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Original Paper

WHITE SHRIMP POPULATION DYNAMIC IN RIAU PROVINCE: THE EFFECTS OF INTRINSIC GROWTH RATE AND EFFORT

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ABSTRACT

Fisheries management at Indonesia during the time is relatively responsive to unsustainable management. This caused by this management which is not yet considering population dynamic aspects, such as intrinsic growth rate, catch ability of fishing gears and carrying capacity. The objectives of these researches are to develop and decide of the intrinsic growth rate and catch effort effects to white shrimp population dynamic at Riau Province. Modeling was conducted to growth and harvesting model with numerical simulation technique. The result of numerical simulation represents that intrinsic growth rate of white shrimp is equal 0.88 tons/years and carrying capacity is equal 38,023.26 tons. Existence standard effort 54,447 trips/years cause decreasing maximum population growth became 10,941 tons of population with growth rate 2,831.3 tons. The optimal and sustainable management of white shrimp fisheries at Riau Province must be consider population dynamic aspects.

Key words: Numerical Model, Intrinsic Growth Rate, Catch ability, Carrying Capacity

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INTRODUCTION

Economic development program which made by developing countries, including Indonesia often cause a dilemma for the sustainability of resources, including fisheries resources. The increasing demand of the economy resources base causes the high pressure of the resources, so that needs good management. Fisheries management at Indonesia during the time is relatively responsive to unsustainable management. This caused by the fisheries management approach and the pattern are sectored and disintegrated. The fishery ecosystem condition characterized by ecological complexes, multi-species and common property requires that the planning and development of fisheries management was integrated and sustainable.

Initially, the fisheries resources management is based on biological factors approach called maximum sustainable yield (MSY). The main idea of this approach is that each species of fish have ability to be in excess of production capacity (surplus), so that when the surplus is harvested, the fish stock will be sustainable. But this approach concept has many criticized because it is too simple and not sufficient to manage fisheries resources. One of most fundamentals is that the MSY approach does not consider fish population dynamic aspects, such as the intrinsic growth rate, catch ability and carrying capacity in the fisheries resources management.

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This subject study focuses on the case of White Shrimp (*Penaeus merguiensis* de Man) in Riau Province because this species is the dominant catch in this area. The high demand for White Shrimp derivate products in Indonesia and foreign countries cause high prices of these products that stimulate the fishermen to exploit these resources. If this is not offset with the appropriate management can cause depletion of these resources and the extinction occurs. This study aims to develop and determine the population growth and harvesting model for White Shrimp in Riau Province with consider intrinsic growth rate, catch ability and carrying capacity aspects to fisheries resources management.

MATERIAL AND METHODS

Data acquisition

This research was conducted in March to May 2009 at several locations in Indragiri Hilir, Rokan Hilir and Bengkalis Regency, Riau Province. Location is determined by purposive sampling, with the consideration that the selected locations are located in a White Shrimp habitat and fishing ground area.

Field data of fishing ground, effort, catch and cost of effort was collected with direct observation, interviews with fishermen and questionnaire. The number of respondents is 10% of the number of fishermen who catches of White Shrimp. Some of the time series data (12 years) was collected from various institutions such as the Central Statistics Agency of Riau Province, Marine and Fisheries Affair Agency of Riau Province, Marine and Fisheries Affairs Agency of Indragiri Hilir Regency, Marine and Fisheries Affairs Agency of Bengkalis Regency, and Marine and Fisheries Affairs Agency of Rokan Hilir Regency.

Development of Population Growth and Harvesting Model

Gordon (1954) and Schaefer (1957) states that the growth rate of population (x) at the period on a close water is a function of the number of the original population. As mathematically, the relationship can be written as

$$\frac{dx}{dt} = F(x) \quad \text{.....(1)}$$

if that the area is limited, we can assume that the fish population is growing proportionally to the original population or

$$\frac{dx}{dt} = rx \quad \text{.....(2)}$$

Where r is the intrinsic growth rate or often called the fastest growth rate of species. This coefficient can be derived from the Ordinary Least Square Equation developed by Hilborn and Walters (1992); Amron et. al (2005) is

$$\frac{U_{t+1}}{U_t} - 1 = r - \frac{r}{Kq}U_t - qE_t \quad \text{.....(3)}$$

where U_t is the catch per unit effort (CPUE) and E_t is effort. From equation (3) can be converted to the regression coefficients form, where $a = r$, $b_1 = -r/Kq$, $b_2 = -q$, $Y = (U_{t+1}/U_t)-1$, $X_1 = U_t$ dan $X_2 = E_t$. q is a catchability coefficient and K is the carrying capacity.

Assumption that the intrinsic growth rate is the proportion of the differences between the carrying capacity and population, as mathematically the relationship is written as:

$$\frac{dx}{dt} = rx(K - x)$$

$$= rx(1 - \frac{x}{K}) \quad \text{.....(4)}$$

Equation (4) is a model of population growth. Solutions for equation is

$$x(t) = \frac{K}{1 + ce^{-rt}} \quad \text{.....(5)}$$

where

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$$c = \frac{K - x0}{x0}$$

The population growth model in the equation (4) is a fisheries condition that has not been exploited so that the model should be developed to include production factors. To harvest of fish needs variety of facilities that required input factors, which is called the effort. According to Clark (1985) that the catch (h) or fishing activities can be assumed as a function of effort (E) and fish stock so that $h = F(x, E)$.

Generally, we assume that if the fish biomass (stock) and many factors input (effort) are increasing, so the catch has been increasing. In the other words, partial derivative of the both input variable is positive, or $\partial h / \partial x > 0$ and $\partial h / \partial E > 0$.

Explicitly, the production function often used in fisheries management is

$h = qxE$ .....(6)

With the effort activity, then the model in equation (4) will be

$$\frac{dx}{dt} = F(x) - h$$

$= rx(1 - x/K) - qxE$ …….…….(7)

equation (7) is harvesting model.

In open access fisheries, the fishing gear which operating to catches of fish is very diverse so that the CPUE in Equation (3) must be a CPUEs (CPUE standard). According to Hilborn and Walters (1992) CPUEs is h / Es.

Data Analysis

The field and time series data was analyzed to determine intrinsic growth rate, cathability coefficient and carrying capacity, using *Ordinary Least Square* (OLS) estimation with *Microfit* software. That determine coefficients are as input to develop population dynamic model. Modeling was made using *Numerical Simulation Technique* (Chaney and Kincaid, 1999), with *Maple* and *Matlab* software.

RESULTS AND DISCUSSION

Results

White Shrimp is one of the dominant catch in the Riau Province in the year 2008 is equal to 20,078.1 tons, or 6.51% (Marine and Fisheries Affairs Agency of Riau Province, 2009). The dominant fishing gears used to catches White Shrimp in the Riau Province in 1996 – 2008 are guiding barrier and stow nets at the in-shore and trammel net and trawl (BED equipped shrimp nets) at the off-shore. Catch of White Shrimp in Riau Province are fluctuations in 1996 - 2008. The decreased production occurred in 1998 (16.57%), 2000 (11.10%), 2002 (39.61%) and 2003 (16.54%). Significantly increased production occurred in the last three years i.e. 2006 (40.28%), 2007 (50.13%) and 2008 (12.25%).

Fastest intrinsic growth rate (r) of the White Shrimp in Riau Province is 0.88 tons/year and carrying capacity (k) is 38,023.26 tons. According to the coefficients, the growth model of White Shrimp is equal $F(x) = 0{,}88x(1 - 0{,}000026x)$. Based on these equation can be made graphic of White Shrimp population growth model in Riau Province (**Fig 1**).

In (**Fig 1**), at the equilibrium condition, the intrinsic growth rate equal to zero. White Shrimp will increase until the approaching half of carrying capacity or 19,077 tons with a growth rate equal 8330.90 tons. When growth rate has reached the maximum point, growth has decreased and then stopped when the population has reached carrying capacity.

Assumption that the White Shrimp population in 1996 is the original population (x_0) is equal to 28,970.12 tons (simulation results), the population at the time (x_t) will

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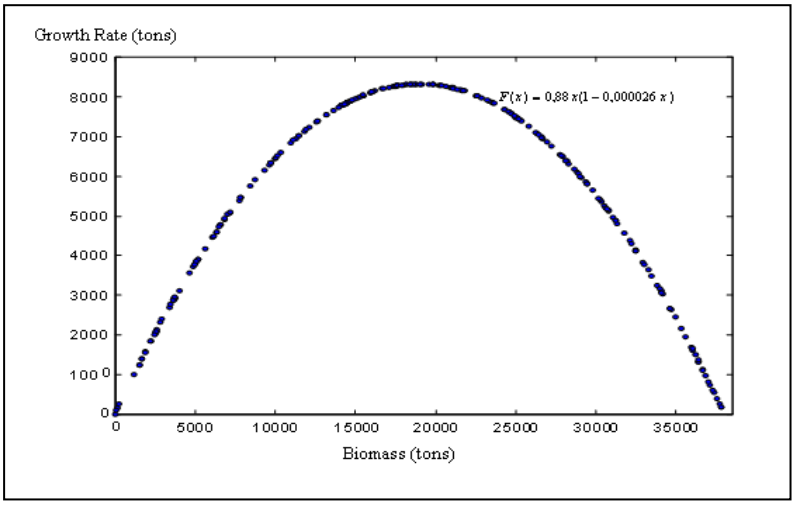

Fig 1. Intrinsic Growth Model of White Shrimp in Riau Province

follow the equation $x_t = \frac{38023{,}26}{1+0{,}31\times 10^{(-0{,}88t)}}$ Shrimp population dynamic which represented sigmoid curve (**Fig 2**).

Based on equation can made graphic of White

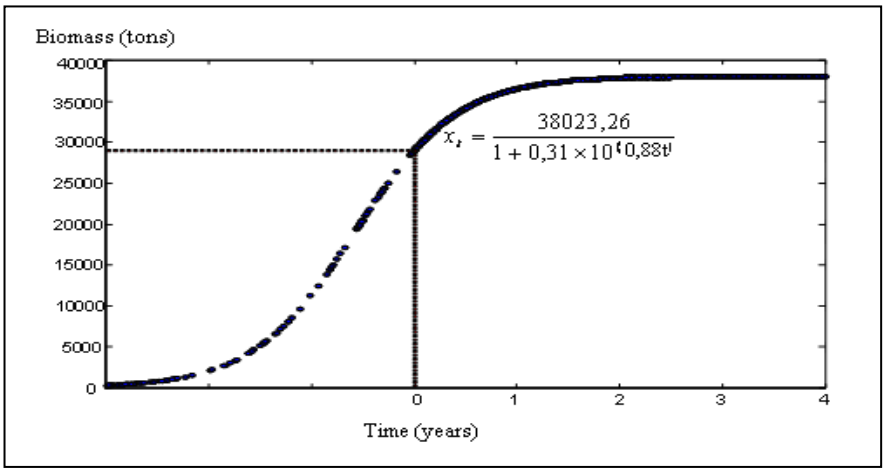

Fig 2. White Shrimp Population Dynamics in Riau Province

There is effort of White Shrimp in Riau Province will affect the intrinsic growth model in **Fig 2**. With an average of standard efforts is 54,447 trips/year (year 1996 - 2008) will provide average of maximum catch is h = 0.36*x* so that the growth model will follow the equtine

$$F(x) = 0{,}88x(1-0{,}000026x) - 0{,}36x$$

Based on the catch of White Shrimp in the Riau Province in the years 1996 -2008, the graph can be made due to the population dynamic affected by intrinsic growth rate and effort (**Fig 3**).

ISSN : 1410-5217
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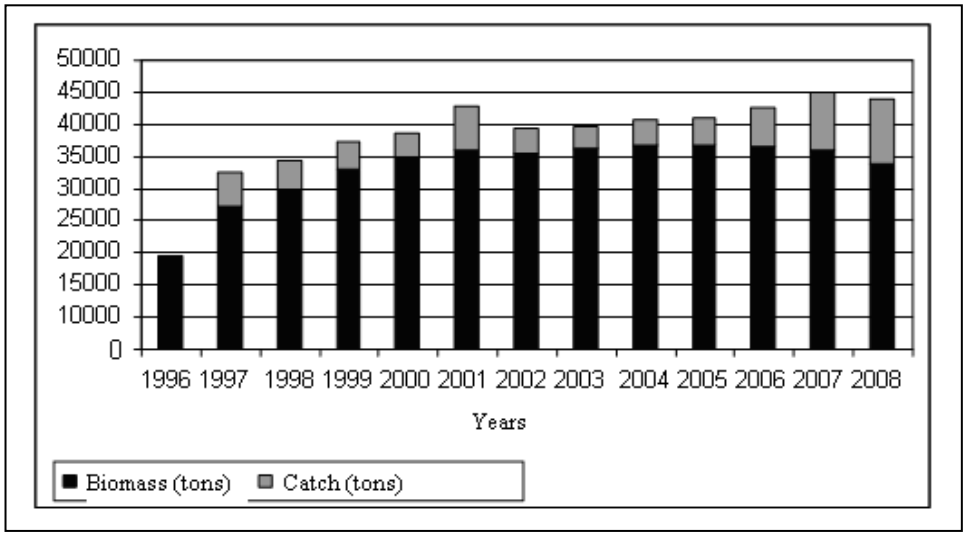

Fig 3. White Shrimp Population Dynamic Affected By Intrinsic Growth Rate and Catch

In (**Fig. 3**) can be seen how the impact of effort to growth rate of White Shrimp population. There is effort will catches the population, so that population growth also decreased. Based on the results of the simulation model, population growth will reach a maximum at the time of a population of 10,941 tons with an intrinsic growth rate of 2,831.3 tons.

Discussion

Some areas in Riau Province are fishing ground of White Shrimp because the area is its habitat. This is described with a number of rivers that carry various nutrients from land to sea, which caused the sea of this area contains many nutrients (*eutrophic*). Beside that, many different types of mangrove growths in the in-shore as the ideal condition for White Shrimp to hold his life as nursery ground and feeding ground (Unar and Naamin, 1981).

Catch of White Shrimp in Riau Province continue to increase. This is caused by high demand of White Shrimp product in the form of fresh or processing product (derivate product), which stimulated to improve the effort this species. Capturing season of White Shrimp occurs throughout the year. However, the highest production occurred during the dry season (April - September) in each year. According to the fishermen that the rainy season (October - March), effort decline occurred because of the high risk, that will decreases the catch of White Shrimp in this season.

Capturing effort by using traditional fishing gear such as stow nets operated in in-shore continues to decrease. According to the fishermen, this is caused by the low productivity of this fishing gears so that the fishermen are explore alternative fishing gears which more productivity, such as trammel net and trawl. Changes of fishing gears causes changes fishing ground from in-shore to off-shore.

White Shrimp and other fisheries resources are open access resources so that the fishermen can access to the resources without the need to have. In simple it can be said that the production or catch from the effort activity is a function of effort and population stock. Generally, can be assumed that the more of White Shrimp population means the more effort could increase production.

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Theoretically, the assumption is not realistic because it does not indicate the diminishing return of the effort in the short term where the White Shrimp stock more or less limited so that has limit of maximum production (Gordon, 1954; Schaefer, 1957; Copes 1972; Berachi, 2003; Chae, 2003; Long (2003); Chae and Pascoe, 2005 and Silvestri, *et.al.*, 2009)).

In the exist condition, the growth model of the White Shrimp population in Riau Province a period is a function of the number of original population. Rationality, population is growing proportionally to the original population. Changes in a White Shrimp Population in Riau Province from year to year have increased to reach the sigmoid population at the time (carrying capacity). This increase occurred because the original population in 1996 less than the carrying capacity at the time so that population changes tend to increase until near the population at the time. The effort will reduce the White Shrimp population, so it will affect the growth model (Clark, 1985; Clark, 1990; Ulricha, 2002; Thanh, 2006 and Merino, *et.al*., 2007).

CONCLUSION

Based on the results can be concluded that:

(1). Maximum population growth rate of White Shrimp in Riau Province will decrease affected by the effort.

(2). The optimal and sustainable of White Shrimp management in Riau Province must consider the population dynamic aspects.

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