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Determination of Fishery Micro Insurance Premium Prices using Poisson-Exponential Aggregate Distribution Approach

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Abstract

Engaging in pond aquaculture is currently an attractive option amid the high demand for fish in the market. Entrepreneurial opportunities in the pond fish farming sector are increasingly open, although the risk of crop failure remains, both due to weather factors and the livestock process. Crop failure can have a significant financial impact on pond aquaculture cultivators. Therefore, it is necessary to have special insurance to protect against financial losses due to risks that can occur, namely Fisheries Micro Insurance. Microinsurance is a type of insurance product that is specifically designed for low-income people, offering simple, accessible, economically priced features and administration, and a fast compensation settlement process. The focus of this research is to calculate premium prices by applying an aggregate risk model approach. The data used is the number of incidents and the amount of losses due to crop failure in shrimp pond cultivation in Pandeglang Regency in the period of January 1, 2019-January 1, 2021. Data on the number of events follows the Poisson distribution, while data on the magnitude of losses follows the Exponential distribution. Furthermore, the *Maximum Likelihood Estimation* (MLE) method is used to calculate the parameter estimation. The average and variance estimates of the aggregate risk are used to determine the amount of premiums. The result of the premium selection in this study is IDR 42,005,600. The amount of premium reflects the collective premium resulting from the calculation based on the standard deviation principle.

Keywords: Fisheries Micro Insurance, premium determination, aggregate risk model, poisson distribution, exponential distribution.

1. Introduction

Entrepreneurial opportunities in the aquaculture sector are increasingly wide open, presenting lucrative profit prospects for cultivators (Muir, 2005). However, in pond aquaculture, it is inseparable from risks, especially in the context of the risk of crop failure. Based on this, this study focuses on managing financial risks in pond aquaculture through the application of Fisheries Micro Insurance (Krishnan, 2022).

Microinsurance is considered a potential solution to protect pond aquaculture farmers from the financial impact that may arise due to the risk of crop failure (Nguyen, 2019). Therefore, this study focuses on calculating premium prices by applying an aggregate risk model approach. By collecting and analyzing data from shrimp pond cultivation in Pandeglang Regency, this study aims to contribute to determining microinsurance premiums that are in accordance with local risk characteristics.

The results of this study will be the basis for determining the amount of premiums that reflect the level of risk faced by pond aquaculture cultivators in the region. This research is expected to provide a deeper understanding of the risks and benefits of fisheries microinsurance in the context of pond aquaculture, as well as provide a foundation for wider implementation at the local and regional levels.

2. Theory

Fadhilah (2023) conducted a study entitled "Determination of Insurance Premiums for Losses Due to Crop Failure in Pond Cultivation with the Principle of Expected Value". The results of the study show that the premium value of fishermen's losses due to not going to sea is based on the expectation principle of IDR25,893,046.00 and with the principle of standard deviation of IDR23,539,132.00. Meanwhile, research by Kusumadewi (2022) entitled "Determination of Fishermen's Micro Insurance Premium Prices Using the Aggregate Risk Model Approach in Cirebon Regency" also provides an understanding of the determination of microinsurance premium prices for fishermen. The results of this study show that the premium value of fishermen's losses due to not going to sea is based on the expectation principle of IDR162,547,612.00 and with the standard deviation principle of IDR153,861,958.00. Both studies provide an important foundation related to risk assessment and premium determination. Based on this, this study will apply the expectation principle to the aggregate risk model to determine the price of fisheries microinsurance premiums, especially in the context of shrimp pond cultivation in Pandeglang Regency.

3. Objects and Methods

3.1. Object

The object used in this study is data on crop failures experienced by fishery cultivators sourced from the research of Septiana (2022). From this data, microinsurance premiums will be calculated using the aggregate risk model approach. The data used is data on losses from the capture of shrimp ponds that fail to harvest in Pandeglang Regency. The tools used are *Microsoft Excel* and Easyfit software.

3.2. Method

3.2.1. Discrete Random Variable Distribution

The distribution used is the Poisson distribution which is to find out the many frequencies of events (Evans, 2006). Random variables N Poisson distributed with parameters $\lambda > 0$ if it has the following probability function:

$$P(N = x) = e^{-\lambda}\frac{\lambda^x}{x!}. \tag{1}$$

The moment generator function of equation (1) is as follows:

$$M_N(t) = \sum_{x=0}^{\infty} e^{tx}e^{-\lambda}\frac{\lambda^x}{x!} = exp\{\lambda(e^t - 1)\}. \tag{2}$$

The function of the opportunity generator from equation (2) is as follows:

$$P(r) = \sum_{x=0}^{\infty} r^x e^{-\lambda}\frac{\lambda^x}{x!} = exp\{\lambda(r - 1)\}. \tag{3}$$

Based on equation (3), the expectations and variances of Poisson's distribution are obtained as follows:

$$E(N) = \lambda \tag{4}$$

$$Var(N) = \lambda. \tag{5}$$

To estimate the parameters of the Poisson distribution, suppose $N_1, N_2, \ldots, N_n$ is a random sample of a population distributed by Poisson with the parameter λ.

$$L(\lambda) = \prod_{i=1}^{n} f(x_i, \lambda) = \frac{e^{-n\lambda}\lambda^{\Sigma x_i}}{\prod_{i=1}^{n} x_i!} \tag{6}$$

$$\ln L(\lambda) = -n\lambda \ln e + \Sigma x_i \ln \lambda - \ln \prod_{i=1}^{n} x_i!. \tag{7}$$

Estimation of Poisson distribution parameters is obtained by maximizing the $\ln L(\lambda)$ in equation (7) as follows:

$$\frac{d(\ln L(\lambda))}{d\lambda} = 0, \tag{8}$$

so that it is obtained

$$\hat{\lambda}_{MLE} = \frac{\Sigma \mathrm{x_i}}{n} \tag{9}$$

3.2.2. Continuous Random Variable Distribution

The distribution used is an Exponential distribution (Carlton, 2017). Random variables X Exponentially distributed with parameters μ if it has the following opportunity density function:

$$f(x) = \frac{1}{\mu} e^{-\frac{x}{\mu}}. \tag{10}$$

Based on equation (10), the distribution function for $x > 0$ are as follows:

$$F(x) = -e^{-\frac{x}{\mu}}. \tag{11}$$

Moment generator function of X are as follows:

$$M_X(t) = \frac{1}{1 - \mu t}, t < \mu, \tag{12}$$

So that you get a moment n of the exponential distribution is as follows:

$$E(X^n) = n!\, \mu^n. \tag{13}$$

Based on equation (10), expectations and variances are obtained from the Exponential distribution:

$$E(X) = \mu \tag{14}$$

$$Var(X) = \mu^2 \tag{15}$$

To estimate the parameters of an Exponential distribution, suppose $X_1, X_2, \dots, X_n$ is a random sample of an exponentially distributed population with the parameter μ.

$$L(\mu) = \prod_{i=1}^{n} f(x_i, \mu) = \left(\frac{1}{\mu}\right)^n e^{-\frac{1}{\mu}\sum_{i=1}^{n} x_i} \tag{16}$$

$$\ln L(\mu) = -n \ln \mu - \frac{1}{\mu}\sum_{i=1}^{n} x_i. \tag{17}$$

Exponential distribution parameter estimation is obtained by maximizing the $\ln L(\lambda)$ in equation (17) as follows:

$$\frac{d(\ln L(\mu))}{d\mu} = 0. \tag{18}$$

so that it is obtained

$$\hat{\mu}_{MLE} = \bar{x}. \tag{19}$$

3.2.3. Distribution Conformity Test

The distribution suitability test used is Kolmogorov Smirnov and Chi-Square.

$$D = \max\{|F_k(x) - F_0(x)|\} \tag{20}$$

H_0 : data follows a specific distribution
H_1 : data does not follow a specific distribution
The assumption of the distribution decision is H_0 if $D > D_{tabel}$.

$$\chi h^2 = \sum_{i=1}^{G} \frac{(O_i - E_i)^2}{E_i}, \tag{21}$$

with
χh^2 : Calculated chi-squared parameters
G : Number of subgroups
O_i : Number of observation values in sub-groups i
E_i : the number of theoretical values in sub-groups i

3.2.4. Collective Risk Model

The collective risk model is formulated as follows:

$$S = X_1 + X_2 + \cdots + X_{N(t)} = \sum_{i=1}^{N(t)} X_i, \tag{22}$$

with N is a random variable that states the number of events and $X_1, X_2, \dots, X_{N(t)}$ is a random variable that states the amount of loss. From equation (22), the expectations and variances of the collective risk are obtained as follows:

$$E(S) = E(N)E(X) \tag{23}$$

$$Var(S) = E(N)Var(X) + Var(N)(E(X))^2 \tag{24}$$

3.2.5. Premium Calculation Model

The premium calculation model with the principle of expected value is formulated as follows:

$$p(t) = (1+\alpha)E\big(S(t)\big), \tag{25}$$

with $0 < \alpha < 1$.

Meanwhile, the premium calculation model with the principle of standard deviation is formulated as follows:

$$p(t) = E\big(S(t)\big) + \alpha\sqrt{Var\big(S(t)\big)}, \tag{26}$$

with $0 < \alpha < 1$.

4. Results and Discussion

The data used in this study was obtained through a survey conducted by Septiana (2022). The data includes crop losses that occurred to shrimp farmers in Pandeglang Regency in the period from January 2019 to January 2021. Loss data can be classified into two categories, namely data on the number of events and data on the amount of losses.

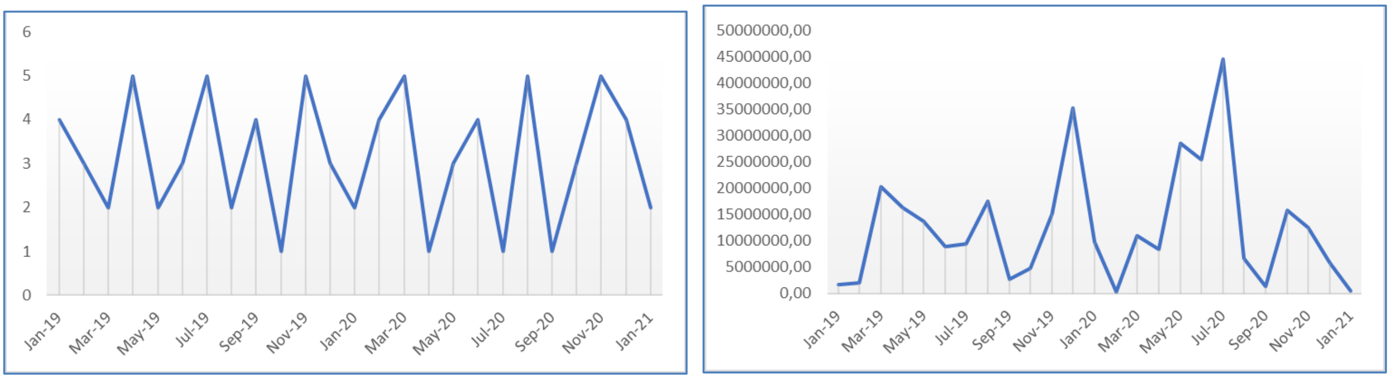

Figure 1: (a) Data on the number of crop failure incidents, (b) Data on the amount of crop failure losses

In determining the amount of premiums that must be paid by shrimp farmers as a preparatory step to face potential losses due to crop failure, it can be done by assessing the expectations and variances of the risk of collective losses. Furthermore, the estimator is applied to formulate the amount of premiums with a premium model of the expectation principle and standard deviation. In this study, the data processing and calculation process uses the help of *Microsoft Excel and EasyFit* software.

4.1 Model of Occurrence

The process of identifying the distribution model is carried out by creating a frequency distribution histogram that records the number of events. From the results of the processing, it is obtained as shown in Figure 2.

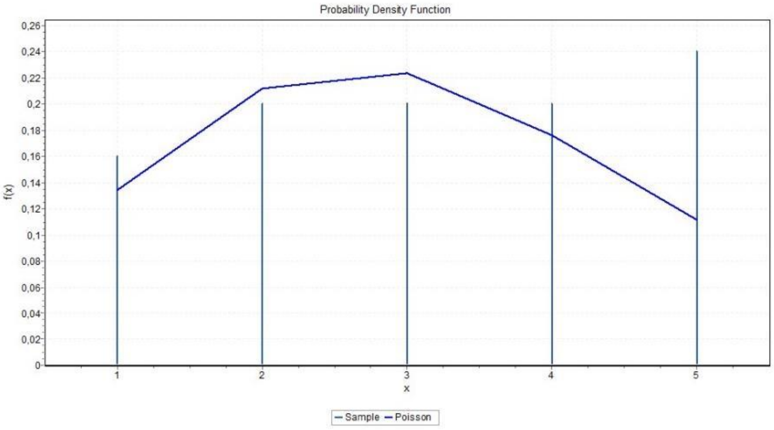

Figure 2: Histogram and Data Curve of Occurrence

Based on Figure 2, it can be assumed that the data on the number of crop failure events following the Poisson distribution will then be carried out a distribution suitability test using *the Kolmogorov-Smirnov* test at the significance level of 95% depicted in Table 1.

Table 1: Results of the Kolmogorov-Smirnov Compatibility Test of Poisson Distribution on the Data of the Number of Events

Many Events	Test Statistics (D)	0.25143
	D_{tabel}	0.26404
	Result	$D < D_{tabel}$ or 0.25143 < 0.26404
	Conclusion	H_0 received, data on the number of Poisson distributed events

Furthermore, the parameter of the number of events will be assessed using the *Maximum Likelihood Estimation* (MLE) method of the Poisson distribution which refers to equation (8).

$$\frac{d(\ln L(\lambda))}{d\lambda} = 0$$
$$\frac{d\left(-25\lambda \ln e + \sum_{i=1}^{25} x_i \ln \lambda - \ln \prod_{i=1}^{25} x_i!\right)}{d\lambda} = 0$$
$$-25 + \frac{\sum_{i=1}^{25} x_i}{\hat{\lambda}} = 0$$
$$\hat{\lambda}_{MLE} = \frac{\sum_{i=1}^{25} x_i}{25}$$
$$\lambda = 3.16. \tag{27}$$

The next step is the calculation of collective risk using the expected value based on equation (4) and variance based on equation (5) of Poisson's distribution with the $\lambda = 3.16$. The function of the opportunity density of the Poisson distribution is as follows:

$$P(N = x) = \frac{e^{-3.16}(3.16)^x}{x!}, \tag{18}$$

so that the expected value is obtained $E(N) = \lambda = 3.16$ and the value of the variance $Var(N) = \lambda = 3.16$.

4.2 The Model of the Big Losses

The process of identifying the distribution model is carried out by making a frequency distribution histogram that records the magnitude of the loss. From the results of the processing, it is obtained as shown in Figure 3.

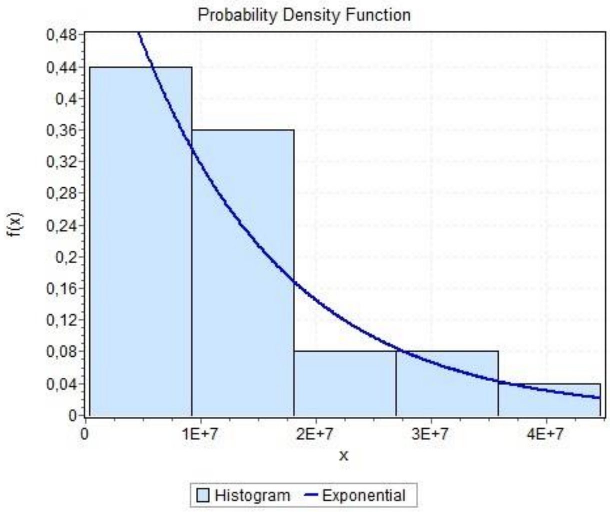

Figure 3: Histogram and Data Curve of the Amount of Loss

Based on Figure 3, it can be assumed that the data on the magnitude of crop failure losses follows the Exponential distribution, which will then be tested for the suitability of the distribution using *the Chi-Square* test at the level of 95% significance depicted in Table 2.

Table 2: Results of the Chi-Square Match Test Exponential Distribution on the Data of the Amount of Loss

Many Events	Test Statistics (χ^2)	0.26409
	χ^2_{cr}	2.5018
	Result	$\chi^2 < \chi^2_{cr}$ or 0.26409 < 2.5018
	Conclusion	H_0 received, data on the number of events distributed exponentially

Furthermore, the parameter of the number of events will be assessed using the *Maximum Likelihood Estimation* (MLE) method from the Exponential distribution referring to the equation (18).

$$\frac{d(\ln L(\mu))}{d\mu} = 0$$

$$-\frac{25}{\hat{\mu}} + \frac{1}{\hat{\mu}^2}\sum_{i=1}^{25} x_i = 0$$

$$\hat{\mu} = \frac{1}{25}\sum_{i=1}^{25} x_i$$

$$\hat{\mu}_{MLE} = \bar{x}$$

$$\mu = 12.784.367. \tag{29}$$

The next step is the calculation of collective risk using the expected value based on equation (14) and variance based on equation (15) of the Exponential distribution with parameters $\mu = 12{,}784{,}367$. The function of the opportunity density of the Exponential distribution is as follows:

$$F(x;\mu) = \int_0^z \mu e^{-\mu x}, \tag{30}$$

so that it is obtained $E(N) = \mu = 12{,}784{,}367$ and $Var(N) = \mu^2 = (12{,}784{,}367)^2 = 163{,}440{,}039{,}590{,}689$.

4.3 Risk Calculation and Premium Value

The next step is to calculate the risk level as a whole. The estimated value of expectations and the variance of collective risk can be calculated using equations (23) and (24).

$$E(S) = (3.16)(12{,}784{,}367) = 40{,}398{,}600 \quad (31)$$

$$Var(S) = (3.16)(163{,}440{,}039{,}590{,}689) + (3.16)(12{,}784{,}367)^2 = 1{,}032{,}941{,}050{,}213{,}154. \quad (32)$$

When determining the amount of premium value, the main factors that are taken into account involve how much loss is experienced by shrimp farmers and the number of failures during the harvest period. Applying the principle of expected value in accordance with equation (25), the calculation of the premium value is as follows:

$$p(t) = (1 + 0.1) \cdot 40{,}398{,}600 = 44{,}438{,}460. \quad (33)$$

Furthermore, by applying the principle of standard deviation based on equation (26), the premium calculation is as follows:

$$p(t) = 40{,}398{,}600 + 0.05\sqrt{1{,}032{,}941{,}050{,}213{,}154} = 42{,}005{,}600. \quad (34)$$

Thus, a premium amount is obtained that can function as a storage fund to overcome losses that may be experienced by shrimp farmers during the harvest period. This is achieved through the application of the principle of expected value and the principle of standard deviation obtained from the overall estimate of loss risk as illustrated in Table 3.

Table 3: Calculation of the Largest Premium Loss of Shrimp Ponds Experiencing Crop Failure

Calculation Method	Premium Amount/year
Principle of Expectations	IDR 44,438,460
Standard Principles of Deviation	IDR 42,005,600

The results of the premium calculation are used as a reference for insurance companies in determining the amount of individual microinsurance premiums that must be paid by shrimp farmers. The premium value of IDR 42,005,600 was chosen because the value is lower than other calculations so that it can produce a lower individual premium price also by the insurance company.

5. Conclusion

Based on data analysis and discussion of research results, several conclusions can be drawn. First, in the period from January 1, 2019 to January 1, 2021, it shows that the number of crop failure incidents is in the range of 1 to 5 times, while the data related to losses covers the range of IDR 345,724 to IDR 44,671,851. Second, the data from the number of crop failure incidents is data that follows the Poisson distribution with estimated parameters λ as $\lambda = 3{,}16$. Estimation of expectations and variances of Poisson's distribution is $E(N) = 3.16$ and the value of the variance $Var(N) = 3.16$. Meanwhile, the data on the magnitude of crop failure losses follows the Exponential distribution with parameter estimates μ as $\mu = 12{,}784{,}367$. Estimated Expectations of the variance of this Exponential distribution are $E(N) = 12{,}784{,}367$ and $Var(N) = 163{,}440{,}039{,}590{,}689$. Finally, based on the principle of expected value with *a loading factor* $\alpha = 0.05$, The premium for shrimp pond losses due to crop failure has a value of IDR 44,438,460, while based on the standard deviation principle, it has a value of IDR 42,005,600.

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