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Pricing of Aquaculture Industry Microinsurance Premiums with Standard Deviation Principle Approach (Case Study: Tasikmalaya)

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Abstract

Aquaculture is a rapidly growing industry and has enormous potential to increase the income and welfare of fish farmers. The majority of aquaculture businesses in Indonesia are small-scale cultivators, low productivity and limited business accessibility. As a result, there is an aquaculture industry that does not understand the use of aquaculture-specific financial risk management tools. Therefore, an insurance instrument is needed to manage losses that occur so as to achieve financial and income benefits, namely Micro Insurance. This study aims to calculate premium prices with a standard deviation principle approach. The data used is loss data if aquaculture cultivators do not pay in accordance with the initial capital in Tasikmalaya obtained through primary data based on the results of field surveys through questionnaires. The method of analyzing the number of event data uses the Poisson distribution, while the loss data uses the Exponential distribution. Next, calculate the parameter estimation using the Maximum Likelihood Estimation method. The results of parameter estimation are used to find a collective risk model. From the calculation results in this study, a premium price of IDR 120,156,477.00 was obtained.

Keywords: Aquaculture, Micro Aquaculture Insurance, Premium Determination, Poisson Distribution, Exponential Distribution, Standard Deviation.

1. Introduction

Indonesia is a country that has an area of 1,905,507 km2. Geographically, Indonesia is surrounded by two continents, namely the Asian continent and the Australian continent and stretches from 6 North Latitude to 11 South Latitude and 92 to 142 East Longitude. Most of Indonesia is surrounded by the sea with a monitoring line area of 95,181 km2 (Rani, 2016). Indonesia is the largest archipelagic country in the world that has a huge diversity of marine and fishery resources. As the largest archipelagic country in the world with a strategic geographical layout, Indonesia has enormous potential to become the world's maritime axis. Indonesia has a responsibility to participate in determining the future of the Pacific Ocean and Indian Ocean Regions to remain peaceful and secure in international trade and support the Indonesian economy (Mustari et al., 2018). One of the regions that plays an important role in supporting the economy and is engaged in the aquatic industry or aquaculture industry is Tasikmalaya City and Regency.

Economic and environmental problems in aquaculture occur due to lack of guaranteed production and/or income (Secretan et al., 2007). The aquaculture industry as a whole is growing rapidly, but in some countries growth is delayed and in some systems there is high producer turnover caused by many entities exiting the industry after the initial failure (Nash, 2011). To reduce the risk of aquaculture, aquaculture will often use inefficient management practices, such as the use of microinsurance in the aquaculture industry (Rico et al., 2012). This can help maintain large and consistent yields in the near term, but often comes with long environmental costs, which can ultimately lead to disasters that impact not only individual farmers, but also the surrounding environment as these negative impacts are widespread (Asche et al., 2009).

Insurance can help incentivize the aquaculture industry, to adopt best management practices that reduce income losses as well as other risks (Coble et al., 2003). However, these advantages can only be realized when insurance products are appropriately designed for aquaculture production systems.

2. Literature Review

2.1. Micro Insurance

Microinsurance is a type of insurance that provides financial protection for the general low-income public against certain risks with premium payments made every month and proportional to the risks and expenses that may occur (Awaloedin, 2021). In developing countries, the majority of the population is uninsured, mainly because they engage in economic activities outside the formal sector that are traditional targets of mainstream insurers. The microinsurance activity itself must be within the purview of the relevant domestic insurance regulator or supervisor or other competent body under the national law of any jurisdiction (Wrede et al., 2016).

2.2 Poisson Distribution

In the book entitled Insurance Risk and Ruin by David C.M. Dickson in 2006 that the random variable N is a poisson distribution with parameter $\lambda > 0$, the probability of the function is given by

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

For $x = 0,1,2,\ldots\infty$, the function of the moment generator is

$$M_N(t) = e^{\lambda(e^t - 1)} \tag{2}$$

The value of expectation is:

$$E(N) = \lambda \tag{3}$$

The variance value is:

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

Use $P(\lambda)$ to denote the Poisson distribution with the parameter λ (Dickson, 2006).

2.3 Exponential Distribution

The exponential distribution is a special case of the gamma distribution. This distribution is used to determine the amount of income loss in the aquaculture industry. This distribution is also a gamma distribution with parameter $\alpha = 1$ (Dickson, 2006).

For $x > 0$, the distribution function

$$F(x) = -e^{-\frac{x}{\mu}}, \tag{5}$$

and its moment generator function is:

$$M_X(t) = \frac{1}{1-\mu t}, \tag{6}$$

The $E(X)$ and $Var(X)$ values of the exponential distribution with μ parameters are:

$$E(X) = \mu \tag{7}$$

and

$$Var(X) = \mu^2 \tag{8}$$

2.4 Kolmogorov-Smirnov Distribution Conformity Test

The distribution conformity test is used to test the suitability of the observed sample distribution to a particular distribution. The Kolmogorov-Smirnov test is the absolute difference of $F_n(x)$ which is a function of the empirical distribution with $F_0(x)$ which is the cumulative distribution of the population. $X_1, X_2, X_3, \ldots, X_n$, n-sized random sample of a population with an unknown $F(x)$ distribution function.

Test the hypothesis:

$$H_0: F(x) = F_0(x)$$
$$H_1: F(x) \neq F_0(x) \tag{9}$$

Statistical Test:

$$D = max|F_n(x) - F_0(x)| \tag{10}$$

with:

$F_n(x)$: Empirical distribution function of the sample.

$F_0(x)$: Cumulative distribution function.

The established hypotheses of this distribution are:

H_0 : Data is distributed the same as the theoretical distribution,

H_1 : Data is not distributed the same as theoretical distribution.

The assumption of the decision is to reject H_0 if $D > D_{tabel}$ which means that the distribution of the observed sample has data that is not distributed the same as the theoretical distribution.

2.5 Chi-Square Distribution Conformity Test

The chi-square distribution suitability test is used to test the relationship or influence of two variables with other nominal variables (Heryana, 2017). This test uses parameters χ_h^2, which can be calculated by the equation:

$$\chi_h^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}, \quad (11)$$

Information:
χ_h^2 : computed chi-squared parameters
O_i : the number of observation values in subgroup I
E_i : the number of theoretical values in the subgroup.
Heryana 2017 explained the test criteria of the chi-square distribution conformity test, namely:

- If $\chi_h^2 \leq \chi_{tabel}^2$, so H_0 accepted.
- If $\chi_h^2 > \chi_{tabel}^2$, so H_0 rejected.

2.6 Distribution Parameter Estimation Using Maximum Likelihood Estimation

Parameter estimation of both distributions by the maximum likelihood method is obtained by differentiating the lognormal function of the probability function of the distribution. The estimated parameters of the Poisson distribution are:

$$\hat{\lambda}_{MLE} = \frac{\sum x_i}{n}. \quad (12)$$

As for the Exponential distribution, the formula for the estimate is:

$$\hat{\mu}_{MLE} = \bar{x}. \quad (13)$$

2.7 Collective Risk Model

In risk models, random variables $S(t)$ becomes the magnitude of the collective risk that occurs. Variabel random N shows the number of claims from risk, number of events, and random variables X_i great loss (Dickson, 2006). The aggregate claim amount is simply the sum of individual claims, so it can be written:

$$S(t) = \sum_{i=1}^{N} X_i. \quad (14)$$

Equation (12) represents the aggregate claims generated by events from the period during which the event occurred. Because the collective risk estimator that has been analyzed becomes the company's reference in determining insurance reserves. The solution model used in determining the expectation estimator and variance of $\boldsymbol{S(t)}$ becomes the determination of the amount of collective risk to be paid. The magnitude of collective risk that occurs can be assumed to be a random variable $\boldsymbol{S}$. To find out the amount of collective loss, you can use the value of expectations and variances $\boldsymbol{S}$. Mathematically, the expectations and variance of collective risk can be formulated as follows:

$$\begin{aligned} E(S) &= E[E(S = x|N = n)], \\ &= E(N)E(X), \end{aligned} \quad (15)$$

Furthermore, variance can be formulated as follows:

$$Var(S) = E(N)Var(X) + Var(N)\big(E(X)\big)^2 \quad (16)$$

2.8 Premium Calculation Model

The insurance premium calculation model in this study considers collective risk in the form of many events and the magnitude of natural disaster losses. In addition, this model also considers the premium loading factor ($\propto$). Referring to Djuric (2013) and Sukono et al (2018), the model used in the calculation of insurance premiums is based on the principle of standard deviation. The pure premium value in this study can be found using equation (13). The premium price based on the standard deviation principle can be formulated as follows:

$$p(t) = E(S) + \alpha\sqrt{Var(S)}, \quad (17)$$

with $0 < \alpha < 1$.

3. Materials and Methods

3.1. Materials

The object used in this study is to determine microinsurance premiums for the aquaculture industry in Tasikmalaya using the standard deviation principle. The data used in determining the aquaculture micro insurance premium is data on the risk of loss of income for the aquaculture industry in Tasikmalaya due to payments less than the estimated initial capital from September 2021 to August 2022 based on the survey results. The survey was conducted by means of open interviews with the aquaculture industry regarding the many incidents of the aquaculture industry if the payment is not in accordance with the initial capital and losses.

3.2. Methods

The stages carried out in this study are as follows:

a) Carry out the distribution of questionnaires that have been made to aquaculture industry players in Tasikmalaya to obtain data. The data obtained are collected and prepared for the next stage of research.
b) The distribution model hypothesis for data on the number of events in which the aquaculture industry makes payments less than the initial capital is Poisson distributed data according to equation (1) and parameters λ, and for data on the amount of loss of the aquaculture industry due to the event is Exponential distributed data according to equation (5) and parameters μ.
c) The method used for testing discrete distributions is the Kolmogorov-Smirnov method corresponding to equation (9). As for the continuous distribution modal fit test using the Chi-Square method and according to equation (11).
d) The method used to estimate the parameters of the distribution is the Maximum Likelihood Estimation method. The estimated parameters are parameters λ on equation (12) for the Poisson distribution and parameters μ on equation (13) of the Exponential distribution.
e) After obtaining the parameter estimation calculation, then calculate the expectation value and variance of the data distribution so as to determine the collective risk model. Expectations and variances in the Poisson distribution can be calculated by equations (3) and (4). While the Exponential distribution can be calculated by equations (7) and (8).
f) The calculation of premium value is carried out using the principle of expected value. The results of this calculation can be used as a comparison of the premium value using the standard deviation principle. Mathematically, the formula for finding a pure premium can be seen through equation (15).
g) Calculate premiums using the standard deviation principle by considering the loading factor value. To calculate the premium price using equation (17).

4. Results and Discussion

4.1 Research Data

The aquaculture industry that is used as the object of this study is in the City and Regency of Tasikmalaya where the area is one of the industrial areas that has considerable potential for the aquaculture industry. The following is the average data on the number of incidents when the aquaculture industry pays not in accordance with the initial capital and the amount of losses experienced by the aquaculture industry due to paying not according to the initial capital every month for 12 months. The data are presented in Table 1.

Table 1: Data on many events and losses of the aquaculture industry do not pay according to the initial capital every month

No	Month	On average, many aquaculture industries do not pay the initial capital	Average Loss of Aquaculture Industry does not pay according to initial capital
1	Sep-21	7	IDR 1,163,643.00
2	Okt-21	7	IDR 1,180,109.00
3	Nov-21	7	IDR 1,184,300.00
4	Des-21	7	IDR 1,087,916.00
5	Jan-22	7	IDR 1,187,331.00
6	Feb-22	7	IDR 1,174,099.00
7	Mar-22	7	IDR 1,161,542.00
8	Apr-22	8	IDR 1,553,634.00

No	Month	On average, many aquaculture industries do not pay the initial capital	Average Loss of Aquaculture Industry does not pay according to initial capital
9	Mei-22	8	IDR 1,506,559.00
10	Jun-22	8	IDR 1,225,561.00
11	Jul-22	9	IDR 1,575,931.00
12	Agu-22	7	IDR 1,267,390.00

Based on table 1, the average data on the number of events and the amount of loss of the aquaculture industry if it does not pay in accordance with the estimated initial capital in the period 1 September 2021 to 1 August 2022 is referred to as collective loss risk.

Table 2: Descriptive Statistics

Data	Lots of Data	Minimum	Maximum	Mean	Standard Deviation
Many Occurences	50	3	12	7.42	2.339457464
Big Loss	50	1,380,000.00	61,380,000.00	15,394,360.00	16,390,319.40

Table 2 shows descriptive statistics from data on the number of events and the magnitude of losses in the aquaculture industry that paid less than the estimated initial capital in Tasikmalaya.

4.2 Data Distribution Model Hypothesis

The model of the number of events in which the aquaculture industry does not pay according to the initial capital estimate is a discrete distributed line of random events. From the results of data processing, a diagram is obtained from the data of the number of events as shown in Figure 1.

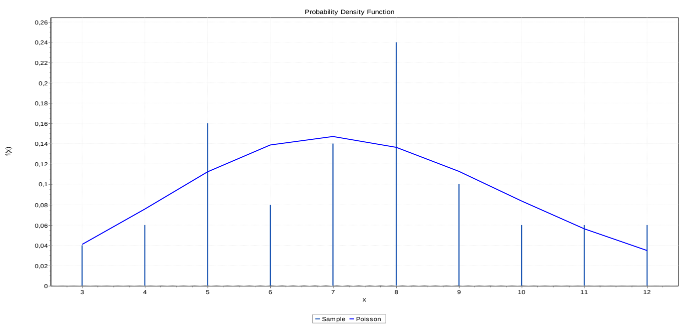

Figure 1: Diagram of lots occurances

Based on Figure 1, it can be identified that the data on many aquaculture industry events paid did not match the estimated initial capital distributed Poisson, while the large model of losses of the aquaculture industry did not pay according to the estimated initial capital is a series of random events that are continuously distributed. From the results of data processing, a diagram of large data losses is obtained as in Figure 2.

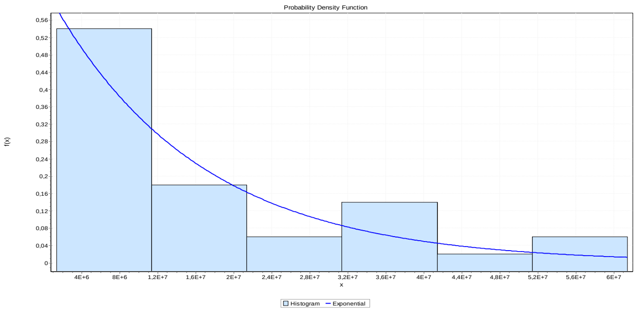

Figure 2: Big data loss diagram

Based on Figure 2, it can be identified that the big data on the loss of the non-payment aquaculture industry is in accordance with the estimate of exponentially distributed initial capital.

4.3 Distribution Parameter Estimation Using Maximum Likelihood Estimation.

The parameters estimated in the Poisson distribution are parameters λ s while the Exponential distribution is a parameter μ. The likelihood function for the number of event corresponds to equation (12), namely:

$$\ln'(L(\lambda)) = 0$$

$$\frac{d\left(-50\lambda \ln e + \sum_{i=1}^{50} x_i \ln \lambda - \ln \prod_{i=1}^{50} x_i!\right)}{d\lambda} = 0$$

$$-50 + \frac{\sum_{i=1}^{50} x_i}{\hat{\lambda}} = 0$$

$$\frac{\sum_{i=1}^{50} x_i}{\hat{\lambda}} = 50$$

$$\hat{\lambda}_{MLE} = \frac{\sum_{i=1}^{50} x_i}{50}$$

$$\lambda = 7.420$$

From the estimation results, parameters are obtained λ is $7{,}420$. These values are used to calculate expectations and variances. The likelihood function for the amount of loss corresponds to equation (13), namely:

$$\ln'(L(\mu)) = 0$$

$$-\frac{50}{\hat{\mu}} + \frac{1}{\hat{\mu}^2} \sum_{i=1}^{50} x_i = 0$$

$$\frac{50}{\hat{\mu}} = \frac{1}{\hat{\mu}^2} \sum_{i=1}^{50} x_i$$

$$\hat{\mu} = \frac{1}{50} \sum_{i=1}^{50} x_i$$

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

$$\mu = 15{,}394{,}360$$

From the estimation results, parameters are obtained μ is $15{,}394{,}360$. This parameter is used to calculate expectation and variance values.

4.4 Distribution Model Conformity Test

Test the suitability of the distribution model in this study using statistical test analysis. Poisson-distributed data were statistically tested with Kolmogorov-Smirnov testing while exponentially distributed data were statistically tested with Chi-Square testing. The results of the Kolmogorov-Smirnov model fit test are presented in Table 3.

Table 3: Results of the Kolmogorov-smirnov conformity test of the Poisson distribution

Kolmogorov-Smirnov Conformity Test Poisson Distribution		
Lots of Occurances	Test Statistics (D)	0.19639
	D_{tabel}	0.22604
	Result	$D < D_{tabel}$ or $0.19639 < 0.22604$

The results of the Chi-Square model fit test are presented in Table 4.

Table 4: Exponential distribution chi-square fit test results

Exponential Distribution Chi-Square Fit Test		
Big Loss	Test Statistics (χ^2_h)	8.4396
	χ^2_{cr}	13.277
	Result	$\chi^2_h < \chi^2_{cr}$ or $8.4396 < 13.277$

Based on Table 3 it can be concluded that $D < D_{tabel}$ so that H_0 received and data on the number of non-payment aquaculture industry events in accordance with the estimated initial capital distributed Poisson. Based on Table 4 it can be concluded that $\chi_h^2 < \chi_{cr}^2$ so that H_0 received and big data losses of the aquaculture industry do not pay according to the initial capital distributed Exponential.

4.5 Calculating Collective Risk

Expectation and variance values are used to calculate collective risk. The Poisson distribution performs expectation calculations referring to equation (3) and variance refers to equation (4). As for calculating expectations and variances, the exponential distribution refers to equations (7) and (8). Expectation values and variances of the poisson distribution with parameters $\lambda = 7.420$ that is:

$$E(N) = \lambda$$
$$E(N) = 7.420$$

and

$$Var(N) = \lambda$$
$$Var(N) = 7.420$$

While the expectation and variance values of the Exponential distribution are:

$$E(X) = \mu$$
$$E(X) = 15{,}394{,}360$$

and

$$Var(X) = \mu^2$$
$$Var(X) = 15{,}594{,}360^2$$
$$Var(X) = 236{,}986{,}319{,}809{,}600$$

Based on the results of the calculation above, the value of expectations and variances from the data on the number of events is 7,420 and the value of expectations and variances from the big data of losses is as much as $E(X) = 15.594.360$ and $Var(X) = 243{,}184{,}063{,}809{,}600$. It then calculates the value of collective risk based on the expected value and variance of both distributions. The calculation refers to equations (15) and (16), namely:

$$E(S) = E(N)E(X)$$
$$E(S) = (7.420) \cdot (15{,}394{,}360)$$
$$E(S) = 114{,}226{,}151$$

and

$$Var(S) = E(N)Var(X) + Var(N)\big(E(X)\big)^2$$
$$Var(S) = ((7.420) \cdot (236{,}986{,}319{,}809{,}600)) + ((7.420) \cdot (15{,}394{,}360)^2)$$
$$Var(S) = 3{,}516{,}876{,}985{,}974{,}460$$

An estimate of the amount of collective risk is obtained from data on the amount of loss using the value of expectations and variances, namely $E(S) = 114{,}226{,}151$ and $Var(S) = 3{,}516{,}876{,}985{,}974{,}460$. This value is used to calculate the amount of premium based on the standard deviation principle charged by the insurance company to the insured or the aquaculture industry.

4.6 Pure Premium Calculation

In this study, calculate the amount of pure premiums that must be paid by the aquaculture industry to insurance companies. In accordance with equation (15), a premium value of is obtained IDR 114,226,151.00. The pure premium value is used to calculate the amount of premium value based on the standard deviation principle.

4.7 Premium Calculation Based on Standard Deviation Principle

The calculation of the premium amount then uses the standard deviation principle according to the equation (17), namely:

$$p(t) = E(S) + \alpha\sqrt{Var(S)}$$
$$p(t) = 114{,}226{,}151 + 0.1\sqrt{3{,}516{,}876{,}985{,}974{,}460}$$
$$p(t) = 114{,}226{,}151 + 5{,}930{,}326$$
$$p(t) = 120{,}156{,}477$$

Insurance premiums are obtained based on the standard deviation principle, which is IDR $\mathbf{120,156,477.00}$ from a large estimate of the risk of collective loss. The results of these calculations can be used by insurance companies as recommendations in determining the price of microinsurance premiums that must be paid by the aquaculture industry.

5. Conclussion

Based on the results of the study, the calculation of premium size uses the standard deviation principle with the loading factor value $\alpha = 0.1$ is $120{,}156{,}477.00$. The premium value is paid by the government over a period of one year with a total of 50 aquaculture industries. According to the Regulation of the Director General of Aquaculture Number 277 of 2021 concerning Technical Guidelines for Fisheries Insurance Premium Payment Assistance for Small Fish Farmers, it is stated that the provider of fisheries insurance premium payment assistance for Small Fish Farmers in 2022 is the Directorate General of Fisheries.

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