Journal of Environments
ISSN: 2313-660X
Vol. 2, No. 1, 10-17, 2015
http://www.asianonlinejournals.com/index.php/JOEN

Carp Seed Production Factors in India

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Abstract

The carp seed production process is a continuum. In practice, it is too difficult to strictly divide rural from entrepreneurial fish seed producers. Generally, the farmers who have been involved in subsistence level carp seed production increased their production over the years, with the more inputs and better management skill, resulting in enlarging their resource base and gradually becoming entrepreneurial. This report examines the factors which have statistical significant effects on crap seed production. Objective: The responsible factors for carp seed production are varied in nature, and these are not clearly well-known in the literature. Fisheries research often seeks to identify a causal relationship between the fish seed production and the environmental/controlled factors. This article studies three different subject groups (Rohu (24), Mrigal (21) and Catla (12)) for identifying the causal factors of carp seed production. Results: The causal factors of carp seed production are identified here. Statistical significant causal factors for Mrigal are female fish age ($P = 0.01$), her weight ($P< 0.01$), size ($P = 0.07$), 1st-dose ($P < 0.01$), male fish weight ($P < 0.01$). For Rohu, significant factors are female fish age ($P < 0.01$), her weight ($P< 0.01$), 1st-dose ($P = 0.01$), 2nd-dose ($P < 0.01$). For Catla, significant factors are female fish age ($P < 0.01$), her weight ($P< 0.01$), 1st-dose ($P = 0.01$). Effects of these factors on carp seed production are identified. Conclusions: Impacts of female fish age, her weight, size, 1st-dose, male fish weight, 2nd-dose etc., on carp seed production are explained based on mathematical relationships. The present findings support many earlier research outputs. However, these analyses also identify many additional casual factors that explain the means and variances of carp seed production, which earlier researches have not reported.

Keywords: Carp seed, Gamma model, Joint generalized linear model, Log-normal model, Non-constant variance.

Contents

1. Introduction 11
2. Generalized Linear Log-Normal and Gamma Models 11
3. Aanalyses and Interpretation of Carp Seed Production Data 12
4. Concluding Remarks 16
References 16

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1. Introduction

The carp culture practices and farming are rapidly expanding in India. But the shortage of major carp seed is one of the major constraints in the development of fishing industry. To mitigate this problem, efforts are ongoing to establish modern hatcheries in places where the environment is favourable for carp breeding. Even though the method of hypophysation is fairly well standardized and is being employed widely, availability, quality and potency of pituitary glands have become undependable. As a result, wide range of percentage mortality and spawning failure are very common in several farms. With the objective of finding out an effective substitute for pituitary glands, some investigations were undertaken wherein a new drug, Ovaprim-C, was used for induced breeding of three Indian major carps, namely, catla (Catlacatla), rohu (Labeorohita), and mrigal (Cirrhinamrisala) [1-3].

The production, maintenance and distribution system of carp seed are complex and dynamic. Though some of the entrepreneurs produce and supply the fish seed to end users often as a part of complex networks, their supply remains erratic in other part, particularly in rural sectors [4, 5]. The demand supply relationship of quality seeds, by and large, remains a daunting task in rural aquaculture development. This relationship can be regularly maintained, if village farmers produce quality carp seed in their ponds to not only make the access of locally produced and nursed quality seed to the fish farmers but also stimulate and support neighbouring farmers to adopt fish culture within their environmental conditions. Many researches focus on causal factors of carp seed production based on some simple statistical techniques (log-normal and gamma models with constant variance) [6, 7], which are inappropriate in many cases [8, 9]. Thus, the earlier findings invite some doubts and debates.

In general, fisheries data sets are positive, and their variances may be non-constant as the variance may have relation with the mean. For non-constant variance, an appropriate method is the transformation of the response variable which is used for stabilizing variance, making the distribution of the response variable closer to the Normal distribution, and improving the model fit of the data. However, in practice the variance may not always be stabilized under a proper (seems to be suitable) transformation [8, 9]. In analyzing fisheries data, many authors [6, 7, 10, 11] feel that variances are non-constant, thus they have used 'log transformation', which may not always be appropriate [9, 12]. Positive data are generally analyzed by log-normal or gamma models [8, 9, 12-16]. The problem of non-constant variance (for the response variable) in linear regression is a departure from the standard least squares assumptions. This inequality of variance problem occurs relatively often in practice, frequently in conjunction with a non-Normal response variable. This leads us to identify the causal factors of carp seed production using joint modelling of mean and variance simultaneously.

The present article focuses on the causal factors of carp seed production. Three data sets for Rohu, Mrigal and Catla are considered. These data sets are collected from local hatchery breeding. In the present analyses, the significant factors of Mrigal's seed production are female fish age, her weight, size, 1st-dose, male fish weight. Mean value of Mrigal's seed production depends on the female fish age, her weight, size, 1st-dose and male fish weight, but the variance depends on the female fish age and her weight. For Rohu, significant factors of mean seed production are female fish age, her weight, 1st-dose and 2nd-dose. The significant factors of the variance of Rohu's seed production are female fish weight and 2nd-dose. In case of Catla, significant factors of mean and variance of seed production are respectively, female fish age, her weight, and 1st-dose. Effects of these factors on carp seed production are explained based on the derived models.

2. Generalized Linear Log-Normal and Gamma Models

Many continuous positive process variables may have non-normal error distributions, and the class of generalized linear models includes distributions useful for the analysis of such process characteristic data. The simplest examples are perhaps the exponential and the gamma distributions, which are often useful for modelling positive data that have variance with mean relationship, and the variance of the response is non-constant. For heteroscedastic data, the log-transformation is often recommended to stabilize the variance [17]. However, in practice the variance may not always be stabilized under a proper (seems to be suitable) transformation [8]. It is well known that if the variance is constant, the parameter estimates from the log-normal and the gamma models have a common interpretation, except the intercept [13]. Das and Lee [9] have shown that for the analysis of data from quality-improvement experiments the log-transformation may not always be sufficient for stabilizing the variance, so that an alternative structured dispersion model is required; which results in different optimal settings. It is recently shown that these two models give different estimates without (Das and Park, 2012) and with structured dispersion [9, 12]. Box [18] proposed for using linear models with data transformation. For example, when

$$E(y_i) = \mu_i \text{ and } Var(y_i) = \sigma_i^{\,2} V(\mu_i),$$

the transformation $Z_i = \log(y_i)$ gives stabilization of variance $Var(Z_i) \approx \sigma_i^{\,2}$. If the variance of the response Y is stabilized under the log-transformation, the classical regression estimates (assuming log(Y) follows normal distribution) are identical with the generalized linear model estimates of the response Y, assuming Y follows log-normal distribution. However, if a parsimonious model is required (when the variance is not stabilized under the log-transformation, Myers, et al. [8], a different transformation is needed. Thus, a single data transformation may fail to meet various model assumptions. Nelder and Lee [19] proposed to use joint generalized linear models (JGLMs) for the mean and the dispersion. When the response Y_i is constrained to be positive log transformation $Z_i = \log Y_i$ is used. Under the log-normal distribution, a joint modelling of the mean and the dispersion is such that

$$E(Z_i) = \mu_i \quad \text{and} \quad Var(Z_i) = \sigma_i^{\,2},$$

with

$$\mu_i = x_i^t\beta \quad \text{and} \quad \log(\sigma_i^{\,2}) = g_i^t\gamma,$$

where x_i^t and g_i^t are the row vectors for the regression coefficients β and γ in the mean and the dispersion model, respectively.

For the constant coefficient of variation (i.e., the standard deviation increases proportionally with the mean), we have $Var(Y) = \sigma^2\{E(Y)\}^2 = \sigma^2\mu^2$.

Further, if the systematic part of the model is multiplicative on the original scale (i.e., the original random variable is a multiplicative model with its mean and random error as given below), and hence additive on the log scale, then

$$Y_i = \mu_i \varepsilon_i \ (i = 1, 2, ..., n)$$

with $\eta_i = \log \mu_i = x_i^t\beta = \beta_0 + x_{i1}\beta_1 + x_{i2}\beta_2 + ... + x_{ip}\beta_p$ and $\{\varepsilon_i\}$'s are independent identically distributed (IID) with $E(\varepsilon_i) = 1$. In generalized linear models (GLMs), μ_i is the scale parameter and $Var(\varepsilon_i) = \sigma^2$ is the shape parameter. For non-constant variance response, Nelder and Lee [19] proposed a modelling approach for the above multiplicative model. They advocated the use of joint generalized linear models (JGLMs):

$E(Y_i) = \mu_i$ and $Var(Y_i) = \sigma_i^2 V(\mu_i)$,

with $\eta_i = \log(\mu_i) = x_i^t\beta$ and $\xi_i = \log(\sigma_i^2) = g_i^t \gamma$,

where x_i and g_i are the row vectors used in the mean and the dispersion models, respectively.

The regression coefficients (β) of the mean model, and (γ) of the dispersion model are estimated, respectively, by the maximum likelihood (ML) and the restricted ML (REML) method [19].

In GLMs, the variance of the random variable Y_i (i.e., $Var(Y_i)$) consists of two components, one is $V(\mu_i)$, which depends on the mean (μ_i), and the other is σ_i^2, which is independent of the mean adjustment. The variance function ($V(\cdot)$) characterizes the distribution of GLMs family. For example, if $V(\mu) = 1$, the distribution is normal, Poisson if $V(\mu) = \mu$, gamma if $V(\mu) = \mu^2$, etc. Some detailed discussion on GLMs approach is given in [20-25].

3. Aanalyses and Interpretation of Carp Seed Production Data

This study is based on the carp seed production data sets which have been collected from some local hatchery breeding pools located in Birbhum and Burdwan districts. Three data sets of seed production for Rohu (24), Mrigal (21) and Catla (12) have been collected. For each study unit the following characters have been recorded: 1. Female fish age (fAGE) (in years), 2. Female fish weight (fWET) (in Kg), 3. Size of female fish (fSIZ) (in Inch), 4. Female fish 1st Dose (f1st-D) (mg), 5. Female fish 2nd Dose (f2nd-D) (mg), 6. Male fish weight (mWET) (in Kg), 7. Male fish 1st Dose (m1st-D)(mg), and 8. Produced seeds (in Bowels). These three data sets are not given in the paper as it would increase the length of the paper, but we can submit our data sets to verify our results.

3.1. Analysis of Mrigal's Seed Production Data

Generally, positive data sets are analyzed either by log-normal or gamma models [8, 9, 12-16]. In this section, we have analyzed the Mrigal's seed production data using both the log-normal and gamma models (Section 2), to confirm our findings. In the present analysis, Mrigal's seed produced is treated as the response variable (y), and the remaining others are considered as the explanatory variables. It has been identified that the variance of the response is non-constant. Thus, we fit the data using both the joint log-normal and gamma models as in Section 2, and the results are displayed in Table 1. The selected models have the smallest Akaike information criterion (AIC) value in each class. It is well known that AIC selects a model which minimizes the predicted additive errors and squared error loss [26]. It is not necessary that all the selected effects are significant [26]. It is found that both the models give identical results (Table 1) (with respect to AIC, estimates and standard errors). Here we plot the graphical analysis of gamma model fit.

Table-1. Results for mean and dispersion models of Mrigal's seed production from lognormal and gamma fit

			log-normal model				gamma model		
	Covar.	**estimate**	**s.e.**	**T**	**P-value**	**estimate**	**s.e.**	**t**	**P-value**
Mean	Const.	1.87	0.02	81.49	<0.01	1.87	0.02	81.09	<0.01
model	fAGE	−0.02	0.01	−2.59	0.01	−0.02	0.01	−2.55	0.01
	fWET	0.08	0.01	6.17	<0.01	0.08	0.01	6.14	<0.01
	fSIZ	−0.002	<0.01	−1.86	0.07	−0.002	<0.01	−1.85	0.07
	f1st-D	0.02	0.01	3.50	<0.01	0.02	0.01	3.47	<0.01
	mWET	−0.04	0.01	−5.14	<0.01	−0.04	0.01	−5.11	<0.01
Dispers.	Const.	−15.26	3.71	−4.12	<0.01	−15.22	3.72	−4.09	<0.01
model	fAGE	4.72	1.20	3.92	<0.01	4.69	1.21	3.88	<0.01
	fWET	−7.61	1.49	−5.12	<0.01	−7.55	1.49	−5.08	<0.01
	m1st-D	−0.11	0.09	−1.23	0.24	−0.11	0.09	−1.23	0.24
AIC			−50.55				−50.51		

In Figure 1(a), we plot the absolute value of residuals, with respect to fitted values. Figure 1(a) has a flat running means, an indication that the variance is not increasing with mean [22]. Figure 1(b) displays the normal probability plot for the mean model (Table 1). Figure 1(b) does not show any lack of fit with respect to variables and outliers, as there is not any gap in the figure. Neither figure shows any systematic departures, indicating no lack of fit of our selected final model (Table 1).

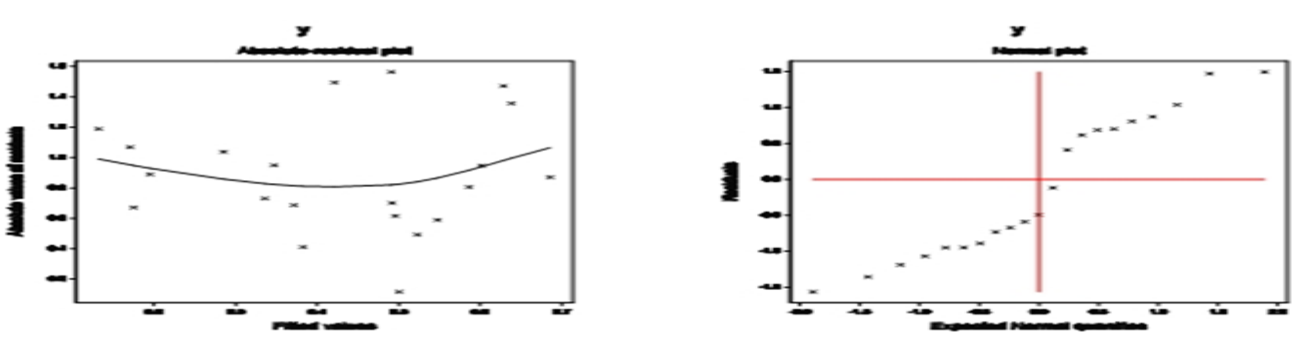


Figure-1. For the gamma fitted models (Table 1) of Mrigal seeds data, (a) the absolute residuals plot with respect to fitted values and (b) the normal probability plot of mean

From Table 1 the following may be interpreted:
1. Female Mrigal fish age is negatively associated with the mean seed production. This indicates that the amount of seed production is lower in higher age.
2. Female Mrigal fish weight is positively associated with the mean seed production. This indicates that the amount of seed production is higher for a fish with higher weight, and vice-versa.
3. The length of female Mrigal fish is inversely associated with the mean seed production. This implies that the amount of seed production is higher for a fish with lower length.
4. For female Mrigal fish, the 1st dose is directly associated with the mean seed production. This means that as the amount of 1st dose increases, the amount of seed production increases.
5. Male Mrigal fish weight is inversely associated with the mean seed production. It implies that the amount of seed production increases if the weight of male Mrigal fish is lower.
6. The variance of Mrigal seed production is positively associated with the female Mrigal age. This indicates that the variance is higher at higher age.
7. The variance of Mrigal seed production is negatively associated with the female Mrigal weight. It implies that the variance is higher for a fish with lower weight.

3.2. Analysis of Rohu's Seed Production Data

In the present section, Rohu's seed produced is treated as the response variable (y), and the remaining others are considered as the explanatory variables. It is found that the variance of the response is non-constant. Therefore, we fit the data using both the joint log-normal and gamma models as in Section 2, and the results are displayed in Table 2. The selected models have the smallest AIC value in each class. Here it is found that the mean parameter estimates from both the models are exactly identical, but the dispersion parameters are not same (Table 2). Note that in log-normal model fit (Table 2), 'fAGE' (in dispersion model) is aliased with the other explanatory variables. Based on AIC rule, the gamma model fit is more better than the log-normal model. Thus, we plot only the graphical analysis of gamma model fit.

Table-2. Results for mean and dispersion models of Rohu's seed production from lognormal and gamma fit

			log-normal model				**gamma model**		
	Covar.	**estimate**	**s.e.**	**T**	**P-value**	**estimate**	**s.e.**	**t**	**P-value**
Mean	Const.	2.20	0.21	10.58	<0.01	2.20	0.06	39.50	<0.01
model	fAGE	−0.21	0.05	−3.89	<0.01	−0.21	0.02	−11.41	<0.01
	fWET	0.50	0.03	16.93	<0.01	0.50	0.03	16.94	<0.01
	f1st-D	−0.05	0.02	−2.86	0.01	−0.05	0.02	−2.87	0.01
	f2nd-D	−0.02	0.01	−3.70	<0.01	−0.02	0.01	−3.68	<0.01
Dispers.	Const.	−11.49	1.52	−7.58	<0.01	16.42	1.502	10.93	<0.01
model	fAGE	-	-	-	-	−6.98	<0.01	9.78	<0.01
	fWET	−5.39	3.60	−1.50	0.15	−5.40	3.39	−1.60	0.13
	2nd-D	0.97	0.43	2.23	0.02	0.97	0.41	2.36	0.02
AIC			− 45.17				− 52.24		

In Figure 2(a), we plot the absolute value of residuals, with respect to fitted values. Figure 2(a) has a flat running means, an indication that the variance is not increasing with the running means. Figure 2(b) reveals the normal probability plot for the mean model (Table 2). Figure 2(b) does not show any systematic departure, indicating no lack of fit.

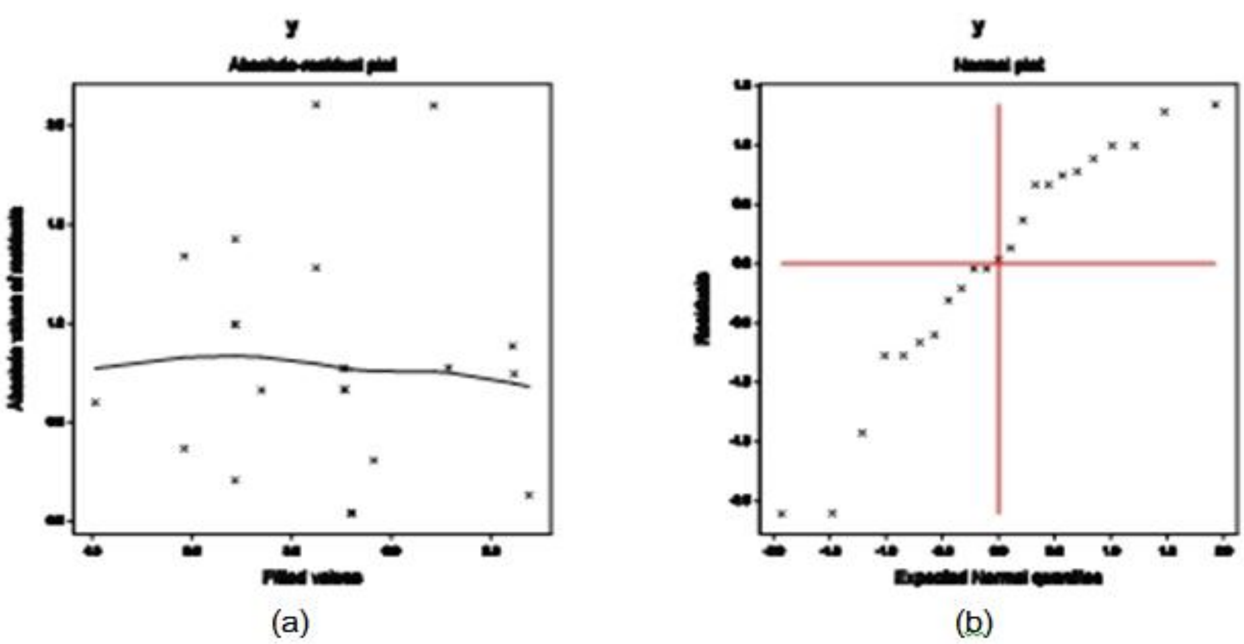


Figure-2. For the gamma fitted models (Table 2) of Rohu seeds data, (a) the absolute residuals plot with respect to fitted values and (b) the normal probability plot of mean

From Table 2 (fitted gamma model) the following may be interpreted:
1. Female Rohu fish age is negatively associated with the mean seed production. This indicates that the amount of seed production is lower in higher age.
2. Female Rohu fish weight is positively associated with the mean seed production. This indicates that the amount of seed production is higher for a fish with higher weight, and vice-versa.

3. For female Rohu fish, the 1st dose is negatively associated with the mean seed production. This means that as the amount of 1st dose increases, the amount of seed production decreases.
4. For female Rohu fish, the 2nd dose is negatively associated with the mean seed production. This means that as the amount of 2nd dose increases, the amount of seed production decreases.
5. The variance of Rohu seed production is negatively associated with the female Rohu age. This indicates that the variance is higher at lower age.
6. The variance of Rohu seed production is negatively associated with the female Rohu weight. It implies that the variance is higher for a fish with lower weight.
7. The variance of Rohu seed production is positively associated with the female 2nd dose, indicating that the variance increases with the increased of female 2nd dose, and vice-versa.

3.3. Analysis of Catla's Seed Production Data

In the present section, Catla's seed produced is treated as the response variable (y), and the remaining others are considered as the explanatory variables. It is found that the variance of the response is non-constant. Therefore, we fit the data using both the joint log-normal and gamma models as in Section 2, and the results are displayed in Table 3. The selected models have the smallest AIC value in each class. Table 3 shows that both the models give identical results (with respect to AIC, estimates and standard errors). Note that '0.0∗' indicates that the first three digits after the decimal are zeros (Table 3). For graphical analysis, we consider the gamma fitted models.

Table-3. Results for mean and dispersion models of Catla's seed production from lognormal and gamma fit

			log-normal model				**gamma model**		
	Covar.	**estimate**	**s.e.**	**t**	**P-value**	**estimate**	**s.e.**	**T**	**P-value**
Mean	Const.	13.06	0.03	405.1	<0.01	13.06	0.03	406.9	<0.01
model	fAGE	0.03	0.01	5.9	<0.01	0.03	0.01	5.9	<0.01
	fWET	0.0∗	<0.01	9.8	<0.01	0.0∗	<0.01	9.8	<0.01
Dispers.	Const.	−1.61	1.28	−1.26	0.24	−1.63	1.28	−1.28	0.23
model	1st-D	−4.46	0.78	−5.72	<0.01	−4.46	0.78	−5.71	<0.01
AIC			238.20				238.09		

In Figure 3(a), we plot the absolute value of residuals, with respect to fitted values. Figure 3(a) is almost a flat diagram with the running means, except the right tail. Right tail is increasing due to a large boundary value. Figure 3(b) presents the normal probability plot for the mean model (Table 3). Figure 3(b) does not show any systematic departure, indicating no lack of fit.

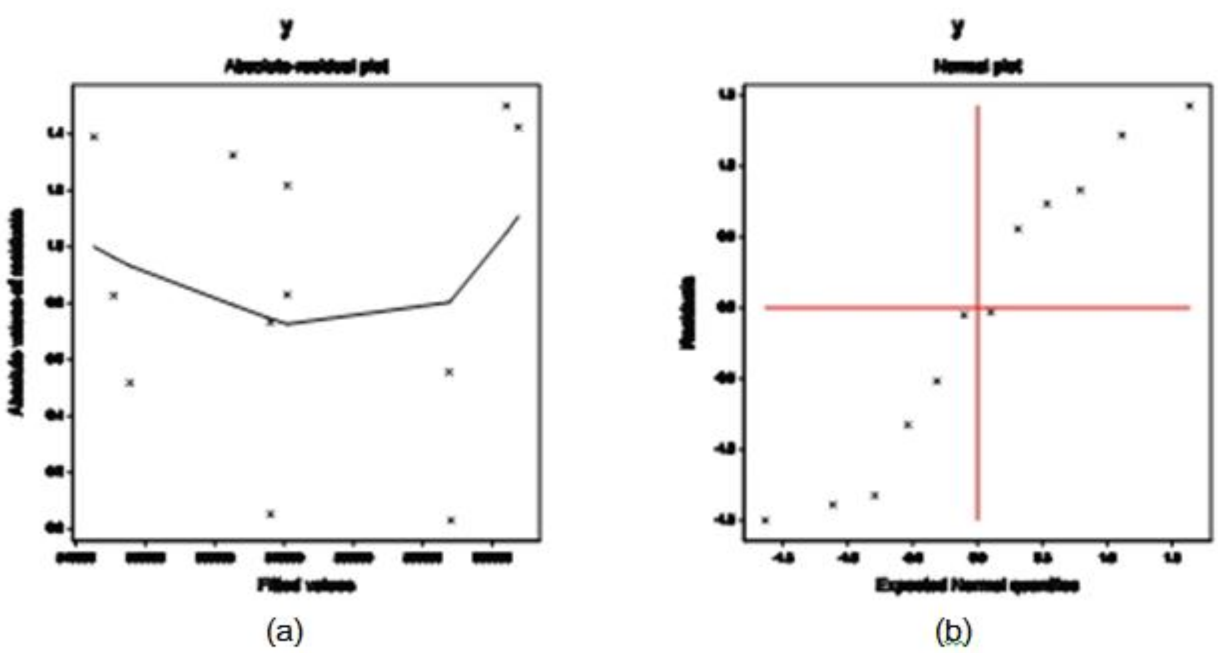


Figure-3. For the gamma fitted models (Table 3) of Catla seeds data, (a) the absolute residuals plot with respect to fitted values and (b) the normal probability plot of mean

From Table 3 the following may be concluded:
1. Female Catla fish age is positively associated with the mean seed production. This indicates that the amount of seed production is higher at higher age.
2. Female Catla fish weight is positively associated with the mean seed production. This indicates that the amount of seed production is higher for a fish with higher weight, and vice-versa.
3. For female Catla fish, the 1st dose is negatively associated with the variance of seed production. This means that as the amount of 1st dose increases, the variance of seed production decreases.

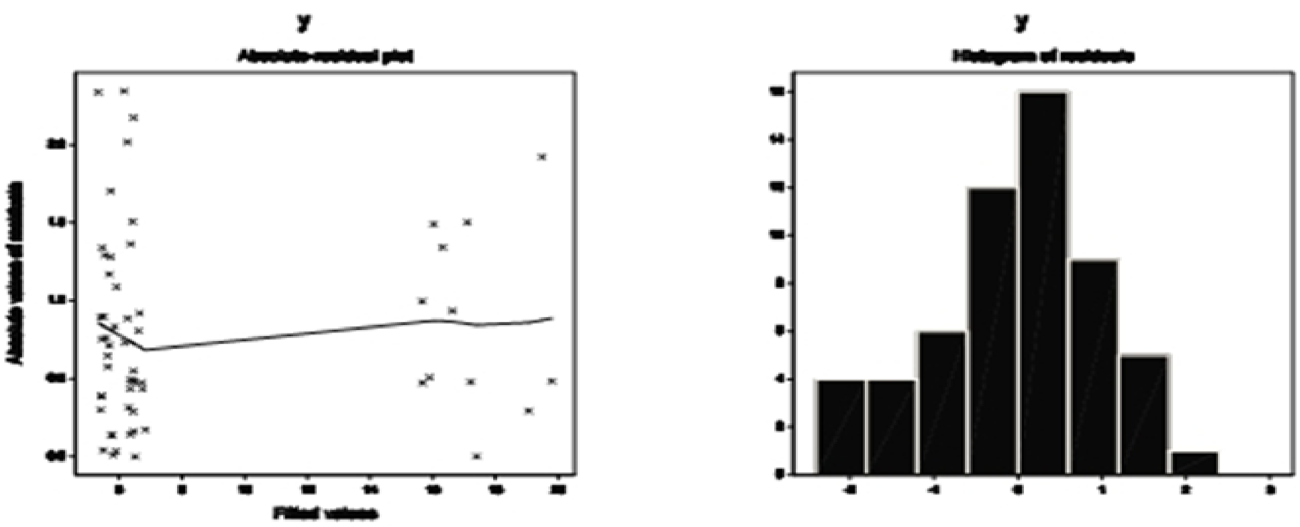
3.4. Analysis of Rohu, Mrigal and Catla's Seed Production Data

In the present section, seed produced by carps (Rohu, Mrigal and Catla) is treated as the response variable (y), and the remaining others are considered as the explanatory variables. We level Rohu by 1, Mrigal by 2 and Catla by 3. Type of carp is denoted by 'TYP'. For factors, we accept the constraint that the effects of the first levels are zero. That is, we take the first level of each factor as the reference level by estimating its as zero. Suppose that α_i for i = 1, 2, 3 represents the main effect of A. We take $\alpha_1 = 0$, so that $\alpha_2 = \alpha_2 - \alpha_1$. For example, the estimate for the effect A2 means the effect of difference between the second and the first levels in the main effect A, i.e., $\alpha_2 – \alpha_1$. It is found that the variance of the response is non-constant. Therefore, we fit the data using both the joint log-normal and gamma models as in Section 2, and the results are displayed in Table 4. The selected models have the smallest AIC value in each class. Table 4 shows that both the models give identical results (with respect to AIC, estimates and standard errors). Note that ‘0.0∗’ indicates that the first three digits after the decimal are zeros (Table 4). For graphical analysis, we consider the gamma fitted models.

Table-4. Results for mean and dispersion models of Rohu, Mrigal and Catla’s seed production from log-normal and gamma fit

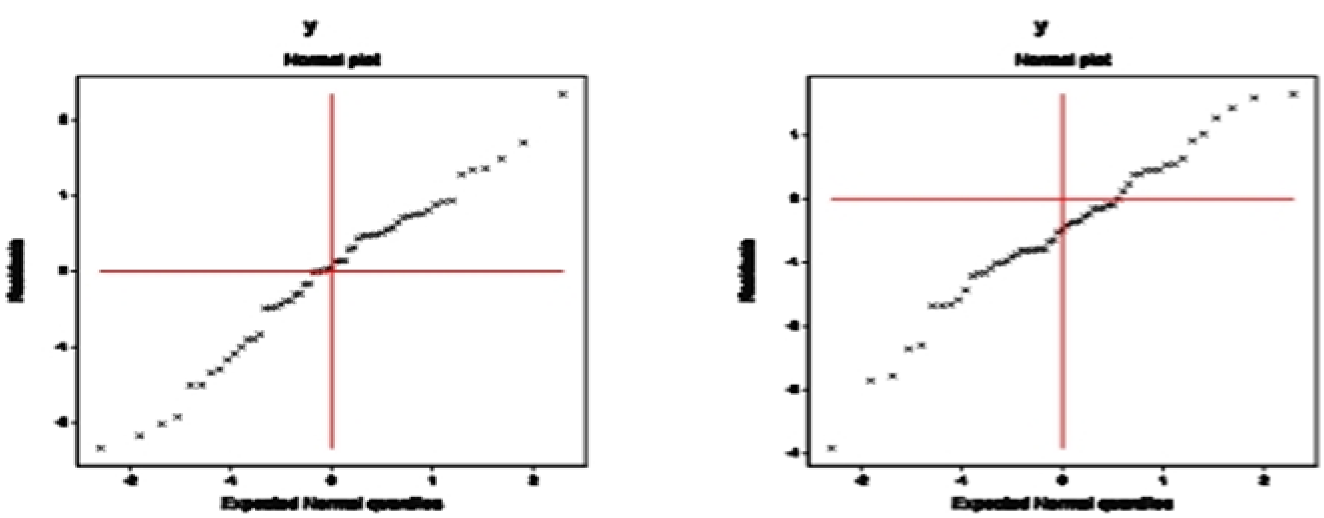
			log-normal model				gamma model		
	Covar.	**estimate**	**s.e.**	**t**	**P-value**	**estimate**	**s.e.**	**T**	**P-value**
Mean	Const.	1.51	0.07	23.11	<0.01	1.52	0.07	23.31	<0.01
Model	fAGE	−0.05	0.02	−2.97	0.01	−0.05	0.02	−2.96	0.01
	fWET	−0.0∗	<0.01	−2.04	0.03	−0.0∗	<0.01	−1.94	0.05
	fSIZ	0.02	0.01	3.15	<0.01	0.02	0.01	3.10	<0.01
	f1st-D	0.09	0.03	2.73	0.01	0.09	0.03	2.75	0.01
	m2nd-D	0.003	0.001	2.19	0.03	0.003	0.001	2.20	0.03
	TYP2	0.07	0.02	4.10	<0.01	0.07	0.02	4.09	<0.01
	TYP3	0.68	0.13	5.31	<0.01	0.68	0.13	5.36	<0.01
Dispers.	Const.	−2.54	1.15	−2.20	0.03	−2.54	1.15	−2.22	0.03
Model	1st-D	0.002	0.001	2.82	0.01	0.002	0.001	2.84	0.01
	fSIZ	−0.18	0.06	−2.90	0.01	−0.18	0.06	−2.92	0.01
AIC			47.80				47.43		

In Figure 4(a), we plot the absolute value of residuals, with respect to fitted values. Figure 4(a) is a flat diagram with the running means, indicating that the variance is constant under the structured gamma fitted models (Table 4). Figure 4(b) displays the histogram of the residuals. There is no gap between the bars of the histogram, indicating that there is no lack of fit of the selected models. Figures 5(a) and 5(b) display, respectively, the normal probability plot for the mean and variance models (Table 4). Both the figures do not show any lack of fit of the selected models (Table 4).



(a) (b)

Figure-4. For the gamma fitted models (Table 4) of Rohu, Mrigal & Catla seeds data, (a) the absolute residuals plot with respect to fitted values and (b) the histogram plot



(a) (b)

Figure-5. For the gamma fitted models (Table 4) of Rohu, Mrigal & Catla seeds data, the normal probability plot for the (a) mean and (b) dispersion

From Table 4 the following may be interpreted:

1. Female fish (Rohu, Mrigal and Catla) age is negatively associated with the mean seed production. This indicates that the amount of seed production is lower in higher age.
2. Female fish (Rohu, Mrigal and Catla) weight is positively associated with the mean seed production. This indicates that

the amount of seed production is higher for a fish with higher weight, and vice-versa.
3. The length of female fish (Rohu, Mrigal and Catla) fish is positively associated with the mean seed production. This implies that the amount of seed production is higher for a fish with higher length.
4. For female fish (Rohu, Mrigal and Catla), the 1st dose is directly associated with the mean seed production. This means that as the amount of 1st dose increases, the amount of seed production increases.
5. The male 2nd dose is positively associated with the mean seed production of craps (Rohu, Mrigal and Catla), indicating that as the male 2nd dose increases, carp seed production also increases.
6. We have leveled Rohu by 1, Mrigal by 2 and Catla by 3. Type of carp (TYP) is positively associated. It indicates that seed production is higher for Mrigal and Catla than Rohu.
7. The variance of carps (Rohu, Mrigal and Catla) seed production is positively associated with the female carp's weight. It implies that the variance is higher for a fish with higher weight.
8. The variance of carps (Rohu, Mrigal and Catla) seed production is negatively associated with the female carp's length. It indicates that the variance is higher for a fish with lower length.

4. Concluding Remarks

Response 'carp seed production' has been modeled separately for Mrigal, Rohu and Catla, and also jointly for all seeds together (using a new variable as types of carps). Here it is identified that the carp seed production is a non-constant variance response. Thus, we have fitted both the joint log-normal and gamma models to confirm our analysis. It is well-known that a non-constant variance positive response data set to be analyzed by both the log-normal and gamma models [9, 16, 22]. Fitted models are given in Section 3. Final models are selected based on AIC and graphical analysis. Analyses show that carp seed production fits well the gamma JGLMs.

The present report shows that the separate analysis gives a clear nature of the specific carp seed production. It is identified that the same factors (except the female fish weight) are not significant for all the three types of carp. Note that the effect of female fish age, her weight, and her 1st dose on the carp seed production have some common nature (from Tables 1, 2, 3 and Table 4) for some types of carp. From Table 1 and Table 2, it is observed that Mrigal and Rohu have many similar common effects, but Catla has only one common effect (female fish weight) with Rohu and Mrigal.

To the best of our knowledge, this report has first time derived the variance components in fisheries data analysis. Log-normal and gamma models with constant variance have been suggested by Brynjarsdottir and Stefansson [6], Dick [7] in fisheries research. But these authors have pointed that the variance may not be constant always. For non-constant variance, these authors could not suggest any methodology. So far no author has not derived the variance components in carp seed production data. Moreover, the factors derived herein in the mean and variance models of carp seed production data are also new edition in the fisheries research literature.

This particular research presents the association and the effects of different causal factors on carp seed production, which will be helpful to aquaculture farmers for taking fruitful action. To fill-up the gaps in the fisheries research literature, this study derives the relationships of carp seed production to a few explanatory variables. The mathematical models (in Tables 1, 2, 3 and 4) in this report show the relationships of carp seed production with the other explanatory variables. The models reported here illuminate the complex relationships. Fortunately, a true mathematical model can open the truth that is covered by the complex relationships. Our results, though not completely conclusive, are revealing-
* Our findings confirm many previous research findings (Section 3).
*An important conclusion has to do with the use of earlier used statistical models. While further research is called for, we find that the joint gamma models are much more effective than either traditional simple, multiple regression or Log-Gaussian models (with constant variance), because they better fit the data. In short, research should have greater faith in these results than those emanating from the simple, multiple regression or Log-Gaussian (with constant and non-constant variances) models.

To increase the carp seed production, this study suggests the following: age of female fish for Rohu and Mrigal should not be very high (Tables 1, 2, 4), while the age of female Catla may be high (Table 3); weight of carp female fish should be high (Tables 1, 2, 3, 4); size of the female is also important to increase the carp seed production. The size of Mrigal is to be lower (Table 1), while the size of Rohu or Catla is to be bigger (Table 4). Female 1st dose increases the carp seed production (Tables 1, 4). Female 2nd dose is to be lower to increase the carp seed production (Table 2). Male fish weight should not be to high (Table 1). It is expected that ponds soil and water quality may have some effects on the carp seed production. In our subsequent article, we propose to discuss this problem, which is currently under investigation.

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