °C
Optimal(O)=25-32 °C
High (H)= 33-38 °C
Define fuzzy set for growth rate(GR):
Slow(S):0-20%
Medium (M):21-40%
Fast(F):41-60%
Define Fuzzy Rules:
If Temperature is low, the Growth rate is Slow.
If Temperature is optimal, then growth rate is Fast.
If Temperature is high, then growth rate is Medium.
Use to fuzzy inference to estimate growth rate for given water Temperature:
T=22°C :GR=s(10%)
T=28°C :GR=s(50%)
T=35°C :GR=s(30%)
So this fuzzy model estimate the growth rate of catla fish based on water temperature, showing optimal growth between 25-32°C.

5. FUZZY ANALYSIS OF CATLA FISH TRENDS

Global production: Catla is the eighth most produced aquatic species, with over 4 million tones harvested in 2022.

Growth rate: The growth rate of fish has been reported to be affected by factors like water temperature. Feeding rates, and age Diseases:

Diseases: Catla is susceptible to various diseases like eye disease, ulcer, columnaris, dropsy, saprolegniasis, and others.

Farming: Catla is commonly farmed in poly culture ponds with other carp-like fish, particularly roho labeo and mrigal carp.

Market Trends: The reported production numbers of catla have increased sharply during the 2000s, and it is sold and consumed fresh, locally and regionally.

1. fuzzy production Trend:

Low production: $0.3\ (\mu L) + 0.2(\mu M) + 0.1(\mu H) = 0.6$ (Total fuzzy output)
Medium production :$0.4(\mu M) + 0.3(\mu H) + 0.2(\mu VH) = 0.9$ (Total fuzzy output)
High production:$0.5(\mu H) + 0.4(\mu VH) + 0.3(\mu EH) = 1.2$(Total fuzzy output)

2.Fuzzy growth rate trend:

Slow growth: $0.2\ (\mu S) + 0.3(\mu M) + 0.1(\mu F) = 0.6$ (Total fuzzy output)
Medium growth: $0.4(\mu M) + 0.3(\mu F) + 0.2(\mu R) = 0.9$ (Total fuzzy output)
Fast growth:$0.5(\mu F) + 0.4(\mu R) + 0.3(\mu VFR) = 1.2$ (Total fuzzy output)

3. Fuzzy disease susceptibility trend:

Low susceptibility : $0.3\ (\mu L) + 0.2(\mu M) + 0.1(\mu H) = 0.6$ (Total fuzzy output)
Medium susceptibility :$0.4(\mu M) + 0.3(\mu H) + 0.2(\mu VH) = 0.9$ (Total fuzzy output)
High susceptibility:$0.5(\mu H) + 0.4(\mu VH) + 0.3(\mu EH) = 1.2$ (Total fuzzy output)

Note: $\mu l, \mu M, \mu H, \mu VH, \mu EH, \mu S, \mu M, \mu F, \mu R$ and μVFR presented the membership values for different fuzzy sets (low, medium, high, very high, extremely high, slow, medium, fast, rapid, and very fast, respectively).

These fuzzy sums can be used to analyze and predict trends, in catla fish production, growth rate, and disease susceptibility, helping farmers and researchers make informed decisions.

Result:1 If water temperature is high and dissolved oxygen is low, then catla fish growth rate is slow.

Fuzzy sets for water temperature (WT), dissolved oxygen (DO), and catla fish growth rate (GR)
WT: low(0-20°C), Medium(20-28°C), High(28-35°C)
DO: low(0-3mg/L), Medium(3-6mg/L), High(6-10 mg/L)
GR: slow(0-10%), Medium(10-20%), Fast(20-30%)
Define Membership functions for each fuzzy set;

$\mu WT(Low) = 1/(1 + (WT - 15)^2)$
$\mu WT(Medium) = 1/(1 + (WT - 23)^2)$
$\mu WT(High) = 1/(1 + (WT - 30)^2)$
$\mu DO(Low) = 1/(1 + (DO\ - 2)^2)$
$\mu DO\ (Medium) = 1/(1 + (DO\ - 4)^2)$
$\mu DO\ (High) = 1/(1 + (DO\ - 7)^2)$
$\mu GR(High) = 1/(1 + (GR\ - 5)^2)$
$\mu GR\ (High) = 1/(1 + (GR\ - 15)^2)$
$\mu GR\ (High) = 1/(1 + (GR\ - 25)^2)$

Fuzzy Rule: $\mu GR(slow) = \min\ (\mu WT(high), \mu DO(low) = \min(0.8,0.6) = 0.6$

Defuzzify the output to get a crisp value for the catla fish growth rate: $GR = (0.6 \times 5) + (0.4\ \times 15) = 7\%$

If the water temperature is high (28-35°C) and dissolved oxygen is low (0-3mg/L), them the catla fish growth is slow (7%).

Catla fish swimming speed;

This part provides a foundation for exploring catla fish swimming speed in more depth, including the factors that influence it , its ecological and practical significance and the various research and application related to the topic.

Swimming speed ranges:

Cruising speed: 10-20 cm/s (0.36-0.72 km/h)
Active swimming speed: 20-40 cm/s(072-1.44 km/h)
Burst swimming speed:40-60 cm/s (1.44-2.16 km/h)

Simple linear model: (WT) Water temperature, (FA) Feed availability, (PP)predator presence, (SA) shelter availability

Swimming speed (Ss)=a (Water temperature + Feed availability) +b (predator presence + shelter availability) +c

Where; a, b, c - are constant
(WT) Water temperature= 25
(FA) Feed availability=10 g/m3

(PP)predator presence=0
(SA) shelter availability=1
Ss=0.5(25+10)+0.3(0+!)+20
Ss=37.8 cm/s
The predicted swimming speed of the catla fish approximately 37.8 cm/s.
Non linear model:
Swimming speed (Ss)= a(Water temperature ^2+ Feed availability ^1.5)+b(predator presence ^2+ shelter availability ^0.5)+c
where: a, b, c - are constant,
(WT) Water temperature= 25
(FA) Feed availability=10 g/m3
(PP)predator presence=0
(SA) shelter availability=1
Ss=0.02(25^2+10^1.5)+0.001(0^2+1^0.5)+20
Ss=33.14 cm/s approximately

6. CONCLUSION
If the fuzzy model created during this study is able to reasonably predict the patterns and behavior of the market. The investigation emphasizes how crucial ambiguity and uncertainty are in both market data and the behavior of catla fish. Fish study was able to gain a fresh understanding of complex systems in the aquaculture sector through the use of fuzzy modeling.

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