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Fuzzy combined effect time quantity dependent data matrix for predicting phytal fauna distribution and diversity

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Abstract
Fuzzy logic can be used to analyse and classify flora and faunal diversity. It uses fuzzy logic to describe richness and complexity of plant and animal life. Fuzzy logic can identify patterns in data to better understand diversity of an ecosystem. This study used a fuzzy combined effect time quantity dependent data matrix to predict the distribution and diversity of phytal fauna in Erayumanthurai coast. The method involved the use of Initial Raw Data Matrix (IRDM), Average Quantity Dependent Data Matrix (AQDM), Refined Quantity Dependent Data Matrices (RQDMs) and Combined Effect Quantity Dependent Data Matrix (CEQDM). Results showed that the high number of fauna was recorded in sites at $\alpha = 0.75$ level and the faunal ranges were medium at $\alpha = 0.5$ level. Negative values in the sites of S2, S3, and S4 indicated that faunal composition in these sites was not preferred. This fuzzy combined effect time quantity dependent data matrix was able to predict the exact place that had more anthropogenic disturbance to disturb the diversity and distribution of phytal fauna.

Keywords: Fuzzy logic, biodiversity and Erayumanthurai

1. Introduction
Fuzzy logic can be used to analyse and classify different types of flora and faunal diversity. Phytal faunal diversity is a concept that uses fuzzy logic to describe the richness and complexity of plant and animal life. Fuzzy logic can be used to identify patterns in the data, which can be used to better understand the diversity of a particular ecosystem De Cáceres, *et al.* [1]. Fuzzy logic allows us to think about things in terms of degrees of membership and gradations of similarity Fiorentino Dario *et al.* [2]; Bagnaro *et al.* [3]. In the case of phytal faunal diversity, this means that species are grouped together based on their shared characteristics and the degree of similarity between them. This concept is important to understand in order to preserve biodiversity and promote sustainable development De Cáceres, *et al.* [1]; Bandelj *et al.* [4].

Fuzzy matrices and fuzzy cognitive maps were used by Bart Kosko [5]; Vasantha Kandasamy [6]. They studied on socioeconomic and psychological problems using theory of fuzzy matrices and fuzzy based models. They assumed four categories of matrices such as, initial raw data matrix (IRDM), average time dependent data matrix (ATDM), refined time dependent data matrix (RTDM), and combined effect time dependent data matrix (CETDM), respectively. Afterward these concepts were successively applied in medical sciences, engineering sciences, Industry and biological diversity studies.

Raw Data Matrix (IRDM) is essential for biodiversity research because it provides a complete picture of the structure of a particular ecosystem. It includes the abundance, species composition, and distribution of organismal, functional, and taxonomic groups. This information can be used to assess the current state of an ecosystem and make predictions about how it may respond to future changes. Average Quantity Dependent Data Matrix (AQDM) is provides an average value for the abundance of certain species or groups over a period of time. This provides an indication of the relative abundance of different species in a given ecosystem.

Refined Quantity Dependent Data Matrices (RQDMs) is provide more detailed information about the abundance of particular species or groups within a given ecosystem. This data can be used to identify areas of high diversity and to assess the impact of human activities on species distributions. Combined Effect Quantity Dependent Data Matrix (CEQDM) is combines the information from the IRDM, AQDM, and RQDMs to provide a more comprehensive view of the abundance of different species in a given ecosystem Vasantha Kandasamy [6].

Victor Devadoss *et al.*, [7] worked on dimensions of women personality in Chennai using combined effect time dependent data matrix. Narayanamoorthy [8] estimated the maximum age group of silk weaver as bounded labours using fuzzy combined effect time dependent data matrix. Narayanamoorthy *et al.*, [9] obtained maximum age group of endosulfan pesticide victims in Kerela using fuzzy combined effect time dependent-data-matrix. Kokila [10] worked on student's information gathering attitude by applying fuzzy matrix combined effect time dependent data matrix. Jon Arockiaraj and Murali [11] reported that the using fuzzy matrix analysis of seasonal fishing in Cuddalore. Iftikhar *et al.*, [12] estimated the maximum age group of stressed students studying in Higher Education using combined effect time dependent data matrix. Radhika. *et al.*, [13, 14] studied that the risk factor of breast cancer and uses in aquaculture by using CETD data matrix analysis.

In this study, we used the combined effect time quantity dependent data matrix for the prediction of distribution and diversity of phytal fauna in Erayumanthurai coast. The present study focus on whether the physio-chemical parameters, fishing activities and pollution disturb the diversity and distribution of phytal fauna by using fuzzy combined effect time quantity dependent data matrix.

2. Preliminaries

This section includes some basic definitions and notations on different types of fuzzy matrices.

Definition 2.1: An initial raw data matrix (IRDM) is the collection of initial data into matrix form by taking birds common name as rows and point count sites as the columns.

Definition 2.2: An average quantity dependent data matrix (AQDM) is derived by transforming initial raw-data matrix by dividing each row with the percentage difference in given point count sites.

Definition 2.3: A number of refined quantity dependent data matrices (RQDMs) are derived by varying a parameter $\alpha \in$ [0, 1] and using mean and standard deviation methods. The only entries of refined quantity dependent data matrices are -1, 0 or 1.

Definition 2.4: A transformation of average quantity dependent data matrix into a number of refined quantity dependent data matrices by varying a parameter$\alpha \in$ [0, 1] and using mean and standard deviation is obtained using the following mathematical formulae:

If $a_{ij} \leq \mu_j - \alpha\sigma_j$ then $b_{ij} = -1$

Else $a_{ij} \geq \mu_j + \alpha\sigma_j$ then $b_{ij} = 1$

Else if $a_{ij} \in (\mu_j - \alpha\sigma_j, \mu_j + \alpha\sigma_j)$ then $b_{ij} = 0$

Where $\mu_j$simple mean and$\sigma_j$is standard deviation of corresponding to each column of the average quantity dependent data matrix, respectively.

Definition 2.5: A combination of different refined quantity dependent data matrices by varying $\alpha \in$ [0, 1] gives cumulative effect of all the entries, and known as combined effect quantity dependent data matrix (CETDM).

3. Observed Attributes with Short Descriptions

The collection of phytal fauna associated with the seaweeds was carried out following the procedure advocated by Azhaguraj *et al.* [15]. Phytal faunal samples were collected by randomly at each stations (S1, S2, S3, S4 S5, S6, S7, S8, and S9). The faunas of amphipods, polychaetes, molluscs, amphipods, crustaceans and isopods were counted and recorded. The examination of phytal fauna on the Erayumanthurai, revealed the presence of a rich variety of crabs, isopods and amphipods. In addition, a number of polychaetes, gastropods and bivalvia were also present.

4. Methodology

Step 1: Using entries of phytal faun as common name as rows and point count locations as columns, we provide the raw data as a matrix.

Step 2: The initial matrix is transformed into an average quantity dependent data (AQD) matrix in the second stage.

Step 3: To make the computations simpler and easier, we apply basic average techniques in the third step to transform the above-average quantity-dependent data matrix into a matrix with entries$b_{ij} \in \{-1,0,1\}$.This matrix has the term Refined Quantity Dependent Data Matrix (RQD Matrix).

Step 4: Using the RQD matrices, we create the Combined Effect Quantity Dependent Data Matrix (CEQD Matrix), which shows the cumulative effect of all these entries.

Step 5: Finally, we derive the CEQD matrix's row sums. Each stage's tables are self-explanatory. Using Python, the graphs of the RQD matrix and CEQD matrix are shown.

Table 1: Initial raw data matrix of order 6 x 9 based on phytal fauna diversity

Common Name	S1	S2	S3	S4	S5	S6	S7	S8	S9
Amphipods	205	183	142	76	62	49	162	147	198
Isopods	34	36	22	43	29	45	65	69	42
Crab	28	65	1	12	18	14	17	15	10
Polychaetes	19	46	15	21	17	19	19	27	21
Bivalves	32	140	35	132	181	123	125	302	203
Gastropods	35	63	28	82	71	89	46	24	17

Table 2: AQDM of order 6 x 9 based on phytal fauna

Common Name	S1	S2	S3	S4	S5	S6	S7	S8	S9
Amphipods	2.05	1.83	1.42	0.76	0.62	0.49	1.62	1.47	1.98
Isopods	0.34	0.36	0.22	0.43	0.29	0.45	0.65	0.69	0.42
Crab	0.28	0.65	0.01	0.12	0.18	0.14	0.17	0.15	0.1
Polychaetes	0.19	0.46	0.15	0.21	0.17	0.19	0.19	0.27	0.21
Bivalves	0.32	1.4	0.35	1.32	1.81	1.23	1.25	3.02	2.03
Gastropods	0.35	0.63	0.28	0.82	0.71	0.89	0.46	0.24	0.17

Table 3: Column wise mean and standard deviation of AQDM.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Mean	0.58833	0.88833	0.405	0.61	0.63	0.565	0.72333	0.97333	0.81833
Standard Deviation	0.71843	0.58901	0.51072	0.44793	0.62106	0.42141	0.59106	1.1159	0.92549

Obtaining various refined quantity dependent data matrices by taking $\alpha = 0.25, 0.5, 0.75$ and computing their related row sums as column matrices

Obtained RQD matrix for $\alpha = 0.25$ Obtained Row Sum Matrix

$$\begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & -1 & -1 & 0 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & 0 & 1 & 0 & 1 & -1 & -1 & -1 \end{bmatrix} = \begin{bmatrix} 4 \\ 4 \\ -4 \\ -4 \\ 1 \\ -1 \end{bmatrix}$$

Obtained RQD matrix for $\alpha = 0.5$ Obtained Row Sum Matrix

$$\begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & -1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 0 & -1 & -1 & -1 & -1 & -1 & -1 \\ 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & -1 \end{bmatrix} = \begin{bmatrix} 3 \\ -1 \\ -2 \\ -3 \\ 2 \\ 0 \end{bmatrix}$$

Obtained RQD matrix for $\alpha = 0.75$ Obtained Row Sum Matrix

$$\begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & -1 & 0 & -1 & -1 & 0 & -1 \\ 0 & 0 & 0 & -1 & 0 & -1 & -1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 3 \\ -1 \\ -2 \\ -1 \\ 2 \\ 0 \end{bmatrix}$$

Finally, by combining all three matrices, the Combined Effect Quantity Dependent Data Matrix (CEQD - Matrix) is generated, which provides the Cumulative effect of all these entries. This yields the CEQD-Matrix as well as the CEQD Row matrix:

Obtained CEQD matrix Obtained Row Sum Matrix

$$\begin{bmatrix} 3 & 3 & 3 & 1 & 0 & 0 & 3 & 1 & 3 \\ -1 & -3 & -1 & -1 & -2 & -1 & 0 & -1 & -1 \\ -1 & -1 & -3 & -3 & -2 & -3 & -3 & -2 & -3 \\ -2 & -2 & -1 & -3 & -2 & -3 & -3 & -2 & -2 \\ -1 & 3 & 0 & 3 & 3 & 3 & 3 & 3 & 3 \\ -1 & -1 & 0 & 1 & 0 & 3 & -1 & -2 & -2 \end{bmatrix} = \begin{bmatrix} 10 \\ -6 \\ -8 \\ -8 \\ 5 \\ -1 \end{bmatrix}$$

5. Plotting Graphs with Different Values of $\alpha \in$ [0, 1] to Indicate the maximum phytal fauna

Using the technique of fuzzy matrices, the depicted graphs reflect the largest phytal fauna by altering $\alpha \in$ [0, 1].

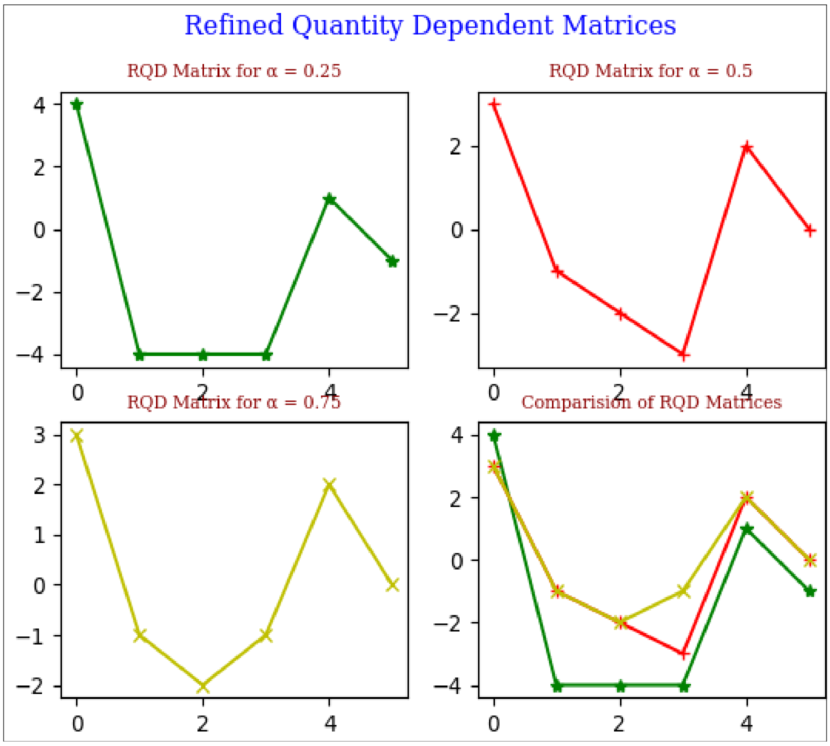

Fig 1: The maximum phytal fauna is depicted graphically for $\alpha = 0.25, 0.5,$ and 0.75.

6. Plotting Graph for the CEQD to Depicting phytal fauna

Combining distinct refined quantity dependent data matrices by altering $\alpha \in [0, 1]$ yields a combined effect quantity dependent data matrix, which represents the cumulative impact of all the entries. The combined effect quantity dependent data matrix is essential in showing the combine effect of all produced RQD matrices for various values of $\alpha = 0.25, 0.5$ and 0.75.

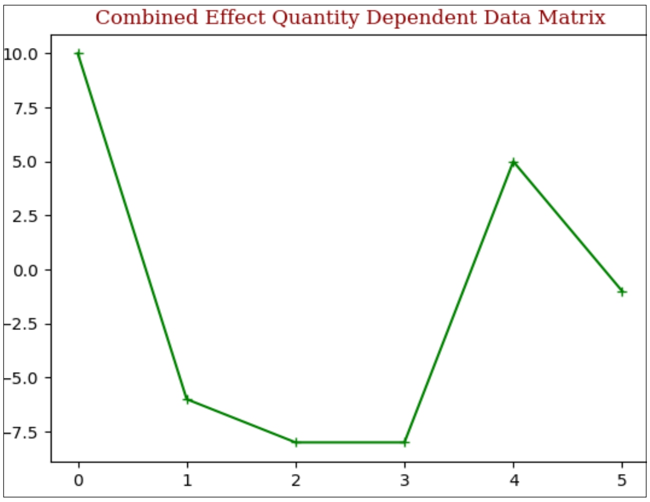

Fig 2: The combined effect quantity dependent data matrix of. $\alpha = 0.25, 0.5$ and 0.75.

7. Conclusion

From the above studies and depicted fuzzy graphs for different values of α = 0.25, 0.5, and 0.75 level on the diversity of phytal fauna in Erayumanthurai coast, we concluded that the high number of fauna recorded in sites at α = 0.75 level is S1 and S5 are dominated by amphipods and bivalves. The faunal ranges are medium at α = 0.5 level the sites S2, S3 and S4 are isopods, crabs, and polychaetes. The low-level fauna distribution sites was at α = 0.25 level the fauna were amphipods, isopods, crabs and polychaetes in the sits are S1, S2 S3, and S4 Erayumanthurai coast. The negative values in the sites of S2, S3, S4 simply indicate that faunal composition in these sites not preferred. This fuzzy combined effect time quantity dependent data matrix predicts the exact place has more anthropogenic disturbance to disturb the diversity and distribution of phytal animals.

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