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Modelling of River Catfish (*Cephalocassis Jatia*) Population in Malaysia

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ABSTRACT

This research presents the mathematical modeling of the economic cycle of fish-population structures in Malaysia. This paper shows how to develop a model of river catfish based on system dynamics and simulates the model for policy planning and sustainable development. These experiences are essential if dynamic systems are to be modelled and simulated. The mathematical model predicts long-term trends for hatching, growth, and harvesting of the river catfish population. Simulated results suggest that the economic harvesting of adults entering the rivers has been discussed and effective strategies for sustainable fish production. Management strategies are put in place to harvest juvenile mortality and spawn adult harvesting, sustainable development of catfish could be maintained.

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1. INTRODUCTION

The River catfish (Cephalocassis Jatia) is a species of catfish [1]. Catfish are a diverse collection of ray-finned fish. Moreover, it is of considerable commercial interest for its deliciousness. However, it is worth mentioning that many large catfish species correspond to food damage.

Catfish are a rich and exceptionally diverse species of fish ranked second or third among vertebrate orders. The Fishes Books database [2] recognizes 2,855 species of catfish as valid. The catfish is roughly 1 in 4 valid freshwater fish species, 1 in 10 fish, and 1 in 20 vertebrates. Although most small and medium-sized catfish (5-20 cm), some aspredinles and trichomycterids are among the smallest vertebrates globally, achieving sexual maturity at less than 10 mm in an extended amount.

The deeper inside the coastal water, there is a living place for catfish species. Catfish make for an attractive target when fishing rivers and streams. These whiskered fish migrate into deep holes during the fall and winter months. They can be found moving upstream or back downstream to their holding lies for the summer months. Catfish not only have good eyesight, but they have an incredible sense of smell they use to find and attack their prey. This keen smelling ability is one of the many challenges of finding and catching catfish in rivers.

Each region's Cephalocassis Jatia biology differed in terms of colour and size. Thai catfish, for example, are yellowish, but Malaysian catfish are grey or black, and Thai catfish have considerably bigger bodies than Malaysian catfish. Likewise, catfish from Perak and Kedah states in Malaysia are black, but catfish from Sarawak state and the UPM cultural group are light grey. These significant differences can be ascribed to various reasons, including habitat and genetic diversity, emphasizing that identical species found in various geographical locations do not always have the same genetic makeup. As a result, a molecular genetic assessment of the natural genetic resources used in any breeding effort is critical.

Most of the catfish are bottom feeders. They are often negatively sized, which means they sink rather than float due to a small gas bladder and a big head. Their body types differ, but most cylindrical bodies have slow vents to allow the benthic to feed. [3] [4].

Mathematical models are valuable tools for explaining, understanding, and predicting biological systems' behaviour [5]. Several studies have been published on the dynamic modelling of fish residents [6] [7] and other species like gooseneck barnacles [8]. Several studies have reported fishing on the decline/collapse of fish stock [9] [10]. In addition, restricted studies have been recorded on parameters such as maximum sustainable yield, capture rate, and mortality[11] [12] [13] [14]. Therefore, the dynamic system study is necessary for river people's catfish residents to hatch, grow, and harvest.

Understanding the fish's production system requires understanding the fish population's dynamic models [15]. The choice of policy and management methods for the sustainable growth of fish can be assessed using the dynamic system simulation model of the fish population. To resolve this void, a brief and detailed overview of the fish production system applicable to the dynamic modelling of the fish dynamics system is presented. We then concentrate on the complex modelling of the framework of the fish population and discuss the policy for juvenile and adult harvesting and the policy for the continued exploitation of fish. The mathematical model forecasts long-term patterns in the population of river catfish for hatching, growth and harvesting. Simulated results indicate that the rise in the harvest of adults entering the river and the optimum plan for sustainable fish production has been resolved.

2. RESEARCH METHOD

2.1. Collection of data

The Department of Fisheries (DOF) of Malaysia provided the river catfish data for this study. The data in figure 1 displays the landing of river catfish in Malaysia for 2008-2018. The total number of licensed fishing machines and gears per state has been calculated based on data projections. Based on marine fish landing by gear group and species, the river catfish or *Cephalocassis Jatia* catch is the greatest on record.

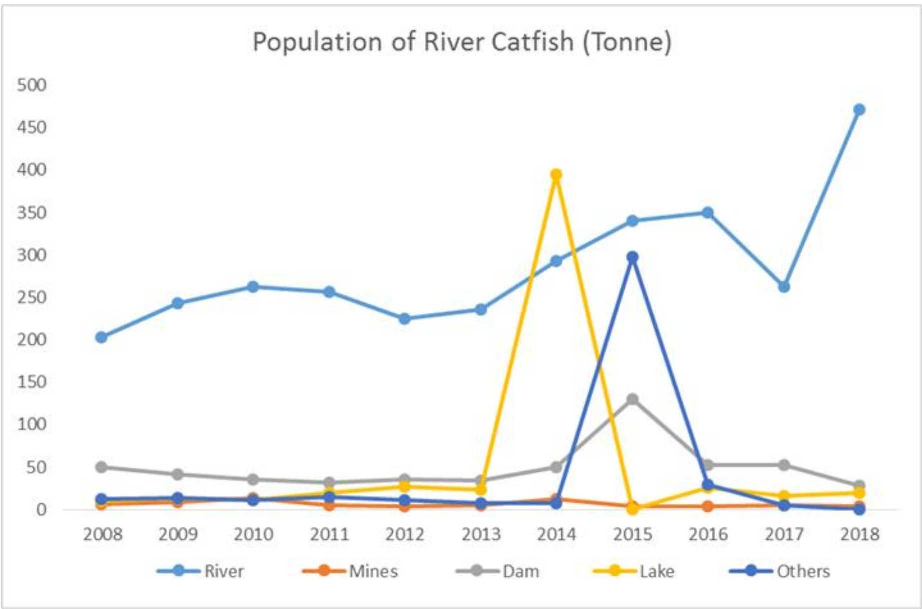

Figure 1. Data input for multiple linear regression of catch per unit (CPU).

2.2. Dynamic Hypothesis

Throughout the dynamical modelling, the causal loop diagrams describe the primary feedback loops of the system, while the stock-flow diagrams illustrate and demonstrate the system's structure are thought to produce the behavioural reference mode over time [16]. A conceptual model of dynamic hypothesis is the hypothesis that critical feedback loops are developed to create stock-flow diagrams that drive the system's behaviour, especially in the base reference model. The model's latent configuration, or endogenous configuration, creates the system's reference mode behaviour as it is simulated, producing changes in its dynamic behaviour. For example, causal loop diagrams and stock-flow diagrams can be used to describe the catfish population. A simulation model will produce dynamic population behaviour based on causal loop diagrams and stock-flow diagrams.

2.3. Causal Loop Diagram (CLD)

Figure 2 shows the catfish model's causal loop diagram. The dynamic system approach used the CLD for simulation analysis [16]. This summarises and conveys model-based feedback observations and explains the underlying causal mechanisms hypothesized for the reference mode of behavior over time [17]. Before simulation review, a CLD was constructed in this research as a qualitative description of the cause-effect relationship between conservation at the study site. The river catfish model of population dynamics is commanded by one positive and four negative loops.

Figure 2 shows that the CLD of river catfish juvenile and river catfish populations creates a reinforcing loop, while juvenile and death populations create a balancing loop. Based on a CLD, the modeller may create a complex chain of effects hypothesized when a specific change occurs within a system. The method assumes that every relation of cause and effect between two variables must be read ceteris paribus [18].

A positive loop indicates the reproductive process and maturity, creating more catfish. The juvenile rates and ripening rates positively impact the development of river catfish. Without any stabilization, this loop will cause the population of the river catfish to expand exponentially. Negative feedback loops act as the balancing loops of the various phases of river catfish's life cycle, the deaths of juveniles and mature adults. The situation that decreases the number of catfish is that the number of deaths among catfish will increase as the number of catfish increases at every point of the life cycle. Therefore, catfish harvesting at any point in the life cycle often has a detrimental effect on the river catfish population.

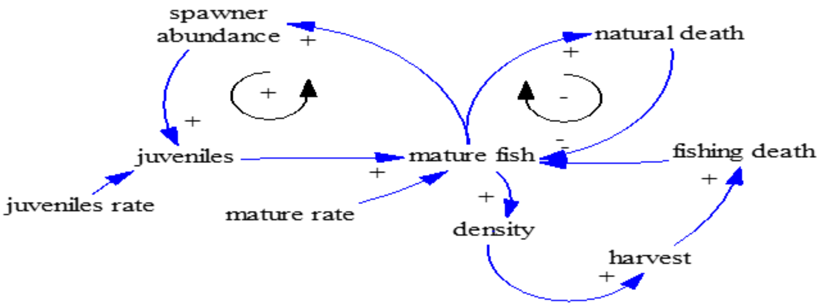

Figure 2. Precedent example of Fish Causal Loop Diagram

2.4. System Dynamic Modelling

System Dynamic model (SD) was formulated and established by Forrester of MIT mid-1950s and has been applied in some research fields [19] [20] [21]. This methodological approach was chosen as the dynamics system was extensively used in social, economic, and environmental (biosphere and hydrosphere) studies. This particular approach has proved helpful in discovering structural changes, feedback, and other vector causes and effects on its unique region [16] [22]. Using this particular research approach, we can provide insight into an artificial model's positive and negative effects based on the real world. Therefore, this research article discovers the use of the System Dynamic Model in a number of fields, such as agricultural and aquaculture, to practice tourism planning, sustainable development, and the survivalist and resiliency of certain climate-based species.

In SD models, diagrammatic distinctions (stocks, flows, auxiliaries, parameters, and constants) are made between different variable types. Stocks are an integral flow equation. Auxiliaries and flows are equations that presuppose particular variables and parameters/constants (constant values over a simulation period). For SD models, the correlation between variables and parameters is only a direct causal relationship. Model structure, historical data fit, and model behaviour comprise a wide range of tests [16]. Stakeholder discussion and a literature study verified the model structure verification and reliability. Mean square error (MSE) is the fit ability of the model compared with historical data [23], which is defined as:

$$MSE = \frac{1}{N} \sum_{t=1}^{n} \left(S_t - A_t\right)^2 \tag{1}$$

n = number of observations
S_t = simulated value
A_t = actual value

A standardized estimate of the error is to be measured. A typical and easily understood quantity without measurements is a square root mean square error (RMSE) (Aryani & Nugroho, 2019), which defines as:

$$RMSE = \sqrt{MSE} \tag{2}$$

The size of the error, it is crucial to know the source of the error. A good model should have a slight error, with an RMSE value near 0. Model behavior is investigated using a sensitivity analysis by simultaneously adjusting values of many parameters using uniform distribution within a given range. The system dynamic modelling and sensitivity analysis were conducted using the software Vensim.

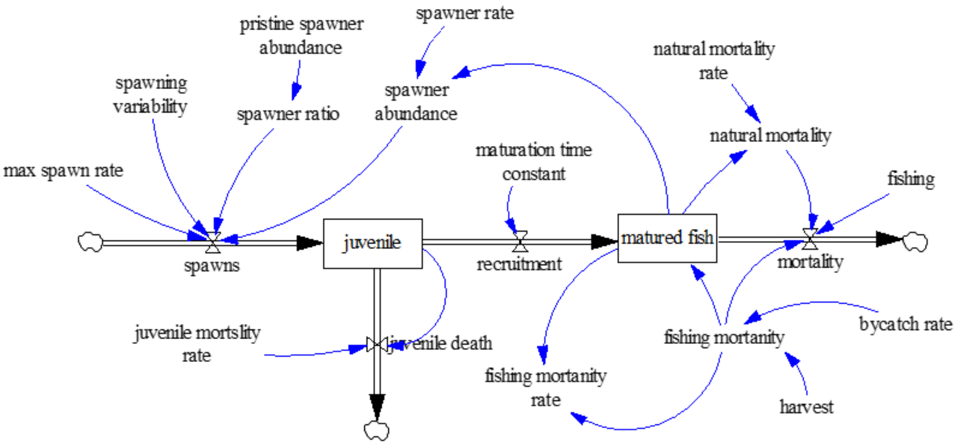

Figure 3. Fish Population Sector

3. RESULTS AND DISCUSSION

3.1. River Catfish Population Dynamics

The dynamic biomass model, proposed by Graham [25] [26], equalizes the population biomass rate to biomass inflows minus biomass outflows. This approach is best written from a device dynamic point [27] [28] [29] [30] of view as:

$$\frac{dP}{dt} = rP\left(1 - \frac{P}{K}\right) - qEP \tag{3}$$

Population biomass growth is a single inflow due to the production and introduction of new fish. It corresponds to the fractional growth rate of biomass r times that of current biomass *P*. Normal decrease in biomass is indicated by *–rP* multiplied by *P* and *K* ratios, where *K* is the maximum possible output or population biomass. The maximum output of *K* causes the fractional natural death rate to decline as biomass decreases. The outflow of population biomass due to by-catch is indicated by an instant fraction of fish biomass captured by each fishing gear unit *q*, times the number of gear units *E*, times the biomass *P*.

In the system dynamics format, the model is shown in Figure 3. Again, there is a disparity in theory between the original formulation and the approach to system dynamics. System dynamics models emphasize progress through time, and system dynamics modelers generally aim to understand and describe the component-link structure of each section of the model individually.

This equation is transformed into a linear equation to estimate the value of *r*, *q*, and *K* as follows:

$$P_{t+1} = P_t + rP_t\left(1 - \frac{P_t}{K}\right) - qE_tP_t \tag{4}$$

By multiplying both sides with *q*, the equation becomes:

$$\begin{aligned} qP_{t+1} &= qP_t + qrP_t\left(1 - P_t/K\right) - q^2E_tP_t \\ &= qP_t + qrP_t - qrP_t^{\,2}/K - q^2E_tP_t \\ &= (1+r)qP_t - q^2rP_t^{\,2}/qK - q^2E_tP_t \\ &= (1+r)qP_t - (r/qK)(qP_t)^2 - (qE_t)qP_t \end{aligned} \tag{5}$$

Since catch is *qEP,* catch per unit (CPU) is *qP*. Therefore, the equation can be written:

$$CPU_{t+1} = (1+r)CPU_t - (r/qK)CPU_t^{\,2} - (q)E_tCPU_t \tag{6}$$

The attribute to use as a proxy for fishing gears. The CPU equation can identify the best variables. The data shown in Figure 3 are helpful to the invention of the value of r, q, and K using multiple linear regression.

Table 1 displays the outcome of multiple linear regression models. Moreover, the model throw river as a delegation for fishing produces the lowest error and most good R-square value.

Table 1. Multiple linear regression (MLR) result comparisons

	River	Mines	Dam	Lake	Others
Multiple R	0.758	0.429	0.207	0.115	0.182
R square	0.574	0.184	0.043	0.013	0.033
Adjusted R square	0.527	0.093	-0.064	-0.096	-0.074
Standard Error	2.28123	3.15827	3.42059	3.47277	3.43775

Table 2. Coefficient of River's Model

River' Model	Coefficient	Standard Error	t stat
E_t CPU_t	-0.0003	2.788	-1.224
CPUt	2.033	0.009	3.484
$CPUt^2$	-0.413	0.264	-1.563

From the coefficient of the river's model (Table 2), the value of *r, q,* and *K* can be calculated as:

$$\begin{aligned} -q &= -0.0003 \\ q &= 0.0003 \end{aligned} \tag{7}$$

And

$$\begin{aligned} 1 + r &= 2.033 \\ r &= 1.033 \end{aligned} \tag{8}$$

So,

$$-\frac{r}{qK} = -0.413$$
$$-\frac{(1.033)}{0.0003K} = -0.413 \tag{9}$$
$$K = 8337$$

The following parameter to be specified in the fishery model is the fractional modification of the river model number. Figure 4 shows the data series of the number of rivers catching where the value of fractional change in the number of fishing gears can be estimated as 0.0565.

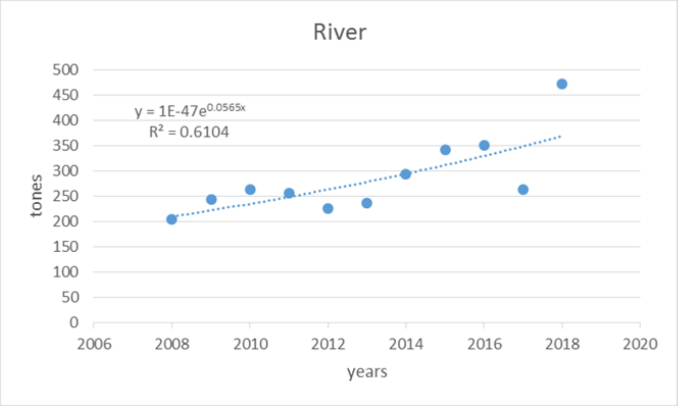

Figure 4. the exponential graph of the number of fish on the river.

Maximum sustainable yield (MSY) is an essential feature of fishery management to assess the correct value. Without fishing, the biomass will develop to a point where it would suffocate fish growth and reduce their chances of survival [31] [32] [33]. The sum allowable catch is set as the MSY, and it is estimated as follows:

$$MSY = \frac{rK}{4} = 2{,}153\,tons \tag{10}$$

3.2. Simulation and Policy Analysis

Tests of structure, behaviour, and policy implications are all used to establish confidence in system dynamics models [15]. Several methods for validating a system dynamics model have been considered, including comparing model results to collected data, determining whether relationships among variables are logical and natural, determining whether the model generates plausible behaviour, and determining whether the model can generate anticipated behaviour under extreme conditions, and determining the quality of parameter values. To assess the model's plausibility, parameters were generated from research, other papers, and publications.

In the base run, the behaviour of the essential variables was investigated. However, the management choices have not been evaluated using time series field data since time series data is not accessible but rather with the available reported values.

Sensitivity analysis offers an opportunity to evaluate the accuracy stage required to determine the model validities and is useful when estimating latent parameters. If the parameter is insensitive to the model's actions, it can be used for policy design. Parameters that have a significant effect on model behaviour should also be selected as candidates for additional data collection [16].

Fish populations, also known as fish biomass or biomass, are divided into juveniles and mature fish. The amount of food available to juveniles is determined by a spawning process that considers Spawner Abundance, Pristine Spawner Abundance, Maximum spawn rate, and Spawning Variability. Pristine Spawner Abundance is an indicator of load capability [34]. Spawns feed the Juveniles stock, which feeds the mature fish stock. The Juveniles Mortality Rate also influences a mortality outflow in the Juveniles stock. Fishing Mortality and Natural Mortality are two types of mature fish mortality. Natural Mortality is determined by the age of the fish and the natural Mortality Rate, whereas fishing mortality is determined by the amount of fish caught and the Bycatch Rate. The flow diagram for the river catfish population sector is shown in Figure 3.

Model's sensitivity to crucial parameter change. Each selected parameter value varied 50% below the base value and 50% above the base value. Over time the diagram biomass was plotted from the parameter picked.

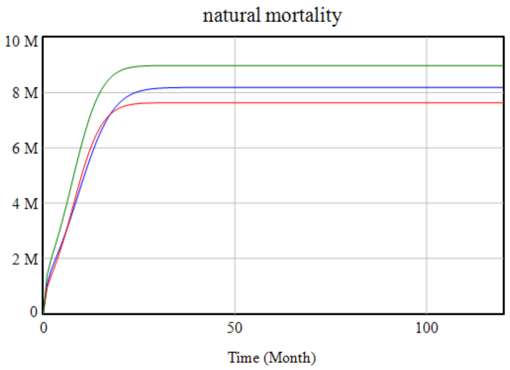

Figure 5. Natural Mortality sensitivity test result

Figure 5 shows that the sensitivity test result Natural Mortality Rate (NMR) is tested by adjusting its value from 0.05 to 0.15, increments of 0.1. It shows how NMR affects biomass. The graph of lines blue and green is the accept the capacity.

When the parameter Spawner rate (SR) is varied from 0.2 to 0.6, as shown in Figure 6, the model will be super sensitive. The system achieves equilibrium earlier when SR is higher. The SR toughens the only loop in the model, reinforcing a loop on which the entire fishery depends. SR lower values have a significantly more significant impact than the higher value and are not symmetrical [35].

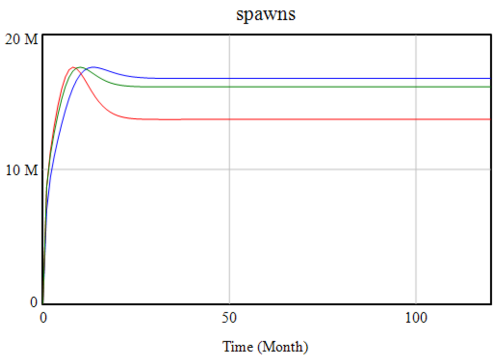

Figure 6. Spawner Rate sensitivity test result

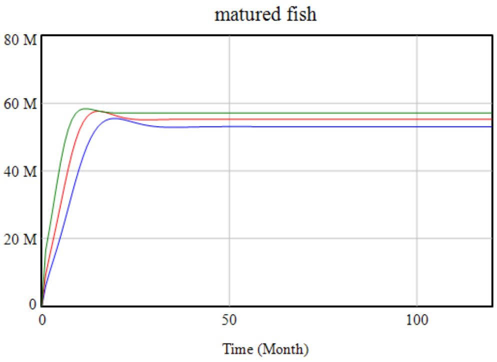

Figure 7. Maturation Time Constant sensitivity analysis

Figure 7 above shows that varying the maturation Time Constant (MTC) from 2 to 6 years significantly impacts the *Mature Fish* population. *Mature fish* is displayed instead of biomass because it also includes *juveniles*. The model is susceptible to MTC. When the MTC is 2, the result is lower biomass because the blue line graph lowers from equilibrium points.

Figure 8 is designed to establish sustainable adult harvesting strategies and reduce the loss fraction of juveniles required to preserve river catfish carrying capacity. This strategy also considers the equal harvesting of adults, ensuring the fishers' survival during the year. Figure 7 represents the stabilization of simulated juvenile, matured, and harvested fish for the long-term growth of the river catfish fishery. The ideal adult harvesting and juvenile harvesting fractions to support the river catfish fisheries growth were 0.85 and 0.935, respectively. Thus, this policy stabilizes catfish fishing in the river, increases mature fish harvested, and maintains maximum sustainable yield.

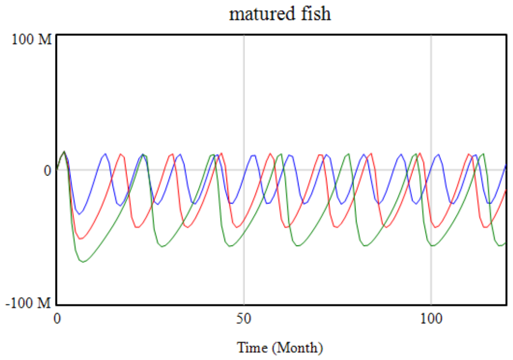

Figure 8. Total juvenile and mature river catfish population for optimum harvesting of mature fish for sustainable river catfish fishery

Figure 9 shows the population of the river catfish throw this research. The simulation has been developed for ten years. As a result, the matured fish increases access to the carrying capacity.

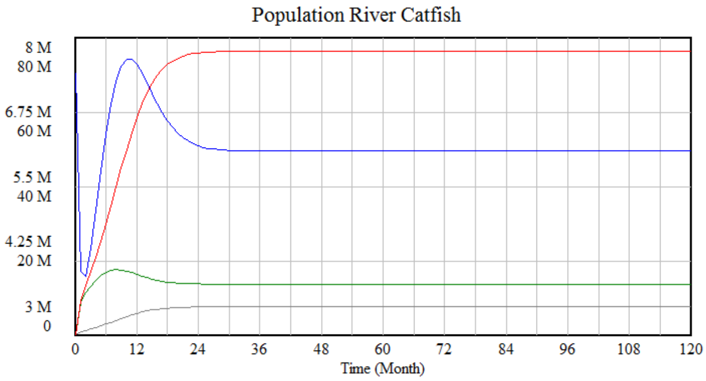

Figure 9. Population of the river catfish

4. CONCLUSION

The computer simulation model for river catfish population dynamics was developed using the system dynamics technique, and the model was simulated over a 10-year time horizon. If successful policy options and management strategies are put in place to harvest juvenile mortality and spawn adult harvesting, sustainable development of catfish could be maintained. Sustainable catch size and management policy must be put in place to control the harvest of fish below the matured fish. Fortunately, the fisheries system has been improvised and stabilized by establishing the optimal harvesting strategy for sustainable river catfish fisheries. Using this model, a new policy option and strategies for the sustainable conservation of river catfish could be realized. Training coastal fishermen on the use of nets and empirical and visual Estimation of the sizes is necessary by the (DOF) Malaysia.

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REFERENCES

[1] M. Y. Hossain, M. A. S. Jewel, L. Nahar, M. M. Rahman, A. Naif, and J. Ohtomi, "Gonadosomatic index-based size at first sexual maturity of the catfish Eutropiichthys Vacha (Hamilton, 1822) in the Ganges River (NW Bangladesh)," *Wiley Online Library*, 03-Mar-2012.

[2] W. N. Eschmeyer, Catalog of fishes. Vol. 1: Introductory materials; species of fishes A-L. San Francisco, CA: California Academy of Sciences, 1998.

[3] M. N. Bruton, "Alternative life-history strategies of catfishes," *Aquatic Living Resources*, vol. 9, pp. 35–41, 1996.

[4] M. C. Lucas and E. Baras, "Migration of freshwater fishes. Malden," MA: Blackwell Science, 2001.

[5] G. de Vries, "A course in mathematical biology quantitative modeling with mathematical and computational methods," *Amazon*, 2006.

[6] Y. Tian, T. Akamine, and M. Suda, "Modeling the influence of oceanic-climatic changes on the dynamics of Pacific saury in the northwestern Pacific using a life cycle model," *Fisheries Oceanography*, vol. 13, no. s1, pp. 125–137, 2004.

[7] D. Robadue and R. Del M. Simanek, "A system dynamics perspective on a global fishing enterprise: The case of tuna ranching in Mexico Submitted to The 25th International Conference of the System Dynamics Society Boston, Massachusetts," July 29 - August 2, 2007.

[8] J. Bald, A. Borja, and I. Muxika, "A system dynamics model for the management of the gooseneck barnacle (Pollicipes policies) in the marine reserve of Gaztelugatxe (Northern Spain)," *Ecological Modelling*, vol. 194, no. 1-3, pp. 306–315, 2006.

[9] M. E. Lillegård, "Harvesting strategies for Norwegian spring-spawning herring, Oikos," DeepDyve, 01-Sep-2005.

[10] V. Kaitala, N. Jonzén, and K. Enberg, "Harvesting Strategies in a Fish Stock Dominated by Low-frequency Variability: The Norwegian Spring-spawning Herring (Clupea harengus)," *Marine Resource Economics*, vol. 18, no. 3, pp. 263–274, 2003.

[11] M. S. Miah, G. C. Haldar, M. A. Rahman, "Estimation of growth and mortality parameters of hilsa tenualosa ilisha (HAM.) Population in the Meghna river of Bangladesh," *Indian J Fish* 44 (2):111–13, 1997.

[12] S. M. N. Amin, M. A. Rahman, G. C. Haldar, S. Nahar, S. Dewan, M. A. Mazid, "Population dynamics of jatka (juvenile hilsa) in the Meghna River, Bangladesh. Asian Fish Sci 13:383–38, 2000.

[13] G. C. Haldar, and S. M. N. Amin, "Population Dynamics of Male and Female Hilsa, Tenualosa ilisha of Bangladesh," *Pakistan Journal of Biological Sciences*, vol. 8, no. 2, pp. 307–313, 2005.

[14] S. Hashemi, G. Mohammadi, G. Eskandary, "Population dynamics and stock assessment of hilsa shad (Tenualosa ilisha Hamilton-Buchanan, 1822) in coastal waters of Iran (Northwest of Persian Gulf)," *Aust J Basic Appl Sci* 4(12):5780–5786, 2000.

[15] B. K. Bala, M. A. Fatimah, E.F. Alias, S. F. Sidique, K. M Noh, M. K. Rowshon, "Modeling of hilsa fish (Tenualosa ilisha) population in Bangladesh: modeling and policy implications," Ecol Model 283:19–30, 2014.

[16] J. D. Sterman, "Business Dynamics," S. Massachusetts: Jeffrey J. Shelstad, 196, 199-201, 2000.

[17] J. Homer, and R. Oliva, R, "Maps and models in system dynamics: a response to Coyle," *System dynamics review*, 17(4), 347-355, 2001.

[18] D. C. Lane, "Diagramming conventions in system dynamics," *Journal of the Operational Research Society*, 51(2), 241-245, 2000.

[19] J. W. Forrester, "Industrial Dynamics. A major breakthrough for decision makers," Harvard business review, 36(4), 37-66, 1958.

[20] S. H. Isa, M. N. A. Ramlee, M. S. Lola, M. Ikhwanuddin, M. N. Azra, M. T. Abdullah, and Y. Ibrahim, "A system dynamics model for analysing the eco-aquaculture system of integrated aquaculture park in Malaysia with policy recommendations," *Environment, Development and Sustainability*, 1-23, 2020.

[21] M. S. Lola, M. N. A Ramlee, M. F. Hussin, M. T. Abdullah, A. A. Kamil, I. M. Yusof, and N. Z. A. Khadar, "Sustainable Development of Tasik Kenyir Eco-Tourism Using System Dynamic. In Greater Kenyir Landscapes," *Springer*, Cham, pp. 257-270, 2019.

[22] J. T. Stern Jr, "Computer modelling of gross muscle dynamics," *Journal of biomechanics*, 7(5), 411-428, 1974.

[23] N. R. Ariyani, and L. Nugroho, "Conceptual Design Methodology of A 3-DOF Dynamic Model Holder System for Open Subsonic Wind Tunnel," In 2019 IEEE International Conference on Aerospace Electronics and Remote Sensing Technology (ICARES) (pp. 1-7). IEEE, 2019.

[24] M. S. Lola, W. S. W. Alwi, and N. H. Zainuddin, "Sample Selection Model with Bootstrap (BPSSM) Approach: Case Study of the Malaysian Population and Family Survey," *Open Journal of Statistics*, 6(5), 741-748, 2016.

[25] M. B. Schaefer, "Some aspects of the dynamics of population important to the management of the commercial marine fisheries," Bull. IATTC-1: 26-56, 1954.

[26] M. B. Schaefer, "A study of the dynamics of the fishery for Yellowfin tuna in the eastern tropical Pacific Ocean," Bull IATTC, 2: 247-285, 1957.

[27] M. S. Lola, W. S. W. Alwi, M. A. Ramlee, F. A. Zulkifli, C. N. Noor, Y. Ibrahim, and M. T. Abdullah, "A system dynamic of the harvesting strategies to sustain the population of squid using logistic growth model," *In Journal of Physics: Conference Series*, Vol. 1613, No. 1, p. 012072, IOP Publishing, 2020.

[28] J. A. Logan, and J. C. Allen, "Nonlinear dynamics and chaos in insect populations," *Annual Review of Entomology*, 37(1), 455-477, 1992.

[29] Y. Y. Y. Noupoue, Y. Tandoğdu, and M. Awadalla. "On numerical techniques for solving the fractional logistic differential equation," Advances in Difference Equations, 2019(1), 108, 2019.

[30] H. R. Thieme, "Mathematics in population biology," (Vol. 12). Princeton University Press, 2018.

[31] E. F. Watt, Kenneth, "Ecology and Resource Management: A Quantitative Approach," New York: McGraw Hill, 1986.
[32] V. Raya, J. Salat, and A. Sabatés, "The box-balance model: a new tool to assess fish larval survival, applied to field data on two small pelagic fish" Marine Ecology Progress Series, 650, 289-308, 2020.
[33] J. T. Thorson, "Predicting recruitment density dependence and intrinsic growth rate for all fishes worldwide using a data-integrated life-history model," Fish and Fisheries, 21(2), 237-25, 2020.
[34] A. Ford, and F. A. Ford, "Modeling the environment: an introduction to system dynamics models of environmental systems," Island Press, 1999.
[35] W. Wakeland, O. Cangur, G. Rueda, and A. Scholz, "A system dynamics model of the Pacific coast rockfish fishery," 2003.

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