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Study of Meiofaunal Population on Coastal Chennai using experts opinion -a Bayesian Perspective

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Abstract

Ecology and environmental studies could be most challenging in terms of usage and interpretation of appropriate statistical measures for analysis. Ecological research has a unique feature in that a component of ecological community might yield different results when repeating the experiment and expected not to exert the conditions of identical samples. In contrast to long run frequentist approach, Bayesian inference could provide a more pragmatic alternative to the field of ecological uncertainty. Its ability to incorporate objective or subjective hypotheses or theories into prior distributions could encourage ecologists to analyse the data and interpret the results. In this study, an attempt has been made to estimate the prevalence of Meiofaunal population based on the data collected in five stations (Adyar, Marina, Napier, Pulicat and Royapuram) of Chennai coast (13° 06' N. 80° 18'E), India and the elicited information forms the basis for constructing realistic priors. Further, data pertaining to foraminiferans, a rare group of meiofauna from the five stations of Chennai coast is subjected to Bayesian analysis and the results are discussed.

Keywords: Bayesian methods, Meiofauna Population, Subjective Priors.

1. Introduction

The research on meiofauna started way back in 18^{th} century; however, it has become popular only after the studies of Remane (1933, 1952). Meiofauna is a heterogeneous assemblage of animals belonging to 25 phyla inhabiting interstices of sandy beaches. These animals pass through 1000 micron mesh size and retained in 63 micron mesh size. In the past decades, the basic taxonomic studies on meiofauna continued with addition of more species. Experiments have been carried out on the effect of phytodetritus and pollutants such as petroleum hydrocarbons and heavy metals on different taxa of meiofauna. Studies of Remane on meiofauna of intertidal beaches, subtidal sand and mud and algal habitats with standardized methodology along with the contributions of Swedmark (1964) generated interest in this field. The ecological data as observed in Ellison (1996)has a vast store of natural history and experimental data to address the uncertainty and it has been observed that Bayesian inference could be the most straightforward way of analyzing and interpreting the related ecological hypotheses.

The development of modern statistical theory has been characterized by three-sided approaches namely Bayesian, Frequentist and Fisherian with its own merits and demerits and divergent views. In Bayesian inference, known quantities are treated as observed values of random variables and unknown quantities are observed as random variables; the conditional distribution of unknowns given knowns follow from applying Bayes theorem to the model specifying the joint distribution of known and unknown quantities. The knowns refer to values that are both available and considered worthwhile to include in model specifications (Rubin, 1984).

A rich literature is available for the Philosophical, Mathematical, Statistical, and Computational aspects of Bayesian approach. Also, Bayesian approaches provide a powerful tool for interpretation of study results and evaluation of hypotheses considering a much broader class of conceptual and mathematical models than would have been possible using non-Bayesian approaches. Indeed the growth and strength of Bayesian methodology lies in its wide applications to complicated problems that are not so obvious even to formulate for a more traditional analysis. A short yet commendable list of contributions could be followed from Gelman et al (1995), Dunson (2001), Berger (2006), Goldstein (2006) and Wolport (2004).

Also, Ellison (1996, 2004), Harwood and Stokes (2003), Ronquist (2004), and Stephens et al (2006) provide elaborate details for the application of Bayesian inference in ecological data analysis and modeling. Reckhow et al (1987) and Reckhow (1988) have demonstrated the advantage of using expert opinion in obtaining an improved model of fish population response to acid deposition in lakes.

In this context, the scope of inbuilt advantages in Bayesian approach for estimating the prevalence of meiofaunal population has been identified by incorporating ecological experts' opinion on historical and/ or theoretical aspects into properly transformed prior distributions. Data collected from five different (Adyar, Marina, Napier, Pulicat, Royapuram) coastal areas of Chennai, India has been used and the study includes logit transformation for constructing a vague prior for a comparative purpose. Further, the computational strategies involved in the analysis particularly when the data is sparse in nature has also been discussed by comparing with non-Bayesian approach

2. Statistical Methods

Many natural phenomena could be described using binary classifications, such as presence or absence of species and in estimating those proportions have been considered as a part of statistical procedure. Parameter estimation in empirical models has been done using frequentist methods in which judgments or experts' opinion could be involved in the model specification but may not be in the actual estimation procedures. The experienced investigators could have a greater understanding of the built-in theories and sensitivities of the collection of data and adequate knowledge could be derived from them to incorporate into the analysis that may not involve mathematical optimization.

If X_i denotes the presence of taxa, then the appropriate model would be a Binomial distribution with parameters, number of events (n_i) and population proportion (p_i). The logical choice for p_i is $\beta(a,b)$ distribution on $(0,1)$ leading to mathematically tractable results. Then, the posterior distribution for p_i, based on a prior distribution and the likelihood function would be $\beta(x_i+a, n_i-x_i+b)$ and the Bayes estimator requires selecting prior for hyper parameters a and b. Also, Subbiah (2009) and Tuyl et al (2008) have discussed priors for the binomial parameter p, ranges from Uniform distribution; conjugate Beta families to logistic-normal density and Jeffreys prior.

Further, the zero numerator problems in particular, has been discussed in literature such as Tuyl et al (2008) for a careful prior analysis based on informative and non-informative priors. As a point of recommendation, the use of a prior with $a, b < 1$ should be avoided, both for non-informative and informative priors. In this paper, a scheme of constructing an informative prior based on ecologists' observations for binomial proportion has been exercised. Ecological experts' belief about the presence of the group has been categorized into six forms (mostly present, rare, and four very rare groups for much scanty taxa) excluding two deterministic cases on presence or totally absence of specific taxa. There are 26 groups of animals and in a specific area the certain number of each group is sampled. This assessment is based on more hypothetically (extracted from previous study) or this characteristic may be more specific to a geographical location.

The six classifications and assessments derived by ecological experts have been considered as lower and upper limit of uniform distribution U $(\mathrm{a}_1,\ \mathrm{a}_2)$. Then mean $\mathrm{M} = \dfrac{(\mathrm{a}_1 + \mathrm{a}_2)}{2}$ and variance $\mathrm{V} = \dfrac{(\mathrm{a}_1 - \mathrm{a}_2)^2}{12}$ could be obtained. Subsequently, M and V are equated to mean $\dfrac{\mathrm{a}}{\mathrm{a} + \mathrm{b}}$ and variance $\dfrac{\mathrm{ab}}{(\mathrm{a} + \mathrm{b})^2\ (\mathrm{a} + \mathrm{b} + 1)}$ of the underlying prior distribution Beta (a, b) and solving for $a\&b$, to get the values for hyper parameters a, b.

M and V are calculated from $0 < \mathrm{a}_1 < \mathrm{a}_2 < 1$, $\mathrm{M} = \dfrac{(\mathrm{a}_1 + \mathrm{a}_2)}{2}$ $\mathrm{V} = \dfrac{(\mathrm{a}_1 - \mathrm{a}_2)^2}{12}$ and equate $M\&V$ to the mean and variance of the transformed Beta distributions

$$\mathrm{V} = \frac{\mathrm{ab}}{(\mathrm{a}+\mathrm{b})^2\ (\mathrm{a}+\mathrm{b}+1)} = \frac{\mathrm{a}}{\mathrm{a}+\mathrm{b}}\ \frac{\mathrm{b}}{(\mathrm{a}+\mathrm{b})\,(\mathrm{a}+\mathrm{b}+1)} = \frac{\mathrm{a}}{\mathrm{a}+\mathrm{b}}\ \mathrm{b}\ \frac{1}{\mathrm{a}+\mathrm{b}}\ \frac{1}{\mathrm{a}+\mathrm{b}+1} \tag{1}$$

$$\left.\begin{aligned} \mathrm{M} &= \frac{\mathrm{a}}{\mathrm{a}+\mathrm{b}} \\ (\mathrm{a}+\mathrm{b})\,\mathrm{M} &= \mathrm{a} \\ \mathrm{bM} = \mathrm{a} - \mathrm{aM} \ &\Rightarrow \mathrm{b} = \frac{\mathrm{a}\ (1-\mathrm{M})}{\mathrm{M}} \end{aligned}\right\} \tag{2}$$

Now a+b $= \dfrac{\mathrm{a}}{\mathrm{M}}$; $\mathrm{a}+\mathrm{b}+1 = \dfrac{\mathrm{a}}{\mathrm{M}} + 1 = \dfrac{\mathrm{a}+\mathrm{M}}{\mathrm{M}}$. Then using (2) in (1)

$\mathrm{V} = \mathrm{M}\ \dfrac{\mathrm{a}\ (1-\mathrm{M})}{\mathrm{M}}\ \dfrac{\mathrm{M}}{\mathrm{a}}\ \dfrac{\mathrm{M}}{\mathrm{a}+\mathrm{M}} = \dfrac{\mathrm{M}^2(1-\mathrm{M})}{\mathrm{a}+\mathrm{M}} \ \Rightarrow \mathrm{a}+\mathrm{M} = \dfrac{\mathrm{M}^2(1-\mathrm{M})}{\mathrm{V}}$ leading to

$$\mathrm{a} = \frac{\mathrm{M}^2(1-\mathrm{M})}{\mathrm{V}} - \mathrm{M} \tag{3}$$

Proposition : $a > 0$ **and** $b > 0$

From the choice of M, it could be observed that, $0 < M < 1$ and $0 < a_1 < a_2 < 1$.

Further, $0 < a_1 < M < a_2 < 1$

$\Rightarrow -a_1a_2 < -Ma_1$ and $0 < M - a_1 < 1$ together imply $M^2 - a_1a_2 < M^2 - Ma_1 = M(M - a_1) < M$

$M^2 - a_1a_2 < M$ implies $\dfrac{M^2 - a_1a_2}{3} < \dfrac{M}{3} < M$

Now $V = \dfrac{(a_1 - a_2)^2}{12} = \dfrac{(a_1 + a_2)^2}{12} - \dfrac{4a_1a_2}{12} = \dfrac{1}{3}\left\{\left[\dfrac{(a_1 + a_2)}{2}\right]^2 - a_1a_2\right\}$

$$V = \frac{1}{3}\left[M^2 - a_1a_2\right] \quad \therefore \quad V < M$$

Also, if $V = \dfrac{(a_1 - a_2)^2}{12} > 0.25$

$$\Rightarrow (a_2 - a_1)^2 > 12 \times 0.25 = 3$$

$$\Rightarrow (a_1 - a_2) > \sqrt{3} > 1$$

$$\Rightarrow (a_1 - a_2) > 1$$

$\Rightarrow a_2 > 1 + a_1$ which contradicts the choice of a_2

$$\therefore \quad V < 0.25$$

Further the maximum value of $f(M) = M(1 - M)$ as 0.25 with the boundary conditions $0 < M < 1$ and $0 < 1 - M < 1$, could be obtained using second derivative test by equating the first derivative $f'(M) = 1 - 2M$ to zero and finding the sign of $f''(M)$ as negative.

This implies $M(1 - M) < 0.25$ and $V < 0.25 \Rightarrow \dfrac{1}{V} > 1$

$$\Rightarrow \frac{M(1 - M)}{V} - 1 > 0$$

$\Rightarrow a > 0$. (from (3)) Hence, $b = \dfrac{a\,(1 - M)}{M} > 0$.

The choices of a_1 and a_2 and subsequent transformations would bring plausible values for the Beta prior parameters. The traditional logit transformation of proportions have been discussed extensively in statistical literature as in Montgomery et al (2004) in the context of linear models, and Gelman et al (1995) for Bayesian modelling and hence the details of this model has been presented directly as programming code in Section 4.

3. Ecological details

The present study on meiofauna and the related data (Altaf et al, 2004) has been conducted on five selected intertidal sandy beaches along the coast of Chennai, India that are located within a distance of about 60 km (Figure 1). All the stations are exposed, unvegetated sandy beaches with variations in the rate of exposure, slopeness and width of the intertidal region. The width of the intertidal region was generally maximum during summer and minimum during winter. Though the human disturbances in the form of tourists are common in all these stations, the rate of their disturbance and the level of pollution vary. Meiobenthic samples were collected randomly from the mid-tidal level of the intertidal zone during low tide and high tide. The partition corer was used for the collection. The samples were collected upto 20 cm depth and divided into four divisions (0-5cm, 5-10cm 10-15 and 15-20cm) each of this division was kept separately in a container and fixed immediately with 5% Rose Bengal (0.5 g/l) formalin. Following table provides the overall summary of data collection methodology.

Description	Variable Name	Number of variables
Taxa	T1 to T26	26
Place	P1 TO P5	5
Tide level	L AND H	2
Sample Frequency	S1 TO S25	25
Measurement Division	L1 TO L4 and H1 TO H4	8
Measurement Frequency	M1 TO M3	3

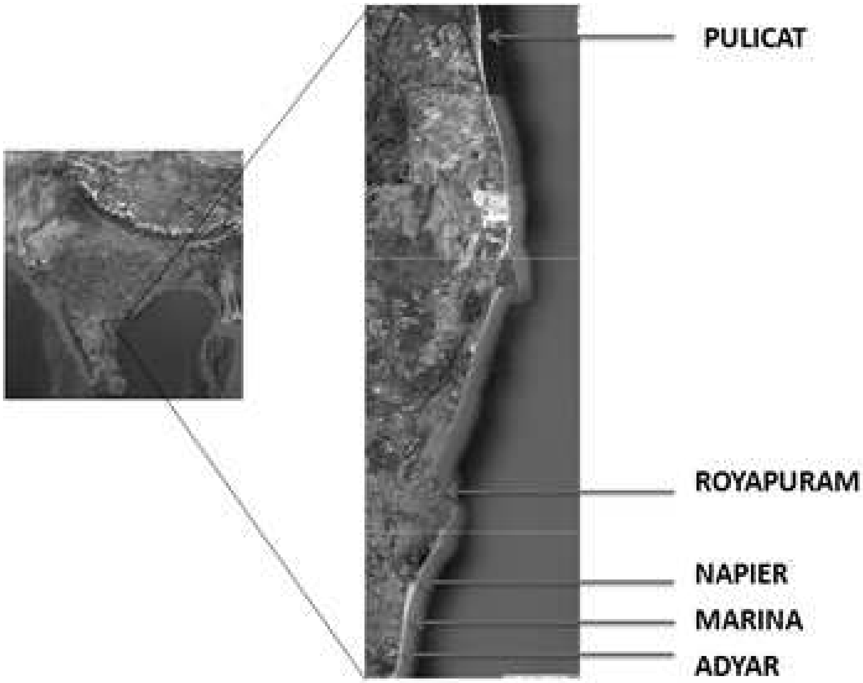

Figure 1: Map that shows the five stations along Chennai coast

In the laboratory, fixed meiofaunal samples were separated by decantation method by passing the supernatant through 1000μm and 62μm sieves. The separated fauna was immediately preserved in 5% Rose Bengal formalin. Since fixation and preservation distorts the soft meiofaunal taxa (ciliates, turbellarians, gastrotrichs, gastropods and holothurians) they were isolated alive by elutriation method.

In elutriation method, the live meiofaunal samples were narcotized in 6% Magnesium Chloride ($MgCl_2$) and the sample was placed in the separating funnel of the elutriation set-up and a jet of water was allowed to pass through this funnel. The fauna separated from this funnel was allowed to pass through 1000μm and 62μm sieves. These animals were immediately identified in living condition under different magnifications of compound microscope. The major and minor meiofaunal taxa were identified following Higgins and Thiel (1988). The meiofauna separated by decantation method were enumerated in Sedgwick-rafter counting chamber. Density and vertical distribution of the meiofauna was expressed as mean $\pm$ SE (standard error of mean) of number of individuals /10cm^2. The pooled up mean values of 0-5cm, 5-10cm, 10-15cm and 15-20cm were considered as total density.

Animal taxa which come into mostly present category are those taxa which are encountered or recorded in all the samples. This includes nematodes which are the most dominant taxa with regard to diversity as well as density (Altaf et al, 2004), followed by polychaetes, ostracods, isopods, gnathostromolids, archiannelids, copepodites and nauplii (larval stages of copepods). Mostly not seen category includes cnidarians, eggs & others (these comprises of eggs of various taxa and those taxa which were not identified in the present study). Rare group includes foraminiferans, turbellarians oligochaetes, harpacticoids, nemertines and gastropods. Very rare group includes gastrotrichs, kinorhynchs, ciliates and holothurians. Very very rare group includes collembolans, cyclopoids, insects, rotifers and cladocerans. Very very very rare group include those which were recorded not more than three times in a given station and these include halacarids and bivalves.

4. Results and Discussion

Analysis includes finding mean of the response data corresponding to the sampling frequencies that has been considered as number of successes that will be the known parameter of Binomial distribution. The Bayesian estimation of prevalence factor using Binomial-Beta model has been implemented in WinBUGS 1.4 and summary measures include mean and 95 % Bayesian Confidence Intervals have been obtained. An MCMC run of 50000 has been carried out and initial 25000 values are discarded as burn-in and the kernal density has been used as a tool to check convergence of this single MCMC chain. Following is the syntax corresponding to the two procedures based on transformations

```
for (i in 1:N)
{
x[i] ~ dbin(p[i], n[i])
p[i] ~ dbeta(a,b)
}
a1<-0.4
b1<-0.7
m<- (a1+a2)/2
v<- (pow((a1-a2),2))/12
a<-     (((1-m)*pow(m,2))      -
(m*v))/v
b<-a*(1-m)/m
```

```
for( i in 1 : N )
{
r[i] ~ dbin(p[i], n[i])
logit(p[i]) <- mu[i]
mu[i] ~ dnorm(d, tau)
}
d ~ dnorm(0.0,1.0E-6)
sigma <- 1 / sqrt(tau)
tau~dgamma(3,1)
```

However, due to the paucity of space, the presentation of the result has been restricted to taxa foraminiferans, one among the rare category and considering four low tidal statuses in all the five stations. Also, Tables 1 and 2 provide a partial list of posterior summary measures for the prevalence factor of the foraminiferans only for two stations, Adyar and Royapuram together with corresponding Caterpillar plots for L1 and L2 (Figure 2 and 3); nevertheless the analysis includes all the parameters considered in the study.

TABLES 1 – 2

FIGURE 2 – 3

Point and interval estimates together with caterpillar plot of prevalence are compared between tide levels, locations to understand presence / absence of taxa using the above binomial model. From the tabulated values and other estimates, it could be observed that the classification of taxa has an impact in knowing about the distinctive features of taxa across different locations. Though tide levels do not show an appreciable difference in the estimates, it helps in detailing the pattern of taxa and their abundance. Hence, ecologists can study the relative importance of tides and location in estimating prevalence of taxa.

Among all taxa, estimates of eggs & others show its specific characteristic that its presence is completely dependent on seasonal reproduction. Also, this type includes possible taxa that may be beyond the list under study. Hence, a careful investigation brings systematic and similar distribution in both tide levels. Similar conclusion could be arrived at with respect to different locations, except Adyar where little higher prevalence estimates can be observed uniformly in this group.

In the very rare classification, Holothurians show an apparent different pattern in its prevalence estimates between different locations ranging from Pulicat to Adyar. Pulicat has a higher rate of proportion followed by Marina and least at Adyar. However, noticeable difference does not exist as far the tide levels are concerned at all the locations.

Collembolan, which is classified as very very rare taxa, has totally distinct prevalence estimates across all stations as well as over two tide levels. Pulicat records a low value where as other stations show higher but little different value. The practicing ecologists are interested in probing further this phenomenon to understand the specific feature of Pulicat. Another classification, extremely rare also exhibits slight difference between tide levels except in Adyar where a higher difference is noticed during low tide. However, over all prevalence among the places have similar estimates as far this group is concerned.

Caterpillar plot indicates that Adyar station showed high prevalence of meiofauna; nevertheless mean dots appeared to the left of the global mean. The caterpillar plot of Napier station also shows features similar to Adyar station signifying that these stations are located closer to Coovam and Adyar river mouth and the impact of pollution is high on the meiofaunalprevalence. The caterpillar plot of the foraminiferan meiofauna of different stations of the Chennai coast clearly indicates that their prevalence is influenced by many factors such as nature of the substratum, availability of food, physico-chemical parameters and state of pollution (Higgins and Thiel, 1988, Sandulli and Pinckney, 1999 and Altaf, 2004). Adyar station showed high prevalence; nevertheless mean dots appeared to the left of the global mean. The caterpillar plot of Napier station also shows features similar to Adyar station signifying that these stations are located closer to Coovam and Adyar river mouth and the impact of pollution is high on the meiofaunal prevalence.

The caterpillar plot of Marina station showed higher number of mean dots toward right of global mean base indicating favourable conditions for meiofaunal prevalence. Though caterpillar plot of Pulicat station shows features of Marina station, however the prevalence value of Pulicat is lower compared to Marina station. Higher mean values of foraminiferan prevalence in Royapuram can be attributed to the higher organic matter which forms suitable food for many groups of meiofauna. The caterpillar plots that supplement the results of classical enumerations of meiofauna and further identify the influence of other factors in determining the prevalence of foraminiferans of different stations. In the caterpillar figures, the mean dots which are found to be on the left side of the global mean results because of Bayesian approach with expert opinion which in conventional computation might not be figured out. Also, the results have shown a complete agreement between the notions followed for classification schema and subsequent Bayesian prior specifications that produce reasonable estimates amongst the classified taxa groups.

Further comparison with the model that has a transformed non-informative prior, it could be observed that flat priors do not exhibit enough variability and all the estimated values do concentrate heavily around the global mean; however the variation pattern among the 25 sampling periods do have similarity with informative prior model. The modelling technique that has been discussed in the paper would enable to incorporate sample data together with experts' opinion pertaining to the prevalence of Meiofaunal Population in the five stations. This ability to account for extra variation would be an additional advantage over conventional methods and provide extended scope and flexibility in modelling similar studies.

The results of present study clearly project that the Bayesian approach is helpful in understanding the seasonality in the prevalence of foraminiferans. Nevertheless unique feature of this group such as patchy distribution, poor locomotory mechanism as well as importance of calcareous shell and pseudopodial food capture mechanisms (Nybakken, 1997, Sandulli and Pinckney, 1999 and Khare and Nigam, 2000) might also be responsible for such prevalence. Ecological studies and the prevalence of different taxa mostly restricted to their presence, absence or density. However, Bayesian approach on the prevalence at five stations of Chennai coast provided a natural and principled way of combining prior information with data.

5. Conclusion

Ecological studies and the prevalence of different taxa mostly restricted to their presence, absence or density. This study illustrates a Bayesian statistical model within which ecological analysis for the estimation of Meiofaunal Population using elicited information. Using classical approach, in different places (India and other countries), for each group, proportion of existence has been estimated as a ratio of number of successes to the number of cases.al form. This approach and corresponding interval estimation have serious statistical limitations in the zero or total success cases. However, it has been observed that a method which incorporates the background information regarding the prevalence factor for each of these groups in different places would be quite appropriate. The perception of "dominating" groups may differ between global and local settings and these perceptions could be quantified as suitable subjective forms and Prior elicitation could be made based on the solicited opinions.

The geographical patterns for the prevalence of Meiofaunal Population has been studied by taking into account of other appropriate attributes Hence the study emphasizes the importance of area-level characteristics in determining the presence of a specific taxa. The Bayesian model could be applicable to estimate such factors even if the sample data is of sparse nature and a systematic evaluation could be implemented. Also, this model could easily be extended to include any other area-level or other parameters which might be influential in estimating the Meiofaunal Population. The analysis and conclusions of the paper might raise interesting and potentially important questions about the use of Bayesian analysis of data relating to estimation of Meiofaunal Population using elicited information. In particular the results suggest that value added approaches such as experts' opinion as additional yet meaningful input to study could encourage exploring the flexibility of Bayesian methods that would be more appropriate in drawing meaningful conclusion.

References

Altaff K, Naveed Md S, Sugumaran J (2004). "Meiofauna of Chennai coast of Bay of Bengal with special reference to sampling and extraction methods." *Convergence,* 661-90.

Berger J (2006). "The case for objective Bayesian analysis." *Bayesian Analysis*, **3**, 385 – 402.

Dunson DB (2001). "Practical advantages of Bayesian analysis of epidemiologic data." *American Journal of Epidemiology,* **153**, 1222 – 1226.

Ellison MA (1996). "An Introduction to Bayesian Inference for Ecological Research and Environmental Decision-Making," *Ecological Applications*, **6**, 1036-1046.

Ellison MA (2004). "Bayesian inference in ecology," *Ecology Letters*, 7509–520.

Gelman A, Carlin JB, Stern HS, Rubin DB (1995). *Bayesian Data Analysis.* Chapman & Hall, London.

Goldstein M (2006). "Subjective Bayesian analysis: principles and practice." *Bayesian Analysis*, **3**, 403 – 420

Harwood J, Stokes K (2003). "Coping with uncertainty in ecological advice: lessons from fisheries." *Trend in Ecology and Evolution*, **18**, 617-622

Higgins RP, Thiel H (1988). *Introduction to the study of Meiofauna*, Smithsonian Inst. Press

Khare N, Nigam R (2000). "Laboratory experiment to record rate of movement of cultured benthic Foraminifera." *ONGC Bull.* **37**

Nybakken JW (1997). *Marine Biology: An ecological approach. Mass landing marine invertebrates,* Addition – Wesley Educational Publ. Inc., pp. 285-303.

Reckhow KH, Black RW, Stockton Jr TB, Vogt JD, Wood JG (1987). "Empirical models of fish response to lake acidification." *Canadian Journal of Fisheries and Aquatic Sciences*, **44**, 1432-1442

Reckhow KH (1988). "A Comparison of Robust Bayes and Classical Estimators for Regional Lake Models of Fish Response to Acidification." *Water Resources Research.* **24**, 1061-1068

Remane A (1933). "Verteillung und organization der benthonischen mikrofauna der kieler bucht." *Wissenschaftliche meeresuntersuchugen N.F., Kiel*, 21H. **2**, 161-221

Remane A (1952). "Die Biesiedlung des Sandbodens im Moeere und die Bedeutang der Lebensformtypen fï£¡r die ï£¡kologie." *Verhandlungen der Deutschen Zoologischen Gesellschaft, wilhelmshaven(1951), Zool. Anz. Supp.,* 16327-359

Ronquist F (2004). "Bayesian inference of character Evolution." *Trends in Ecology and Evolution*, **19**, 475 – 481

Rubin DB (1984). "Bayesianly justifiable and relevant frequency calculations for the applied statistician." *Annals of Statistics,* **12**, 1151 – 1172

Sandulli R, Pinckney J (1999). "Patch sizes and spatial patterns of copepods and benthic microalgae in sandy sediments: a micro scale approach." *J.Sea Res.,* **41**, 179 -187.

Stephens PA, Buskirk SW, Rio CM (2006). "Inference in ecology and evolution." *Trends in Ecology and Evolution*, **22**, 192 - 197

Subbiah M (2009). *Bayesian inference on sparseness in 2 × 2 contingency tables and its applications*, Ph.D. thesis, University of Madras, India,

Swedmark B (1964). "The interstitial fauna of marine sand." *Biol. Rev.,* **39**, 1-42

Tuyl F, Gerlach R, Mengersen KA (2008). "Comparison of Bayes-Laplace, Jeffreys, and other priors: The case of zero events." *The American Statistician*, **62**, 40 – 44

Wolport RL (2004). "A conversation with James O. Berger." *Statistical Science*, **19**, 205 – 218

S. No	L1				L2				L3				L4			
	Mean	SD	LL	UL	Mean	SD	LL	UL	Mean	SD	LL	UL	Mean	SD	LL	UL
1	0.0338	0.0079	0.0199	0.0500	0.0318	0.0074	0.0189	0.0500	0.0250	0.0059	0.0148	0.0400	0.0331	0.0078	0.0196	0.0500
2	0.0219	0.0051	0.0130	0.0300	0.0198	0.0047	0.0117	0.0300	0.0442	0.0064	0.0325	0.0600	0.0652	0.0094	0.0481	0.0800
3	0.0580	0.0133	0.0350	0.0900	0.0316	0.0046	0.0231	0.0400	0.0473	0.0074	0.0340	0.0600	0.0190	0.0035	0.0127	0.0300
4	0.0564	0.0102	0.0382	0.0800	0.2052	0.0151	0.1762	0.2400	0.3700	0.0269	0.3180	0.4200	0.3290	0.0259	0.2793	0.3800
5	0.0415	0.0076	0.0279	0.0600	0.0664	0.0109	0.0468	0.0900	0.0225	0.0053	0.0133	0.0300	0.0532	0.0088	0.0374	0.0700
6	0.0196	0.0036	0.0131	0.0300	0.0239	0.0044	0.0159	0.0300	0.0133	0.0032	0.0079	0.0200	0.0197	0.0046	0.0116	0.0300
7	0.0128	0.0030	0.0076	0.0200	0.0150	0.0036	0.0089	0.0200	0.0205	0.0048	0.0121	0.0300	0.0183	0.0043	0.0108	0.0300
8	0.0115	0.0021	0.0077	0.0200	0.0159	0.0029	0.0106	0.0200	0.0460	0.0054	0.0358	0.0600	0.0123	0.0023	0.0082	0.0200
9	0.0122	0.0029	0.0072	0.0200	0.0179	0.0042	0.0106	0.0300	0.0199	0.0047	0.0117	0.0300	0.0352	0.0082	0.0209	0.0500
10	0.0497	0.0064	0.0378	0.0600	0.0295	0.0050	0.0207	0.0400	0.0938	0.0101	0.0749	0.1100	0.0252	0.0059	0.0150	0.0400
11	0.0294	0.0054	0.0197	0.0400	0.0808	0.0109	0.0609	0.1000	0.1363	0.0138	0.1103	0.1600	0.1962	0.0162	0.1656	0.2300
12	0.0163	0.0038	0.0096	0.0200	0.0170	0.0040	0.0102	0.0300	0.0115	0.0027	0.0068	0.0200	0.0148	0.0035	0.0087	0.0200
13	0.0361	0.0085	0.0215	0.0500	0.0195	0.0046	0.0115	0.0300	0.0234	0.0055	0.0139	0.0400	0.0281	0.0066	0.0167	0.0400
14	0.0376	0.0069	0.0252	0.0500	0.0217	0.0051	0.0129	0.0300	0.0279	0.0051	0.0188	0.0400	0.0462	0.0084	0.0311	0.0600
15	0.2230	0.0251	0.1758	0.2700	0.0257	0.0043	0.0179	0.0300	0.0370	0.0068	0.0250	0.0500	0.0171	0.0032	0.0114	0.0200
16	0.0206	0.0049	0.0122	0.0300	0.0252	0.0040	0.0181	0.0300	0.0132	0.0031	0.0078	0.0200	0.0262	0.0048	0.0175	0.0400
17	0.0861	0.0131	0.0621	0.1100	0.0123	0.0029	0.0072	0.0200	0.0183	0.0034	0.0123	0.0300	0.0215	0.0040	0.0143	0.0300
18	0.0277	0.0051	0.0187	0.0400	0.0173	0.0041	0.0101	0.0300	0.0159	0.0038	0.0094	0.0200	0.0127	0.0030	0.0075	0.0200
19	0.0209	0.0049	0.0124	0.0300	0.0290	0.0069	0.0171	0.0400	0.0230	0.0054	0.0135	0.0300	0.0211	0.0050	0.0126	0.0300
20	0.0624	0.0144	0.0372	0.0900	0.0580	0.0134	0.0346	0.0900	0.0163	0.0039	0.0096	0.0200	0.0135	0.0032	0.0080	0.0200
21	0.0488	0.0113	0.0292	0.0700	0.0474	0.0110	0.0283	0.0700	0.0177	0.0041	0.0105	0.0300	0.0107	0.0025	0.0063	0.0200
22	0.0886	0.0203	0.0532	0.1300	0.0414	0.0097	0.0245	0.0600	0.0424	0.0066	0.0303	0.0600	0.0109	0.0026	0.0064	0.0200
23	0.0256	0.0060	0.0152	0.0400	0.0155	0.0037	0.0091	0.0200	0.0172	0.0041	0.0101	0.0300	0.0212	0.0050	0.0126	0.0300
24	0.0728	0.0131	0.0493	0.1000	0.0469	0.0109	0.0279	0.0700	0.0302	0.0071	0.0179	0.0500	0.0192	0.0045	0.0114	0.0300
25	0.0568	0.0103	0.0382	0.0800	0.0236	0.0056	0.0140	0.0400	0.0216	0.0051	0.0127	0.0300	0.0486	0.0089	0.0326	0.0700

Table 1: Posterior mean and Standard Deviation (SD) of Foramineferans prevalence in Adyar based on the four level of measurements

S. No	L1				L2				L3				L4			
	Mean	SD	LL	UL	Mean	SD	LL	UL	Mean	SD	LL	UL	Mean	SD	LL	UL
1	0.0550	0.0099	0.0372	0.0757	0.0318	0.0074	0.0190	0.0478	0.0250	0.0059	0.0148	0.0379	0.0745	0.0113	0.0539	0.0982
2	0.0219	0.0052	0.0129	0.0331	0.0690	0.0085	0.0532	0.0865	0.1247	0.0103	0.1052	0.1456	0.0966	0.0112	0.0759	0.1198
3	0.0579	0.0134	0.0344	0.0870	0.0240	0.0040	0.0166	0.0324	0.0544	0.0079	0.0400	0.0709	0.0335	0.0046	0.0251	0.0431
4	0.0348	0.0082	0.0207	0.0529	0.0247	0.0058	0.0146	0.0373	0.0553	0.0129	0.0329	0.0828	0.0727	0.0144	0.0470	0.1034
5	0.0256	0.0060	0.0152	0.0387	0.0338	0.0079	0.0201	0.0510	0.0443	0.0074	0.0311	0.0598	0.0441	0.0081	0.0297	0.0613
6	0.0423	0.0053	0.0325	0.0531	0.0380	0.0055	0.0279	0.0495	0.0381	0.0052	0.0284	0.0490	0.0689	0.0084	0.0532	0.0861
7	0.0409	0.0053	0.0312	0.0519	0.0389	0.0056	0.0286	0.0506	0.0332	0.0061	0.0222	0.0463	0.0524	0.0072	0.0392	0.0672
8	0.0071	0.0017	0.0042	0.0107	0.0098	0.0023	0.0058	0.0148	0.0119	0.0028	0.0071	0.0180	0.0076	0.0018	0.0044	0.0115
9	0.0122	0.0029	0.0072	0.0185	0.0180	0.0043	0.0106	0.0272	0.0198	0.0047	0.0117	0.0300	0.0352	0.0082	0.0209	0.0528
10	0.1129	0.0093	0.0954	0.1319	0.1577	0.0107	0.1375	0.1791	0.0736	0.0090	0.0569	0.0924	0.0810	0.0104	0.0619	0.1024
11	0.0181	0.0042	0.0107	0.0273	0.0984	0.0119	0.0765	0.1228	0.2072	0.0163	0.1762	0.2400	0.1129	0.0130	0.0885	0.1393
12	0.0163	0.0038	0.0097	0.0246	0.0278	0.0051	0.0187	0.0386	0.0444	0.0053	0.0346	0.0554	0.0427	0.0059	0.0318	0.0550
13	0.0585	0.0105	0.0394	0.0807	0.0659	0.0082	0.0505	0.0828	0.0234	0.0055	0.0138	0.0353	0.0904	0.0115	0.0693	0.1140
14	0.0231	0.0054	0.0137	0.0351	0.0624	0.0085	0.0467	0.0802	0.0385	0.0060	0.0276	0.0512	0.0992	0.0120	0.0771	0.1239
15	0.0638	0.0147	0.0381	0.0955	0.0295	0.0046	0.0211	0.0392	0.0514	0.0080	0.0370	0.0682	0.0338	0.0044	0.0257	0.0430
16	0.0335	0.0061	0.0225	0.0465	0.0220	0.0037	0.0155	0.0299	0.0260	0.0043	0.0182	0.0350	0.0161	0.0038	0.0096	0.0243
17	0.0621	0.0112	0.0419	0.0858	0.0416	0.0053	0.0318	0.0526	0.0363	0.0047	0.0275	0.0461	0.0379	0.0052	0.0283	0.0489
18	0.0278	0.0051	0.0186	0.0388	0.0172	0.0041	0.0102	0.0260	0.0761	0.0079	0.0614	0.0924	0.0689	0.0068	0.0562	0.0828
19	0.0339	0.0062	0.0228	0.0473	0.0573	0.0095	0.0400	0.0771	0.0517	0.0079	0.0373	0.0683	0.1113	0.0109	0.0906	0.1332
20	0.0624	0.0144	0.0373	0.0937	0.0941	0.0167	0.0638	0.1297	0.0368	0.0058	0.0265	0.0488	0.0474	0.0059	0.0365	0.0596
21	0.1100	0.0165	0.0800	0.1445	0.1228	0.0170	0.0913	0.1582	0.0933	0.0092	0.0761	0.1122	0.0448	0.0051	0.0353	0.0554
22	0.3395	0.0336	0.2754	0.4078	0.1446	0.0170	0.1127	0.1796	0.0907	0.0094	0.0731	0.1099	0.0314	0.0044	0.0233	0.0405
23	0.0823	0.0104	0.0630	0.1037	0.0748	0.0078	0.0603	0.0908	0.0603	0.0075	0.0464	0.0758	0.0740	0.0091	0.0571	0.0928
24	0.1160	0.0161	0.0860	0.1494	0.0467	0.0109	0.0278	0.0702	0.0302	0.0071	0.0179	0.0456	0.0192	0.0046	0.0114	0.0291
25	0.0350	0.0082	0.0207	0.0527	0.0384	0.0071	0.0260	0.0536	0.0351	0.0064	0.0236	0.0488	0.0487	0.0088	0.0330	0.0676

Table 2: Posterior mean and Standard Deviation (SD) of Foramineferans prevalence in Royapuram based on the four level of measurements

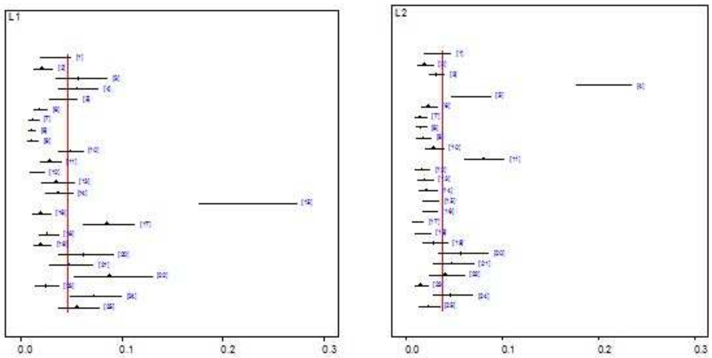

Figure-2: Caterpillar plots on the prevalence of foraminiferans at Adyar based on measurements (L1 and L2)

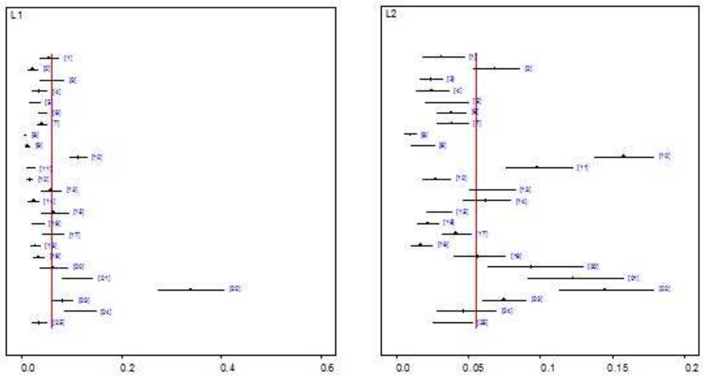

Figure-3: Caterpillar plots on the prevalence of foraminiferans at Royapuram based on measurements (L1 and L2)

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